Human Dynamics in Smart Cities

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Cities as Spatial and Social Networks

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ISSN 2523-7780 ISSN 2523-7799 (electronic)
Human Dynamics in Smart Cities
ISBN 978-3-319-95350-2 ISBN 978-3-319-95351-9 (eBook)
https://doi.org/10.1007/978-3-319-95351-9

Library of Congress Control Number: 2018947475

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

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Chapter 1
Introduction: Cities as Social and Spatial Networks

Xinyue Ye and Xingjian Liu

1.1 Introduction

Urban societies are composed of many interrelated contexts where individuals influence and interact with each other over space, time, and network (Hillier and Hanson 1984; Shaw et al. 2016; Andris et al. 2018). As Andris (2016, p. 2009) argues, "we are simultaneously born into a geographic landscape and a social network (SN), i.e., a configuration of relationships that individuals develop and maintain. Members of our SN include our family, friends, and professional contacts. Throughout our lives, we use the intertwined, inextricable systems of the SN and the geographic landscape to grow and develop". A great number of studies explore social networks from the topological perspective regarding either how nodes are positioned to each other or how nodes evolve over time (Lee and Kwan 2011). Meanwhile, human activities across social networks are operating in space and time along with plenty of mismatch (Andris et al. 2018). For example, Travers and Milgram (1967) consider human society as a small-world network featured with many short path-lengths, raising the concept of six degrees of separation (every two persons can be connected through six steps by average). The notion of "the strength of weak ties" points out that an individual's weak ties (a person you got to know for the first time or might meet in a very rare situation) might be able to offer greater support in finding a job, while strong ties such as close friends and family members usually fail to do so, because they share a similar position in the network as the individual job seeker (Granovetter 1977). Extending Granovetter's argument into

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X. Ye and X. Liu (eds.), *Cities as Spatial and Social Networks*, Human Dynamics in Smart Cities, https://doi.org/10.1007/978-3-319-95351-9_1

the spatial context, Zenou (2013) finds that workers who cannot easily access jobs tend to have much fewer opportunities to meet weak ties, due to the lack of convenient public transportation and time-costly travel in US cities. Hence, both social and spatial separation lead to high unemployment rate among ethnic minorities communities. Another example would be Hagerstrand's (1967) pioneering research on the spatial diffusion of innovation. The social network structure of nodes and links has been adopted to study innovation diffusion across space. Network structure, actors, content, and the diffusion procedure are the four most important elements in the studies of social media information diffusion (Weng et al. 2013). Spatiality of social networks rests on the assumption that the existence of two individuals' social tie is negatively related to their geographical distance (Lee and Kwan 2011). This conclusion also echoes the first law of geography (Tobler 1970).

1.2 Cities as Social and Spatial Networks

The relationship between relational and geographical spaces, representing social-spatial interaction in the cities, has long been an important issue in urban and regional studies, planning, and design (Barthélemy 2011; Adams et al. 2012; Andris 2016). Cities have been evolving through human-human and human-environment interactions. More importantly, a community/city grows as a system within a system of communities/cities (Berry 1964). Furthermore, 'systems' at different geographical scales and levels are also interacting with one another (Neal 2012). According to Batty (2013), cities should be treated as systems of network and flow instead of being simply viewed as places in space. Hence, the integration of spatial and social network analytics is necessary to reveal the flow across places and spaces. Much discussion has been devoted to how developments in social network and spatial analyses have separately contributed to our understanding of cities and urban system. Researchers have also examined various types of urban networks, such as the investment, traffic, and infrastructure network (Zhao et al. 2018; see also Barthélemy 2011 for a review of spatial networks). Nevertheless, the debate on how social network and spatial analyses could be synthesized seems to be inconclusive.

For example, the debates regarding how geographic constraints affect different social networks have been drawing great attentions across disciplines. Kwan (2013) states that human mobility essentially enriches people's spatiotemporal life experiences in the built environment beyond their residence. She further extends the static feature of spatial-social relationship into the dynamic context, arguing the essence of spatial social network could be much enhanced if time and human mobility can be taken into consideration. Novel research questions can be asked when we can model the convergence of virtual and physical dimensions in the dynamic context across multiple scales. Moreover, academia, decision makers, and citizens have gradually realized the close interactions between the social and physical dimensions of our cities. For example, the Internet and cellular data networks significantly change our mode of communication and reshape the formation of networked groups which were previously strongly constrained by distance and location, releasing the power of social interactions and group assembly across much larger territory. The revolution of transportation and information technology has re-configured the boundary and definition of neighborhood and communities. In recent years, the increasing affordability of technology has accelerated such spatiotemporal shrinkage processes at an increasing rate (Han et al. 2015).

Relatedly, another emerging strand of study is spurred by the new urban data environment, which offers us new opportunities in understanding the spatial and social dimensions of cities (Liu et al. 2015; Tsou and Yang 2016). One notable example would be the social media data. Social media provides an unprecedented data source for better understanding network and flow within cities (Croitoru et al. 2015). Wang and Ye (2017) analyze social media data from four key perspectives (space, time, content and network) to enhance information richness for disaster response. Through context-sensitive analysis of geo-tagged social media data, Shelton et al. (2015) highlight urban socio-spatial inequality. The massive messages texted by residents of different cities can be regarded as a form of spatial interactions between cities expressed by many individuals' perceptions. Specifically, if text messages from a city mentioned the name of another city (toponym), it would indicate that social-spatial interactions exist between the two cities (Han et al. 2015).

As noted, attempts have been made by scholars from different fields to facilitate the social-spatial network representation of cities (Andris 2016; Andris et al. 2018). For example, the pioneering work on Space syntax by Hillier et al. (1976) shows that the power of spatial configuration can reveal a considerable proportion of the human movement difference between various locations from indoors to urban environment (Penn 2003). The tool SpaceSyntax was developed to characterize and quantify where and how people interact and communicate with the environment (Hillier and Hanson 1984; Penn 2003). Space syntax research has revealed a strong correlation between spatial configuration and human dynamics (e.g., Hillier et al. 1983; Penn et al. 1998; see also Ratti 2004; Hillier and Penn 2004). Furthermore, the theory and techniques have been applied to analyze spatial and social interactions at building and architecture plan levels (e.g., Sailer and McCulloh 2012). While we may not be able to mention all relevant studies in this short introductory piece, this edited volume is among the efforts to promote spatial-social network research of human dynamics studies, treating cities as spatial-social systems involving complicated networks and flows.

1.3 About This Book

This volume is the second volume in the Human Dynamics in Smart Cities book series published by Springer and composed of 11 chapters. This first chapter provides a guidance of the themes and briefly introduce all the chapters in this book. The following chapters cover a variety of interesting and timely topics on Cities as Social and Spatial Networks. This book is summarized with a concluding chapter to outline the research roadmap and next steps: integrating spatial and social network analysis for urban research in the new data environment. The chapters focus on three aspects: Conceptualization and Framework Implementation, Intra-City Analytics, and Inter-City Analytics as below:

Conceptualization and Framework Implementation: Lai (2018) suggests a framework of system/network and develop a prototype for urban planning based on cellular automaton. He argues that making plans is to predict the planner's spacetime trajectory in the universal system, while revision of plans tends to reset the current state. He defines the benefits yielded by such a definition of making plans as the computational or self-organization capability of the system. According to the author, decisions are networked in the event-driven system while actions are inseparable. Calling for a deeper theoretical integration of geography, social network, and semantic spaces, Luo et al. (2018) propose a spatio-socio-semantic analysis framework to better grasp the logic aspects of human behaviors to augment the spatial-social models in the urban systems. For instance, the similarity of semantic trajectories retrieved from geo-tagged social media data can be employed to recommend potential collaborative travels. The authors also propose a prototype to conduct visual analytics based on the data fusion of heterogeneous sources.

Shen (2018) discusses the hub-spoke network, which employs a relatively smaller amounts of edges to connect many origin and destination nodes via its hubs. He states that the strength of a hub-spoke network rests on the cost minimization at the expense of flow delay incurred to all flows rerouted via hubs. Hence, a hub-spoke network may not be better than point-point in the context of delay cost. The chapter suggests a system-wide optimality and the tradeoff consideration. To validate these statements, a group of quadratic integer optimization programs are proposed and linearized under a heuristic strategy.

Intra-City Analytics: Hu (2018) examines spatial characteristics of social networks to explain the disadvantaged groups' low socioeconomic outcomes. This paper notes that though most studies argue that a lack of social networks is associated with the poverty, the policy implementation is shaky due to various definitions of network indicators. This chapter summarizes different social network indicators and their validity based on a group of empirical studies. The author suggests more feasible and conceptually sound indicators to explain employment outcomes. This research especially promotes social network indicators featured with the household or neighborhood characteristics. Using a case study of urban land development issues facing 121 families in Delhi, Diehl et al. (2018) highlight the importance of community participation in the planning practices in this large city in India, especially from the perspective of poor and marginalized areas. The authors state that integrating spatial and social network approaches can better understanding the operation of social networks in the real world. To achieve the sustainability goal in urban planning and development, it is crucial to include people who are difficult to reach but vulnerable to development plans. They argue that the integrated social network and spatial analysis can shed light on the relationship between social ties and participant behavior. Such integrated thinking can improve the community-based urban management. This chapter aims to measure spatial and social aspects of household social networks and examine whether households of similar social networks demonstrate closer beliefs or behaviors towards land development. The authors utilize a mixed-methods approach integrating spatial analysis and field-based interviews, finding that social ties play a very important role in household opportunities and behaviors.

Rajendran (2018) examine how international students identity themselves in urban environments featured with multiple cultures in UK cities. Through the people-identity-place perspective including human geography, phenomenological philosophy and social psychology, this chapter weaves these elements towards a geo-social interpretation of identity sense and formation in the built environment. The author also provides guidance for urban design and planning, in particular in relation to human-environmental interaction issues and sustainability. Systematic study of such topic is important as a basis for the sustainable development of these rapidly globalizing landscapes.

Inter-City Analytics: Cai et al. (2018) investigate China's mega-regions from a network perspective. In order to facilitate inter-regional cooperation on infrastructure and economic development, the connection level of cities need to be evaluated. The authors adopt time series company investment records aggregated at the prefectural level to denote the dynamic city network and the evolution pattern such as network density and degree distribution. Urban hierarchical structure is also revealed through machine learning approaches. The algorithm for detecting interconnected subgroup is further developed to identify mega-regions' development structure. Xiong and Nijhuis (2018) propose the concept of urban deltas with the significance in their population size, ecosystems service and economic power. However, these areas face various challenges of social, environmental, and economic risks. The authors adopt a multi-scale framework to characterize urbanizing deltas as complex systems formed by many interacting subsystems. The Pearl River Delta (PRD) serves as a case study to demonstrate the complexity of the built environment as well as the relationships between landscape, networks and urbanization. Using the same region as the case study, Zhao et al. (2018) analyze leisure activities in this megacity region. Douban Event is a child website of Douban where leisure activities and related interests are shared, resulting in potential interactions between physical and virtual spaces. The authors retrieve the urban networks in the PRD based on leisure activities by capturing inter-city activities on Douban. An asymmetric matrix of inter-city network is developed based on focal cities' residents' attention towards other cities. The results reveal a polycentric spatial structure of leisure activities networks, with Guangzhou and Shenzhen being the hub cities in the PRD.

Shifting attention towards 'shrinking cities', Nakamura (2018) explores how to adjust spatial network of transportation infrastructure towards adequate accessibility to the society and the market in the context of long-run population decline. Local agencies are constrained by budget and financial shortage to deliver sufficient public services to landscapes and re-shape their spatial networks. Hence, these regions are challenged by inadequate economies of scale to promote economic development, and the re-organization of market areas is needed. This chapter demonstrates a methodological framework of developing more effective spatial planning and design under such condition. Varol and Soylemez (2018) observe that marginalized border regions have been transformed into spaces of social, economic and political relationship dynamics and interaction in the context of globalization. They study spatial-socio network structures in the west and east borderlands in Turkey. The relational border space defines the border as both a physical gate and the place where geopolitical, socio-cultural and economic forces interact with each other. Border contains all economic, social and spatial flows passing through the borderline.

Last but not the least, the concluding chapter (Liu et al. 2018) summarize the pros and cons within the new urban data environment, highlight the research challenges in the literature and ongoing efforts, and suggest opportunities and next-step directions towards smart and connected communities. The editors especially emphasize the integration of social network and spatial analyses for urban research on conceptualizations, analytics and methods, software environments, and mixed methods towards comprehensive understanding of urban systems. A SWOT analysis is also conducted to identify strength, weakness, opportunity, and threats of such integration.

Acknowledgements Xinyue Ye would like to thank the financial support from National Science Foundation (1416509, 1535031, 1637242, 1739491). Xingjian Liu is grateful for the financial support from the National Science Foundation of China (41501177) and would like to thank the organizers and participants at the 'Future of Urban Network Research' symposium, Ghent, Belgium, 18–20 September 2017, for their illuminating discussions.

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Chapter 2
Planning as Computational Intelligence in Complex Socio-spatial Systems

Shih-Kung Lai

2.1 Introduction

Planning is a set of activities to acquire information and to make contingent decisions for the future. It is also considered as procedures for taking actions. Such a definition of planning is consistent with that of intelligence (e.g., Ghallab et al. 2004; LaValle 2006). Intelligence in the context of planning connotes different meanings (e.g., Mandelbaum 2008), but we define intelligence as computation so they are used interchangeably here. Can these procedures of planning as intelligence be reduced to steps similar to computer algorithms? Systems in which planning takes place are complex in that there are numerous elements interacting with each other forming a coherent whole. Can such systems be described as complex systems capable of universal computation? If the answers to both questions are yes (c. f., Ghallab et al. 2004; Wolfram 2002), then it is possible to model planning effects using simple models, such as cellular automata, and examine the conditions under which making planning is useful. Note that Arthur (2015) argues for complexity economics in which the economy could be thought of as computation. Based on the same logic, we tend to view the city as computation as well.

The chapter is grounded on two assumptions that a city is a discrete dynamical system and that it is capable of universal computation. These two assumptions are based on the fact that there are an increasing number of attempts to model urban spatial evolution through simulations (e.g., White and Engelen 1993) and the hypothesis that systems showing some level of complexity are computationally equivalent (Wolfram 2002). It is well known that systems capable of universal computation are inextricable computationally so that prediction of the behaviors of the systems is impossible. The only way to study such systems is through direct

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X. Ye and X. Liu (eds.), *Cities as Spatial and Social Networks*, Human Dynamics in Smart Cities, https://doi.org/10.1007/978-3-319-95351-9_2

evolution. The two assumptions proposed imply that planning based on forecasts is impossible, or at least difficult, because there is no way we can predict what would happen and do something with it in advance. On the other hand, Hopkins (2001) argues that under the conditions of four I's of decisions in a complex system, that is interdependence, indivisibility, irreversibility, and imperfect foresight, making plans should lead to different, beneficial outcomes. We would argue in this chapter that the two seemingly contradictory arguments can be reconciled through investigating computer simulations of elementary cellular automata. It is well known that socio-spatial systems are complex, and we have proved elsewhere that the four I's are the sufficient condition for complexity and that plans work in such complexity (Lai, forthcoming). An elementary cellular automaton is a one-dimensional cellular automaton with two possible values for each site ($k = 2$) and the transition rule is based on the nearest neighbors ($r = 1$).

Rather than providing the results of the simulations, the chapter proposes a simulation design based on the elementary cellular automata to explore into effectiveness of making plans in a complex system capable of universal computation, and conditions under which making plans are likely to yield benefits for the planner. Section 2.2 depicts why a city can be viewed as a discrete dynamical system capable of computation. Section 2.3 reviews Wolfram's recent work on the simulations of the elementary cellular automata. In particular, how his principle of computational equivalence can help enhance the validity of our simulation design. Section 2.4 introduces our simulation design. Section 2.5 provides some preliminary results and Sect. 2.6 discusses some issues related to realism. Section 2.7 concludes.

2.2 City as a System Capable of Computation

That much has been done recently in simulating urban spatial change suggests that the spatial system of a city can at least be viewed as many agents, fixed in locations or floating in a space, interacting with each other forming a complex system. Most of such work is given different names, including cellular automata (e.g., White and Engelen 1993), agent-based modeling (e.g., Axelrod 1997), and artificial life (e.g., Langton 1989). The theme of such work is that a city can be viewed from the bottom up so that the whole spatial phenomena can be simulated by interacting agents based on simple rules forming complex outcomes. This is equivalent to saying that the city can compute in that given initial configurations or data, the results can be traced definitely through the rules. Therefore, these models of the city are also deterministic dynamical systems.

We are mainly interested in cellular automata, in particular the elementary cellular automata, because of their simplicity in construction and complexity in results. However, most urban spatial simulations based on cellular automata seem to deviate from the original construction of cellular automata. In the original cellular automata (e.g. Wolfram 1994), there is a single set of transition rules in the course of simulation, while in most urban spatial simulations, there may be more than one set of transition rules and the rules become complicated (e.g. Webster and Wu 1999a, b). Regardless, these models seem to assume that urban spatial systems are capable of computation. Lai (2003) investigated deductively the characteristics of urban spatial evolution using the elementary cellular automata, and found that among the 256 transition rules, only eight rules can result in complex structures with semi-lattice structures in the transition graph. He further argued that these deterministic transition rules could give rise to seemingly stochastic phenomena of urban spatial evolution as we observed in our daily lives. But not satisfactory explanation was provided as to how the elementary cellular automata model fits the real urban spatial system.

2.3 Principle of Computational Equivalence

In his recent provocative book, Wolfram (2002) conducted numerous simulations of simple programs, including the elementary cellular automata, to explain persuasively many natural phenomena, including natural evolution and thermodynamics. His interpretation of these simple programs was also extended to explain some social phenomena, such as fluctuations of stock prices. The validity of his theory is yet to be proved, but he proposed an interesting hypothesis: the principle of computational equivalence in that in the natural world, many phenomena of complexity are capable of universal computation and thus equivalent. We take his hypothesis as the basis on which we propose our simulation design and claim its validity. In particular, we argue that since some elementary cellular automata rules are capable of universal computation, such as rule 30, and urban spatial systems are capable of computation, according to Wolfram's principle of computational equivalence, the two systems are computational equivalent. Put differently, ignoring the substances of different systems, the elementary cellular automata can be seen as microcosms of a simplified world capable of emulating other complex systems of computation, including urban spatial systems. By simulating the elementary cellular automata, we should be able to gain insight into the characteristics of the transition rules underlying the evolution of real urban spatial systems.

Consider each cell as a decision situation in which there are only two choices represented by two colors or binary values. A one-dimension cellular automaton with two colors and nearest neighbors can be constructed to represent the evolution of the choices in the spacetime. At time step t, the color of a particular cell in the next time step $t + 1$, is determined by its color at the current time step and the colors of the two nearest neighbors. Assume that the two colors of cells are represented by 0 and 1, forming two possible choices of the decision situation. This simple formulation implies that the choice of a particular cell in the next time step depends on a set of three decision situations. The transition rules specify how the choices of the three decision situations determine the choice of that cell for the next time step. This simple construct can create very complex structures in the evolution of the spacetime. According to the principle of computational equivalence, a city viewed as a discrete dynamic system, can also evolve into spatial patterns that can be emulated by the elementary cellular automata.

2.4 Planning as Computation in a Universal System

Making plans requires mental, analytic investments. Considering contingent, related actions, guessing moves of others, measuring uncertainty, and making forecasts all require investments in gathering information. We assume for the present purposes that the underlying mechanisms of these mental investments are indistinguishable from the notion of computation, and that the planner does not know the rules based on which the system of interest evolves. Put differently, the planner makes plans according to a logic different from the rules underlying the system evolution. This assumption is plausible because in reality planners do not have the complete knowledge of how the spatial change of the city takes place. They make forecasts and plans and act accordingly depending on the information gathered, not the complete knowledge of how the system works. Therefore, there are two types of logic: the logic of how plans are made and the logic of how the system evolves.

The value of a plan depends on the cost of making the plan and the benefits it might yield compared to that without the plan (Hopkins 2001). The benefits of a plan can be calculated as the difference through a decision tree between the expected value of an optimal path with the plan and that without the plan. This notion is equivalent to the calculation of the value of sample information in any management science text (e.g., Anderson et al. 2003). Schaeffer and Hopkins (1987) applied the Bayesian approach to describe how a land developer manipulated right during the investment process to yield profit. This approach can be used for the present purposes to describe the logic of making plans in the elementary cellular automata. Consider a spacetime plot of ten cells and ten time steps based on rule 30 of nearest neighbors as shown below. The initial state is given randomly where 0 and 1 represent two possible states for a cell.

In order to apply the Bayesian approach to the simple system, the state of the system at each time step is given a benefit index, which could be the mapping between the states and a set of integers. The greater the index is, the more self-organized the state is, and the more preferred the state is. This index of self-organization can be measured by entropy (Wolfram 1994). The probability of the state of a cell to be zero or one at a particular time step can be evaluated through the Bayesian theorem based on the values of the state at previous time steps. Given the planning logic, we can set the number of time steps backward before the current time step for calculating the Bayesian probabilities as the information gathering scope. We can also set the number of time steps forward after the current time step for predicting the Bayesian probabilities as the planning horizon. Making a plan according to this definition is equivalent to changing the values of the cell states based on the results calculated from the Bayesian theorem. In this way, the logic of planning is blended into the system evolution.

Time	State
1	1001101000
2	1111001101
3	0000111000
4	0001100100
5	0011011110
6	0110010001
7	0101111011
8	0101000010
9	1101100111
10	0001011100

Similar to the self-organization index for a particular state of the system, the effects of planning can be measured by comparing the global index as defined by entropy for the spacetime plot with planning to that without planning. Information gathering scope and planning horizon are parameters in the simulation design that we can manipulate in order to evaluate the sensitivity of the system behavior to the amount of investment of planning. The greater the information gathering scope or planning horizon is, the greater the amount of planning investment. All this can be done on the Mathematica platform (Wolfram 1999).

Based on this simulation design, we can test whether the four conditions proposed by Hopkins (2001) are sufficient for planning to be effective. That is, we can test the following four hypotheses:

Hypothesis 1 If the decisions in the system are interdependent, then planning may yield benefits.

Hypothesis 2 If the decisions in the system are indivisible, then planning may yield benefits.

Hypothesis 3 If the decisions in the system are in part irreversible, then planning may yield benefits.

Hypothesis 4 If the planner in the system has imperfect foresight, then planning may yield benefits

It is possible to test these hypotheses in the simulation design because in the elementary cellular automata, decisions (or states of the cells in the cellular automaton) are interrelated; the states of the cells at one time step are partially irreversible in time; actions are indivisible and thus discrete in the spacetime; and unpredictability and thus uncertainty defies perfect foresight. We can also expect that making plans defined here does not affect the system's fundamental characteristics, including universality.

2.5 Preliminary Results

It is difficult to make forecasts in the elementary cellular automata systems, i.e., to predict the value of the state of a particular cell at a particular time step. This is because the effects of the rules propagate throughout the system after some time steps, making forecasting difficult. In particular, the 'cone' where the values of the states are determined by the initial states shrinks at the speed of two cells a time step, and vanishes eventually. If we view the spatial evolution of a city as a cellular automata model, this observation is consistent with the fact that urban spatial change is extremely difficult to predict. Without knowing the initial condition *and* the transition rules, it is impossible to acquire the complete knowledge of how the system works. Unfortunately, in reality we usually do not know both, and complete forecasting is impossible, or at least prohibitively costly. The type of research proposed in the present chapter could however shed some light on resolving such difficulty.

Entropy has long been an interesting topic for planning theorists (e.g. Wilson 1970). In modeling land use/transportation activities, maximizing entropy is treated as the objective function, implying that without intervention, agents should find themselves in locations so that the aggregate patterns approach random, chaotic distribution. Planning, in contrast, seeks order so as to minimize entropy. Therefore, maximizing entropy is equivalent to assuming that the system lacks planning, which is not true in most real urban developments. The proposed simulation design blended planning logic into the underlying rules of the elementary cellular automata evolution so it is close to reality. Entropy can be used, however, as an index of the degree of self-organization. For example, low entropy means agents are less randomly distributed, and are thus highly self-organized. In the simulation design, we assume self-organization is a desired characteristic of the distribution pattern of the system because it might enhance computation capacity of the system and make the system more capable of universal computation. For example, agglomerative economy is a type of self-organization, and is a result of interactive agents maximizing self-interests.

According to Wolfram (1994), there are four classes of the elementary cellular automata rules. Class 1 rules quickly result in homogeneous states. Class 2 rules fix to a periodic pattern. Class 3 rules create chaotic patterns. Only Class 4 rules are capable of universal computation evolving into complex structures. We argue that urban spatial change can be thought of as cellular automata models of Class 4 rules because none of the other three classes of rules can characterize the spatial evolution of a city. Universal computation is also a fundamental characteristic of urban spatial change, which cannot be modified regardless of planning.

Given the above conceptions and the simulation design, we conducted a set of simulations using Rule 110 as defined by Wolfram in one-dimensional cellular automata. Rule 110 is one of the simplest 256 elementary rules that is capable of universal computation. More specifically, it specifies that $000 \rightarrow 0$, $001 \rightarrow 1$, $010 \rightarrow 1$, $011 \rightarrow 1$, $100 \rightarrow 0$, $101 \rightarrow 0$, $110 \rightarrow 1$, $111 \rightarrow 0$, where the three values on the left hand side of the arrow sign are the initial states of the triplet of cells and the value on the right hand side is the state of the central cell in the triplet at the next step after transformation. We considered the 100 × 100 spacetime plot, meaning that there are 100 cells evolving over 100 time steps. The initial values were assigned randomly to the 100 cells at time step zero. Planning as computation was defined by the following Bayesian rule:

$$P(S_i/X) = \frac{P(X/S_i) \cdot P(S_i)}{\sum_{i=1}^{n} P(X/S_i) \cdot P(S_i)} = \frac{P(X/S_i) \cdot P(S_i)}{P(X)} \tag{2.1}$$

where

S_i are the possible states of each cell for i = 1, 2,…, n,
X is the sample information gathered through planning,
$P(S_i)$ is the prior probability,
P(X) is the probability of the sample outcome,
$P(X/S_i)$ is the probability of the sample outcome under the condition that S_i obtains, and
$P(S_i/X)$ the posterior probability.

In the simulations, we considered two states: zero and one, and when $P(S_i/X) \geq 0.5$, the value of the cell becomes one. If $P(S_i/X) \leq 0.5$, the value of the cell becomes zero. In addition, we considered three regimes of planning: time-driven, event-driven, and random planning. The *time-driven* system requires that planning take place at a particular time step within a fixed time interval. The *event-driven* system demands that planning be undertaken when a pre-specified event comes about, which is the condition that at any time step if the number of states with values of zero is not equal to that of one. The *random* system simply requires that planning take place at any time step in a random fashion.

In order to assess the evolutions of the universal system under the three regimes of planning, following Wolfram (1994), we computed the spatial set entropy for each simulation given as below:

$$S^{(X)}(X) = -\frac{1}{X} \sum_{j=1}^{|A|^X} p_j^{(X)} \log_{|A|} P_j^{(X)}, \tag{2.2}$$

where $P_j^{(X)}$ represents the probability that over the length of X, all the neighboring cells have the outcomes $|A|^X$.

In other words, in a sequence of cells with the length of X with all neighboring cells classified into $|A|^X$ the frequency distribution can be calculated by P(X) = $\{p_j\}$. The distribution remains the same in the case of a circular system. Wolfram (1994) applies set dimension to estimate the density of the overall structural evolution to indicate the degree of information content. In the case of an infinite number of cells, the degree of information content is approximately equivalent to the spatial set entropy as shown below:

$$d^{(X)} = \lim_{x \to \infty} S^{x}(X) \tag{2.3}$$

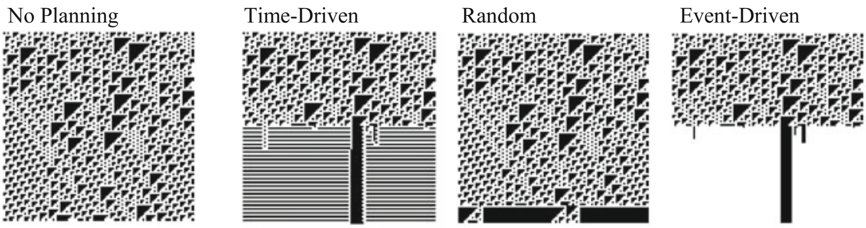
Note in (3) that when the probability that all state occurs remains the same, $d^{(x)}$ is equal to one; if the states of all the cells are the same (homogeneous structures), then $d^{(x)}$ is equal to zero. In our experiments, the degree of information content was used as a measurement of effectiveness of planning to examine whether planning resulted in reduction of spatial set entropy and set dimension.

In addition to three regimes of planning, two other control variables considered in the simulations were planning intervals and planning scopes. Planning intervals indicate the fixed number of time steps between those at which planning takes place in the time-driven system, whereas planning scopes specify the number of neighboring cells considered in planning behavior. Since the planning intervals were increased incrementally up to time step 50 and the planning scopes up to 25 neighboring cells on each side of a central cell, there were totally 25 × 50 = 1250 simulation runs for each regime of planning, which in turn resulted in 3750 simulation runs.

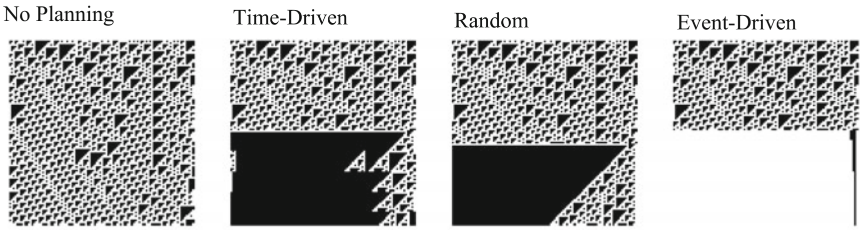
A multiple regression analysis was conducted considering information content as the independent variable and all other control variables as the dependent variables, including planning scope, planning interval, and planning regime. The results showed that an increase in a unit of planning scope reduced information content in 0.12 units and an increase in a unit of planning interval increased information content in 0.212 units. The more information content is, the less effective planning performs. As to the three regimes of planning, the time-driven system was less effective than the event-driven system by 0.236 units; the random system was less effective than the event-driven system by 0.798 units; and the event-driven system was more effective than the time-driven and random systems by 0.236 and 0.798 units respectively. In short, the event-driven planning was most effective in reducing information content and entropy. A sample of illustrations of the simulation runs is provided in Fig. 2.1.

2.6 Discussion

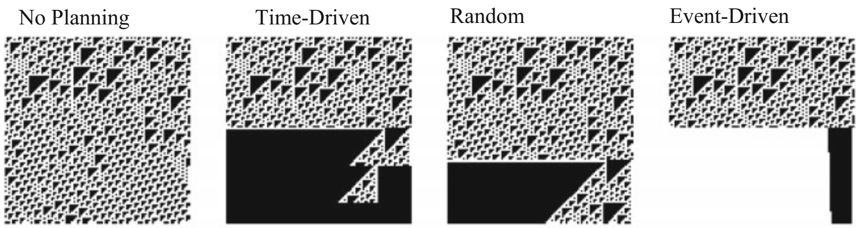
The 1D CA model presented here is an abstract one capable of universal computation and planning as intelligence intervenes the evolution of the system. The model represent, to some extent, the real urban dynamics in that the 4 I's of urban development decisions as observed by Hopkins (2001) are well characterized by the model: interdependence, indivisibility, irreversibility, and imperfect foresight. Interdependence can be thought of as the propagating principle of the cells in time and space so that a change in the state of a cell would cause the changes of the states



(a) Planning interval is two time steps and planning scope is two cells



(b) Planning interval is 13 time steps and planning scope is 25 cells



(c) Planning interval is 20 time steps and planning scope is 19 cells

Fig. 2.1 A sample of illustrations of the simulation runs

in other cells over time. Indivisibility can be characterized by discrete unites of time and space. Irreversibility can be modeled by the second law of thermodynamics of the 1D CA system, which is known to be irreversible. Imperfect foresight can be represented by the unpredictability of the evolution of the system.

To attain realism, the 1D CA model proposed here can be explained in the context of urban change. For example, the zero- or one- state of the cells could be explained as "developed" or "undeveloped" spatial units as proposed by Lai (2003). In addition, the model could be extended to be coupled with economic theory to explain economic behavior of spatial change. For example, Caruso et al. (2009) extends Lai's (2003) formulation by using rules derived from economic theory in the 1D CA model to bring time dependence and distance dependence of urban structures to explain how discontinuous spatial patterns would emerge.

2.7 Conclusions

It is well known that socio-spatial systems are complex, and we have proved elsewhere that the four I's proposed by Hopkins (2001) are the sufficient condition for complexity and that plans work in such complexity (Lai, forthcoming). Urban spatial change can be modeled as cellular automata simulations. Effects of planning can be examined through such simulations. The simple programs of the elementary cellular automata can serve as a metaphor based on which urban spatial change can be studied. The principle of computational equivalence implies that this approach is plausible because these simple programs capable of universal computation can emulate cellular automata models of urban spatial change. In order to incorporate planning behavior into the simple programs, we need however to distinguish between the logic of planning and the underlying rules based on which the elementary cellular automata systems evolve. The simulation design proposed here intends to achieve this aim by testing four hypotheses each of which with a condition where making plans is likely to yield benefits. Insight can be gained through such simulations as to when making plans is useful, how it affects system behavior, and whether it works. Preliminary results imply that increase in planning investment in terms of shortened planning intervals and widened planning scopes enhances planning effectiveness, whereas the event-driven system is more effective than the time-driven system.

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Chapter 3
Cities as Spatial and Social Networks: Towards a Spatio-Socio-Semantic Analysis Framework

Wei Luo, Yaoli Wang, Xi Liu and Song Gao

3.1 Introduction

Cities have become highly interconnected techno-social systems embedded with intricate and complicated spatial and social networks (e.g., transportation, telecommunication, and internet). A variety of flows (e.g., daily commuting, information, and disease spread) are disseminated through these complex networks (e.g., road networks, human contact networks) within cities. Batty (2013) proposed to view cities as systems consisting of points, flows, and networks in order to understand the underlying structure of cities beneath the urban form. Traditionally, spatial analysis concentrates on the identification of spatial patterns and physical movement flows (e.g., disease, crime, and travel) from the perspective of geographical locations (Bailey and Gatrell 1995). However, physical movements are also driven by social network factors that have been overlooked (Andris et al.

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X. Ye and X. Liu (eds.), *Cities as Spatial and Social Networks*, Human Dynamics in Smart Cities, https://doi.org/10.1007/978-3-319-95351-9_3

2018). Social network drives human interactions that induce travel movement (Crandall et al. 2010; Yuan et al. 2012b; Bapierre et al. 2015; Wang et al. 2015). For example, Cho et al. (2011) found that human short-range travel, which is periodic both geographically and temporally, is not influenced by social network structure; while long-distance travel is more impacted by social network ties. Such patterns have called on the necessity of the marriage between geographical and social network space (Geo-social space), which contributes to further insights into the interactive evolution in both spaces (Batty 2003). Both Luo and MacEachren (2014) and Andris (2016) thoroughly discussed the intimate connections between the two spaces and described the relevant techniques that allow for a combined spatial analysis and social network analysis.

Geo-social space provides new opportunities to explore the complex interactions within cities, but such integration is still short of one important component—semantic space. Semantics study the logic aspects of meanings behind behaviours and phenomena, such as motivation, sense, reference, and implications. It contains at least two levels: *conceptual* and *formal*. Conceptual semantics focus more on the cognitive aspects while formal semantics lie in the logical reasoning perspectives. In urban studies, the essential role of semantics is to develop deeper insights into the motivations of spatial behaviors (Yan et al. 2011; Ying et al. 2011). For example, similar travel patterns and activity spaces can be driven by semantics (i.e., the reasons and motivations behind such activities). Though social network can reinforce the similarity of two or multiple individuals' travel behaviors, it should also include the travel aims (i.e., what you do rather than where you go) as well. Semantics also explains the functionality structure of cities, and why different parts of a city are connected. For example, two relatively far-away regions in a city may be closely connected due to commutes of certain groups of people. In public health, semantics explains how an infectious disease is transmitted because of certain types of disease (e.g., influenza) and human activities, so it determines human transmission network over geographical space. In social segregation, semantics explains why certain activities are to be conducted collectively instead of individually, so it also overcomes the coincidence by chance. Recent research has found that social network is associated with spatial overlap (Luo et al. 2011; Radil et al. 2013; Luo et al. 2014), but it is hard to conclude that spatial/social connections are always associated with semantic similarity. The ability to explain spatial-social behaviors makes semantics an irreplaceable complement to the geo-social systems. Semantics distinguishes network analysis from abstract network analysis by mathematical studies and network analysis embedded in urban context by geographical studies.

The interconnections of spatial, social, and semantic domains are not yet well recognized, let alone the deeper theoretical integration of geography, social network, and semantics. Knowledge into the integration of geographical, social, and semantic space is far less than sufficient due to the lack of recognition on its importance, restricted access to datasets, and insufficient methods of analysis. In order to fill the gap, this work proposes a novel theoretical framework for the integration of spatial, social and semantic spaces for the urban study based on the discussion of four diverse but inherently connected research domains: urban transportation, urban structure and land use, geo-social segregation, and infectious disease transmission and control. The framework aims to improve urban studies through the spatial-socio-semantic integration. We also summarize the available datasets and discuss their advantages and disadvantages in studying the interaction among geographical, social, and semantics spaces. We conclude the vision paper by discussing potential future research challenges for advancing the integration of spatio-socio-semantic spaces.

3.2 Literature Review

The urgency of the integration of spatial, social, and semantic aspects emerges from the observations and reflections in existing works from different application domains. We will discuss four particular domains in the context of urban studies in detail, i.e., transportation, spatial and social segregation, urban structure and land use, and air-borne infectious disease transmission and control. These four domains share a common characteristic that is human movement and interactions in which a combined perspective of spatial, social and semantic analysis will be introduced.

3.2.1 Transportation

The interaction between human travel and social network has been realized in recent years. Presumably, social network contacts are possible to indicate similarity in travel behaviors in addition to random spatio-temporal co-occurrence, because they may travel together for the same activities, or have similar daily routines. However, spatial movement, i.e., the trajectories in particular, is not equivalent to travel behaviors, of which the latter conveys more the semantics behind a spatial location, e.g., the function and service provided by a place (Adams and McKenzie 2013; Tuan 2013; Liu et al. 2015). For example, the sequence of activity types (work—grocery, shopping—home) to be conducted during a day may be similar while the spatio-temporal trajectories different, which highlights the importance of activity-based travel analysis (Bhat and Koppelman 1999; Wang et al. 2016). Also, people showing up at similar places or exactly the same place may conduct different activities. Many existing works on analyzing the *stops* of movements (e.g., Miklas et al. 2007; Eagle et al. 2009; Crandall et al. 2010; Bapierre et al. 2015; Hu et al. 2015; Toole et al. 2015; Wang et al. 2015) focus on the association between social network and location similarity rather than travel behavior similarity. The spatial similarity of social network contacts has also been considered in *trajectory*-mining to infer social connections by measuring geometrically the spatio-temporal overlapping between two trajectories (Li et al. 2008; Zheng et al. 2011). However, this is yet identical to travel behavior similarity between persons beyond simply spatio-temporal coincidence. Two overlapped trajectories are not guaranteed to infer social interaction to a great extent due to random coincidence, unless semantic information is infused to attest that people have similar travel aims or activities that might indicate shared travel activity.

Locations actually are not equally effective as the indicator for social network since some locations are overall more popular and one location can be multi-functional (Cranshaw et al. 2010; Pham et al. 2013). The challenges come from many technical difficulties of a comprehensive socio-semantic trajectory analysis. Parent et al. (2013) did a thorough survey on semantic trajectory analysis, specifying the importance of spatio-temporal semantics for travel behavior analysis for stops (e.g., Liao et al. 2005; Li et al. 2008; Xie et al. 2009), movements (e.g., Zheng et al. 2010; Xiao et al. 2015), individual and collective trajectories, and many methods. It is pointed out that no precise definition of trajectory behavior is reached. Trajectory behaviors can be an individual's selection of travel mode on different travel segments, the travel schedules/activities of a person, or a group of people's convergence to a same destination, bundled travel, to name a few. A thorough understanding of travel behavior depends on the (spatio-temporal) granularity and richness (how many details) of semantics collected on that geometric segment. Some trajectory data only contains geographic location and timestamp, while others contain travel mode, the number of co-travellers, and the activities at the destination. Moreover, there is still inadequate work to find the linkage between semantics of travel and stops. For example, the association remains unknown between the frequency of travel mode choice and certain travel aims.

3.2.2 Spatial and Social Segregation

Spatial and social networks are intertwined. Although some studies on the information age have argued for "the death of distance" in the cyberspace (Cairncross 2001), scholars still find that distance plays an important role in virtual space, e.g., human telecommunications and social media platforms on the Internet (Ratti et al. 2010; Han et al. 2015). Geo-social network analysis facilitates the understanding of social behaviors that relate to both the structure of the network and the relative location-context in physical space. For example, Radil et al. (2010) investigated the network structure and geographical context of gang violence in Los Angeles, showing the effectiveness of spatialized social network analysis that allows for real-time examination on social actors' positions in spatial and social networks simultaneously. The analysis identified gangs that are similarly embedded in the territorial geography and positioned in the rivalry network. Underlying spatial structures can be revealed by social network analysis as well. Thiemann et al. (2010) analyzed a human travel network represented by the circulation of banknotes, finding that the effective boundaries partially overlap with existing administrative borders and also physical barriers like rivers and mountains. Also, by applying a network-partitioning algorithm on a large telecommunication database in Great Britain, Ratti et al. (2010) also found geographically cohesive telecommunication regions that correspond remarkably well with administrative regions. Similarly, Gao et al. (2013b) employed a modularity-based network community detection method to successfully identify urban phone-call interaction patterns in both cyberspace and physical space; they also discovered anomalies relating to urban functional regions and human activities. Network community structure in the cyberspace can also be taken as proxies for the society. Walsh and Pozdnoukhov (2011) found a clear phone-call communication divide between the south and the north in Dublin, Ireland, where there is also a social divide between these two regions separated by a physical barrier—the River Liffey. In another study in Senegal, Gao et al. (2015) discovered that both digital divide and physical divide existed in a developing country via large-scale mobile phone data analysis. Those new datasets generated from emerging information communication technologies usually have high spatiotemporal resolution but lack rich individual semantics. Traditionally, social segregation patterns are revealed based on the analysis on demographic data, household income and transportation survey data. The integration of spatio-social-semantic spaces will provide a more holistic perspective for understanding geo-social segregation and environmental factors.

3.2.3 Urban Structure and Land Use

Although cities are usually planned and designed through a top-down approach, human movement is able to show how cities are actually used by their residents. Scholars tried to infer the function of regions from the complex travel flow system in cities since 1970s (Goddard 1970). Current literature mostly focus on revealing the sub-regional structure and/or polycentric structure based on various human-mobility related data (Roth et al. 2011; Cranshaw et al. 2012; Yuan et al. 2012a; Liu et al. 2015a; Sun and Axhausen 2016), as well as temporal changes of urban structure and the influence on people's travel behaviors (Zhong et al. 2014; Sun and Axhausen 2016).

Social networks reflect urban structures on a more 'intangible' perspective. Similar to spatial networks, we can also get a sub-regional structure of cities based on social networks. This structures emphasize more on social divide instead of physical divide (Gao et al. 2015). Social networks also affect the urban space by influencing the interactions among people and social communities. For example, cross community dyads may generate new travel flows to connect places that have few interactions (Andris 2016). However, spatial and social connections alone cannot tell us 'why' certain urban structures are formed. While spatial and social networks reflect urban structure and land use based on spatial/social flows and activity intensities of people, semantics provide explanations for these underlying patterns. By enriching the semantics of urban flows, we are able to have more precise understanding on urban structure and land use, which can aid the policy making process. For example, if we know that two areas in a city are connected by the commuting behaviors of home-work separated people, we would be able to design and plan related facilities in cities to assist or reduce their commuting time and cost. Some studies are trying to incorporate semantics into social and spatial analysis: they use point of interests (POI) data to infer trip purposes (Gong et al. 2016) or area functions (Yuan et al. 2012a). It is also possible to link topics mined from Twitter to trajectories by location and time (Kling and Pozdnoukhov 2012). The activity transitions between origin and destination of trips have also been used to improve land use inference precision (Liu et al. 2016).

3.2.4 Air-Borne Infectious Disease Transmission and Control

Cities play an important role in fostering and amplifying the transmission of air-borne diseases (e.g., influenza) because of dense human contacts within cities (Meade and Earickson 2005) and both intra-city and inter-city movements (Grenfell et al. 2001). Infectious disease transmission is a mutual interaction of social and spatial relationships among individuals and locations (Bian 2004). Spatial heterogeneity in the population distribution determines the spatial layout of disease transmission while the frequent city-wide travel of individuals contribute to the temporal sequence of transmission (Mao and Bian 2010b). A travel-based vaccination strategy (i.e., prioritizing the frequent city-wide travelers) is preferable for a population with a large number of intercommunity travelers in urban areas (Mao and Bian 2010a). Guo (2007) discovered sub-regional structure within cities based on human mobility data, which can provide valuable insight for designing effective pandemic control measures. Luo et al. (2018) further found that vaccination strategies considering the sub-regional structure within an urbanized area can lead to a significant reduction of epidemic size because they can prevent spread to other regions.

Infectious disease simulation models help understand disease transmission mechanism in both geographical and social spaces, whereas internet and social media platforms such as Twitter open the new way to monitor the disease outbreak. Google Flu Trends (GFT) rely on flu-related search terms from which the estimated prevalence is calculated based on both semantic data mining and computer modelling have exactly matched the surveillance data from the Centers for Disease Control and Prevention (CDC) (Butler 2013). Compared to CDC, GFT can span much larger population and deliver faster estimates, but significantly overestimated peak flu levels. Similar research have been conducted using tweets with a mention of flu indicators and found a high correlation with CDC data (Aramaki et al. 2011; Lampos and Cristianini 2010). Thus, such new flu-tracking techniques can complement the CDC data to help build regression models to predict influenza-like illness (ILI) activity data from "sentinel" medical practices collected by CDC (Achrekar et al. 2011). The geolocation of tweets and early prediction of influenza outbreak are most important aspects to reduce impacts and help authorities plan their response in time critical situations.

The above discussion of four domains demonstrates that though semantic analysis has the potential to enrich urban studies, most research only focus on geo-social perspective with little or implicitly semantic components. Semantics can reveal human purposes and behaviors from both cognitive and logical reasoning perspectives, whereas geo-social analysis focuses more on the observed human interaction and movement patterns in the urban context. Semantics would come underneath as the latent information to explain the observed patterns in both geographical and social spaces, but the integration of both geo-social and semantics analysis is still limited. Thus, in the following section, we propose a combined framework of spatial, social and semantic analysis that is essential to future urban studies.

3.3 Conceptual Framework

Here, we propose a spatio-socio-semantic conceptual analysis framework to understand city-related topics from a comprehensive perspective. The framework is focused on the 3-*S* (spatio-socio-semantic) aspects in a layered manner that marks their different roles in the system. In the spatio-socio-semantic analysis framework (Fig. 3.1), spatial and social networks are closely intertwined in city systems as geo-social systems (Luo and MacEachren 2014). While spatial behaviors are conventionally the direct observations of geography studies, social network has been gaining attention as it is both the driver for and the result of spatial behaviors. Social connections between people have strong influence on their decisions about when and where to travel and stay, which formulates the egg-and-chicken problem on the mutual interactions between spatial and social behaviors. People travel for social purposes when they build up new social links via spatial encounter. Thus, modeling people's behaviors in a connected network instead of isolated individuals is a necessity to study cities.

In addition to the duo of spatial and social aspects, semantics come underneath as the latent information to explain their behaviors in both geographical and social spaces. Semantics provide information, such as activity types of people, to enrich the geo-social models for spatial phenomena. Semantics infer the activity behind people's spatial choices and the functions of places, transform coordinates of trajectories/spatial flows into certain types of activities, and remark locations in space with meaningful labels of functions of cities. While semantics are usually implicitly recognized, we are proposing a way to explicitly express and analyze semantics in geographical studies. For example, Gao et al. (2013a) proposed novel analysis operators of place-based GIS joins according to the semantics in order to complement traditional geometric reference systems that include coordinates, distances, topology, and directions. Specifically, these analysis operations need to take geographical background information and/or human cognition and descriptions on places to decide which point should be joined to which region. Additionally, semantics extract the general behavioral patterns in space regardless of specific

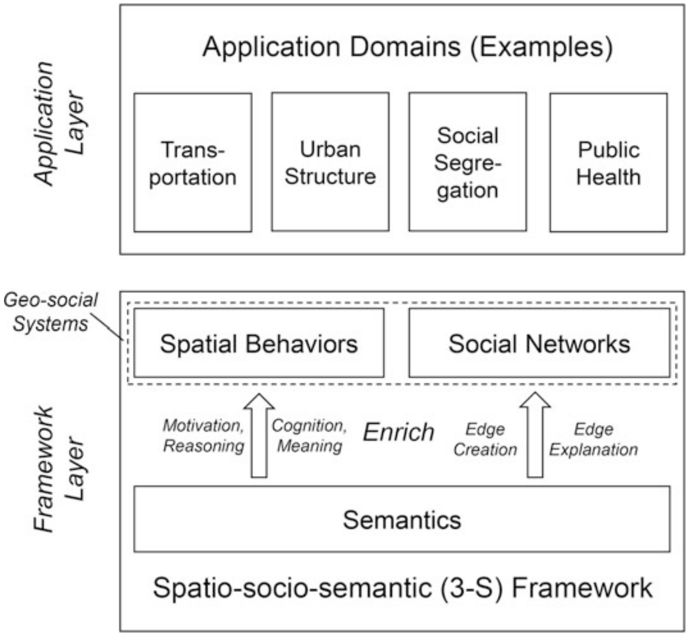

Fig. 3.1 The spatio-socio-semantics analysis framework. While spatial and social perspectives are closely intertwined as geo-social systems, semantics can enrich the systems by providing information to explain people's spatial behaviors and the aggregated patterns in cities

geographic coordinate locations. This is a recall of the importance of non-spatial attributes attached to spatial entities. For instance, the pattern of travel flow in the morning is usually inbound to city center for work, and outbound from city back home is widely observed in different cities. The semantic knowledge is not geographically constrained. Such non-spatial information helps to explain spatial behaviors from individual and collaborative (i.e., multiple persons') perspectives. The daily travel pattern induced by *activity* regularities is of a higher hierarchical level to the pattern detected from *location-visiting* regularities in space. The study of the activity regularities potentially contributes to activity-based travel analysis (e.g., Axhausen and Gärling 1992; Bhat and Koppelman 1999; Wang et al. 2016). The disease dispersion in space is likely to have similar spatial pattern regardless of particular geographical locations. For example, air-borne disease outbreak tends to spread from local growth to long distance transmission within cities (Mao and Bian 2010b) or from large 'hub' cities to smaller 'satellite' towns (Grenfell et al. 2001) because of human spatio-temporal hierarchical travelling patterns.

Rather than an independent methodology, the proposed framework works as an add-on to existing methods and models. Current methods, e.g., statistical analysis, data mining, simulations, and other computational models are feasible, but should bear the three factors of spatial, social, and semantic together. Spatial factor (including both geographical and virtual space) is quantified according to the specific study, e.g., range of an activity space, overlap of trajectories, the distribution and range of detected communities, and the affected area by a disease. Social network aspect is usually measured as the connection intensity between pairs of people, which can be represented by, but not limited to, cell phone call time duration, the number of calls or messages, and the number of shared friends. Semantic factor exists throughout any geographical phenomena, but was not explicitly analyzed in the past in geographical studies.

Semantic analysis in spatial studies is not restricted to such as text-mining or natural language processing, or semantic trajectory mining. It is more about understanding spatial processes from behavioral perspective rather than pure geometrical perspective. For example, in travel behavior analysis, knowing the type of activities can complement knowing just the locations of origin and destination; in urban structure and land use, knowing more about people's behaviors and ideas at certain places can enhance our recognition of place and space; in social and spatial segregation, knowing the type of flow (e.g., commuting flow or goods transport flow) and the underlying land use is better than simply the directions and geometric lengths of movements; in public health domain, knowing the type of disease as well as its transmission properties, and the type of activities that are more vulnerable to such transmission is better than only the spatial pattern of disease breakouts and dissemination.

Note that semantics also exist in social factors. The background information on the type of social link (e.g., friendship, phone call), the temporal stamps of link construction and maintenance, and other attributes all belong to semantics. A comprehensive framework of analysis is to bring generality into the duo-analysis of spatio-social interaction, the generality represented by semantics that seemingly diverse phenomena in particular scenarios may share common rules. The suggested way is analyzing spatio-social processes based on genres, e.g., genres of flows, of activities, of diseases, of land uses, of link types, of connection intensity. For example, infectious disease is transmitted from one person to another through direct or indirect contacts. The type of disease determines human contact network in which the type of human activities in terms of both geographical and social spaces are more vulnerable to such transmission. Chang et al. (2016) mapped HIV prevalence among people in agrarian, trading, and fishing communities in Rakai, Uganda, in which HIV prevalence shows substantial heterogeneities with the highest prevalence in fishing communities. In this way, findings in one geographical area are comparable and maybe transferrable to another area. Particular methods are contingent on specific fields.

3.4 Data Sources

The biggest challenge involved in urban related research from an integrative spatio-socio-semantics perspective would be the requirement of high-quality spatiotemporal datasets with semantics information. A combination of traditional data collection approach (e.g., households survey) with increasingly social-technological approach (e.g., location-based social media) to collect individual travel, social interaction behaviors, and semantic background information (e.g., tweet content) could be a potentially good source to tackle those challenges.

Current data collection approach to capture spatio-socio-semantic information relevant to urban studies include surveys, mobile devices, large scale human interaction simulation models, socio-technological networks (e.g., location based social media data), and sensor network (Table 3.1). Each of these approaches has advantages and disadvantages to represent geographical, social, and semantic aspects for different urban related research domains. Traditional survey approach has detailed semantic information (e.g., activities for travels) and social interactions relevant for disease transmission, but is often limited by an inherently low spatio-temporal resolution and a small number of surveyed individuals. The use of mobile devices can help to generate an ideal sample of social networks of the whole city based on people's reciprocal call patterns with high spatial resolution, but it does not provide any semantic information. POI provides information on the geographical location including details of semantic features (e.g., business, leisure). Associating POI data with individual trips generated from survey data or mobile devices, semantics of spatial flows (Alvares et al. 2007; Gong et al. 2016) and the nature of a place could be inferred (McKenzie and Janowicz 2015). However, the representativeness of such datasets is not guaranteed since it only shows activities in certain contexts. Daily activities that take a majority of time fall into the shortage of data.

While large scale human interaction simulation models with census data can provide human travel and interaction information for transportation and disease research, they cannot capture the spatio-temporal resolution for disease research and can only provide limited semantic information (e.g., demographic information) for both transportation and disease research. Socio-technological networks that can provide large and long-term datasets on social interactions and semantics information on each individual have been used to infer the function of that place and thus potential travel demand (e.g., Yang et al. 2014; McKenzie and Janowicz 2015), the latent events that triggered certain travels of people (Kling and Pozdnoukhov 2012; Coffey and Pozdnoukhov 2013), and human health behaviors in the virtual space (Lampos and Cristianini 2010; Aramaki et al. 2011). However, socio-technological networks suffer from the low temporal resolution issues for both disease transmission and transportation research, as well as low spatial resolution issues for disease transmission research. Socio-technological networks also require advanced text-mining to filter out space-related semantics (Imran et al. 2016a). Sensor network is the only approach which can capture perfect spatial resolution for human interaction that are transmitted through the close contact route, but cannot provide any semantic information for privacy concerns. There are many non-behavioral datasets, e.g., land use data, demographic dataset, which can be used to provide spatial or semantic context to complement the above datasets on human behaviors.

We can see the advantages and disadvantages among different datasets when studying urban research. An ongoing project Future Mobility Survey in Singapore

Table 3.1 Pros and cons in terms of spatio-temporal, social, and semantic aspects among six data collection methods.

Data collection	Spatial/temporal resolution	Social interaction size	Semantic richness	Example
Survey	Spatial: low temporal: low	Small	Limited	Questionnaire
Mobile device	Spatial: high temporal: high during call; low in break	Large	No	Phone call records
Socio-technological networks	Spatial: depends on domains temporal: low	Large	Enough	Twitter, Facebook check-in; POI database (e.g., Yelp)
Large-scale simulation models with census data	Spatial/temporal: depends on domains	Large	Limited	Simulation results
Sensor network	Spatial: high temporal: high	Small	No	Radiofrequency identification devices (RFID) (Cattuto et al. 2010)
Supplementary database	Spatial/temporal: depends on domains	No	Enough	Land use database; demographic census

Data resolution, size, and richness in terms of spatial, social network, and semantics are application dependent, so several descriptions (e.g., enough, limited) are ambiguous classification

can be very helpful to integrate spatio-socio-semantics aspects for transport modeling purpose. The Future Mobility Survey (FMS) is a smartphone-based prompted recall travel survey. It records the travel mode, the number of people who travel together, and activities at the destination of travel, which are all potential resources for inferring travel patterns rather than simply geographic locations. Travel patterns for different activities may be varied from solo travel to group travel. The background information with enriched semantics thus will be able to facilitate deeper insight into spatial movement flows.

3.5 Discussions and Challenges

The integrated spatio-social-semantics framework can help to explore several interesting research areas including but not limited to: (1) understanding geo-social dynamics in shaping neighborhoods with mixture of demographic characteristics (race, income, social status) and the impact of people's semantic activities;

(2) studying human mobility patterns at different spatial scales with the consideration of both geographical context and social contacts; (3) investigating the complex relationships among social segregation, urbanization, human mobility, and public health. Our analysis of the literature provides several potential research directions for further investigation of spatio-social-semantics framework. We conclude this review paper by highlighting several core challenges that will require interdisciplinary efforts to meet.

Addressing privacy issues when integrating semantic analysis into spatio-social analysis. Given that semantic analysis usually happens on a very detailed level, blending semantic analysis with spatio-social analysis puts the difficulty in collecting data and privacy issue more on the spot. Current social network information is collected either in a passive manner as by mobile phone calls and GPS trajectories, or in a voluntary manner as by location-based social networks (LBSN). The former usually yields higher spatio-temporal resolution but lacks semantic or social information, while the latter conveys ampler semantic and social information but is biased by selective occasions (e.g., people only post for certain purposes rather than continuously). Daily activities that take a majority of time fall into the shortage of data category. Dashdorj et al. (2013) enriched semantics of mobile phone dataset by integrating POIs drawn from open geographical data and given time to day. The low spatial resolution of cell phone data, nevertheless, is not resolved. That being said, it is capable of demonstrating intra-urban dynamics at an aggregated level rather than a detailed level. The voluntary data is contingent on the contributors' willingness and agreement, which brings up concerns of data quality as any type of volunteering geographic information (VGI) may do, as well as the urgency of improving privacy protection.

Addressing spatial information extraction issues from semantic information. Despite the difficulty in collecting semantics being acknowledged, attributes affiliated to spatial features such as keywords of Twitter posts, activity labels on trajectories, and texts on LSBN provide feasible foundation for the spatio-socio-semantic analysis. It, however, requires advanced text-mining to identify geographical locations (Imran et al. 2016a, b). The linguistic discernment, erroneous labelling, or inappropriate extraction of keywords lead to difficulty in location-oriented text-mining (Karimzadeh et al. 2013; Wallgrün et al. 2014). For example, though semantic data extraction from web and crowdsourced tracking systems provide a faster way to extract and monitor human health behaviors information (e.g., flu-related keywords) in the virtual space, it suffers from news bias during the excessive news period, especially after the early stage detection (Aramaki et al. 2011). Appropriate location-oriented text-mining approach to distinguish human health behaviors from news burst phenomenon is a key to provide near real-time feedback to adjust and validate disease simulation models.

Developing theory, methods, and tools to consider spatial, social network, and semantic factors simultaneously. Addressing the three aspects in the analysis at the same time is challenging. Much attention has been paid to the integration of either two components such as spatial-social (Mao and Bian 2010b; Wang et al. 2015; Luo 2016), spatial-semantic (Gao et al. 2013a; Wang et al. 2016), and social-semantic (Liu et al. 2015b). As discussed in the chapter, urban research requires the spatio-social-semantics integration. For example, both Guo (2007) and Luo et al. (2018) research shed light on the necessity and feasibility of designing sub-regional control strategies at the city scale. Current literature have already revealed various sub-regional structures according to different human mobility data with semantic information (Yuan et al. 2012a; Liu et al. 2016). We believe that integrating sub-regional structures determined by both geo-social interaction and semantic analysis into the control strategies would provide valuable insight for designing effective pandemic control measures.

To sum up, this chapter proposes a new spatio-social-semantics framework for urban relevant research. In addition to viewing cities as network systems consisting of points, flows, and interactions, this framework also emphasizes the semantic context behind individuals, locations, and connections. Spatial, social, and semantic spaces can complement each other. The increasing availability of various datasets capturing human interaction and movement and their spatial and semantic contexts make the urban research with the integrated spatio-social-semantics framework possible. Based on the data from the traditional and new sources, we are in the era of integrating heterogeneous data sources and creating innovative analytical approach to have a deeper and clearer understanding of our cities.

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Chapter 4
Optimal Hub-Spoke Network Design with Hub Reroute and Point-Point Connection: A Physical Perspective with Social Relevance

Guoqiang Shen

4.1 Introduction

A network, consisting of nodes and links, is a structural representation of physical or social relationships. Depending on application domains, nodes can be specifically referred to as agents, actors, markets, cities, etc. or generally as origins, destinations, points, or vertices. Likewise, links are viewed as edges, arcs, connections, or interactions. Network performance is described by nodal or link attributes such as size, length, path, direction, flow, capacity, etc. and measured by congestion, degree, centrality, clustering, density, etc. While graph theory is the branch mathematics behind the network science, it is combinatorial optimization that provides practical tools or algorithms for network applications possible in physical, biological, and social worlds. For example, transportation networks physically move people and goods, communication and social networks digitally transmit bits of information between electronic machines or individuals (organizations).

The hub-spoke (H-S) network is a special yet widely used network typology in both physical and social worlds. Hubs are those nodes that can transship or switch goods, people, or bits between nodes. Spokes are links that connect to hubs. Hubs in a H-S network often connect many more links than non-hub nodes. For examples, of the six representative network configurations in Fig. 4.1, (a) is a point-point (P-P) or fully connected network, allowing direct interaction between any pair of nodes. However, transshipment or flow switching is also possible at any node. For instance, node ① can only reach node ③ by node ②. (b)–(f) are partially connected networks, allowing some disconnections, and hence, hubs. Also, (a)–(b) and (e) may have one hub and (c)–(d) may have two hubs, depending on certain nodal interactions (physical or social).

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X. Ye and X. Liu (eds.), *Cities as Spatial and Social Networks*, Human Dynamics in Smart Cities, https://doi.org/10.1007/978-3-319-95351-9_4

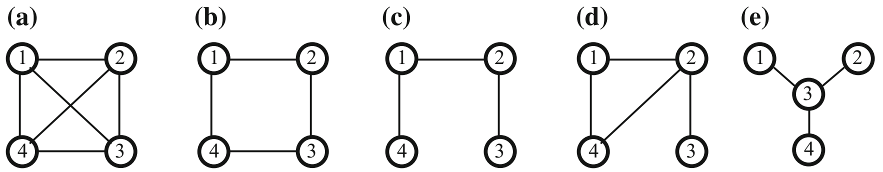

Fig. 4.1 Sample configurations for a hypothetical 4-node networks

The hub location and hub-spoke (H-S) network design problem has been drawing attention from many researchers over the past three decades. A H-S network uses a relatively small number of links (thus, paths) and hubs to serve many interacting origin-destination (O-D) nodes. Express mail delivery and passenger airline in transportation, computer and telecom systems in communication, or social networks in social media (i.e., Facebook, Twitter, Wechat, QQ) are well-known examples with certain H-S configurations. The H-S network design problem is to locate or identify a certain number of hubs out of a known set of potential hub locations and allocate non-hub origins and destinations to the hubs. All routes that visit at least one hub include an origin-to-hub link and a hub-to-destination link, both of which can be regarded as hub-to-nonhub (H-N) links. A route that visits more than one hub also includes at least a hub-to-hub (H-H) link. A link or route from a nonhub origin to a nonhub destination (N-N) is usually not allowed in a pure H-S network. However, in a mixed H-S network, N-N, H-N, and H-H links, or in other words, O-D point-to-point (P-P) connections, are all possible. Almost all social networks today are mixed H-S networks.

The pros of H-S networks can be attributed to: (1) cost discount for flow concentration on a smaller number of H-H links; hence (2) very likely smaller overall investment cost for network implementation and operation; and (3) powerful flow (traffic, data, etc.) control and management functions at hub facilities. The cons of H-S networks lie in: (1) larger investments (mainly fixed and operating costs) at hubs; (2) longer distances or time required for O-D movements routed via hubs than otherwise via P-P connections.

Generally, the following information must be specified for any H-S network design problem: (1) a set of origins, destinations, and potential hub locations; (2) O-D matrices on flows, distances, costs, or time, etc.; and (3) one or more rational network design strategies (i.e., cost minimization, utility and/or reliability maximization).

Although the concept of H-S network has been increasingly utilized in transportation and communication networks and beyond, due to the complexity of the H-S network design problem, operational models with efficient algorithms for determining optimal H-S networks with large O-Ds are yet to be found. On the one hand, most current studies focus on H-S networks with single-hub or multiple-hub without hierarchy, that is, even though multiple hubs are considered, they are treated as at the same level in terms of hub size, function, transshipping capability, so are the H-H links in terms of flow concentration, cost discount rate, and carrying capacity. On the other hand, the existing studies are based on the cost minimization rationale solely from the hub network investment perspective. O-D flow (traffic, data, etc.) delays generated by hub(s) in a H-S network with respect to its P-P counterpart have been largely ignored. Moreover, many important common network modeling issues, such as network reliability, flow patterns, hub queuing, system optimal and equilibrium, and P-P versus H-S, efficient algorithms, etc. have just been addressed recently and yet to be investigated further.

This paper thus focuses on some of the important issues mentioned previously. Specifically, section two reviews the literature on discrete hub location and network design initialized by O'Kelly (1987). Section three presents several discrete quadratic models which consider flow delay cost generated by routing through hubs, P-P versus H-S network, and mixed hub network design. Section four gives linearized programs to the quadratic models developed in Section three. Conclusions and remarks for future efforts completes this paper.

4.2 Literature Review

4.2.1 Hub Location and Network Design Literature

Since transportation and communication are the major domains for hub location and network design research and applications, the literature review here focuses on these two fields with research from transportation, geography, operations research, management science, and regional science. For comprehensive reviews on the hub location and network design problem, the readers are referred to Campbell (1994a), Campbell et al. (2002) and Campbell and O'Kelly (2012).

In communication, Miehle (1958, p. 232) perhaps is the earliest paper on optimally locating hubs or "communication centers, road junctions, or distribution centers" in a network. Hakimi (1964, 1965) modeled the location of a single switching center in a communication network, showing that its optimal location is always at a network node, and then extended this work to the case of multiple centers. Goldman (1969), analyzing multi-center location and multi-stage (origin-to-center, center-to-center, and center-to-destination) problems in a communication network, recognized the likely lower unit cost of hub-hub (H-H) links and the importance of scale economies. He developed a model to locate n centers in a network while minimizing the total multi-stage transportation cost.

In transportation, Marsten and Muller (1980) developed a mixed-integer program for hub-spoke (H-S) network design and fleet deployment. Their study was probably the first to recognize the nature and advantage of a H-S structure, discussing pure and mixed H-S networks, single and multiple hub allocations, interactions between hubs, and airplane assignments. The deregulation of transportation in America, such as the Air Cargo Deregulation Act in 1977, the Airline

Deregulation Act in 1978, and the Motor Carrier Act in 1980 stimulated the interests in and adoptions of hub networks in the airline, trucking, railroad, and express delivery businesses, whose applied efforts provided cases and motivations for hub location and network design research (Chan and Ponder 1979; Mason et al. 1997; Fisch 2005).

In social networks and social network analysis (Moreno 1956; Granovetter 1976; Granovetter 1983; Wasserman and Faust 1994; Freeman 2004; Scott and Carrington 2011), hubs and hub-spoke networks are discussed more through network centrality, degree, influence, or connection (Freeman 1977, 1979; Friedkin 1991; Kadushin 2012). Research on markets, facilities, and cities as hubs in geographical or urban contexts can be found in (Easley and Kleinberg 2010; Berlingerioa et al. 2011). Selected studies on hierarchical urban system based on the central place theory and related to social networks include Christaller (1966) Brian and Parr (Brian et al. 1988), Batten (1995) and Fujita et al. (1999).

Concerted academic research on hub location and network design formally started with O'Kelly (1986). His seminal piece (O'Kelly 1987) developed the first integer quadratic programming hub model. For given O-D flow and unit transportation cost matrices, this model minimizes the total transportation cost from origin-to-hub, hub-to-hub, and hub-to-destination. One distinct feature of this model is a discount rate associated to H-H links to reflect scale economies due to flow concentration. The integer quadratic program is NP-hard, and has not been solved exactly for large problems. A related quadratic programming model was proposed by Helme and Magnanti (1989) to design satellite communication networks. Campbell (1994) presented the hub location and network design problem as an un-capacitated mixed integer linear program hub location problem. Aykin and Brown (1992) and Aykin (1994) developed a capacitated hub-spoke model allowing for non-hub to non-hub links. Ernst and Krishnamoorthy (1996) made some smaller hub location formulations with linear integer programming and solved for larger problems.

The hub location and network design models reviewed above are variants in one way or another of O'Kelly (1987) and Campbell (1994b) which spurred the development of many alternative formulations and solution heuristics or algorithms, such as Klincewicz (1991), Aykin (1994) Skorin-Kapov et al. (1996), Jaillet et al. (1996) and more recently Bolan et al. (2004), Wagner (2007) Alumur et al. (2009) Contreras et al. (2011) Also, recent reviews on linearization of quadratic integer programming can be found in Eliane et al. (2007) and Fischetti et al. (2012). Although diverse hub location and network design models have been formulated, "the considerably more difficult equilibrium adjustment of interactions to network structure is largely unexamined" (Campbell and O'Kelly 2012, p. 156). Also, "more complex and less idealized hub location models provide strong challenges" (Campbell and O'Kelly 2012, p. 165).

4.2.2 O'Kelly's Quadratic Integer H-S Model

O'Kelly first formulated a quadratic integer program for discrete p-hub facilities location and network design problem. The objective function is to minimize the total transportation investment costs incurred on all links in H-N and H-H sub-networks, including origin-to-hub, hub-to-hub, and hub-to-destination links.

The original notation and problem formulation in O'Kelly's model can be rewritten as:

$$\text{Min} \quad Z = \sum_i \sum_j W_{ij}(\sum_k X_{ik}C_{ik} + \sum_m X_{jm}C_{jm} + a\sum_k \sum_m X_{ik}X_{jm}C_{km}) \tag{4.1}$$

$$\text{S.t.} \quad (n-p+1)X_{jj} - \sum_i X_{ij} \geq 0 \quad \text{for all}\, j, \tag{4.2}$$

$$\sum_j X_{ij} = 1 \quad \text{for all}\, i, \tag{4.3}$$

$$\sum_j X_{jj} = p \quad \text{for all}\, j, \tag{4.4}$$

$$X_{ij} \in \{0, 1\} \quad \text{for all}\, i, j, \tag{4.5}$$

$$0 \leq a \leq 1 \tag{4.6}$$

where
$$X_{ik} = \begin{cases} 1 & \text{if node } i \text{ is linked to a hub at } k \\ 0 & \text{other} \end{cases}$$
$$X_{jj} = \begin{cases} 1 & \text{if node } j \text{ is a hub} \\ 0 & \text{other} \end{cases}$$

W_{ij} = unit flow from node i and j, exogenously given with $W_{ii} = 0$

C_{ij} = unit transportation cost from node i to j, exogenously given with $C_{ii} = 0$
p, n = the total number of hubs and demand points, respectively.

The objective function contains three terms. The first two terms evaluate the costs of allocating a node to its hub for incoming and outgoing flows respectively. The third term evaluates the costs of H-H link flows. The a is a parameter reflecting the discount policy for interhub connections and flows. Constraint (4.2) ensures that no node is assigned to a location unless a hub is opened at that node. This constraint requires no N-N links. Constraint (4.3) specifies that each node can only be assigned to one hub. Constraint (4.4) ensures that p hubs be located. Constraint (4.5) specifies that $X_{ik} = 1$ if node i is linked to a hub at k, $X_{ik} = 0$ otherwise.

Of the three terms in the objective function, the first two are linear and represents the interaction between O-D nodes and hubs. The third one, representing the interactions between hubs, contains an integer quadratic part $X_{ik}X_{km}$, which makes the model NP-hard, and thus, very difficult to solve exactly. With given n origin and destination points and p hubs in the model, the exact p-hub location is considered. The O'Kelly's model has n^4 variables, $2n^2 + n$ constraints, and $p(2n - p + 1)/2$ H-N and H-H links, on which flows are considered. However, since the flows on H-H links are concentrated and encouraged, their costs are associated with a discount rate a $(0 \leq a \leq 1)$.

Most models stemmed from O'Kelly's (1987) model stick to the convention of minimizing total distance- or flow-based transportation investment cost. This design strategy can shed some lights on the H-S network design on the one hand, but one the other hand, can also lead to biased "optimal" hub locations, and thus, biased H-S network configurations. The biased design strategy lies in the fact that it only considers minimizing the total transportation investment cost from the investment perspective, rather than minimizing the total system-wide cost from a system optimality consideration, in which the flow delay costs caused by flows' rerouting through hubs should also be included.

Also, most of these studies focus on pure hub networks in which only flows routed by one or more hubs are allowed. Little hub research has been on such fundamental issues as under what condition(s) a H-S network rather than a P-P configuration should be used and vice versa according to the cost minimization rationale, nor has been on mixed H-S networks, in which some parts may have H-S configurations while other parts may take P-P configurations. In reality, a pure H-S network without any N-N or P-P links between some O-D nodes is indeed rarely seen.

As such, in the next section several quadratic optimization models are formulated and corresponding hub network configurations are presented. Specifically, a less biased total cost minimization program considering the system-wide optimality is formulated first. In this program, both the total investment cost and the total flow delay cost (often regarded as social externality cost) are considered. Then, the decisions on whether to use a P-P network or a H-S network are analyzed. Finally, a linearization-based solution strategy is developed to solve the programs formulated. The notations and definitions used in this research are based on the discrete integer quadratic hub facilities location and network design model developed by O'Kelly (1987).

4.3 New Hub Location and Network Design Models

4.3.1 System-Wide Optimal Design

Previous research on hub facilities location and network design uses a common objective—to minimize total transportation investment cost, either flow-based or distance-based. This strategy is valid from investment point of view. However, it is biased if assessed from the standing of system-wide optimization, in which the network investment costs and flow delay costs must be considered at the same time and their total be minimized. The typical routing scheme in O'Kelly's model can be shown in Fig. 4.2.

From this diagram we can see that the flow W_{ij} goes from origin i along the bold route containing hub k and m to the destination j. Considering a discount scale for the flow on H-H link L_{km} and the special utilities of hubs (k and m), O'Kelly's model investigates the locations of hubs and the allocations of O-D nodes to the hubs such that the total transportation investment cost is minimized. The resultant H-S network is thus considered to be superior to its direct P-P counterpart.

However, the diagram also shows that $L_{ij} < L_{ik} + L_{km} + L_{jm}$. This suggests that the flow W_{ij} may take more time by the bold route than by the P-P direct path from i to j. This flow delay, of course, generates a cost, which is incurred to the flow (users, cargoes, data, etc.) rerouted via hubs and generally ignored in previous H-S network studies. It appears intuitively that to minimize this flow delay cost, we should use a P-P network rather than a H-S configuration.

However, a closer look at the problem leads us to a dilemma. On the one hand, while a P-P configuration minimizes the transportation time or distance between each O-D pair, it requires more links, and thus, may lead to a higher total investment cost. Moreover, we must ensure that the functions that a H-S network provides

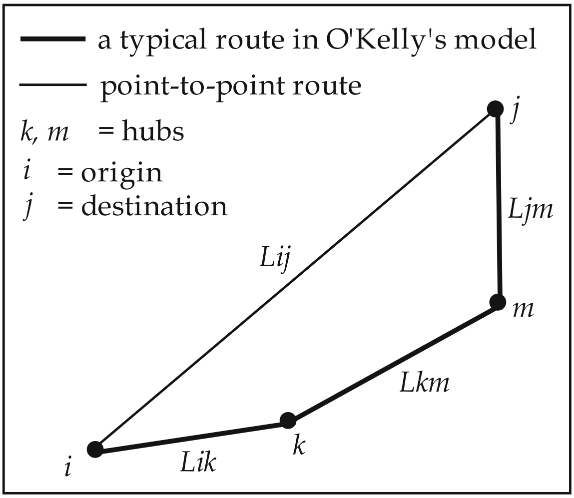

Fig. 4.2 A typical path in O'Kelly's model with a P-P route

(i.e., sorting, switching, etc.) be equally furnished by the P-P network. To be so, it is necessary that each node in the P-P system be regarded and designed as a hub with certain size and functions on the one hand. These hubs are likely smaller in size and simpler in functions (due to lower levels of traffic concentration at these hubs) as compared with hubs in the H-S network. On the other hand, the H-S network needs much fewer links, and thus fewer paths, to serve the flows of all O-D pairs, but it requires relatively large, functionally sophisticated, and financially expensive hubs.

Intuitively, this dilemma is also reflected in the relationships between the number of hubs (N), the transportation investment cost (TTIC), and the flow delay cost (TFDC) in a H-S network. These two relationships can be graphically represented in Fig. 4.3.

This chart tells us that generally the larger the number of hubs, the higher the total transportation investment cost, but the lower the total flow delay cost. This is particularly true when fixed hub costs are not considered in the optimization process. When fixed hub costs are considered, however, there are trade-offs between the fixed hub costs, transportation cost, flow delay cost, and the optimal number of hubs. This dilemma can only be solved by utilizing some network design strategies that are to compromise the advantages and disadvantages of the two network configurations. One such a strategy is to construct and minimize an objective function which includes the total transportation investment cost and the total flow delay cost.

The following discussion will focus on two design strategies that are based on system-wide optimality considering both the transportation investment cost and flow delay cost. One idea is to minimize the total system-wide cost: the sum of the total transportation investment cost and the total flow delay cost. The other idea is to balance or "equilibrate" TTIC and TFDC in a way that neither the TTIC nor the TFDC is emphasized one over the other. This strategy can be changed slightly into one that minimizes the absolute difference between the TTIC and TFDC. Mathematical programs are formulated using both strategies with consideration of fixed hub costs.

Define:

L_{ij} = Euclidean distance between point i and j,
C_{ij} = unit cost moving a unit flow over a unit distance from i to j
F_{h-s} = fixed cost for a hub in the H-S network

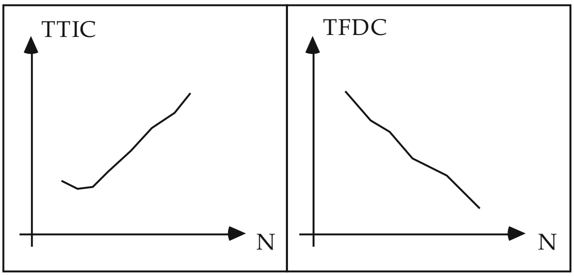

Fig. 4.3 Relationships between TTIC, TFDC, and number of hubs (N)

$L_{ij} = L_{ji}, C_{ij} = C_{ji},$, L_{jj} = 0, $C_{jj} = 0$ by definition
i, j, k, m = 1, 2,…, n

Then, the objective function of O'Kelly's hub facilities location and network design model (4.1) becomes:

$$Z_{h-s} = \sum_i \sum_j W_{ij}(\sum_k C_{ik}X_{ik}L_{ik} + \sum_m C_{jm}X_{jm}L_{jm} + a\sum_k \sum_m C_{km}X_{ik}X_{jm}L_{km}) + \sum_i \sum_j X_{ij}F_{h-s} \quad (4.7)$$

The user delay in terms of distance for a route from i to j through hub k and m is:

$$D_{ij}^{km} = L_{ik}X_{ik} + L_{km}X_{ik}X_{jm} + L_{jm}X_{jm} - L_{ij} \quad (4.8)$$

The total flow delay cost is:

$$\begin{aligned} Z_d &= \sum_i \sum_j \sum_k \sum_m W_{ij}C_{ij}D_{ij}^{km} \\ &= \sum_i \sum_j W_{ij}C_{ij}(\sum_k X_{ik}L_{ik} + \sum_k \sum_m X_{ik}X_{jm}L_{km} + \sum_m X_{jm}L_{jm} - L_{ij}) \end{aligned} \quad (4.9)$$

Therefore, the complete program using the strategy one can be expressed as:

$$\text{Min} \quad Z_{s1} = Z_{h-s} + Z_d = \sum_i \sum_j \sum_k W_{ij}X_{ik}L_{ik}(C_{ij} + C_{ik}) + \sum_i \sum_j \sum_m W_{ij}X_{jm}L_{jm}(C_{ij} + C_{jm}) + \sum_i \sum_j \sum_k \sum_m W_{ij}X_{ik}X_{jm}L_{km}(C_{ij} + aC_{km}) + pF_{h-s} \quad (4.10)$$

$$\text{S.t.} \quad (n - p + 1)X_{jj} - \sum_i X_{ij} \geq 0 \quad \text{for all}\, j, \quad (4.11)$$

$$\sum_j X_{ij} = 1 \quad \text{for all}\, i, \quad (4.12)$$

$$\sum_j X_{jj} = p \quad \text{for all}\, j, \quad (4.13)$$

$$X_{ij} \in \{0, 1\} \quad \text{for all}\, i, j, \quad (4.14)$$

$$0 \leq a \leq 1 \tag{4.15}$$

$$L_{ij} \leq L_{ik} + L_{km} + L_{jm} \quad \text{for all}\, i, j, \tag{4.16}$$

For strategy two, the absolute difference of the total transportation investment cost and the total flow delay cost can be written as:

$$\begin{aligned} Z_{s2} = |Z_{h-s} - Z_d| = |\sum_i \sum_j \sum_k W_{ij} X_{ik} L_{ik} (C_{ij} - C_{ik}) + \sum_i \sum_j \sum_m W_{ij} X_{jm} L_{jm} (C_{ij} - C_{jm}) \\ + \sum_i \sum_j \sum_k \sum_m W_{ij} X_{ik} X_{jm} L_{km} (C_{ij} - aC_{km}) + pF_{h-s}| \end{aligned} \tag{4.17}$$

Suppose Z_s is the smallest, the complete program can be expressed as:

$$\text{Min:} \quad Z_s \tag{4.18}$$

$$\begin{aligned} \text{S.t.} \quad Z_s < \sum_i \sum_j \sum_k W_{ij} X_{ik} L_{ik} (C_{ij} - C_{ik}) + \sum_i \sum_j \sum_m W_{ij} X_{jm} L_{jm} (C_{ij} - C_{jm}) \\ + \sum_i \sum_j \sum_k \sum_m W_{ij} X_{ik} X_{jm} L_{km} (C_{ij} - aC_{km}) + pF_{h-s} \end{aligned} \tag{4.19}$$

$$\begin{aligned} Z_s > -\sum_i \sum_j \sum_k W_{ij} X_{ik} L_{ik} (C_{ij} - C_{ik}) - \sum_i \sum_j \sum_m W_{ij} X_{jm} L_{jm} (C_{ij} - C_{jm}) \\ - \sum_i \sum_j \sum_k \sum_m W_{ij} X_{ik} X_{jm} L_{km} (C_{ij} - aC_{km}) - pF_{h-s} \end{aligned} \tag{4.20}$$

plus: constraints (4.11)–(4.16) as shown above.

The underlying notions of these two models are of total system-wide cost minimization and equilibrium. Since a H-S network and a P-P network are simultaneously considered in both optimization formulations, some parts of the resulting optimal hub networks may be H-S configuration while other parts may be P-P configuration. In other words, the resultant optimal networks from the above two programs are mixed, which allow not only H-N and H-H links but also N-N links, and therefore, are more realistic in reflecting the real world situations.

4.3.2 P-P Network Versus H-S Network

On the one hand, if only link cost is considered, it is clear that a P-P configuration is inferior to its H-S counterpart, judged from the investment cost minimization point of view. This is simply because that the P-P network requires more links. But on the other hand, if fixed hub cost and transportation cost are also taken into consideration, it is not clear whether the H-S network has advantages (in terms of cost-efficiency) over the P-P network since the total fixed hub cost plus the total transportation cost in the H-S network may be well over its total link cost and not easily be compared with that in the P-P network. This means that when the number of hubs is over a certain threshold, the H-S configuration may be more costly, and thus, inferior to its corresponding P-P network. This suggests an interesting problem: under what condition(s) should the P-P network and/or the H-S network be used according to the total cost minimization rationale? The solutions to this problem will undoubtedly affect hub location and network configuration. The following mathematical model is formulated specifically for this problem.

Define:

A_{ij} = the unit cost for a link from i to j.
$A_{ij} = A_{ji}$ by convention.
F_{p-p} = the fixed cost for a hub at each node in the P-P network.

Assume that the fixed hub cost for each node in the P-P network is smaller than the fixed hub cost in the H-S network, that is, $F_{p-p} < F_{h-s}$. Specifically, assume that the fixed cost for each hub in the P-P network is $1/c$ ($c > 1$) of the fixed hub cost in the H-S network, or $F_{p-p} = \frac{1}{c} F_{h-s}$. Then, the total fixed hub cost in the P-P network can be written as $TF_{p-p} = \frac{n}{c} F_{h-s}$.

Thus, the total cost including transportation flow cost, fixed hub cost, and link cost in the P-P network is:

$$Z_{p-p} = \sum_i \sum_j W_{ij} C_{ij} L_{ij} + \sum_i \sum_j A_{ij} L_{ij} + \frac{n}{c} F_{h-s} \tag{4.21}$$

and the total cost including flow transportation cost, fixed hub cost, and link cost in the H-S network is:

$$\begin{aligned} Z_{h-s} = {} & \sum_i \sum_j \sum_k W_{ij} X_{ik} L_{ik} (C_{ik} + A_{ik}) + \sum_i \sum_j \sum_m W_{ij} X_{jm} L_{jm} (C_{jm} + A_{jm}) \\ & + \sum_i \sum_j \sum_k \sum_m W_{ij} X_{ik} X_{jm} L_{km} (aC_{km} + bA_{km}) + pF_{h-s} \end{aligned} \tag{4.22}$$

Here, $b \geq 1$ is assumed for up scaling the link costs for the H-H links. This assumption is reasonable since intuitively the costs for implementing and operating H-H links are higher than other links. $0 \leq a \leq 1$ is for down scaling the transportation costs for H-H links, on which flows are concentrated and encouraged.

Obviously, we need to compare Z_{p-p} and Z_{h-s}. If $Z_{p-p} > Z_{h-s}$, we choose the H-S configuration, otherwise if $Z_{p-p} < Z_{h-s}$, we select the P-P network, and if $Z_{p-p} = Z_{h-s}$, we are indifferent of the H-S and P-P networks. However, this type of comparison is not trivial since we have parameters *p, a, b, c,* and F_{h-s}, which need to be exogeously specified or derived in a certain manner. Two ideas may be used to carry out the comparison.

On the one hand, for a specified p, we can always experiment with various sets of reasonable *a, b, c,* and F_{h-s} values, calculate the corresponding Z_{p-p}'s and Z_{h-s}'s, and identify the relationships between the Z_{p-p}'s and Z_{h-s}'s for appropriate network configurations (P-P, H-S, or a mix of the two). On the other hand, for a given set of values *a, b, c,* and F_{h-s} the number of hub p can be derived and used for network selection. To do so, we can increment the number of hubs by one each time and minimize (4.22) subject to the set of constraints (4.11)–(4.16). Then, compare each of $Z^1_{h-s}, Z^2_{h-s}, \ldots, Z^{n^*}_{h-s}, \ldots, Z^n_{h-s}$ with the Z_{p-p}. If $Z^{n^*}_{h-s}$ is the closest to Z_{p-p}, then the corresponding p^* specifies the number of hubs that can be used as the threshold for determining the network configuration. Generally, for a large n, if $p > p^*$, it is good to design a P-P network, otherwise, a H-S network is the right network configuration.

To find out p^* using the second idea, we can build an objective function $Z = |Z_{h-s} - Z_{p-p}|$, the absolute difference of Z_{h-s} and Z_{p-p}. Suppose Z_1 is the smallest of all Z, then, mathematically the second idea can be expressed as:

$$\text{Min}: \quad Z_1 \tag{4.23}$$

$$\begin{aligned} \text{S.t.} \quad Z_1 < & \sum_i \sum_j \sum_k W_{ij} X_{ik} L_{ik} (C_{ik} + A_{ik}) + \sum_i \sum_j \sum_m W_{ij} X_{jm} L_{jm} (C_{jm} + A_{jm}) \\ & + \sum_i \sum_j \sum_k \sum_m W_{ij} X_{ik} X_{jm} L_{km} (aC_{km} + bA_{km}) + pF_{h-s} \\ & - (\sum_i \sum_j W_{ij} C_{ij} L_{ij} + \sum_i \sum_j A_{ij} L_{ij} + \frac{n}{c} F_{h-s}) \end{aligned} \tag{4.24}$$

$$\begin{aligned} Z_1 > & - \sum_i \sum_j \sum_k W_{ij} X_{ik} L_{ik} (C_{ik} + A_{ik}) - \sum_i \sum_j \sum_m W_{ij} X_{jm} L_{jm} (C_{jm} + A_{jm}) \\ & - \sum_i \sum_j \sum_k \sum_m W_{ij} X_{ik} X_{jm} L_{km} (aC_{km} + bA_{km}) + pF_{h-s} \\ & + (\sum_i \sum_j W_{ij} C_{ij} L_{ij} + \sum_i \sum_j A_{ij} L_{ij} + \frac{n}{c} F_{h-s}) \end{aligned} \tag{4.25}$$

$$(n - p + 1) X_{jj} - \sum_i X_{ij} \geq 0 \quad \text{for all}\, j, \tag{4.26}$$

$$\sum_j X_{ij} = 1 \quad \text{for all}\, i, \tag{4.27}$$

$$\sum_j X_{jj} = p \quad \text{for all } j, \tag{4.28}$$

$$X_{ij} \in \{0, 1\} \quad \text{for all } i, j, \tag{4.29}$$

$$0 \le a \le 1,\ b \ge 1 \tag{4.30}$$

$$L_{ij} \le L_{ik} + L_{km} + L_{jm} \quad \text{for all } i, j, \tag{4.31}$$

For a given set of a, b, c, and F_{h-s} values, we can solve the program (4.23)–(4.31) up to p times by increasing the number of hubs by one each time from one until p. The corresponding solutions $Z_1^1, Z_1^2, \ldots, Z_1^{P^*}, \ldots, Z_1^P$ can then be compared and the minimal be selected. The number of hubs p^* corresponding to the minimal solution $Z_1^{P^*}$ can then be regarded as the threshold. For any $p > p^*$, the P-P network is the right choice. For any $1 \le p < p^*$, the H-S network is the rational choice. For $p = p^*$, the mixed H-S and P-P should be used.

Notice that for simplicity the above discussion on P-P and H-S networks only focuses on the comparison of a pure H-S network and a P-P network in terms of the total cost (transportation cost, fixed hub cost, and link cost), without being linked to the flow delay cost. In fact, the total flow delay cost can be added to (4.22) as part of the total system-wide cost of the H-S network, which, can then be compared with the total cost (4.21) of the P-P network to determine the appropriate conditions for using the pure P-P network or the H-S network or a mixed configuration of the two.

4.4 Solution Strategies

All the mathematical models developed in Sects. 4.3.1 and 4.3.2 contain one or more zero-one integer quadratic terms, which make these models belong to a family of non-polynomial programs that are very hard to solve exactly when the number of O-D pairs become large. However, linearization heuristics and algorithms are available to solve these programs. Specifically, the two modified algorithms based on Christofides et al. (1980) and Kaufman and Broeckx (1978). For the sake of simplicity, the following solution strategies are based on the second approach discussed and formulated in Shen (1996).

For the discussions on system-wide optimality in Sect. 4.3.1 and P-P versus H-S network in Sect. 4.3.2, we define one binary decision variable for a H-H link as:

$$X_{km} = \begin{cases} 1 & \text{if hub } k \text{ is linked to hub } m \\ 0 & \text{otherwise} \end{cases}$$

Then, Eq. (4.7) in Sect. 4.3.1 can be rewritten as:

$$\text{Min} \quad Z'_{h-s} = \sum_i \sum_j W_{ij} (\sum_k X_{ik} C_{ik} L_{ik} + \sum_m X_{jm} C_{jm} L_{jm} + a \sum_k \sum_m X_{km} C_{km} L_{km}) + \sum_i \sum_j X_{ij} F_{h-s} \tag{4.41}$$

Similarly, Eq. (4.9) can be rewritten as:

$$Z'_d = \sum_i \sum_j W_{ij} C_{ij} (\sum_k X_{ik} L_{ik} + \sum_k \sum_m X_{km} L_{km} + \sum_m X_{jm} L_{jm} - L_{ij}). \tag{4.42}$$

Notice that (4.41) and (4.42) are different from (4.7) and (4.9) in that they do not contain any integer quadratic terms. In fact, all terms in (4.41) and (4.42) are in linear form. Therefore, the quadratic objective function (4.10) can be transformed into the following linear expression:

$$Z'_{s1} = Z'_{h-s} + Z'_d \tag{4.43}$$

For constraints, however, not only (4.11) and (4.16) should be kept, but also the following constraint:

$$X_{km} = X_{ik} X_{jm} \tag{4.44}$$

must be added to ensure that at least one of the k and m be allocated on each O-D path. However, (4.44) is still in integer quadratic format, and thus, has to be linearized.

To do so, the integer quadratic term on the right-hand side of Eq. (4.44) should be linearized. The linearization procedure is shown below.

Since:

$$X_{ik}^2 = X_{ik},\ X_{jm}^2 = X_{jm},$$

$$(X_{ik} - X_{jm})^2 \geq 0, \tag{4.45}$$

we have:

$$(X_{ik}^2 + X_{jm}^2)/2 \geq X_{ik} X_{jm}, \tag{4.46}$$

that is:

$$(X_{ik} + X_{jm})/2 \geq X_{km}. \tag{4.47}$$

Then, after replacing constraint (4.44) by (4.47) and replacing objective function (4.10) by (4.43), we get the following linearized program (A) for the integer quadratic program (4.10)–(4.16).

$$\begin{array}{ll} \text{Min} & Z'_{s1} = Z'_{h-s} + Z'_d \\ \text{S.t.} & (11)-(16) \\ & (47) \end{array} \tag{A}$$

Similarly, for strategy two, Eq. (4.17) can be written as:

$$Z'_{s2} = |Z'_{h-s} - Z'_d| = |\sum_i \sum_j \sum_k W_{ij}X_{ik}L_{ik}(C_{ij} - C_{ik}) + \sum_i \sum_j \sum_m W_{ij}X_{jm}L_{jm}(C_{ij} - C_{jm}) + \sum_i \sum_j \sum_k \sum_m W_{ij}X_{km}L_{km}(C_{ij} - aC_{km}) + pF_{h-s}| \tag{4.48}$$

Suppose Z'_s is the smallest of Z'_{s2}, then, the linearized program (B) using strategy two discussed in Sect. 4.3.1 for the system-wide optimality can be written as:

$$\begin{array}{ll} \text{Min} & Z'_s \\ \text{S.t.} & Z'_s \geq Z'_{h-s} - Z'_d \\ & Z'_s \leq -Z'_{h-s} + Z'_d \\ & (11)-(16) \\ & (47) \end{array} \tag{B}$$

Similarly for P-P versus H-S analysis in Sect. 4.3.2, the Eq. (4.22) can be written as:

$$Z'_{h-s} = \sum_i \sum_j \sum_k W_{ij}X_{ik}L_{ik}(C_{ik} + A_{ik}) + \sum_i \sum_j \sum_m W_{ij}X_{jm}L_{jm}(C_{jm} + A_{jm}) + \sum_i \sum_j \sum_k \sum_m W_{ij}X_{km}L_{km}(aC_{km} + bA_{km}) + pF_{h-s} \tag{4.49}$$

To find out p^*, we build an objective function using Eqs. (4.49) and (4.21):

$$Z' = |Z'_{h-s} - Z_{p-p}| \tag{4.50}$$

Assuming that Z'_1 is the smallest of all Z', then, mathematically the program (4.23)–(4.31) can be reformulated into the following linearized program (C):

$$\begin{array}{ll} \text{Min} & Z'_1 \\ \text{S.t.} & Z'_1 \leq Z'_{h-s} - Z_{p-p} \\ & Z'_1 \geq -Z'_{h-s} + Z_{p-p} \\ & (26)-(31) \\ & (47) \end{array} \tag{C}$$

4.5 Conclusions and Remarks

Hubs and Hub-spoke networks can be found in virtually all physical or social networks. Hubs connect many spokes, transship people, goods, or bits at a large volume, and incur a reroute delay or cost. P-P connections allow for direct interactions, which may generate a large number of links with small O-D interactions. This paper extends O'Kelly (1986, 1987) models for optimal hub-spoke network designs with hub reroutes and P-P connections and provides an algebraic linearization.

This paper, instead of using the biased transportation investment cost minimization convention for the H-S network design problem, proposed and mathematically constructed the system-wide optimality concept, which considers both transportation investment cost and flow delay cost. Since the flow delay phenomena is common to all H-S networks due largely to flow consolidation on H-N/N-H or H-H links, it is indeed worth of investigating. Solving the H-S network design model formulated for the system-wide optimality will result in a mixed H-S network in which some parts may have H-S configuration while other parts may take P-P configuration.

A H-S network may not be superior to its P-P counterpart if the total cost including transportation cost, fixed hub cost, and link cost is minimized. Thus, a program was developed to derive the favorable conditions for a P-P, H-S, or a mix of the two. Generally, most social networks are mixed H-S networks, with the degree of mixture varies according to the link/hub cost, flow, and capacity.

The programs developed in this paper are integer quadratic programs, which are NP-hard and very difficult to solve exactly for a large number of O-D pairs. Therefore, a linearization strategy based on the binary nature of the decision variables was developed to solve these programs. However, the validity of these programs and the linearization strategy should be verified by future studies, particularly those application oriented studies for real world problems, such as in transportation and social networks.

Immediate future studies should also be on the time impact on the flow delay cost, and thus, on the hub network modeling. This is because that on the one hand the flow delay cost is actually affected by the life cycle of the hub network. In general, within the life cycle the total fixed hub and link costs increase occasionally and slightly verse the total flow delay cost which is accumulated steadily through O-D distances and flows. The longer the system's life cycle, the larger the total flow delay cost. On the other hand, the total flow delay cost is also affected by the flow concentrations on individual links. Some H-H links generate more flow delay costs than others, therefore, the higher frequencies of flow using the H-H links with higher levels of flow concentrations, the larger the total flow delay cost generated. Finally, the behavioral variations and optimal configuration patterns of a H-S network when applied to physical networks (i.e., highway freight logistics or passenger transportation) or social networks (i.e., web chat messages and direct sales) need to be captured for better domain applications.

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Chapter 5
Spatial Characteristics of Social Networks

Lingqian Hu

5.1 Introduction

The inferior employment outcomes of the disadvantaged groups—e.g. minorities, women, low-income—in the post-WWII U.S. have many causes. One of them is the lack of social networks and related job information channels, which affects the range and the efficiency of disadvantaged groups' job searches (Granovetter 1973, 1974). Including social network theories was a logical step when researchers cannot satisfactorily explain disadvantaged groups' inferior employment outcomes in the existing research framework. But, there has been some inconsistency in the interpretation and application of social network theories in empirical research, and this chapter aims to assess different social network indicators and suggest feasible indicators in studying disadvantaged groups' employment outcomes.

Originated from the disciplines of sociology and anthropology, social networks were considered aspatial when first proposed (Webber 1963; Wellman 1979). It is difficult for researchers in other disciplines to apply social network theories, especially when their research purposes are not to identify or measure social networks but to examine other issues, such as employment outcomes, using social networks as an explanatory factor. In these cases, researchers tend to rely on proxies of social networks, which are usually spatially confined, such as in neighborhoods. Consequently, the operational measurements of social networks diverge from the original concepts. Additionally, these spatial indicators of social network vary to a great extent, and hence policy implications of these empirical studies are unclear with the wide range of the indicators. Therefore, we need to evaluate whether these spatial indicators are valid; if not, we need to consider other indicators.

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X. Ye and X. Liu (eds.), *Cities as Spatial and Social Networks*, Human Dynamics in Smart Cities, https://doi.org/10.1007/978-3-319-95351-9_5

This paper aims to answer four questions. First, how do social network theories contribute to the research on employment outcomes of disadvantaged groups? Second, what are the commonly-used indicators of social networks in the research and how effective are they? Third, can these commonly-used spatial indicators represent social networks in explaining employment outcomes? And fourth, are there other spatial indicators that affect employment outcomes? Seeking answers to these questions not only assists empirical research in refining social network indicators but also informs policies that aim to foster social networks to improve employment for disadvantaged groups. Specifically, many social welfare and economic development policies are place-based; these policies especially require an understanding of the connection between space and social outcomes.

This paper is organized as the following. The next section reviews the theoretical literature on social networks and related concepts, followed by the four sections that each answers one question. The final section concludes the research.

5.2 Social Networks and Related Concepts in Explaining Employment

Wasserman and Faust (1994) suggest that interests in social networks arose as scholars in many disciplines struggled to make sense of real-world observations. It is no exception that the application of social network theories in explaining the unequal employment outcomes of disadvantaged groups became compulsory when research at that time could not satisfactorily explain the inequality. Specifically, it had been recognized that employment prospects could be explained by individual characteristics, economic conditions, and location characteristics (Falcón 1995). These factors together, however, still cannot address the gap in employment outcomes between disadvantaged groups and the others, and therefore the lack of social networks was suggested and quickly accepted as an additional explanatory factor by researchers.

There are many different ways to describe the structure of a social network, and the most pertinent way in explaining employment outcomes is based on the strength of social ties—strong ties are close friends and families, and weak ties are acquaintances (Granovetter 1973, 1983). Granovetter (1973) suggests that through weak ties, individual persons link to other social circles and acquire useful information that is otherwise unlikely to be available in their own circles. However, full applications of Granovetter’s framework are challenging in the empirical literature, because identifying weak ties can only be achieved through extensive surveys.

Social networks are closely connected to some key concepts in the literature on employment outcomes, and it is important to connect and distinguish these concepts. “Community” is a commonly used one. Communities, freed from geographic locations, are manifestations of social networks. Communities are tight social networks, and members of the same communities share common interests (Webber 1963), regardless of the content of the interests. Wellman and Berkowitz (1988) directly transmute “communities” into “social networks”, noting that “this shift in perspective from community to network allows analysts to examine the extent to which large-scale social changes have simultaneously created new forms of association and altered the structure of older interpersonal bonds such as kinship”. This conceptual linkage between communities and social networks is important to connect existing literature, much of which uses both terms interchangeably.

Much research freely, although incorrectly, interchanges the terms “community” and “neighborhood”. Modern communities are no longer based on residential neighborhoods, which are geographically located units where people living near one another, whereas communities can be place-specific or spatially-dispersed. Therefore, a community and a neighborhood do not necessarily co-occur, and the degree of their co-existence declines as communities were freed from their traditional attachments to neighborhoods with the development of information technology. Specifically, interest-based communications and interaction do not rely on spatial proximity, and thus communities do not have to coincide with the neighborhoods in which people live. This is the reason why Webber (1963) suggests “community without propinquity”. As a result, theoretical analysis of communities was shifted from locality-based to network-based (Wellman 1988). Although many scholars adopt this type of locality-free definition of communities (e.g. Keller 1988; Wellman 1979; Calhoun 1998), confusion remains in empirical literature as researchers use neighborhood characteristics as indicators of social networks (e.g. in O’Regan and Quigley 1996b; Fernandez and Harris 1992; Weinberg et al. 2004; Ihlanfeldt and Scafidi 2002). To avoid the confusion, Talen (2000) suggests using specific components of “community”, such as resident interaction, rather than the term “community” itself in the research that centers around neighborhoods.

5.3 Explaining Employment Outcomes

This section reviews the literature on disadvantaged groups’ unequal employment outcomes. In addition to the lack of human capital and other individual characteristics, two main explanatory factors are structural barriers and the lack of social networks. Researchers first focused on the structural barriers and then recognized the importance of social networks.

5.3.1 Structural Barriers

Disadvantaged groups face two major structural barriers. The first is spatial inaccessibility to jobs and other opportunities, and the second is the structural shift in the economy. It is noteworthy that the pioneers in the two streams of research have already noted the importance of social networks.

Spatial Mismatch Hypothesis (SMH), proposed by Kain (1968), guides the subsequent research that explores how spatial structure transformation affects disadvantaged groups. SMH identifies three important spatial factors: (1) Because of housing market discrimination, the disadvantaged groups have fewer residential choices and are constrained in the inner city, while the affluent majority do not face such constraints and have rapidly suburbanized. (2) Jobs have also suburbanized, especially those traditionally held by low-skilled, low-wage workers, such as manufacturing jobs. (3) Affordable or efficient transportation systems are unavailable for the inner-city residents to travel to the suburban jobs. SMH argues that the three factors combined resulted in greater spatial barriers between disadvantaged groups residing in the inner cities and their potential job opportunities in the suburbs and consequently affect their labor market outcomes.

Wilson (1987) links economic restructuring to the employment challenges faced by inner-city minorities residents, arguing that the structural shift in the economy exacerbated the employment problems of those who used to be employed in the manufacturing sector. Economic restructuring indeed has reduced good-paying, low-skilled manufacturing jobs but increased jobs that require high-education and high-skills (Muller 2004; Sassen 1990), which disadvantaged groups usually do not possess. The economic restructuring continues to polarize the U.S. labor market (Autor 2011).

In the two streams of literature, researchers have noticed the importance of social networks. In Kain's seminal paper, he posits that African Americans "may have less information about and less opportunity to learn about jobs distant from their place of residence or those of their friend" (Kain 1968). Wilson (1987) similarly observes that poverty concentration creates a social environment that lacks the institutions, roles, and values conducive to success in the larger society.

5.3.2 *Social Networks*

Research that studies the effects of social networks on labor market behavior was initiated in the 1950s. The earliest study might be Myers and Shultz (1951), who estimate that 62% of interviewed textile workers in a New England mill town found their first jobs through social contacts. Later, social networks are found to be important in explaining the labor market experiences of females in Los Angeles in the U.S. (Johnson et al. 1999) and of both natives and migrants in Australia (Piracha et al. 2016). Using a theoretical model, Montgomery (1991) explains the relationship between social networks and economic benefits for both employers and employees: firms hiring through referral might earn higher profits, and employees who possess social ties to jobs might fare better than those who are poorly connected.

Granovetter's (1974) research provides probably the most influential framework for analyzing the effects of social networks on employment outcomes. He examines how information about job openings flows through networks and how such information helps job seekers obtain jobs. In the survey on professional, technical, and managerial workers, Granovetter detects three basic job searching methods: formal means, personal contacts, and direct applications. Among them, personal contacts are the predominant method. Granovetter also finds the varying intensity of using personal contacts: managerial workers use more personal contacts than professional and technical workers, maybe because the former have already established more personal relations in their work. Granovetter's study has been recognized as one of the most important empirical works that illustrate the significance of social networks in job searching.

Much research that aims to study the relationship between social networks and employment applies Granovetter's analysis framework. Informal job search is a commonly used method (Corcoran et al. 1980; Bewley 1999). Job searches through informal methods (friends and relativities) help to get more offers than those who use other information channels (Blau and Robins 1990; Holzer 1988). More contacts with currently employed persons can shorten the unemployment duration (Cingano and Rosolia 2012; Bentolila et al. 2009). Workers who are more connected to workers living in the same neighborhoods have lower turnover (Hellerstein et al. 2014). Informal searches are the least costly in terms of time and money (Holzer 1988). Overall, the value of informal personal contacts could be that they provide job information that otherwise is unavailable through formal channels (Hanson and Pratt 1990).

Job information transmitted through social networks not only concerns job openings information but also wage rates. Nevertheless, the wage effects are uncertain. Marmaros and Sacerdote (2002) observe that utilizing social networks helps to obtain high-paying and prestigious jobs, but their samples are college senior students and hence the results are difficult to be generalized. Rosenbaum et al. (1999) specifies that relatives and school contacts help youth to get jobs with higher earnings not immediately, but years later in their career. Supporting the above arguments from a different perspective, Hofler and Murphy (1992) find that many workers are underpaid, and they suggest that the "underpayment" occurs because wage information is costly to obtain in a dispersed social network. In other words, workers with a dense or a high level of social networks might be able to avoid underpayment. On the other hand, some research finds no effect (Bridges and Villemez 1986; Loury 2006) or even negative effect (Bentolila et al. 2009) of using social networks on wage rates. The reason could be that "workers sacrifice their productivity advantage so as to find a job more easily" (Bentolila et al. 2009).

Disadvantaged groups—female, low-educated, low-skilled, minorities—tend to be affected by social networks or the lack of them. But there is no consensus on whether disadvantaged groups are more or less likely to use social networks. Females tend to use less informal searching methods to obtain low-skilled jobs than males (Campbell and Rosenfeld 1985), and African Americans and Hispanics are more likely to use informal contacts than whites (Mattingly 1999; Green et al. 1999; Corcoran et al. 1980).

More importantly, the effects of using social networks vary across population groups. Campbell and Rosenfeld (1985) find no sex differences in the relative returns to search methods, but Bortnick and Ports (1992) observe that it take longer time for women to find jobs than for men. Moore (1990) suspect that women have more strong ties than weak ties that offer job information. Corcoran et al. (1980) find no difference in wage advantages for whites through informal searches than blacks, but most later research suggests that the returns on employment and wage rates tend to be lower for African Americans than for white (Bortnick and Ports 1992; Korenman and Turner 1996; Stoll 1999). Holzer (1987) proposes that African Americans face more barriers than whites when using informal job search methods.

The usage of social networks also differs across space, but again the results are mixed. Elliott (1999) finds that workers in high-poverty neighborhoods are more likely to use informal job search methods than those from low-poverty neighborhoods. Stoll (1999) observes that minority job seekers search in more areas than whites and that the geographical areas where minority workers search for jobs are centered around their residential locations where tend to concentrate high-skilled jobs. Additionally, Stoll and Raphael (2000) find that blacks and Latinos tend to search in areas where employment growth is low, whereas whites tend to search in areas where it is high.

In short, social networks are important for disadvantaged groups, but the effects of social networks on their employment are yet uncertain.

5.4 Social Networks Indicators in Explaining Employment

In the literature to explain employment outcomes, the indicators of social networks vary. A few studies use individual person or household characteristics as proxies for social networks. Parks' (2004) research on native-born African American and immigrant women in Los Angeles finds that living with other employed adults significantly and substantively decreases a woman's likelihood of unemployment, indicating the importance of household-based social accessibility.

Neighborhood characteristics are commonly used indicators. However, the validity of such indicators is debatable. Wilson (1987) argues that people living in underclass neighborhoods have poor information about legitimate jobs because they lack contact or interaction with the mainstream society. On the contrary, Ihlanfeldt (1997) finds that people living in underclass neighborhoods in Atlanta, Georgia are not poorly informed relative to those living outside of the areas, but he does find the racial disparity in job information: African Americans are less informed than whites. Green et al. (2005) find that young people in deprived areas have quite accurate basic knowledge of the location of employment opportunities as they correctly identify places with job concentrations.

Still, research generally finds significant impacts of neighborhood characteristics when they are used as social network indicators. O'Regan and Quigley (1996b) use neighborhood characteristics, including the share of each ethnic group and the share of employed workers, to measure social access, and they find positive impacts of these characteristics on the employment outcomes of New Jersey teenagers.

O'Regan and Quigley (1996a) and Ihlanfeldt and Scafidi (2002) similarly use the share of racial groups. Pastor and Adams (1996) use the neighborhood poverty level as an indicator of network quality and find that the quality matters greatly and, in fact, may even dominate spatial employment gaps.

To what extent these neighborhood characteristics can represent social networks is uncertain. Fernandez and Harris (1992) find that neighborhood poverty affects the size and structure of African American females' social networks in Chicago. Similar effects of ethnic concentration on social ties between minorities and native citizens are observed in the Netherlands (Laan Bouma-Doff 2007; Vervoort 2012). But Drever (2004) finds no association between ethnic neighborhoods and social interaction with the racial majority in Germany.

Better indicators of social networks might include multiple neighborhood characteristics. Weinberg et al. (2004) use employment rate, educational attainment, public assistance income, and poverty rate, in addition to job proximity, as proxies of social interactions. Pastor and Marcelli (2000) develop a more convincing indicator of social network quality, which involves the ranking of individuals by both the number and "quality" of their ties to others, and find that social network quality matters the most for Anglos than other race/ethnicity or immigrants. Nevertheless, it is difficult to adopt Paster and Marcelli's indicator because they rely on a unique dataset of Los Angeles Survey of Urban Inequality (LASUI), which provides detailed information of social contacts.

Apparently, gaps exist in the literature between the conceptual definition of aspatial social networks and their operational measurements based on neighborhood characteristics. Empirical literature that focuses on explaining disadvantaged groups' employment outcomes tends to use very crude measurements, which probably cannot capture the network structure or the richness of job information. Therefore, the question arises whether we can use characteristics of spatially defined areas, such as neighborhoods, as indicators of social networks?

5.5 Spatial Characteristics of Social Networks

This section reviews a broad social network literature to investigate, first, to what extent space shapes social networks and, second, how space and social networks are interrelated in explaining employment outcomes.

Much literature on social networks emphasizes their aspatial nature. In his "community without propinquity", Webber (1963) argues that space plays a decreasingly important role in communities, although he implies that space still matters. Studying the intimacy of kin and non-kin, Fischer (1982) confirms the aspatial nature of many social networks, which are free from blocks, neighborhoods, and cities. Wellman (1988) argues that most social ties are nonlocal and thus supports the aspatial treatments of communities. Particularly, spatial proximity is less critical in the networks that involve "the most intimacy, sacrifice, and faith" (Fischer 1982).

Consequently, job information interchange also occurs beyond spatial boundaries. Wilson (1987) concerns that workers who live outside the inner city may find out about job vacancies in the inner city sooner than those who live in the inner city because the latter are not tied to the job networks, but he does not show empirical evidence. Kasinitz and Rosenberg's (1996) study on the Red Hook section of Brooklyn, New York find that some workers have to be recruited from unions, many members of which have moved out of the neighborhoods where the unions were originally organized. In other words, where the union members used to live and work is more important than where they currently live.

However, much research still recognizes the theoretical connection between space and social networks. Zipf's law (1949) posits that it takes more energy to connect to those who are far away than those who are readily available. Therefore, social contacts are more likely to occur among those who are closer in geographic locations than those who are distant (McPherson et al. 2001). Webber (1964) states that "it is accessibility rather than the propinquity aspect of 'place' the crucial factor for social communities" (p. 109). Accessibility is "equally as important as social similarity in determining the likelihood of tie formation" (Hampton 2002) or the "thickness" of a relationship, indicated by the multiplexity and the frequency of actual contacts (McPherson et al. 2001). Accessibility, in the current context, is still largely determined by spatial proximity (Grengs 2010).

Empirical research also finds the vital role of space in social networks. Although supporting the view of "community without propinquity", Fischer (1982) still recognizes that distance affects social contacts. In a study on local performance and graphic art groups, Kavanaugh (1999) notes that face-to-face settings, such as public meetings, church gatherings, and artistic exhibitions, are the main venues for community leaders to inform and communicate with community members, suggesting that social networks are partly based on physical contacts. In another careful study on communities, Wellman, Carrington, and Hall (1988) show that stable social networks need spatial accessibility, with the finding that most communities in East York, Canada, are confined in usual spaces: workplaces and neighborhoods. A number of studies identified that 35–49% of close ties-friends live in short distance (within one mile or in the same neighborhood) (Connerly 1985; Hunter 1974).

The continuing dependence of communities on residential neighborhoods and workplaces makes communities still connected to spatial accessibility and communication costs, which largely decides the ease of contacts between network members. The dependence on space indicates that spatial dispersion decreases the density of the respondents' communication networks (Baybeck and Huckfeldt 2002).

Advances in telecommunications and emergence of cyberspace increase information accessibility, and arguably reduces the significance of spatial propinquity. Almost five decades ago, Webber (1968) predicted that technology development would further encourage community without propinquity. To empirically test whether information and communication technology (ICT) can free communities from geographic places, Hampton (2002) use Netville, Canada, one of the first residential developments in North America to have a broadband high-speed local network, as a case study. He finds that compared to non-wired residents, Netville residents have tighter social contacts with their neighbors and more local communication through the use of email. In Netville, ICT encourages communication and interaction where intuitively least expected—in the neighborhoods. Studying the electronic village in Blacksburg, Virginia, Kavanaugh (1999) reaches a similar conclusion that computer networks are not just reinforcing, but expanding existing social networks within a neighborhood. Mok, Wellman, and Carrasco (2010) compare the role of distance in social connections between the 1970s and 2000s and find that email has slightly changed the way people maintain contacts but the relationship between distance and face-to-face contacts and between distance and phone contacts remain similar.

The social networks that contain job information and facilitate informal job search are no exceptions. Topa (2001) argues that "physical distance is an important determinant of social ties" (p. 270). Specifically, he observes that spatial distribution of unemployment is partly associated with social interactions across neighborhood boundaries, and the social interactions are weaker across neighborhoods with different ethnic compositions and across perceived different neighborhoods. In a subsequent paper, Conley and Topa (2002) specify that racial/ethnic distance, which considers both spatial distance and racial/ethnic compositions, explains the spatial correlation in unemployment. Similarly, Patacchini and Zenou (2012) find that a higher percentage of a given ethnic group nearby is associated with a higher probability of finding a job through social contacts, but the effect declines rapidly with distance. Zenou (2013) suggests a theoretical model and concludes that both social and physical distance hinders ethnic minorities to find jobs.

5.6 Suggested Measurements of Social Networks

This section suggests social network measurements based on a broad literature that considers a wide range of factors that can describe social networks.

Individual characteristics could affect the size, density, and intimacy of social networks. Some researchers argue that race/ethnicity is the biggest divide in social networks (McPherson et al. 2001; DiPrete et al. 2011; Reingold 1999), some argue that education is the strongest indicator (Fischer 1982), and some suggest strong effects of age and gender (Haggerty 1982; Campbell and Lee 1992). Webber (1964) maps a hierarchy of "urban realms" and suggests that more highly specialized people participate in communities that are larger in spatial ranges (pp. 112–113). Nevertheless, Knoke and Yang (2008) suggest that relationship within social networks are more important in understanding observed behavior than individual person's attributes.

Spatial proximity could be the most straightforward and the strongest spatial indicator of social networks. Patacchini and Zenou (2012) even suggest that "one can … approximate the social proximity by the geographical proximity" (p. 939).

Such spatial proximity is commonly represented by neighborhoods. Neighborhoods can decide who residents interact with (McMillan and Chavis 1986; Greenbaum and Greenbaum 1985). Campbell and Lee (1992) assert that relations with neighbors are vital components of personal networks. One empirical study by Bayer et al. (2005) finds evidence of significant social interactions operating at the block level: residing on the same block increases the probability of working together.

In addition to the common neighborhood characteristics used in the above-reviewed empirical research, other neighborhood characteristics are particularly important for the formation and the maintenance of social networks. Length of residence has direct effects on “local friendships, attachment to community, and participation in local social activities” (Sampson 1991), and therefore the length can be an indicator of the strength of one’s ties to local networks. Additionally, Cabrera and Najarian (2013) emphasize that homophily has a great influence even in a diverse neighborhood. Galster et al. (2015) note the effects of neighborhood safety on the social attachment of low-income, minority youth.

The geographic setting and design of neighborhoods also matter. If people are given opportunities to interact and exchange information in the local setting, they are more likely to form local social ties (Hampton 2002). Therefore, physical design is important to form communities. Jacobs (1961) recommends mixed-use and active street life to encourage social interactions. Gans (1962) observes that structural features of buildings—window and door placement—affect resident interaction in Boston’s West End. Common areas and amenities, such as shopping, religious and recreational facilities, encourage resident interaction (Ahlbrandt 1984; Fleming et al. 1985). Brown and Werner (1985) find that well-designed streets facilitate neighborhood attachment by increasing resident interaction. These locally built environment characteristics could be categorized as density, diversity, design, and destination accessibility, as summarized in Ewing and Cervero (2010). Nevertheless, Talen (2000) warns using physical planning to create a “sense of community”, although she acknowledges that “physical factors affect certain aspects of social interactions”.

In addition to residential neighborhoods, workplaces are also important for the formation and maintenance of social networks. Those who are employed have established workplace-based social networks. Again, personal characteristics affected the strength of social networks, including workers’ race (Ibarra 1995) and sex (Brass 1985), as well as the number of workers who occupy the same jobs (Lazega and Van Duijn 1997).

Bridging residence-based networks and workplace-based networks is important, particularly for those who are seeking jobs. Indicators of such bridges are crude in empirical research. Common indicators are employment status of household members (Parks 2004), industries in which the parents work (O’Regan and Quigley 1996b), employment rates of neighborhoods (Weinberg et al. 2004), and poverty rates of the neighborhoods (Weinberg et al. 2004). All of the above indicate certain components of workplace-related networks, but to what extent those characteristics capture job information and employment networks is uncertain.

A few studies have attempted to simulate social networks based on easily available datasets, and the simulations predict pretty well the observed social networks. The studies that predict friendship formation are quite successful using data in Eindhoven, the Netherlands (Arentze et al. 2012), in Sweden (Preciado et al. 2012), and in Australia (Daraganova et al. 2012). Hipp and Perrin (2009) also find that in a "new urbanist" neighborhood in a southern U.S. city, physical distance is important for the formation of both weak and strong ties between neighbors. Verdery et al. (2012) similarly find a significant association between dwelling unit proximity and kinship relatedness, using data from Nang Rong, Thailand. In all the studies, spatial distance is significantly related to tie formation: long distance reduces such formation.

In general, space is still necessary for the formation and sustaining of social networks. In additional the characteristics of the commonly used neighborhood, additional spatial characteristics should be considered, including but not limited to the length of residence, built environment, and workplace-based networks.

5.7 Conclusion and Discussion

This chapter attempts to advance current literature by examining the importance of space in social networks that affect disadvantaged groups' employment outcomes. Existing empirical research tends to use household or neighborhood characteristics as the proxies of social networks. This literature review provides support for these proxies: spatial characteristics are closely related to the formation and maintenance of social networks.

Additionally, this chapter suggests other spatial variables that should be considered, including the homogeneity of the neighborhoods, the length of residence, and neighborhood built environment. Additionally, social networks are not limited to residential neighborhoods; workplace-based networks can be equally important, and it is vital to link residence-based social networks with workplace-based networks for people seeking employment.

These findings provide support for policies and planning that aim to encourage social interaction and information exchange through improving physical environment. Inclusionary zoning and mixed-use, mixed-income development can be beneficial to increase disadvantaged groups' exposure to the mainstream society. Creating viable physical and social environment at workplaces, such as the Central Business Districts or employment centers, is similarly important. Public spaces, such as parks, libraries, and farmers' markets, can encourage social interactions. It is also important to channel employment and relevant information into the neighborhoods with concentrations of disadvantaged groups. Possible strategies include establishing job information or job training centers in disadvantaged neighborhoods or connecting these neighborhoods with major employers or employment clusters.

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Chapter 6
A Social and Spatial Network Approach to Understanding Beliefs and Behaviors of Farmers Facing Land Development in Delhi, India

Jessica A. Diehl, Mallika Bose and Deborah S. Main

6.1 Walking into a Field of Social Networks

The first time I walked into the field—literally into a field of okra on the floodplain of the Yamuna River—I was interested in whether the farmers grew enough produce to make a meaningful impact on food security in Delhi. After the five-week pilot study, I left the field with pages of notes from my conversations with farming families that described impending development of the land and their consequent displacement. Despite in-depth conversations, I had more questions than answers about why no one talked about doing anything in response to land development. Why weren't farmers voicing their concerns? Were they even talking to each other about impending displacement? It was as if the very idea of starting a dialog—among themselves, with city planners, or even directly with the developers—was not even within the realm of possibility. Surely their lack of engagement was not an indication of their lack of desire to be included?

The reality was that Delhi farmers were not invited to participate in the planning and development of the land they had cultivated for years—some for generations. We often concern ourselves with who does or does not show up at the table. Yet, our work is too often shaped by those who do show up, with limited consideration of missing voices. What happens to those who aren't invited? A growing body of evidence suggests that social relations play an important role in how community members understand and experience participatory planning, and, consequently, engage or disengage from the process. Delhi famers, who lived on small plots close to their farming neighbors and interacted with many

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> of the same people, presented an opportune case to explore in-depth social and spatial dimensions of the city environment within the context of planning and land development.
>
> It was with this in mind that I walked into the field the second time—this time, a field of budding heads of broccoli. This chapter reports on what we learned about how farmers, embedded in the physical environment, are also embedded in social networks, and how those networks can influence household beliefs and behaviors related to land development.
>
> —J. Cook

This chapter first introduces readers to the literature that shows the important role of social networks in how marginalized groups engage (or disengage) the participatory planning process—typically through informal spaces. Central to Social Network Analysis (SNA) theory is the concept that social structures facilitate or constrain opportunities, behaviors, and cognitions. The case of Delhi farmers provides an opportune context to observe how social structures facilitate and constrain beliefs and behaviors in relation to land development. Since land development impacted the entire community, we were able to link variations in spatial and social networks with the different reactions to the shared event.

Next, we include a description of a theoretically grounded method for measuring social networks. By carefully operationalizing the core assumptions of SNA, we developed a comprehensive social network model able to capture social and physical dimensions of networks at multiple spatial and temporal scales and with very fine granularity (at the household-level). The methodology bridges traditional ethnographic field methods with use of GIS and other technologies in a way that balances breadth and depth, and produces a rich characterization of household networks. Our method differs from emerging network analysis trends that rely on big data and other uses of technology in investigation of urban social-spatial interactions. Such approaches can cast a wide net in mapping networks, but are limited in measuring complete social networks with all their nuanced variations. Conversely, the risk with deep analysis at the individual-level (such as use of surveys or interviews) is in losing the larger context—and the ability to compare across cases and see patterns. Therefore, we use a mixed methods approach to harness the advantages of both approaches while minimizing limitations.

To demonstrate our methodology and illustrate how social networks can enable or constrain the ability of marginalized groups to participate in the planning and development process, we present a case study of urban farmers facing land development in Delhi, India. We provide a brief summary of findings on household social networks and beliefs/behaviors. Then, using the context of land development, we describe how variations in social networks related to variations in household beliefs/behaviors. We define five social network types that emerged from findings related to differences in the way households understood the land development situation, intended (or did not intend) to act, and their level of confidence in the impact of their actions. The implication of this research is that by modeling how different types of social networks enable or constrain household opportunities, behaviors, and cognitions, we gain a better understanding of who is more likely and who is less likely to engage in the planning process.

6.2 Participatory Planning, Marginalized Groups, and Social Ties

Community participation is an essential component of sustainable planning and development (UN-HABITAT 2010). But there are many challenges to engaging communities because they are dynamic, multi-cultural entities, and represent many voices (Irvin and Stansbury 2004; Maginn 2007). The poor and marginalized present a unique challenge to planners. They are difficult to reach, yet their homes and livelihoods are often tied to places development projects target, making them an important population to include in sustainable planning practices (Kabeer et al. 2012).

There is evidence that participation can effectively take place outside formal structures through informal connections (or social networks) (Beebeejaun and Vanderhoven 2010; Daniere et al. 2005) Informal spaces are where community members negotiate varying beliefs, values and norms to produce a shared way of understanding (Daniere et al. 2005). And, informal participation through social networks might be more effective in achieving community goals than formal means. This is due to the likelihood of a higher level of social integration in informal (versus formal) community spaces. But even when community-driven, tensions and disagreements can also play out in informal spaces, influencing how and which community members or groups participate (Beebeejaun and Vanderhoven 2010).

Social relations offer more than camaraderie and conversation; they often provide access to tangible and intangible 'assets' and 'capital.' However, poverty and marginalization can act to regulate how and with whom community members establish social relationships (Nygren and Myatt-Hirvonen 2009). Particularly in the case of migrants, who may face everyday hostilities because they are outsiders, coping methods like conflict avoidance can pose a barrier to establishing new and beneficial relationships—and access to resources. In the pursuit of a viable livelihood, the marginalized are often faced with discrimination from mainstream residents, which can limit their ability to access resources like health care, education and police services (Parizeau 2015). Even when relationships are established, there is evidence that the poor can't or don't always turn to social relations for personal gain or opportunities (Nygren and Myatt-Hirvonen 2009; Parizeau 2015; Wong 2008). The persistent lack of human capital combined with structural factors can further constrain participation in the new host society (Wong 2008). There is a need to examine people's daily strategies of living in a way that highlights their perceptions about accessing and obtaining resources through social relationships.

Establishing social relations solely as a means to meeting daily needs can also severely limit the potential for poor and marginalized groups to gain access to invited participatory spaces. The potential for local mobilization is dependent on the interconnectedness of residents in specific geographic locales; interconnectedness impacts how individuals and communities place value on their environment, are compelled to act, and further expand their social networks (Daniere et al. 2002). But, while it may be tempting to focus on the poor and marginalized as "target groups," it is also important to recognize that they do not exist in social isolation (Cornwall 2008). Their carefully selected economically and socially significant relationships may link them to those who are better off, link women with men, or link those worse off with potentially better advantaged individuals or groups. Because of these complex ways of establishing relationships, there may be opportunities to reach marginalized households outside formal means of participation, through informal channels and local initiatives. A dynamic understanding of the role of social networks in the pursuit of sustainable livelihoods is warranted (Cornwall 2008).

6.3 Social Networks: Access to Resources

Social networks are a critical mechanism for mobilizing resources beyond the household (Blaikie et al. 1994). As a result, they play a particularly important role in household sustainability for poor and marginalized groups. A core assumption of Social Network Analysis (SNA) theory is that direct or intensive contact exposes individuals (called "agents") to better information, greater awareness, and higher susceptibility to influence; whereas indirect contact exposes agents to new ideas, and potential access to useful resources (e.g. livelihood opportunities). Social networks act to channel information and resources to particular structural locations, help create interests and shared identities, and promote shared norms and values (Knoke and Yang 2008). As a result of information exchange, social networks affect perceptions, beliefs, and actions through socially constructed structural mechanisms.

SNA theory situates individuals within the larger community rather than seeing the community as composed of unrelated individuals, and allows the observation and location of exchanges among individuals (LeCompte and Schensul 1999; McKether 2011). Social networks are comprised of agents and relations: agents are defined as individuals or collectives (such as households), and relations are defined as the contact, connection, or tie between a pair of agents. A relation exists only if two agents maintain association. Central to SNA theory is the concept that social structures facilitate or constrain opportunities, behaviors, and cognitions (Carrasco et al. 2008). In other words, social relationships impact the creation of common meanings, (Norris et al. 2008) and have an important influence on behavior (Knoke and Yang 2008).

SNA theory draws from many disciplines including anthropology, graph theory, and management science, and has roots in sociology in assuming that the whole is greater than the sum of the parts (Carrasco et al. 2008). There are three key assumptions in SNA theory (Knoke and Yang 2008). The first assumption is that agents' attributes (i.e. gender, age) are static, but agents' relations are dynamic; they exist at specific time-place locales and can disappear or be suspended elsewhere. This means that relations are more important in understanding observed behavior than attributes. The second assumption, noted above, is that the type of information exchanged and degree of influence depends on whether the relation is direct or indirect. The third assumption is that agents change relation structures both intentionally and unintentionally; relation structures are a micro-macro level process of within-group (micro) and across-group (macro) interactions.

The core theoretical challenge in developing a methodology to measure a social network is in specifying the occurrence of different relationships (called "ties") between agents and accounting for variation in ties (i.e. the type of relation). Social networks can be measured quantitatively using metrics that identify "nodes" and "links" (agents and relations) and weighting them based on measures such as between-ness, bridging, centrality, closeness, and reach (Scott 1991). In contrast, a qualitative approach can provide information on the degree of connectivity of relationships and type of information exchanged. In other words, a quantitative approach identifies the existence of a social network; whereas, a qualitative approach uncovers *why* it exists. For this reason, SNA is strengthened by a mixed-methods approach (Edwards 2010).

In addition to a move toward mixed-methods approaches to measuring social networks, *what* is measured is also evolving. This change is based on emerging empirical evidence of a relationship between physical proximity and social interactions. Early research documented that physical proximity is associated with friendship, but studies have only recently begun to explicitly map social networks using specific geographic locations (Hipp et al. 2012; Verdery et al. 2012; Butts et al. 2012; Doreian and Conti 2012). Spatial proximity increases the likelihood of social interaction through shared routines and activities, which can lead to greater similarity in behaviors. In the remainder of this chapter, we detail a case study in which we've used SNA theory to operationalize and describe the link between social and physical dimensions of social networks. We then examine the effect of social networks on perceptions, beliefs, and actions in the context of land development.

6.4 The Case of Delhi Farmers

Using the case of urban farmers facing land development pressures in Delhi, India, we examined how social networks can enable or constrain the ability of marginalized groups to engage in the participatory process related to land development. At the time of this study, the Delhi Development Authority (DDA) was constructing a new line of the Delhi Metro on the actively cultivated land of this particular group of farmers. Farmers were in a state of unease, many distressed, and some were in the process of being displaced or had recently lost land they had cultivated. The DDA has a policy for community engagement in development projects, but often, as reflected by this case, falls short on public inclusion (Ahmad et al. 2013; Datta and Jha 1983; Rao 2010). Metro construction served as an opportunity to examine the relationship between spatial and social aspects of households' networks and household land development beliefs and behaviors.

With few exceptions, farmers in this case were migrants from nearby small cities and villages (many from the same place), but two-thirds had been living on or near their current plot between 4 and 20 years. The typical household had six to ten members across two or three generations. Most families lived on the land they farmed, although some owned a house or property elsewhere in Delhi or in their village of origin. Dwellings included tents and informal woody structures, but there were a handful of permanent concrete houses. Farm plot sizes varied, but three-quarters ranged from 0.3 acres (0.13 ha) to 1.67 acres (0.67 ha). The farmers produced a wide variety of goods; most common were high-value vegetable crops including eggplant, okra, and cilantro, grown over three annual seasons. Once crops were harvested, most were sold through one or more of the local markets or *mandis* (vegetable wholesalers), as well as through roving third party vendors. We heard again and again, "We can sell something every day"; and, "There is a market for every quality of vegetable".

Based on recent estimates that 40% of households in Delhi are self-employed, three-quarters live in unplanned settlements, (Ahmad et al. 2013) 22% live in *jhuggies* (informal structures), (Prashar et al. 2012) and 9.84% are below the poverty line,[1] (Government of India 2013) urban farmers in this study did not represent the extreme poor—in fact, households might be considered typical poor Delhi residents except that they were agriculturalists rather than the more common construction workers, rickshaw drivers, and domestic help. And in reality, more than one-quarter of farming households were also employed in construction, drove a rickshaw, or worked as domestic help. Although location on the Yamuna River floodplain was unique—only an estimated 2500 households live-work on the floodplain within Delhi NCT, (Cook et al. 2015) a city of 25 million people and growing—the study population could be considered representative of many other informal and marginalized communities in Delhi and other large cities in India.

6.5 Study Design

The purpose of this research was to measure social and spatial aspects of household social networks and investigate if households with similar social networks also had similar land development beliefs and behaviors. Research aims were to (1) measure household-level social networks and development beliefs/behaviors; (2) illustrate spatial patterns in social network similarity among households; (3) illustrate spatial

[1]The monthly per capita poverty line for urban Delhi is 1134 INR or 37.8 INR per day (approximately $20.50 USD or $0.70 per day) (Government of India 2013). India sets its own poverty rate. It is currently slightly more than half the $1.25 per day set by the World Health Organization (WHO) as the poverty line (www.who.int—accessed 12/5/14). It is estimated that up to 60% of the Indian population lives on $1 per day or less.

patterns in household development beliefs and behaviors; and (4) test the relationship between household social networks and development beliefs and behaviors.

Using an ego-centric (i.e. household-centric) unit of analysis, we employed a mixed methods approach (GIS mapping, interviews, observations) to determine the social networks of 121 households. Interviews were conducted between March 7, 2013 and February 17, 2014. We used an adjacent sampling method to select households. The geographic location of each farm household was recorded with iPad 2 with 3G using the Bento app.[2] Hindi to English translated interviews were recorded with pen and paper and coded using Atlas.ti 6. Household locations were imported into ArcMap 10.0 and linked to coded interview data.

Analysis was conducted using ArcMap 10.0 and STATA 11 to examine the relationship between spatial and social dimensions of household networks and beliefs/behaviors. We tested three assumptions: (1) that households near each other would exhibit similar social networks (spatial component); (2) that households near each other would exhibit similar development beliefs/behaviors (spatial component), and (3) that households with similar social networks would exhibit similar development beliefs/behaviors (no spatial component). Using ArcMap, we selected the hotspot analysis tool to test assumptions because it has been used in studies to explore spatial patterns of social indicators (childhood health, crime rates) (Anselin et al. 2007; Chainey et al. 2008). Although we were unaware of hotspot analysis application in social network research, it was a good fit for the intended analysis.[3] Hotspot analysis uses the Getis-Ord Gi* to identify statistically significant hotspots and coldspots based on a set of weighted features. It identifies clusters of points (in this case households) that are higher or lower in magnitude than one would expect to find by random chance and outputs the results as a z-score. We weighted households using the Inverse Distance option, which gives more weight to points (households) that are closer in distance, and used Euclidean distance since Manhattan distance was not relevant in this geographic context (farm fields with numerous footpaths). Results mapped clusters of households that were more similar to one another than one would expect based on random chance. We used findings to define different social network types, and compared/contrasted the different ways households understood the land development situation, intended (or did not intend) to act, and their level of confidence in the impact of actions, for each type of social network.

[2]The Bento app is no longer available or supported by Filemaker.

[3]Geo-referenced social network data can be analyzed with programs including Pajek, Ucinet, R, and ArcMap; however, because this research collected within-household (egocentric) social network data and did not measure inter-household (dyadic or complete networks) connections, it was not relevant to perform typical SNA tests such as centrality, density, cohesiveness, etc.

6.6 Measuring Social and Spatial Dimensions of Networks

The method we developed for measuring social networks was based on the assumption that social networks are critical, particularly among the poor, for gaining access to resources beyond the household, to meet daily needs and, ultimately, sustain livelihoods (Blaikie et al. 1994). With this in mind, and relying on the three core assumptions of social network theory, we developed a method for collecting, analyzing, and summarizing household social networks (refer to Table 6.1):

Assumption #1: Structural relations exist at specific time-place locales. We captured time-place attributes by asking households where, when and frequency of household interactions with each identified social tie.

Assumption #2: The type of information exchanged (transaction) and degree of influence depends on whether the relation is direct or indirect. We conceptualized the type of transaction in terms of livelihood assets comprised of five capitals (Scoones 2009):

- Human capital is defined as knowledge and labor potential.
- Natural capital is defined as ecosystem assets.
- Financial capital is defined as money.
- Physical capital is defined as tangible "things."
- Social capital is defined as positive social connections (a subset of the overall social network, which can be comprised of positive or negative social connections).

Table 6.1 Measuring social and spatial dimensions of social networks

Relation type	Measurement				
	Location & frequency of interaction(s)	Type of transaction(s)	Degree of Influence	Relation direct or indirect	Dimension
	Where, when, frequency	Human, natural, financial, physical, social	Invest, withdraw, exchange, block	Bond, bridge	Within-household, within-community, outside-community
Other farmers					
Hired labor					
Market/ vendor					
Industry					
Landlord					
Other relations					

To operationalize the degree of influence, we used the concept that social structures facilitate or constrain opportunities, behaviors, and cognitions. We conceptualized facilitating and constraining functionalities of social ties:

- Invest (facilitating): things the family gives to other farmers (information, tangible resources, etc.).
- Withdraw (facilitating): things the family gets from other farmers (information, tangible resources, etc.).
- Exchange (facilitating): sharing knowledge (discussion) and labor (labor for labor) as well as giving something in exchange for getting something different.
- Block (constraining): negative relationships (distrust, fighting, not knowing anyone).

In social network theory, direct relations are defined as being more intensive, whereas indirect relations are defined as weaker and more distal contacts (Knoke, D. and S. Yang, Social Network Analysis. 2nd ed. Quantitative Applications in the Social Sciences 2008). We conceptualized direct relations as bonding ties and indirect relations as bridging ties:

- Bond (direct): a strong tie between immediate family members, neighbors, and friends.
- Bridge (indirect): a connection with a person or people of different socioeconomic and/or cultural backgrounds.

Assumption #3: Agents change relation structures both intentionally and unintentionally; structures are a micro-macro level process of within-group and across-group relations. Social networks were defined across three micro to macro dimensions:

- Within-household (micro): interactions among family members living together as a unit.
- Within-community (meso): interactions within the farming community—primarily with other farmers. It also included laborers, if they were other farmers, and agricultural sales people or experts, if farm inputs and/or advice came from inside the community.
- Outside-community (macro): interactions or connections beyond the farming community—primarily through the landlord and market vendors, but also including laborers, industry folks, and other relations, if they were outside the community.

We carefully considered the different aspects of household-level (ego-centric) social networks based on the type of relation, location and frequency of interaction, the type of transaction, the degree of influence, whether the relation was direct or indirect, and micro to macro dimension (refer to Table 6.1).

After cleaning and coding the interviews, we began to summarize the different components of household social networks. Aggregating all household relations into an overall social network was not a simple sum of relationships. Particularly among poor and marginalized groups, relations often have trade-offs; risks are weighed against benefits. For example, a person may trade health risks for better pay or turn a blind eye to crime or corruption by someone who offers charity (Parizeau 2015). In other words, social networks are a complex web of benefits and risks. With that in mind, household social networks were characterized across a broad spectrum. Again, we were mindful of the SNA concept that social structures facilitate or constrain opportunities, behaviors, and cognitions. Through careful consideration, we dichotomized social networks as strong (facilitating) or weak (constraining) relative to household pursuit of a sustainable livelihood.

To illustrate the aggregation process, we provide an example of part of our analysis. While the details are specific to this case study, the general method is replicable. In this case, as part of the overall household social network, it was critical to understand household relationships with other farmers, so we focus on that in this example.

For information gathering during the interview, we asked each family: *Do farmers generally know each other? What kinds of things do you talk about?* Depending on the response, we prompted for additional information by asking: Do you ask other farmers or tell other farmers what to grow, where to sell, how to get schemes (i.e. government services) or identification cards? Do farmers generally help each other? How? Do you share laborers, tractors, borrow or lend money? When a new family comes here, how do you get to know them? Can you tell us about your experience when you first came here?

Table 6.2 includes interview responses that show the various ways that the families in this case study associated with other farmers. *Other* farmers represent a bonding relation for interviewed families.

Based on responses in Table 6.2, we determined that households could: (1) invest in financial and social capital by giving other farmers loans; (2) withdraw financial, social, and physical capital by borrowing money from other farmers, and finding land through other farmers; and, (3) exchange human, financial, social, and physical capital by talking to, helping, and building relationships/ friendships with other farmers, exchanging loans or labor, having relatives living nearby, and having the same homeland. Blocks to household relations with other farmers involved not talking, fighting, not trusting, not loaning money, and generally not helping other farmers. From this, we created a scale from strong (5) to weak (−3):

5 Farmers talk, trust or help | loan money or goods | exchange | found land through contacts | from [same village] | discuss land use

4 Farmers talk, trust or help (can include exchange) | loan money or goods (or no comment) | found land through contacts | from [same village] | may discuss land use

3 Farmers talk, trust or help (can include exchange) | may or may not loan money or goods | either found land through contacts or are from [same village] OR landowner | may discuss land use

2 Farmers talk, trust or help (can include exchange) | may or may not loan money or goods

Table 6.2 Matrix for measuring "other farmers" as part of the household social network

Interaction with other farmers	Invest	Withdraw	Exchange	Block	Bond	Bridge	Capital
In general farmers talk (personal, work, or in general)			X		X		H/S
Farmers don't talk, sometimes fight, or only talk to family or immediate neighbors				X			–
Families borrow/lend money			X		X		F/S
People don't trust each other				X			–
This family knows a lot of people			X		X		S
People are cooperative			X		X		S
This family's relatives live here/nearby			X		X		S
Famers don't borrow or loan money				X			–
Borrow/loan with security or interest			X		X		F
Borrow/loan on good faith			X		X		F/S
Borrow/loan in exchange for labor			X		X		F/S
This individual/family gives loans to others	X				X		F/S
This individual/family borrows money from others		X			X		F/S
People don't trust each other with money				X			–
They borrow only from the landlord		X				X	F
No one has any money				X			–
No one loans money				X			–
Farmers help a lot			X		X		S
Farmers help when they can			X		X		S
Farmers don't help				X			–
Farmers share produce			X		X		P
Farmers help if there are health problems			X		X		H
They share laborers			X			X	H

(continued)

Table 6.2 (continued)

Interaction with other farmers	Invest	Withdraw	Exchange	Block	Bond	Bridge	Capital
They work for each other			X		X		H
Farmers arrange marriages among their families			X			X	S
Farmers share news			X			X	H
Farmers eat together or celebrate festivals			X		X		S
This family came through relatives who live nearby		X				X	P
This family came through relatives who have moved		X				X	P
This family found land through contacts		X				X	P
This family is from [same village]			X		X		S
They discuss land use change with other farmers			X		X		H

S Social capital; *H* Human capital; *F* Financial capital; *P* Physical capital

1 Farmers loan AND/OR Found land through contacts and/or are from [same village] | No other comments | OR only discuss land use

−1 Farmers don't talk, trust or help | do loan money or goods | found land through contacts and/or are from [same village]

−2 Farmers don't talk, trust or help (or no comment) | don't loan money or goods (or no comment) | found land through contacts and/or are from [same village]

−3 Farmers don't talk, trust or help | don't loan money or goods | didn't find land through contacts | not from [same village] OR Farmers don't talk, trust or help | no other comments.

By conducting the same process of creating a matrix, summarizing and creating a social network scale for each relation type, we incrementally characterized social networks across micro to macro dimensions (within-household, within-community, and outside-community), and overall as strong (positive score) or weak (negative score). To complement the methodical and somewhat quantitative evaluation of social networks, we created social networks maps (Fig. 6.1) for each household, and qualitatively matched them with the "score." This allowed us to make a few fine-grain adjustments in our final social network designation if one particularly strong facilitating or constraining social relation warranted a heavier impact on the overall network.

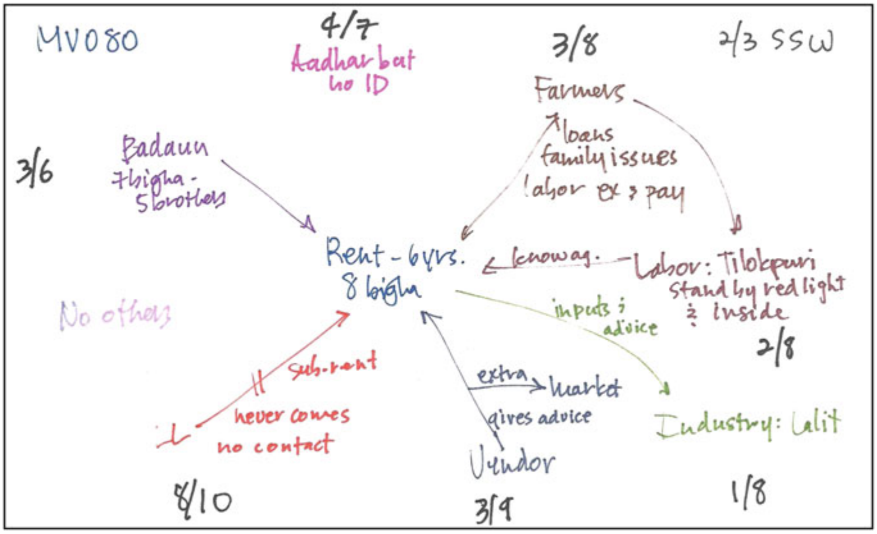

Fig. 6.1 Example of social network cognitive map of one household

6.7 Measuring Beliefs and Behaviors

To measure development beliefs and behaviors, we began the discussion by asking household members if they were aware of or were presently being impacted by any land development. We asked them to describe the situation. Regardless of response (even if the answer was 'no'), we followed up by asking if they thought they had any influence on land development on their land or on land nearby. Lastly, we asked household members if they had any involvement or knew anyone involved in activities related to land development. Based on conversations, we assessed households for: land development knowledge, activities in response to land development, and belief that their actions could influence land development (knowledge, behavior, influence).

6.8 Social and Spatial Network Influence on Beliefs and Behaviors

Of the 121 farming households that participated in interviews, 55 (45%) were characterized with strong (facilitating) social networks, and 66 (55%) were characterized with weak (constraining) social networks. Based on our findings, although not a comprehensive description, characteristics of a strong household social network could include: educated children, multiple sources of income, a positive

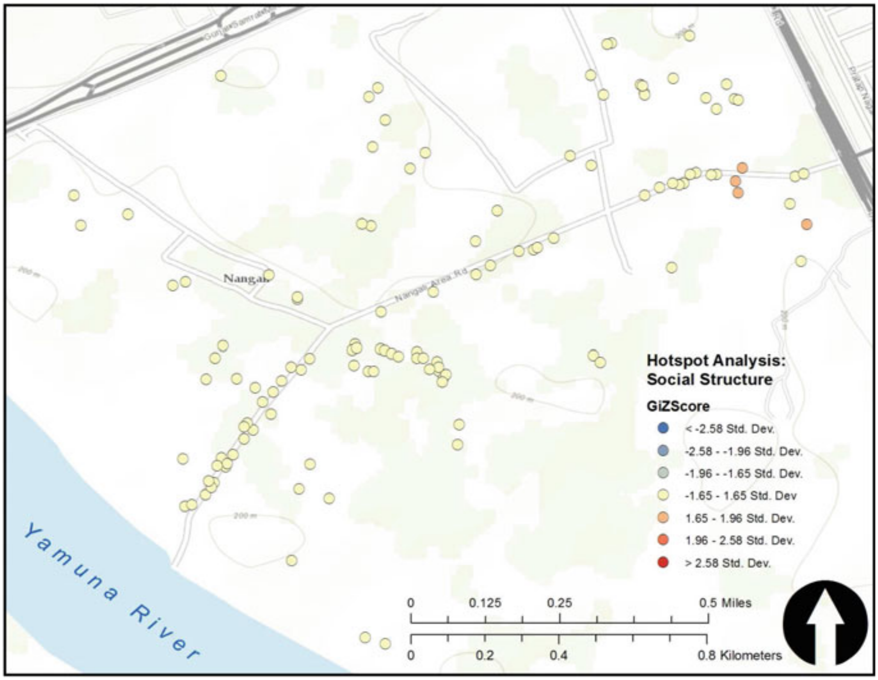

Fig. 6.2 Hotspot analysis of household social network (results map households (HH) that are more similar to each other than would be expected by chance. Red = cluster of HH with strong SN; blue = cluster of HH with weak SN; yellow = random distribution. To protect privacy, interview sites are not shown in the exact location where the household was interviewed)

relationship with neighbors (shared labor, information), a positive relationship with the landlord (fair rent, helped when needed), and other relationships that provided reliable access to resources needed to be successful farmers (seeds, advice re: pests, fair paying customers). In contrast, a weak household social network experienced constraint through one or more critical relationships in their endeavor to achieve a sustainable livelihood. This took shape through distrust of neighbors, landlords who "took advantage" of them, and isolation ("don't know anybody"). We ran the hotspot analysis tool in ArcMap, but found minimal spatial clustering of households based on strong/weak social networks (Fig. 6.2). There was one place where households with strong social networks clustered (illustrated by orange dots); but in general, households with strong social networks were no more likely to be near other households with strong social networks than they were to be near households with weak social networks.

Simply dichotomizing household social networks as strong or weak was problematic for a number of reasons. Most notably, what was most common was for households to have a combination of multiple facilitating and constraining relationships. Returning to social network theory assumption #3, that structures are a micro-macro level process of within-group and across-group relations, we looked at spatial patterns for the three different dimensions of social networks as we defined them (within-household, within-community, and outside-community).

6.8.1 Micro Network: Within-Household

Within-household (micro) social networks related to interactions among family members living together as a unit. Figure 6.3 illustrates two places where households with strong within-household networks clustered geographically (illustrated by red dots): along the main road and among households living closer to the nearby built-up urban edge. Such households were more likely to educate their children (often sending them to government schools in the adjacent built-up neighborhood), have larger extended families, and multiple sources of income. Households with weak within-household networks clustered along the main road closer to the Yamuna River (illustrated by blue dots). Such households were less likely to

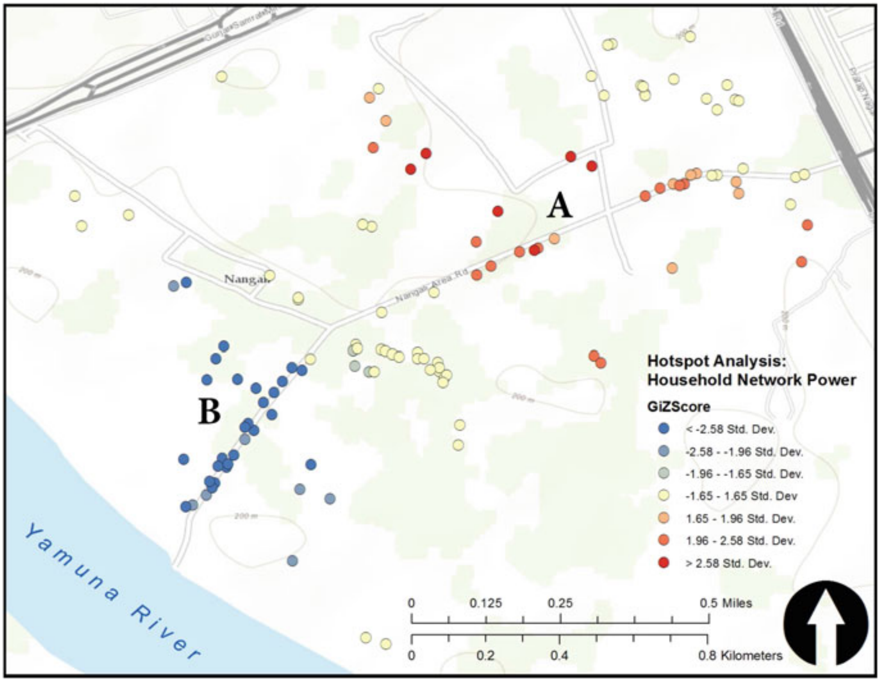

Fig. 6.3 Hotspot analysis (results map households (HH) that are more similar to each other than would be expected by chance. A = cluster of HH with strong SN; B = cluster of HH with weak SN) of *micro* (within-household) social network (to protect privacy, interview sites are not shown in the exact location where the household was interviewed)

educate their children, be comprised of smaller nuclear families (most with relatives living far away), and have a single source of income (only farming).

The measure for within-household networks only captured social ties within the household or family, and, therefore, did not measure ties with neighbors. The clustering of households displayed in Fig. 6.3 may be explained by proximity to the main road and Mayur Vihar, a neighborhood with government schools and opportunities for domestic work, rickshaw pulling, etc. rather than proximity between households. However, clustering could also indicate indirect influence among households. For example, a household might choose to educate their children if they see their neighbors send their kids to school, however, while a likely scenario, further corroboration is needed.

6.8.2 Meso Network: Within-Community

Within-community (meso) social networks related to interactions within the farming community—primarily with other farmers. It also included laborers, if they were other farmers, and agricultural sales people or experts, if farm inputs and/or advice came from inside the community. Figure 6.4 illustrates one place near the main highway where households with strong within-community networks clustered along the main road close to the adjacent highway (illustrated by red dots). Such households had access to a greater variety of livelihood assets through connections and interactions within the farm community. It may have been that close proximity increased the likelihood these families talked with one another, loaned each other money, worked for each other as laborers, or shared transportation costs to get their produce to market. However, limitations of ego-centric collected data, specifically lack of information on which households actually talked to one another, prevent us from explaining the reasons motivating the observed patterns.

6.8.3 Macro Network: Outside-Community

Outside-community (macro) social networks related to interactions or connections beyond the farming community—primarily through the landlord and market vendors, but also including laborers, industry folks, and other relations, if they were outside the community. Figure 6.5 illustrates two places where households with strong outside-community networks clustered (illustrated by red dots). Such households had more access to and influence over a greater variety of livelihood assets through connections and interactions beyond the community. For example, they might have the same landlord, share outside laborers, buy farm inputs and get advice from the same places, or go to the same medical centers. We found some clustering of households with strong outside-community networks. A possible explanation is that the area was owned by one of the landlords who had a positive

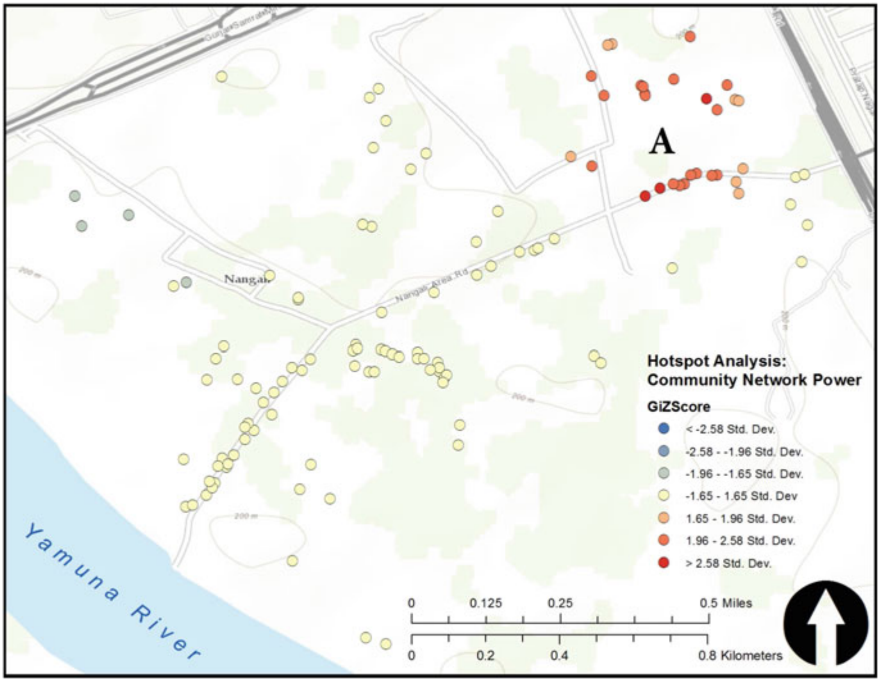

Fig. 6.4 Hotspot analysis (results map households (HH) that are more similar to each other than would be expected by chance. A = cluster of HH with strong SN; B = cluster of HH with weak SN) of *meso* (within-community) social network (to protect privacy, interview sites are not shown in the exact location where the household was interviewed)

relationship with tenants—provided advice, was fair, and helped when asked. The place where households with weak outer-community networks clustered (illustrated by blue dots) is more difficult to explain. Possible explanations could be that the area was managed by multiple landlords who had a lower social standing than landlords with larger holdings, or that the landlord(s) were more interested in collecting rent than the success of the farm.

6.8.4 Land Development Beliefs and Behaviors

We also used the hotspot analysis tool to identify places were households with similar land development knowledge, behavior, and belief in influence clustered. We found minimal spatial clustering (Figs. 6.6, 6.7 and 6.8). Specifically, there was no place where households with similar development knowledge or behavior where more likely to be near to each other than one would expect by random chance. There *was* one small place where households clustered with similar beliefs regarding influence on current development—but the belief was that they did *not*

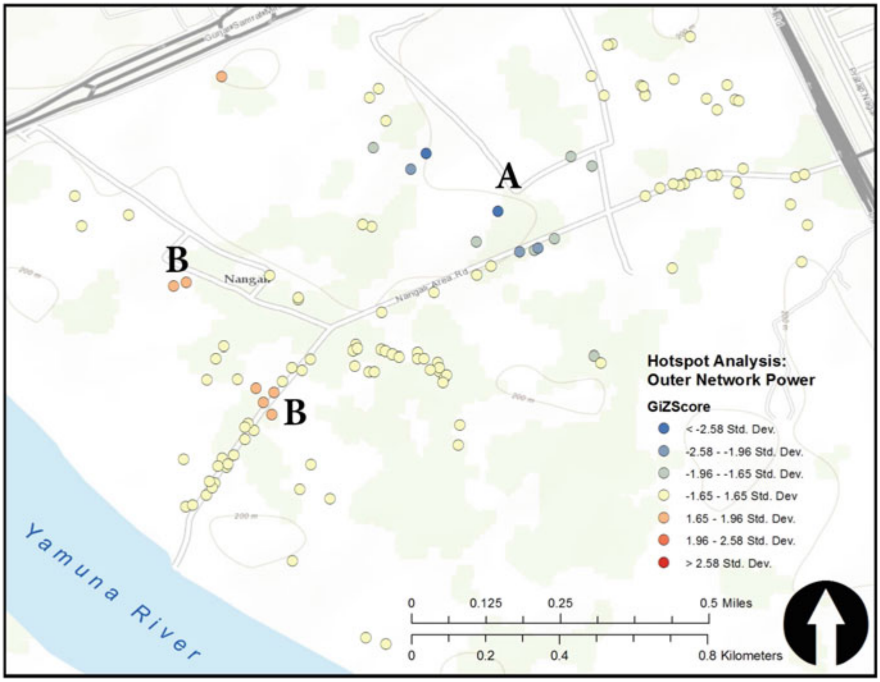

Fig. 6.5 Hotspot analysis (results map households (HH) that are more similar to each other than would be expected by chance. A = cluster of HH with strong SN; B = cluster of HH with weak SN) of *macro* (outside-community) social network (to protect privacy, interview sites are not shown in the exact location where the household was interviewed)

have any influence (Fig. 6.8; illustrated by red dots). This particular place was located in the shadow of metro construction, and these farmers had already experienced a reduction in the land they could cultivate.

6.8.5 Networks and Beliefs-Behaviors

When we crossed social networks with beliefs/behaviors, no spatial patterns emerged through hotspot analysis. In other words, households with similar social networks that clustered in the same place did not necessarily share beliefs or behaviors related to land development. However, when we analyzed the relationship non-spatially in Stata, we found that households with similar social networks were more likely to be similar to each other. So, despite weak spatial influence on development beliefs and behaviors, we found social influence on development beliefs and behaviors. Ordered logistic regression showed strong social networks ($n = 55$) were significantly associated with more detailed land use knowledge ($p < 0.01$), more detailed general knowledge ($p < 0.01$), and perceived ability to

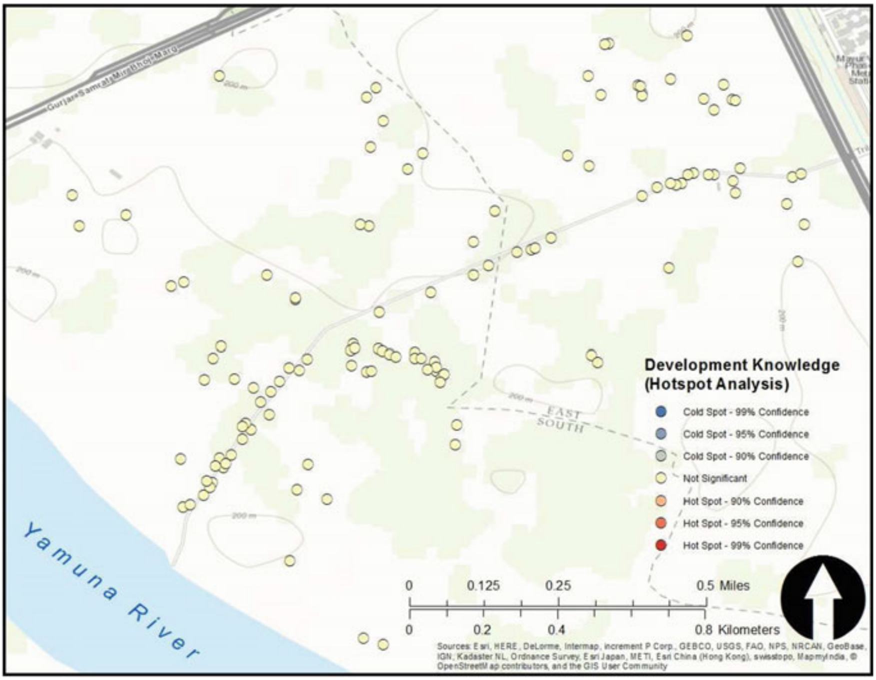

Fig. 6.6 Hotspot analysis (results map households (HH) that are more similar to each other than would be expected by chance. A = hot spot; B = cold spot) of HH *knowledge* (cold spot = HH with specific, detailed knowledge; hot spot = HH said they didn't know anything) (to protect privacy, interview sites are not shown in the exact location where the household was interviewed)

influence land use planning and development ($p < 0.01$). So what was it about these different types of social networks that correlated with beliefs and behaviors? We turn to a typology approach to uncover how social networks can facilitate and constrain beliefs and behaviors.

6.8.6 A Typology Approach

Our methodology for measuring social and spatial aspects of social networks produced a rich characterization of household ties. By summarizing social networks into different types based on micro to macro dimensions, we found a pattern of similar beliefs/behaviors (Table 6.3):

- Type #1: "Family-reliant" exhibited very limited knowledge of land development, and as such, had no motivation to act. Furthermore, this household type lacked confidence that action had any impact. Type #1 was self-reliant in that they did not turn to neighbors or outside influences for information or advice,

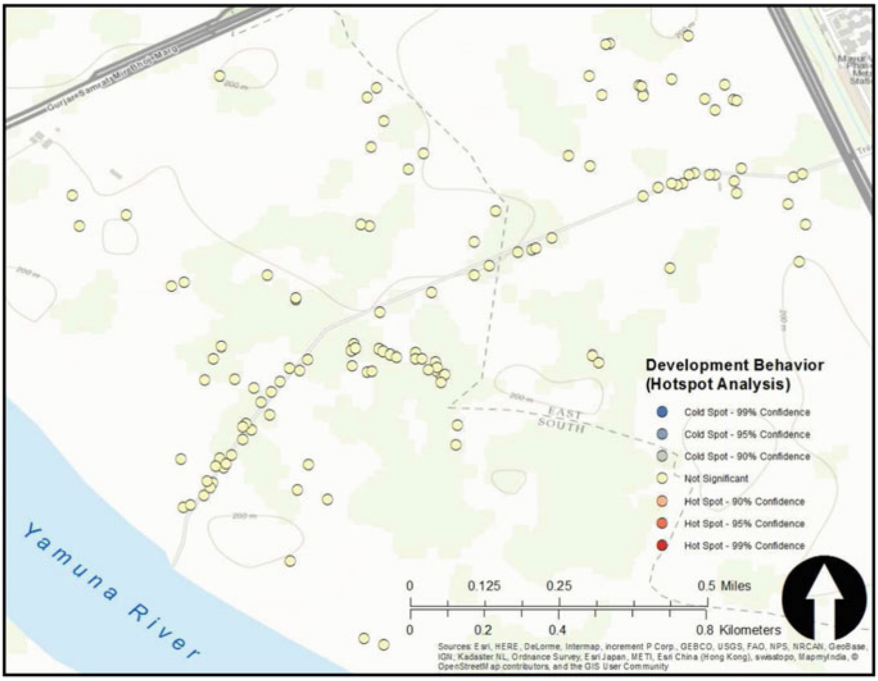

Fig. 6.7 Hotspot analysis (results map households (HH) that are more similar to each other than would be expected by chance. A = hot spot; B = cold spot) of HH *behaviors* (cold spot = HH has acted against development; hot spot = HH has done nothing) (to protect privacy, interview sites are not shown in the exact location where the household was interviewed)

but rather made decisions on their own. The result was that they were vulnerable to outside changes that could happen without any warning.

- Type #2: "Strong bonds" exhibited some general knowledge of land development, and was motivated to take action with other within-community ties. However, this household type lacked confidence that action had any influence. Type #2 was not self-reliant, and was heavily influenced and dependent on within-community ties, which in this case was comprised of similarly marginalized households.
- Type #3: "Bridging ties" exhibited specific knowledge of land development, was motivated to take action, and believed action had some influence. This household type was not self-reliant, lacked within-community ties (which could provide reciprocal resources), and was very dependent on potentially tenuous outside-community ties (a charity situation).
- Type #4: "Mimicry" was an interesting manifestation of the relationship between social networks and beliefs/behaviors. This household type was not self-reliant, didn't have within- or outside-community ties, but persisted in spite of—or perhaps because of—weak social ties. Type #4 was particularly attuned to media and hearsay. Armed with specific knowledge, they took action.

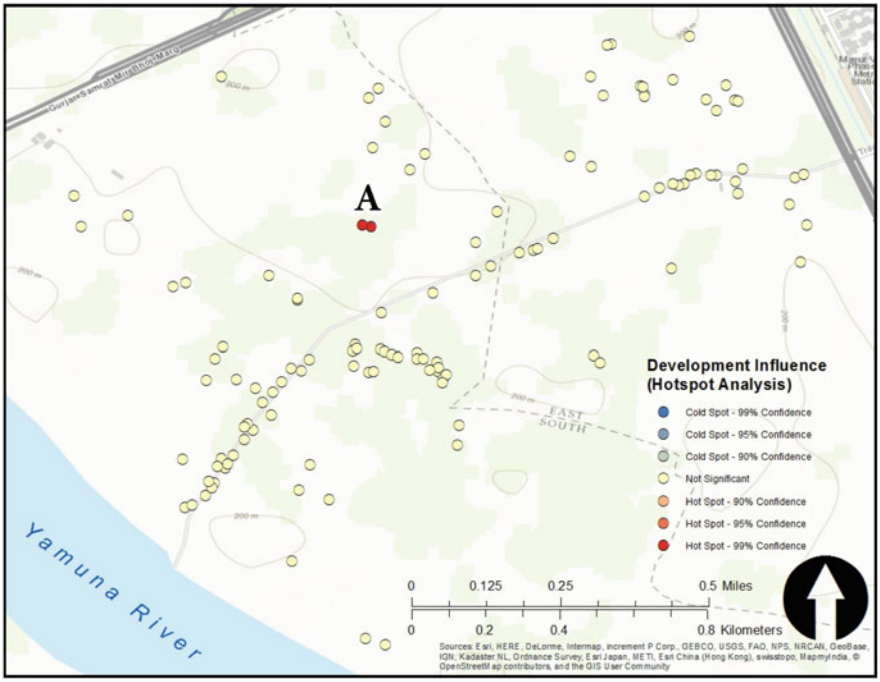

Fig. 6.8 Hotspot analysis (results map households (HH) that are more similar to each other than would be expected by chance. A = hot spot; B = cold spot) of HH *influence* (cold spot = HH believes they cannot influence; hot spot = HH believes they can influence) (to protect privacy, interview sites are not shown in the exact location where the household was interviewed)

Table 6.3 Matrix linking social networks (strong/facilitating (+) or weak/constraining (−)) with beliefs/behaviors

Typology	Within-household (micro)	Within-community (meso)	Outside-community (macro)	Knowledge	Action	Influence
#1	+	−	−	−	−	−
#2	−	+	−	−/+	+	−
#3	−	−	+	+	+	+
#4	−	−	−	+	+	−
#5	+	+	+	+	+	+

However, this household type lacked confidence that action had any influence. The irony was that they took action because there were no other options.

- Type #5: "Many pathways" exhibited specific knowledge, took action, and believed action had influence. This household type was self-reliant, but also had strong within- and outside-community ties. Although equally vulnerable to land development as other households, type #5 engaged directly and indirectly (through others) in voicing beliefs. Although they believed their actions could have influence, they were aware enough of their marginalized status to know that they could still lose land.

6.9 Finding Points of Entry Through Social Networks

This study revealed nuanced dimensions of social and spatial networks; our findings show various ways marginalized households understand the context of their lives, make decisions, and have confidence in the impact of those decisions. The Yamuna farmers represent a case on the far end of the participatory spectrum—and wouldn't even qualify as non-participation according to Arnstein's ladder of participation (in that they weren't asked to participate in land planning or development) (Arnstein 1969). Findings support the notion that those who don't participate may do so not out of apathy, but because they don't feel their opinions will be valued, don't feel they have a right to participate, or don't understand the proposed project (McAlister 2010). There were three overarching themes that emerged from household interviews regarding beliefs/behaviors: (1) there was an overall lack of coherence in their collective voice due to absence of consistent and reliable information related to land development; (2) there was a lack of coordinated action in response to land development; and (3) there was a lack of confidence in the ability of their actions to have an influence on land development. We use the five social network types, described in the previous section, as a guide to suggest potential points of entry into this hard to reach community in addressing these themes.

6.9.1 Lack of Knowledge: What to Say?

Some households were very vocal, and articulate, about on-going development, but there was a lack of overall coherent voice across the community. Farmers said they talked to each other, but as observers, we never came away with a clear sense of what they, as farmers, wanted as a collective group. Our inability to create a cohesive summary corroborates social network analysis findings that farmers gained access to information through a variety of resources. The vast majority of adult farmers were illiterate, and therefore relied on children, neighbors, landlords, customers, metro construction workers, and anyone else who might be knowledgeable about land development and was willing to share their information. The hodgepodge acquisition of information and interpretation, combined with limited sharing of information among households, resulted in a community that lacked a common understanding of the land development process. Without a shared understanding of the problem, they were unable to develop a collective stance on any potential solution.

This study suggests that knowledge comes from social networks beyond the household—households had information only if they were talking to others (those that didn't talk to other families or outsiders said they "didn't know" about any development). Cases where households kept to themselves and turned to media and hearsay for information missed the opportunity to filter and translate the information in a way that was relevant to their social group and situation. On the other hand, households who talked to other families (measured as facilitating meso, within-community social networks) and/or had a good relationship with their landlord (measured as facilitating macro, outside-community social networks) had better information about land development. A potential point of entry to improve access to information and build knowledge in cases where a household does not talk to neighbors is through a willing landlord. Conversely, in cases where a household has a poor relationship with the landlord, neighbors could be encouraged to reach out.

6.9.2 Lack of Action: Participation and Representation

Knowledge is only the first step toward citizen engagement—it does not automatically lead to action. In the case of Delhi farmers, the threat of displacement due to land development was motivation enough for many households to react in some way; households with knowledge also generally took action. Action took the form of active protest and going to court. But action through representation was also common: farmers protested for neighbors who had to work, landlords went to court, and community leaders talked to political advocates. This study suggests that participation was more likely when households had strong ties within the community, whereas representation was more likely when there were strong ties outside the community.

The literature calls for in-depth exploration of relationship dynamics within communities to better understand the role of representation in the participatory planning process (Beebeejaun and Vanderhoven 2010; Brownill and Parker 2010). And, particularly in the case of marginalized groups, how those who aren't involved—either because they are not invited or because they choose not to be involved—find pathways to action through relationships. But, based on research findings, we question whether we should expect most marginalized households or groups to be able to find these pathways. Marginalized groups are different than the mainstream, and we suggest the need to develop new tools and ways for representing the marginalized voice. We call for more research on how different types of social networks can provide different routes to action for members of marginalized groups.

6.9.3 Lack of Influence: Outside the Decision-Making Space

The majority of participants did not believe they had any influence on land development. Even among those involved in active protest or a court case, few believed their actions would make a difference. So, for households who wanted to stop development on the land they farmed, and acted to stop development, few actually believed they could stop or even change the course of development. Complicating the lack of confidence that their actions mattered, many believed that development was inevitable. One household explained that metro construction was a government thing—it "h[ad] to happen," and it was for the "good of the people." In probing deeper, we found that farmers expressed more anger and sadness about the razing of their homes than actual development of the land, over which they felt they had no influence. Through the act and acknowledgement of ineffective participation (going to rallies or meetings, but not believing it could make any difference), farmers reinforced their marginal status.

It is for this reason that we need to contrast invited spaces for participation with those people create for themselves (Cornwall 2008). How can non-profit organizations and government agencies facilitate the process through which these farmers can create their own physical/social spaces for deliberation leading to action? There is also a need to address the process that leads a group of people to perceive themselves as outside the decision-making space. Because, even if they are formally invited to participate and have a voice in the development process, they may not know what to say:

> Societal groups whose historical experience has been marginalization from politics and decision-making may not have a clear sense of their interests as a group, nor of an agenda for change. This may require the creation of spaces of their own, within which to begin a process of becoming aware of their specific circumstances as a group and articulating an agenda for action to address the specific inequities that they face. (Eyben et al. 2008)

The only two social network types that enabled households to believe their actions had any influence had strong relationships outside the community—bridging ties. The Delhi farmers did not have a sense of who they were as a community. Do strong bridging ties act to produce a surrogate community identity? If enough households established strong bridging ties, would they begin to become aware of their own circumstances as part of a bonded group? Or is such a group too varied and ambiguous to establish a common agenda? More inquiry into how bridging versus bonding ties reinforce and alter sense of belonging and group identity is warranted.

6.10 Conclusion and Final Thoughts

In this chapter, we first introduced readers to the literature that shows the important role of social networks in how marginalized groups engage (or disengage) the participatory planning process—typically through informal spaces. We then described a theoretically grounded method for measuring social networks that was able to capture social and physical dimensions at multiple spatial and temporal scales at the household-level. Using the case of Delhi farmers, our approach enabled us to capture a nuanced understanding of how social networks operate in facilitating and constraining beliefs and behaviors related to land development. By summarizing social networks based on micro to macro dimensions and beliefs/ behaviors, a pattern of different types emerged ("family-reliant", "strong bonds", "bridging ties", "mimicry", and "many pathways"). We used the five social network types as a guide to suggest potential points of entry into this hard to reach community in addressing the themes of knowledge, action, and influence.

Rather than focusing solely on individual social networks, we demonstrate how a typology model could allow community outreach groups a more effective way of approaching hard to reach communities. This case study yields important information that can be used for concrete action. Can we identify which households have facilitating within-community networks? Which have facilitating networks outside the community? Where the constraining relationships are? How can we work within existing community networks? Where are the points of entry? In the case of Delhi farmers, some landlords had influence and could be a potential connection point for community groups—but connection through landlords could also increase vulnerability for some farmers. One policy implication is the need to go beyond a simple catalog of key stakeholders for involvement in planning activities, and to qualify the types of social ties that can positively and negatively impact beliefs and behaviors within respective communities. The value of this research is that by modeling how household social networks enable or constrain opportunities, behaviors, and cognitions, we gain a better understanding of who is more likely and who is less likely to engage in the planning process—and who has confidence that actions matter.

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Chapter 7
An Interdisciplinary Socio-spatial Approach Towards Studying Identity Constructions in Multicultural Urban Spaces

L. P. Rajendran

7.1 Introduction

Today people increasingly experience unequal political, economic, symbolic and cultural geographies (Short 2017) which create complex spatial encounters involving greater challenges for the negotiation of one's identity; as a result, the identity undergoes a more dynamic and continuous process of adaptation and reconstruction. The global phenomenon of identity conflict has been dealt with from different perspectives by many scholarly disciplines yet a comprehensive understanding of identity construction amidst the growing multicultural nature of cities that embraces a socio-spatial approach is clearly missing. As a practice and a discipline encompassing all aspects of people and place, the issue implores a liberal address by researchers in the field of urban planning and design, which has surprisingly given it little scholarly attention. Current research on people-place-identity from scholarly fields of human geography, phenomenological philosophy and social psychology has produced rich and diverse literature unfolding notions of identity from different standpoints (Golubović 2011; Jacobs 2010; Leary and Tangney 2005; Howard 2000; Norberg-Schulz 1991). Yet they are mostly rendered ineffective for the domain of urban planning and design, due to the somewhat specific nature of the writing from these disciplines. In addition, there is also a lack of innovative framework and methodology that establish the relationship between social and spatial practices in identity constructions processes which can facilitate better understanding in planning and design of multicultural cities. There is clearly a need for a renewed multi-dimensional and interdisciplinary approach in research to disentangle the complexity of peoples' identity construction in cities that can

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X. Ye and X. Liu (eds.), *Cities as Spatial and Social Networks*, Human Dynamics in Smart Cities, https://doi.org/10.1007/978-3-319-95351-9_7

provide more directly understandable insights and applicable qualities for urban planners, urban designers and architects for augmenting and improving interaction with the built environment for all citizens. Building on the significance of place and identity relationships and its potential to disentangle identity complexities and people behaviour in multicultural cities today, the chapter sets out to examine the significance of socio-spatial practices in understanding peoples' identity construction/negotiation in multicultural urban environments.

7.2 Identity, Place and People

Comparing the historical and present context of identity formation, social psychologist Judith Howard points out:

> At earlier historical moments, identity was not much an issue; when societies were more stable, identity was to a greater extent assigned, rather than selected or adopted. In current times, however, the concept of identity carries full weight of the need for a sense of who one is, together with an often overwhelming pace of change in surrounding social contexts— changes in the groups and networks in which people and their identities are embedded and in societal structures and practices in which those networks are themselves embedded. (2000, p. 326)

In the context of examining identity phenomena there is an increasing ambiguity in comprehending 'where one belongs to'. Concepts of multi-territoriality (Petcou 2001) and global sense of place (Massey 1994) have become common platforms of discussions on identity issues in urban living. The increasingly mobile nature of societies (de Waal et al. 2017; de Waal 2014; Bertolini 2006) results in multiple and fluid identities. In addition, the lack of spatial referents accompanying spatial mobility, which previously provided valuable cues for identifying oneself in urban environments, has created a strong sense of uncertainty, deepening the questions of 'where' and 'how' people identify themselves. Identity itself is caught in a labyrinth of diverse yet interwoven issues which inscribe differences at socio-cultural, economic and political levels. This in turn is spatially manifest, transforming urban environments into places for contestation and negotiation, resulting in a further entanglement of meanings, experiences and place relations that facilitate in constructing one's identity.

Nevertheless, people and place/physical settings relationship still remain a valuable domain to understand identity complexities. Places involve the whole set of physical, perceptual, cognitive, psychological and social experiences, without which, it is difficult to comprehend any human related concepts. Social psychologist Altman (1992) explains that there are three general ways to relate the physical environment to social relationships and psychological processes: (a) as an independent variable in which aspects of the environment affect or cause variations in interpersonal processes; (b) as an aspect of behaviour, for example, use of space, personal spacing, territorial behaviour, use of the environment to regulate privacy, possession and display of prized objects, decorating or personalizing places and so on; and (c) as a context or setting within which psychological processes, relationships and behaviours are embedded. Altman considers the third aspect as superior, as the physical environment becomes part of the definition and meaning of the phenomenon occurring where place and people interact, developing a transactional relationship.

Delving into the rich transactional relationship between people and physical settings, the research aims to understand complex process of identity negotiations in multicultural urban contexts—a multi-faceted and multi-dimensional phenomena, with overlapping layers of people's experiences and perceptions.

7.3 Casestudy: Objectives and Methodology

The objectives of this research are

- To identify the implications of socio-spatial aspects of people and place experiences for identity construction and negotiation in multicultural urban environments.
- To examine the relative significance of socio-cultural and spatial factors in identity construction.

The main case study for this research was based in the multicultural city of Sheffield, UK. The research participants included fifteen international students studying at the University of Sheffield. All participants had been living in Sheffield for a period of two to three years, Sheffield being their first experience of living outside their home country. The research participants included fifteen international doctoral research students from China, Iran, Mexico, Thailand, Nigeria, Netherlands and Romania. The different types of urban spaces in Sheffield that were included in the study was carefully identified for three reasons (1) for their ability in supporting everyday life of international students (2) to avoid the overly 'designed' aspects of many contemporary cities. Such everyday spaces enable an understanding of how contemporary spaces accommodate or allow everyday life and interaction, and how people respond to these spatial experiences, (3) Spaces were also chosen for their frequency of use and familiarity among the international student community, which facilitates a more detailed discussion of participant experiences with the spaces. A total of thirty images of various physical settings (numbered one to thirty) were used in the interview session (see Fig. 7.1). These images included the everyday pathways leading to various university buildings, public parks within the circulation zone of the university students, spaces outside the student union building, bus stops, and city centre spaces.

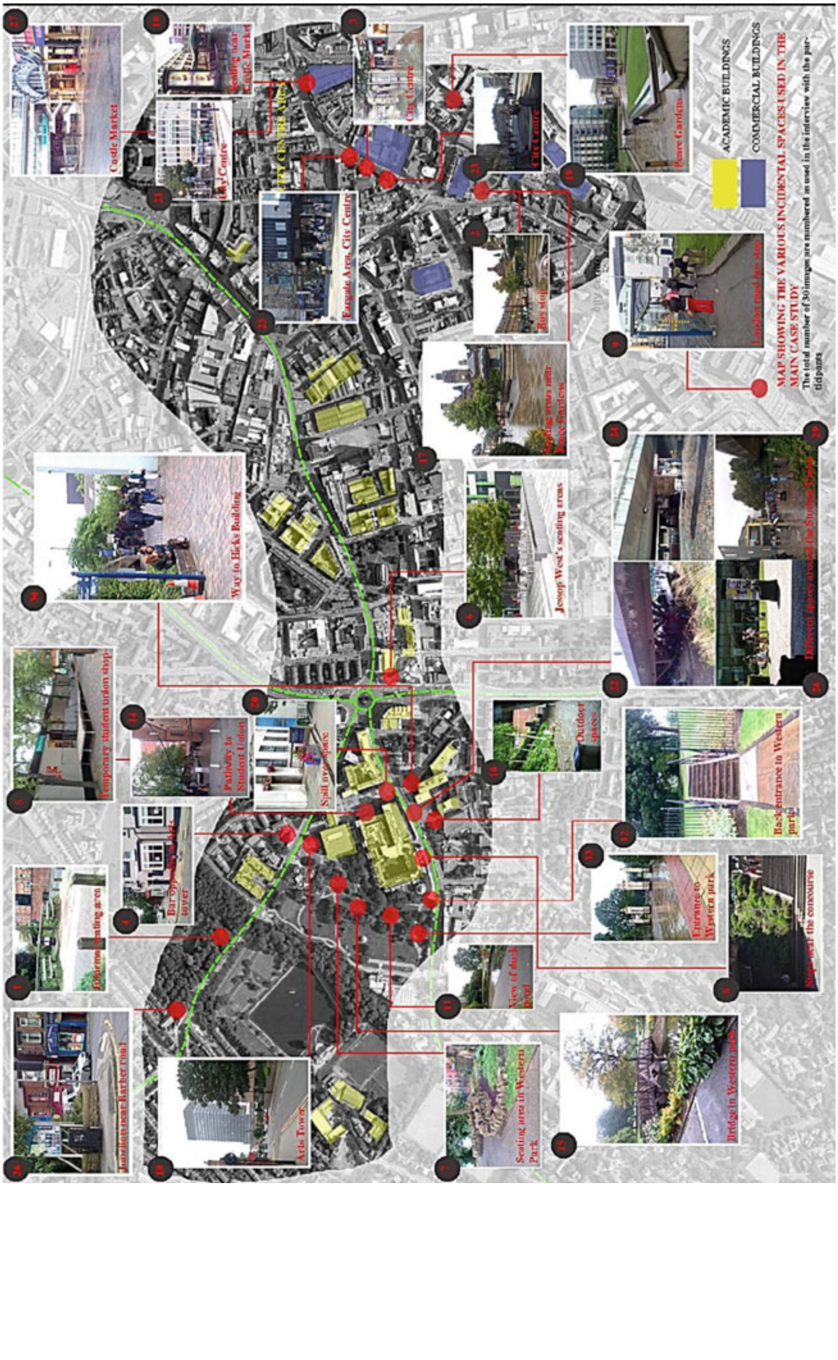

Fig. 7.1 Everyday urban spaces images used in the interview session

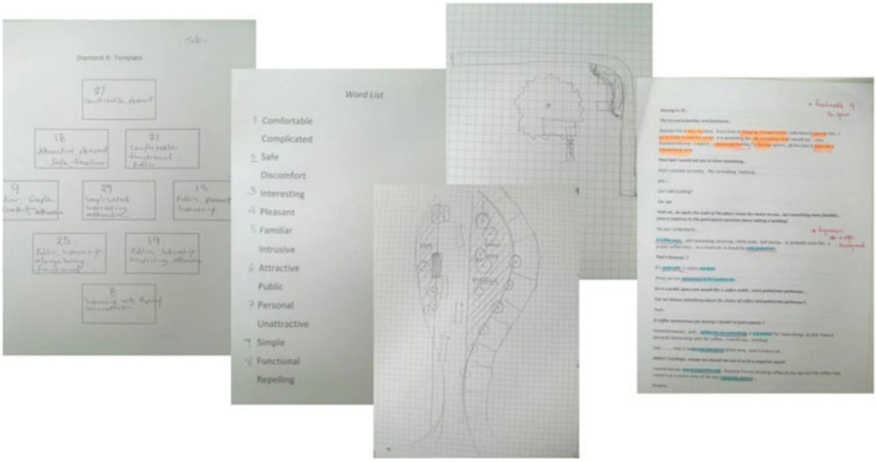

Fig. 7.2 Samples of data collection: Diamond 9 template, wordlist, sketching and interview transcript

Participants were asked to rank the images in a 'Diamond 9' template,[1] based on the extent to which each image and the experiences associated with it related to their identity. The participants then matched the chosen nine images to words in the wordlist provided during the interview. The Diamond 9 method was used as effective tool for promoting discussion, rather than to understand the order of the ranking.

The word list included words such as 'comfort', 'safe', 'pleasant', 'complex' (see Fig. 7.2), which were deliberately chosen for their broad and general connotations- firstly, to easily allow participants to choose and associate them with the images they had chosen; and secondly, to increase the opportunities for exploring the implicit meanings associated with common words describing spatial experiences.

In the final task, the participants were asked to sketch a place based on their personal choices and preferences that make them 'fit in' and feel comfortable. Based on the sketch provided, follow-up questions were posed to help understand the deeper meanings of the spatial narratives. Data at various stages were recorded using smart pen technology.[2]

[1]Diamond 9 ranking allows participants rank their choices from most significant to least significant. The strength of the diamond 9 ranking lies in developing the interconnections between the various choices and basis on which it was organised by the participants.

[2]Echo Smartpen is a ballpoint pen with an embedded computer and digital audio recorder. When used with Anoto digital paper, it records what it writes for later uploading to a computer, and synchronizes those notes with any audio it has recorded.

7.3.1 Interdisciplinary Framework

Dealing with data which contains multiple layers of complex information related to people's spatial practices requires a strong analytical framework to enable significant interrelationships between several factors to emerge. The interdisciplinary concepts used to develop the analytical framework is explained below.

Phenomenology: Interpretative phenomenological analysis

Research into identity construction in everyday life largely focuses on the implicit meanings of perceptual and spatial experiences of people. For this reason, the Interpretative Phenomenological Analysis (IPA) method is considered extremely significant, as it explores and understands the lived experience of a specified phenomenon, providing a qualitative research approach committed to the examination of how people make sense of their experiences (Smith 2009). IPA research follows philosopher Edmund Husserl's advice to go 'back to the things themselves', and denies any attempt to fix experiences in predefined or overly abstract categories. Focusing on the phenomenological understanding of lived experiences, IPA is particularly important for this research as it is context-dependent and contingent upon social, historical and cultural perspectives which have a great impact on identity (Smith 2009). IPA as a method enables understandings of peoples' place experiences that are deeper and unselfconscious, allowing the research to capture the complexity of people-place relationship that is crucial for this study.

Human geography: Relph's seven levels of experiential involvement/identification in place

Relph (2008) explains that the essence of a place is embedded 'in the experience of an inside that is distinct from an outside; more than anything else this is what sets places apart in space and defines a particular system of physical features, activities and the meanings'. He offers an interesting and important means to understand place experiences in terms of peoples' experience of being 'inside' or 'outside' a place. The notion of being 'inside' or 'outside' of a place becomes intrinsically connected to the extent one identifies or feels a belonging to that place. Relph (2008, p. 49) states that 'the more profoundly inside you are the stronger is this identity with the place'. The dynamic changes in contemporary urban living has reconceptualised peoples' involvement and relationship with places. Relph's seven modes of experiential involvement/identification in places offer the required depth in the experiential concepts with different levels and layers for comprehending the complex spatiality and place engagement in contemporary urban environments. Table 7.1 provides a brief explanation of the various levels of Relph's classification.

Table 7.1 Relph's different modes of experiencing places

Types of identification	Characteristics
Existential insideness	The deepest involvement in place where a person feels being part of the place. The person feels at home
Existential outsideness	The person feels out of place. There is no involvement and the place gives a feeling of alienation, of strangeness
Objective outsideness	Involving deliberate distancing. The place is like an object of study, experienced based on reason, surveyed scientifically and logically
Incidental outsideness	Involving the situation where place is just a backdrop, as when the person is heading somewhere else
Behavioural insideness	When the deliberate experience of place is expected, there is a set of elements, views, landmarks which form the new place
Empathetic insideness	When a person from outside shows empathy with what the place demonstrates as the expression of those who created it and live in it
Vicarious insideness	A second-hand feeling, of indirect experience, the person is transported to the place via image, painting, film, mass media

Source Adapted from Seamon (1996)

Social psychology: Motivated Identity Construction theory

The concept of 'motive' brings out both explicit and implicit factors that govern peoples' spatial practices and experiences in a place. This research incorporates Motivated Identity Construction Theory within the framework of analysis. Drawing from the work of Easterbrook and Vignoles (2012) there are six motives of identity construction in people (distinctiveness, meaning, belongingness, continuity, self-esteem and efficacy) which were substantiated by recent studies in social psychology. Originally these motives are fundamentally related to how people develop their identity with the different group of people but in this research these six motives are interpreted as:

- *Distinctiveness*: How much does being part of a place give a unique sense of people's experience?
- *Meaning*: How much does being part of a place give people a sense of meaningfulness to their life?
- *Continuity:* How much does being part of a place make people feel that their past, present and future are connected?
- *Belonging*: How much does being part of a place make people feel that they are included or accepted?
- *Self-esteem*: How much does being part of a place make people see themselves positively?
- *Efficacy*: How much does being part of a place make people feel efficient, competent and capable?

Though these six motives may not be comprehensive (Easterbrook and Vignoles 2012), they facilitate this research by providing valuable insights into the impact of spatial dimensions on these identity motives.

The study employed the theories and concepts discussed above to form an interdisciplinary framework of analysis (Refer Figs. 7.3 and 7.4).

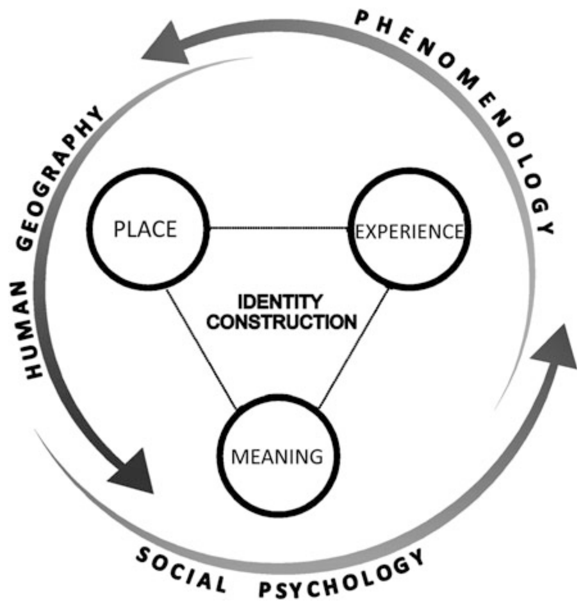

Fig. 7.3 Significance of the three disciplines in studying identity construction (*Source* Drawn by the author)

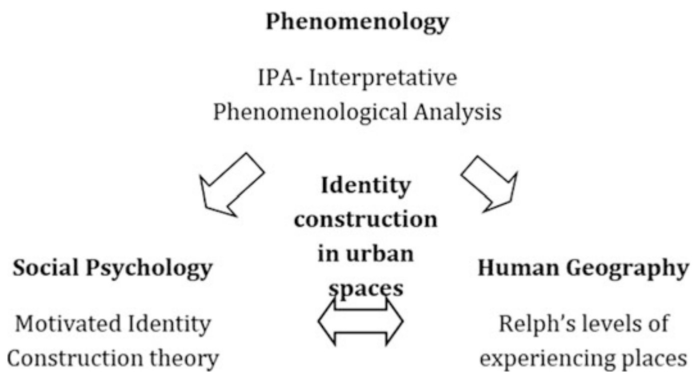

Fig. 7.4 Interdisciplinary framework of analysis (*Source* Drawn by the author)

7.3.2 Analysis

The interview transcripts prepared from the data collection of the 15 participants (referred as P1 to P15) were coded and interpreted using the IPA method, allowing several themes to emerge which were analysed for their socio-cultural and spatial relevance.

In the first stage, data was analysed, interpreted and categorised into three sub-categories from which emergent themes were identified.

- ***More spatial than socio cultural***: more emphasis on the physical elements/ factors
- ***More socio cultural than spatial***: participant's narratives placed more emphasis on the socio-cultural elements
- ***Equally socio-cultural and spatial***: participant's narratives implied equal emphasis on both socio-cultural and spatial elements (sense of enclosure, familiarity with places, enclosures etc.)

In the second stage these themes were used for comprehending the relationship between the identity motives and spatial experiences of participants. Finally the prevalence of various levels of place involvement in the participants' narratives that enabled identity negotiations/construction was analysed.

7.3.2.1 More Spatial Than Socio-cultural

For participants identifying with the urban spaces that were defined more by the spatial aspects of the environment, the themes that emerged consistently in most of their narratives were the notion of **visual appeal** of the place (landscape, natural setting, buildings), **familiarity** (frequency of use, everyday routine, proximity to home/work), **physical comfort and safety** (general safety, thermal comfort) and **functionality** (proximity, efficiency).

The feeling of comfort in urban spaces, which was expressed as a significant factor that enabled participants to develop their sense of identity, was related to the extent to which the environment offered spatial freedom. This was explained in terms of participants' desire for uncluttered spaces, clarity in circulation, spaces without obstacles (behavioural restriction) and wider choices in using such spaces. One of the participants observed that a spatial experience which accommodated spontaneity to pause allowed them to be comfortable as it relieves the need to be cautious while strolling in a public space.

In the category of themes that manifested equal socio-cultural and spatial relevance, were notions of privacy/sense of enclosure and user group comfort. Participants from different ethnic backgrounds clearly expressed different ways in which they perceived the need for privacy in urban spaces. For example, a female Iranian participants expressed this need of privacy and sense of enclosure in public spaces more strongly (preference for physically defined elements and corner space) whereas female Romanians and male Chinese participants were content with places where they were not the centre of attention. Different notions of defining boundaries existed in participants' narratives. Unlike some of the Iranian participants' notions of the absolute need for privacy, boundaries were also perceived as semi-enclosed spaces enabling a sense of comfort that facilitated a deeper engagement with the environment. However it is important to highlight how the notion of safety takes over the other visual aspects when identifying oneself with a place.

7.3.2.2 Equally Socio-cultural and Spatial

Amongst the themes which were defined equally by socio-cultural and spatial aspects of place experiences, the most prominent and frequently occurring themes were **familiarity** and **belonging to a place** (derived from similarity to their native spatial elements), **user group comfort**, **socio-psychological comfort**, and **territoriality**. The key point of discussion here was how participants' spatial experience revealed interesting yet implicit manifestation and negotiations of their need to 'belong' to the place. Participants expressed strong affinity and associations with urban spaces which enabled spatial reinterpretations that linked to their socio-cultural identity in terms of the architectural features or the kind of activities present in the urban environment. Although these themes were defined by the socio-cultural background of participants, they are realised through spatial manifestations. For instance, one of the male Chinese participants, while explaining the notion of territoriality, discussed his preference for circular forms of seating area along with a road defining its location which marks the space of his group when using an urban space. Additionally, the participant highlighted how such an arrangement could give them more privacy from other student groups. Similarly Iranian female participants rarely engaged themselves in some urban spaces which are busy, as they felt uncomfortable due to a strange feeling of being watched. In this case, although the participants' socio-cultural background defined the meaning of 'comfort,' it was influenced and further defined by the particular spatiality of places.

7.3.2.3 More Socio-cultural Than Spatial

The themes that placed more emphasis on the socio-cultural aspects of place experience and which encouraged the sense of identity for participants were **religious needs**, **nostalgic place memories,** and the **sense of community/social life**. Participants' religious backgrounds played a significant role in determining the personal choice of places they could identify themselves with. In this context, the proximity of a mosque or church, meeting people with same religious belief, and the resulting social life, emerged as an important need for participants identifying with a specific urban environment.

Participants' narratives showed the different perceptions of spaces by international students, indicating the influences of socio-cultural conditioning of participants in engaging and identifying themselves with various urban environments. During the interviews when participants discussed their personal space, whether enclosed or outdoor, the prominent theme that emerged was the notion of openness and inside/outside connectedness. Participants viewed this openness and connectedness of urban spaces to be providing them with a sense of safety, and an escape from feeling isolated.

Multiple layers of meaning emerged from participants' responses on accommodating themselves in public spaces. While the chapter did not include the intercepts from the participants narratives, the intercepts below is included to show the richness, depth and complexity embedded in the narratives of place experiences. One of the female Iranian participant while sketching her personal choice of public space where she would identify with the most, explained,

> A coffee area with seats… self-service or probably even like a proper coffee shop or a small van… it should be pedestrian as its safe and makes me feel relaxed [P11]
>
> Does choosing a coffee shop is synonymous for having a break? Or just a pause? [I]
>
> Hmmm, well coffee for me is everything. It is symbol for many things…It's like I have personal relationship with coffee. I would say [smiling] [P11]

Further probing into the participant's coffee drinking habits revealed implicit connection with the socio-cultural aspects of her narrative:

> A coffee area in a public space makes me feel good; it makes public space for me a better place or maybe it is some kind of a social thing. Maybe I cannot see myself sitting in a public space doing nothing, holding a cup is doing something. Gives me a reason to sit in a public space. [P11]
>
> Why do you think you cannot sit not doing anything? [I]
>
> Probably whenever I sit without doing anything, it's just, I don't feel personal. If I'm busy doing something, I'm doing my own thing. [P11]

It can be observed that apart from the physical elements (in this case, the enclosure) which allow the participant to accommodate herself in the public spaces, it is also the activities they perform which helps them to negotiate the urban environment. The above participant's place interaction implies what Castells (2007) explains as, although spatial meanings are culturally created, their final meaning depends on people's interaction with the places.

Table 7.2 shows the summary of various themes derived from the analysis of the interview transcripts using IPA. The themes are categorized and colour-coded according to the socio-cultural and spatial relevance of each theme. This colour-coding is followed throughout the analysis.

Table 7.2 Themes developed using IPA

Summary of emergent themes and their socio-cultural and spatial relevance		
Socio-cultural > spatial	**Equally socio-cultural and spatial**	**Spatial > socio-cultural**
Religious needs	Historic/grandness	Inside/Outside connectedness
Nostalgic place memories	Similarities to native places	Nature
Childhood associations	User group comfort	Spatial freedom
Entertainment	Sense of enclosure	Functional
Social life	More observer/ less observed	Uncluttered spaces
Territoriality	Memory objects	Safety-natural surveillance
Familiarity through native spatial experiences	Familiarity-personal experiences	Attractiveness
	Visual and physical connectedness	Everyday connectivity
	Inspiring	Entertainment
	Visual appeal	Belonging in relation to home/ everyday activities
	Tactile experience	Safety
	Socio psychological comfort	Personal meaning
		Unselfconscious behaviour
		Convenience
		Physical comfort
		Haptic experiences
		Sense of Ownership

Source Drawn by the author

7.3.3 *Identity Motives and Their Socio-spatial Relevance*

The themes under all three categories discussed above were analysed for their interconnections with the various identity motives (namely Distinctiveness, Meaning, Continuity, Belonging, Self-esteem and Efficiency) and their socio-cultural and spatial relevance/significance in participants' place experience as this related to identity constructions (see Table 7.3). Belonging and Distinctiveness

Table 7.3 Identity motives analysis

Identity motives and their socio-spatial relevance															
Identity motives	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15
Distinctiveness															
Meaning															
Continuity															
Belonging															
Self-esteem															
Efficiency															
Non-categorical															

were manifest as the most prominent identity motive in the place experiences of 12 and 9 participants respectively. Distinctiveness was attached to themes which involved more spatial elements (for instance, the historicity of the structure, native style of buildings, the significance of the activities which the spaces lead into etc.).

The Efficiency motive was prevalent to the same extent as the Distinctiveness motive. The Efficiency motive emerged from those narratives where the participants indicated the functional efficiency of the urban spaces as an important criterion for developing a sense of identity with that environment. While Continuity and Self-esteem motives rarely occurred in the participants' experiences, interestingly, some of the themes raised did not fit under any of the aforementioned motives. It is important to note that all the participants' narratives suggested the prevalence of non-categorical motives which indicates how considering spatial aspects of peoples' identity experiences introduces several other interesting factors in identity studies, to name a few physical comfort, inside/outside connectedness, spatial freedom, and familiarity, sense of enclosure, territoriality. It is also interesting to note that the Continuity motive was not reflected in the participants' narratives, and the Self-esteem motive was reflected in only one participant's identity-related place experiences, again highlighting how non-categorical motives can not only offer renewed understanding of peoples' identity construction but also provide important cues for comprehending and addressing the significant concepts of territoriality and boundaries (that was reflected in the participants' narratives), which varies for diverse cultural groups and individuals.

Based on the analysis of identity motives and their socio-spatial significance inferred from the narratives of 15 participants, a summary of their responses was tabulated as shown in Table 7.3. From Table 7.3 it can be observed that the maximum number of identity motives and most prevalent combination that occurred in participant narratives (In 5 participants) were Distinctiveness, Belonging, and Efficiency, in addition to Non-categorical motives, followed by the combinations of Meaning, Belonging and Non-categorical motives (in 6 participants' place experiences). It suggests the relative significance of the combinations of identity motives and their associations with identity constructions.

In Table 7.3 Individual cells are colour-coded, referring to the extent of socio cultural and spatial relevance attached to each motive. Where the motives did not occur in a participant's place experiences, the respective cells are left blank. While Distinctiveness and Efficiency motives largely emphasised the spatial aspects of people experiences, Meaning and Belonging motives involved both socio-cultural and spatial aspects of people's experiences. In this stage of the analysis it became difficult to explain the socio-spatial relevance of responses, due to the complexity of non-categorical motives; hence the coding with grey colour indicates only the prevalence of non-categorical motives in each participant. Analysis of the identity motives based on the various sub-themes that emerged in the first stage of analysis explains the complex factors intertwined in place and identity relationships experiences by the participants. While the analysis importantly identified the prevalence of non-categorical motives in identity related experiences, it also evidenced the significance of Distinctiveness, Belonging and Meaning motives proposed by the Motivated Identity Construction Theory.

7.3.4 Modes of Place Involvement and Sense of Identity

In the final stage of the analysis, participants' narratives were studied in order to comprehend the modes of place involvement experienced in urban spaces that were related to participant identity construction. Table 7.4 illustrates the presence (cells coloured) and absence (blank cells) of various modes of place involvement that occurred in the participants' experiences. It can be observed that Existential Outsideness (complete alienation from the place) and Vicarious Insideness (indirect experience of places) rarely occurred in the participants' narratives. Behavioural Insideness was the most prevalent (14 participants) mode of place involvement in identity-related experiences, followed by Objective Outsideness (13 participants) and Empathetic Insideness (12 participants).

It is important to note here that places that allowed logical reasoning and efficiency (in terms of safety, location and functional aspects of a place) played an equally significant role as the observable qualities, visual patterns (created by the visual appeal of the place) and emotional experiences (associated with the notions of sense of belonging). It was also observed that complete unselfconscious involvement with the people was notably prevalent (8 participants) in the experiences of participants pertaining to identity construction.

Analysing the various levels of place involvement in individual participant's narratives, it was observed that Empathetic Insideness, Behavioural Insideness and Objective Outsideness simultaneously existed in 10 participants' narratives.

Table 7.4 Modes of place involvement analysis

Place involvement and sense of identity relationship															
Modes of Place involvement	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15
Existential insideness		■	■	■		■		■	■	■	■				
Empathetic insideness	■	■	■	■	■	■	■	■	■	■	■			■	
Behavioural insideness	■	■	■	■	■	■	■		■	■	■	■	■	■	■
Vicarious insideness										■					
Incidental outsideness								■		■		■	■	■	■
Objective outsideness	■	■		■	■	■	■	■	■	■	■	■	■	■	
Existential outsideness															

The characteristic nature of these three levels are highly comparable with the notions of Distinctiveness, Belonging and Efficiency, which were are also highly prevalent and coexisted in some of the participant's narratives. This indicates the significance of distinctive experiences, visual quality, belonging and functionality of a place for developing a sense of identity with that place.

7.4 Socio-spatial Propositions Defining Identity Construction and Negotiation in Multicultural Urban Environment

Comparing and correlating the emergent themes with the identity motives (from social psychology) and different levels of place involvement (from human geography), the following list of socio-spatial propositions were formulated to define identity construction and negotiation in multicultural urban spaces; **Boundaries, Restoration, Meaning, Distinctiveness, Belonging, Functionality and Safety**. Figure 7.5 illustrates the seven socio-spatial propositions developed as the research outcome, all of which are grounded in the socio-spatial realm that define the identity in urban environments. Some new propositions were developed from the non-categorical motives while others were based on the socio-spatial reassessment and reinterpretation of the identity motives formulated by Motivated Identity Construction Theory.

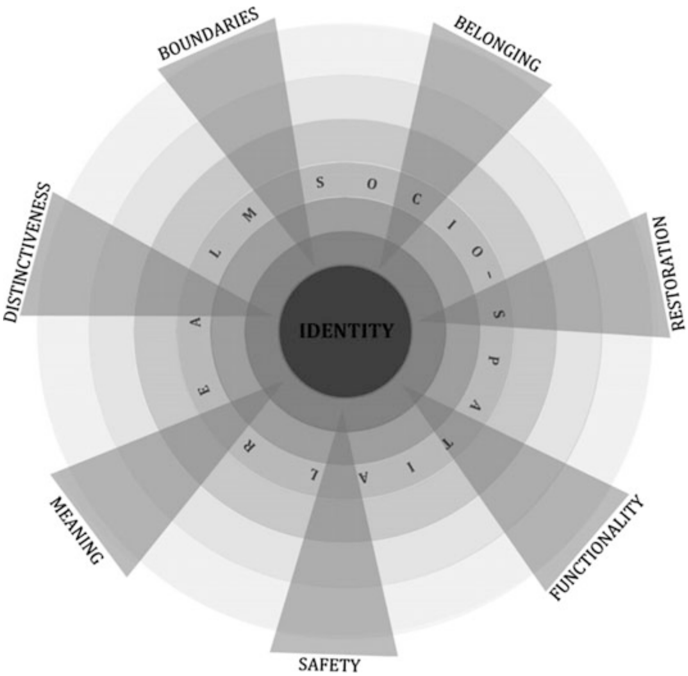

Fig. 7.5 Socio-spatial propositions defining identity constructions in multicultural urban environment (*Source* Drawn by the author)

7.4.1 Boundaries

The need for understanding one's boundaries in the physical environment are strongly linked to the way people identify with that environment. Woodward (2003, p. 167) writes 'difference and sameness involve the marking of boundaries and the identity story is characterised by the moments at which boundaries are drawn, redrawn and transgressed and this is part of the dynamic of identity.' The primacy of boundaries in physical settings are generally well accepted, as to define space literally meant to determine boundaries (Hays and Tschumi 2000). The analysis showed some interesting insights of boundaries embedded in participant's identity experience which ranges from being suggestive and implicit, to an almost necessary and explicit need. Boundaries help in identifying a territory and defining individuals' spatial behaviour within that territory. Kim Dovey explains the importance of territories, which are particularly crucial in urban situations, as 'largely people feel out of place when not aware of "how to act" in that particular place' (Dovey 2009, p. 37).

This become more pronounced in multicultural settings as the boundaries marking territories also act as a haven offering the socio-psychological comfort for different user groups. As in multi-cultural settings, aspects of boundary recognition bring an added layer of complexity as there are more chances of potential mis-recognition of boundaries due to particular cultural expectations with their concomitant spatial manifestations: where meanings and definition of boundaries differ between cultures. However, careful study and understanding of boundaries become a potential means for enabling identity negotiations serving as a socio-cultural buffer particularly in a multicultural urban environment.

7.4.2 Restoration

Korpela et al. (2001) defined restoration as a process of recovery that follows stress or fatigue, involving an enhancement of mood, a renewed capacity for directed attention, and possible self-reflection. Contemporary urban living is often characterised by speed, a sense of alienation and displacement, leading to an increasingly fragile relationship between people and place. Hence people tend to seek restorative qualities in places that enable them to reconstitute their self and identity and develop a sense of attachment to the physical world. Spatial experiences that offer personal and social restoration are considered to be an important factor that enables people to identify with places, hence Restoration is one of the propositions identified in this research which define identity construction/negotiation. Restorative environments make places compatible to one's preference, hence it enables a sense of identity. By being favourable for engaging and connecting with such a place in the contemporary urban environment.

Restorative experiences fall under the characteristic nature of peak experiences which is the 'integrated feeling, spontaneity, creative, ease of functioning, positive etc' as described by Maslow (1961, p. 257), and discussed as the most appropriate situation for evoking a strong sense of identity in a person. In such experiences, Maslow explained that people feel more integrated in many ways and feel a sense of complete relaxation. The research demonstrated how restorative quality of a place which occurred in various ways such as inside-outside connectedness, or landscaping elements allowing people to associate with nature. In addition some spatial tactics were also adopted to overcome the stressful and complex urban condition: places that allowed to pause and accommodated opportunities for reflection and contemplation, and experiences associated with such places of restoration, facilitate the interaction with one's self so as to reconstitute or restructure one's identity.

7.4.3 Meaning

One of the broad definitions of meaning is something that generates perception and is associated with an individual's internal psychological and social processes (Stedman 2003). This research indicated that people identify themselves with urban environments that enable meaningful experience, though they are similar to the restorative experiences in places but are different in terms of providing a sense of purpose and personal meaning being associated with some places. Since the affective perception is generated from the psychological process (meanings and attachments) rooted in the setting, the identity of place is determined not only by the physical components but also by the meanings and associations developed between people and places. Meaning may be generated by various factors but this research, broadly indicates that personal meanings are attached to places associated with people's everyday life, work, memories, sense of restoration and home, whereas religious places, and urban spaces with social activities and interaction, foster social meanings. While personal meaning attached to places, as mentioned earlier, is based on individual experiences which may be diverse for different people, social meaning are often derived based on the cultural background and conditioning of individual and groups.

7.4.4 Distinctiveness

Distinctiveness is the quality or state of being different/and unique. According to this research urban spaces that offer distinctive experiences are considered to be special compared to other spaces. It was also observed in the case study analysis that such spaces were potentially significant for developing a sense of identity, as people were more attracted and eager to be part of such experiences. Distinctiveness in urban spaces, similarly to 'meaning' discussed above, can be manifest through socio-cultural, spatial, visual and symbolic elements in the environment. Distinctive spatial experiences can serve to balance the routine, mundane and homogeneous nature of much of the contemporary urban environment. Distinctiveness can be perceived and experienced through the uniqueness of spatial elements; for instance, the historicity of the building elements, the simplicity of the spatial planning and design to enrich experience, an interesting juxtaposition of activity spaces, and so on.

Contextual experiences that are distinctive offer valuable cues for locating and orienting oneself with the place and serve as points of reference. Such urban environments allow people to confidently manoeuvre through, engage with, and gradually develop a sense of identity with the environment.

7.4.5 Belonging

A sense of belonging creates a deeper and reciprocal relationship with places, where people identify themselves with the place and the place in turn reinforces their identity. Apart from the socio-cultural factors that play a crucial role in belonging to a place, the research case study indicated that familiarity and comfort with a place are also some of the factors that enable the sense of belonging to a place. The notions of being connected (whether through spatial or visual experiences) with the place as a part of one's everyday life also allowed participants to initiate the sense of belonging in the urban environment.

It is exactly these ordinary places, and our everyday performativity in them, which is also reciprocal, in the sense of allowing one to extend one's self to identify in that place and in turn reassuring, reinforcing or restructuring one's identity with the place itself, anchoring and securing them to the physical world. On the other hand, interestingly, places in the present urban context can also evoke a sense of belonging whose underlying characteristics and nature can be linked to Fortier's (1999) observation of how certain nomadic groups, through ritualised repetition of symbolic acts and stylised practices, tend to reinscribe themselves into a space. The comparison that is crucial here is the urban setting which accommodates these repetitive practices, which can also be seen as a spatial tactic of people to develop a sense of identity with the environment. With the multicultural nature of the urban environment, individuals and groups may tend to follow specific spatial practices—for instance, developing a preferred route to visit/reach a place, appropriating specific places—all of which possess and enhance their own social meanings. Hence urban spaces providing opportunities for various spatial tactics create a favourable environment for developing a sense of identity.

7.4.6 Functionality

The functional capacity of an urban environment is observed as an important factor for people to feel attracted to the place and identify with it. The functional efficiency of places is regarded as an essential characteristic of urban spatial experiences. The research case study indicated that people preferred places that ease the complexity of urban activities. The relationship between people and place is more of a necessity which gradually becomes part of their lifestyle. Flexibility and multiple-use of urban spaces manifests the ability of the environment to be efficient when engaged with by different people.

7.4.7 Safety

Physical safety is considered as a default requirement in the urban environment for people to enable any form of interaction and connectedness with them. Safe urban spaces allow people to explore them and help in gradually developing a sense of familiarity and comfort with that environment. Safety for pedestrians is an important factor initiating the process of place engagement, as it reduces feeling of being conscious of the safety factor and fosters spontaneity in activities and movement. As in Maslow's hierarchy of human needs, safety assurance of a place is considered as a prerequisite for other higher-order experiences of identifying one's self with that place. A safer environment also allows people to be more flexible, and offers them the confidence to creatively use or negotiate urban spaces. Safer places enable people to develop a relationship of trust with them, to become more connected with that environment. Physical safety also implicitly offers psychological comfort and freedom in a multicultural environment and fosters healthy social engagement.

7.5 Conclusion

The study demonstrated how by adopting a socio-spatial approach in understanding identity construction and negotiation in urban environments can develop a symbiotic relationship between spatial and non-spatial disciplines. The research showcases the complex interlacing of social and spatial structures in cities defining peoples' everyday urban practices. It is important to highlight that the suggested propositions for identity construction and negotiation are strongly linked to the existing socio-spatial structures as it forms the matrix in which these propositions essentially operate. The higher order of the socio-spatial propositions suggested allows for further research into each of them for more specific spatial interpretations which can be instrumental in examining emergent networks and patterns of belonging and behavior in cities. Some the works undertaken by architects and urban designers have resulted in developing framework/guidelines good urban design, place making etc. such framework and guidelines can be potentially revisited and reinterpreted to understand in depth, how they facilitate in actually enabling people and place interaction which is fundamental for identity construction/negotiation in cities.

7.6 Limitations and Further Research

The very complexity of this research topic, identity in multicultural contexts, poses several difficulties and challenges in conducting the study. Given the constraints of complexity of data, though it was deemed advantageous to limit the sample of participants to 15 student participants' from six countries (China, Thailand, Romania, Nigeria, Iran, and Holland), it clearly is a limitation to delve into the large issues of multiculturalism and present more specific examples which manifested the impact of cultural background of the people in identity construction or negotiation process. However an increased number of participants and greater diversity of nationalities would make further empirical and theoretical contributions to the research topic. The research aimed to study identity construction in multi-cultural environments for which the selection of Sheffield as a case study was justified in terms of the data describing the percentage and diversity of its international student population compared to other cities in UK. Though the multicultural diversity of the case study was justified, the spatial features and characteristics of each and every city would have an impact on the ways in which people interact with the spaces, which make the data analysed here very context-specific. However this limitation can be considered as potential direction for further research.

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Chapter 8
Evaluating China's Investment Network and Mega-regions

Yuheng Cai, Dong Li and Bingruo Duan

8.1 Introduction

Urban agglomeration, mega-region and metropolitan region are all words been used to describe designated areas to imply regional and national policies and engines for economic development. An empirical study about US's 180 industries shows, in a new era, a nation's economy is in a trend of regional economic fragmentation and heightened interregional integration (Feser and Hewings 2007). The interjurisdictional cooperation on infrastructure, regulation and other policy framework is crucial for a country to keep its competitiveness in global economy (Khanna 2016). Mega-regions have been chosen by Chinese central government as interjurisdictional entities for implementing economic incentives and further infrastructure development (Tao 2016). In order to determine the jurisdiction of upcoming inter-regional institutions and provide guidance for infrastructure development across province boundaries, a clear evaluation about the nation's economic connection and the development of mega-regions is needed.

Mega-regions are not mature under clear policy guidance so it is quite hard to identify which cities are within the cluster and cities that are not. As been proposed by Chuanglin, mega-region is not just about a group of cities that are located geographically close to each other, but a group of cities that are closely tied to each

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other by transportation and economic activities (Fang 2014). Pearl River Delta (PRD) and Yangtze River Delta (YRD) are the most well-known city clusters in China. Besides that, in recent years, Chinese central government proposed the "5 + 9 + 6" urban agglomeration structure, including several new mega-regions (Fang et al. 2015). These regions identified by central government are expected to receive more political and economic incentives to support their regional integration development. However, researchers hold different views on the designation of urban agglomeration. Tinghai Wu and Neng Zhang proposed the "3 + 7 + 17" urban agglomeration structure (Wu and Zhang 2015). Yueming Ning proposed the "10 + 3" structure (Fang et al. 2015). Wuhan Mega Region(WMR), as one of the bone of contentions in "5 + 9 + 6" structure, has been pointed out by researchers that it is in fact a combination of three urban agglomerations (Fang et al. 2015).

Several quantitative methods have been proposed by researchers to identify and evaluate potential mega-regions. Li Wang et al. have used both field model and Newtonian gravity model to identify 12 urban agglomerations in China (Wang et al. 2013). Dongqi Sun et al. have used gravity model combining with economic survey data to evaluate the connections within the YRD and the Capital Economic Zone (CEZ) (Sun et al. 2013). Another prevalent method is percolation theory proposed by Stauffer and Aharony (1994). Elsa Arcaute et al. explored the hierarchy level of Britain at different scales based on the street network (Arcaute et al. 2016). By adjusting the threshold of road network, city's hierarchy level can be identified. However, the number of levels, in this case, is difficult to be recognized, as there is no established algorithms for helping to decide a better number of levels. Thus, the method is convenient for testifying the established theories rather than exploring new conclusions. Since traditional annual-survey data is hard to measure the interaction between cities. These researches use models to simulate the results. The lack of proper linking data makes it quite difficult for researchers to argue whether an urban agglomeration is properly identified.

In our research, companies' investment data enable us to evaluate one of the most crucial indicators of mega-region, the strength of economic connections among cities. Since most government policies implemented on mega-regions are expected to enhance the economic interaction within city groups, companies' investment data would be an ideal data source for evaluating these activities. Also, unlike other interactive data simulated by gravity model and field model, companies' investment data as an empirical data does not rely on geographical locations. This makes it easier for us to identify those cities within the existing mega-regions but have a weak connection to other group members. Combining with machine learning tools and social network analysis methods, we are able to study the interaction between cities at a country level. In this paper we will identify the hierarchical structure of cities and divide the nation's cities into small city groups based on the strength of connection between cities. These groups will then be compared with designated mega-regions. Through this research we will introduce a new analytical method for evaluating mega-regions and based on the result providing suggestion for the development of China's existing mega-regions.

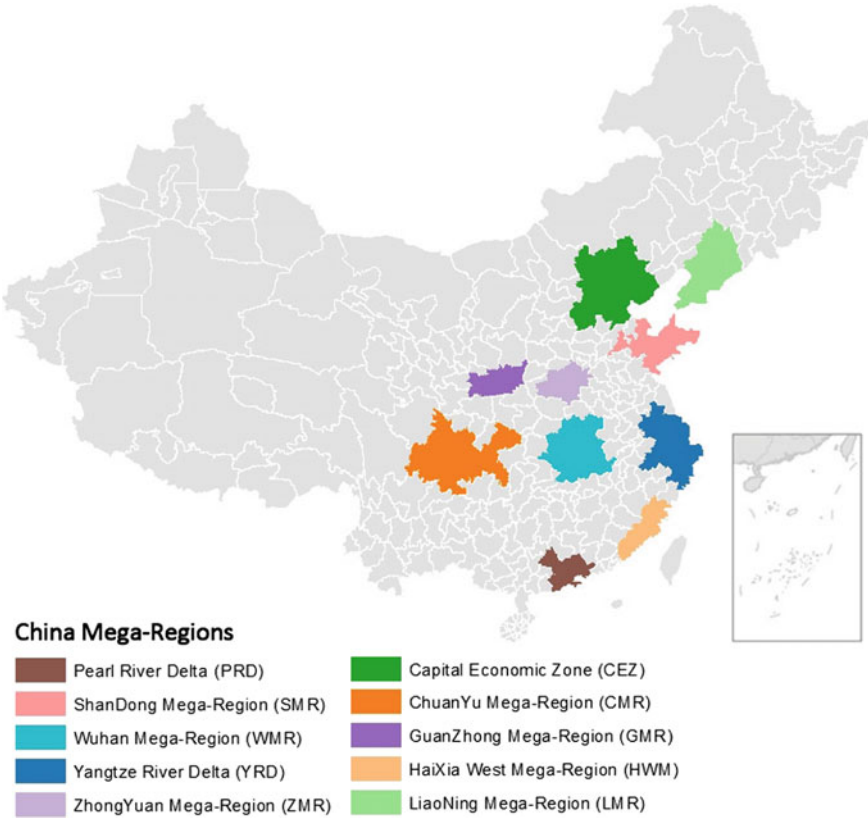

Fig. 8.1 China's mega-regions

Many mega-region structures have been proposed by researchers like "5 + 9 + 6", "5 + 6 + 11" and "3 + 7 + 17" (Fang et al. 2015). In this research we select the 10 most broadly accepted urban agglomerations in China for study, shown in Fig. 8.1 (Zhao and Bai 2012).

ChuanYu Mega-Region (CMR) includes Chongqing, Chengdu, Zigong, Luzhou, Deyang, Mianzhou, Suining, Neijiang, Leshan, Nanchong, Meishan, Yibin, Guangan, Yaan, Ziyang and Anyue.
HaiXia West Mega-Region (HWM) includes Fuzhou, Xiamen, Zhangzhou, Quanzhou, Putian and Ningde.
Capital Economic Zone (CEZ) includes Beijing, Tianjin, Tangshan, Langfang, Baoding, Qinhuangdao, Shijiazhuang, Zhangjiakou, Chengde and Cangzhou.
LiaoNing Mega-Region (LMR) includes Weihai, Rizhao, Shenyang, Dalian, Anshan, Fushun, Benxi, Dandong, Liaoyang, Yingkou, Panjin and Tieling.
ShanDong Mega-Region (SMR) includes Jinan, Qingdao, Yantai, Weifang, Zibo, Dongying, Weihai and Rizhao.

GuanZhong Mega-Region (GMR) includes Xi'an, Xianyang, Baoji, Weinan, Tongchuan and Shangzhou.
Yangtze River Delta (YRD) includes Shanghai, Hangzhou, Nanjing, Suzhou, Wuxi, Changzhou, Zhenjiang, Yangzhou, Taizhou (泰州市), Nantong, Jiaxing, Huzhou, Ningbo, Shaoxing, Zhoushan and Taizhou (台州市).
Wuhan Mega-Region (WMR) includes Wuhan, Huangshi, Ezhou, Huanggang, Xiantao, Qianjiang, Xiaogan, Xianning, Tianmen, Suizhou, Jingmen, Jingzhou, Xinyang, Jiujiang and Yueyang.
ZhongYuan Mega-Region (ZMR) includes Zhengzhou, Luoyang, Kaifeng, Xinxiang, Jiaozuo, Xuchang, Pingdingshan, Luohe and Jiyuan.
Pearl River Delta (PRD) includes Guangzhou, Shenzhen, Zhuhai, Foshan, Huizhou, Zhaoqing, Jiangmen, Dongguan and Zhongshan.

8.2 Data and Methodology

The data we used for this research is the integrated company equity investment records. This dataset contains 336 cities, covering all prefecture-level cities and several county-level cities. Hong Kong, Macao and Taiwan are not included. Each city's whole companies' investments are aggregated by year and target cities (Table 8.1). For this research we select 4 time sections: 2000, 2005, 2010 and 2015. In order to perform network analysis we convert the dataset into four weighted directed graph. The cities are saved as nodes in the network, with investment pairs as link and investment amount as weight. For 2000, the whole network contains 1206 lines. For 2005, the whole network contains 1822 lines. For 2010, it contains 4979 lines. And for 2015, it contains 9218 lines.

The whole analysis will be separated into two parts. In the first part, we will study the interaction of Chinese cities at a country level. We will construct the national investment network. In this part, indicators like network average degree, cities' degree distribution pattern, each city's in-degree, out-degree and total investment will be used to measure the change of national investment network over the past 15 years and the importance of mega-region.

A city's network in-degree is the number of cities that invested in this city. Its network out-degree is the number of cities that this city invested in. A city's

Table 8.1 City's investment data sample

	Year	Source	Target	Total investment (million yuan)
1	2000	Beijing	Beijing	198,412.9669
2	2000	Beijing	Dongying	29,000
3	2000	Beijing	Shanghai	7888.213057
4	2000	Beijing	Tianjing	7168.340943
5	2000	Beijing	Jinan	6425.0233

network degree is the sum of its in-degree and its out-degree. The network average degree is the average number of all cities' network degree within the network.

Based on 2015 cities' investment data, we will use cluster analysis methods to categorize cities into different hierarchical level. And identify those 10 mega-regions' regional urban structures according to the result. The data used in this model is the 336 by 336 investment matrix at city level. Each line of data presents a city's investment amount to 336 cities respectively, including the investment to the city itself. During this step, two unsupervised algorithms will be used in order to better categorize the cities. K-Means model is used to help the detection of a suitable number of clusters for the unsupervised model, as the K-Means model runs a better performance when the size of sample is relatively huge (Hartigan and Wong 1979). The score from the elbow test of K-Means is a good way of estimating the suitable number of clusters to be decided in the model. Moreover, K-Means is also a way for having more insight of the entire dataset by examining the K-Means result as guidance for the model selection and parameter adjustment in the next stage. By randomly assigning k centers and iterating, the model will find the most suitable centers with the minimum sum of inertia for the data in each cluster:

$$\arg\min_{s} \sum_{i=1}^{k} \sum_{x \in S_i} \| x - \mu \|^2$$

where

K is the number of clusters set in the model.
μ_i is the mean of points in S_i.

After having a deeper insight of the dataset, we will use hierarchical clustering based on the character of the dataset (Ward 1963). By placing out the hierarchy of data based on certain distance and linkage criteria, this model has a better ability of outlier distinction. In this research, Ward criteria will be selected thus the distance criteria can only be Euclidean distance. The number of clusters in this hierarchical model will be applied based on the number of clusters estimated by K-Means:

$$d_{ij} = d(\{x_i\}, \{x_j\}) = \| x_i - x_j \|$$

$$\min \sum_{i=1}^{j} d_{ij}$$

where d_{ij} is the distance between input i and j.

In the second part, the study will focus on those mega-regions. We will use 2015 companies' investment data to measure the total amount of money each city cluster invested inside the cluster and outside the cluster. By using these indicators, we will separate those urban agglomerations into different groups: "high outward investment propensity region", "high inward investment propensity region" and "balanced investment region". These investment preference can then be used to support the detection of the development stage of those mega-regions.

A cluster method will be used to identify cohesive subgroups within the national investment network. The algorithm we choose is the fast modularity optimization by Blondel et al. (2008). As tested by Lancichinetti and Fortunato, the fast modularity optimization has a good performance under the LFR benchmark (Lancichinetti and Fortunato 2009). This benchmark is constructed based on GN benchmark but introduced a power law distributions of degree and community size. Lancichinetti et al.'s LFR benchmark test shows this algorithm have a good performance in detecting cohesive subgroups in networks that follows the distribution of power law. The national investment network follows the distribution of power law (Fig. 8.2). The algorithm is able to run on directed and weighted graphs. A modularity indicator ΔQ is used to control the efficiency of the algorithm.

$$\Delta Q = \left[\frac{\sum in + k_{i,in}}{2m} - \left(\frac{\sum tot + k_i}{2m}\right)^2\right] - \left[\frac{\sum in}{2m} - \left(\frac{\sum tot}{2m}\right)^2 - \left(\frac{k_i}{2m}\right)^2\right]$$

$\sum in$ is the sum of the weights of the links inside community C, $\sum tot$ is the sum of the weights of the links incident to nodes in C, k_i is the sum of the weights of the links incident to node I, $k_{i,in}$ is the sum of the weights of the links from i to nodes in C and m is the sum of the weights of all the links in the network (Blondel et al. 2008).

Because mega-region is defined as a group of cities that have both geographically and economically stronger connection to group members rather than non-group members, by studying the distribution of each mega-region's group members in identified cohesive subgroups we will be able to evaluate the development stage of each mega-region. Combined with the hierarchical type we get about each group member, we will get a deeper analysis about the development of mega-region and provides suggestions for their further developing strategy.

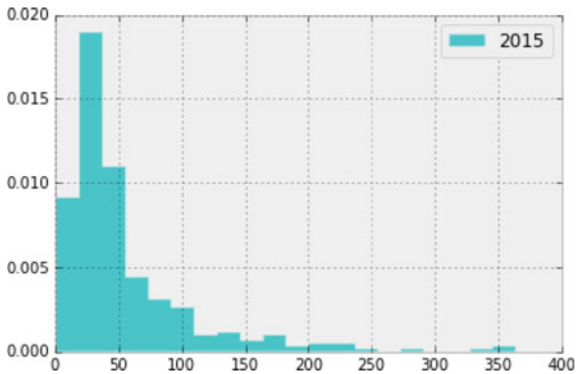

Fig. 8.2 The node degree distribution in 2015 national investment network

8.3 The Development of China's Investment Network

First of all, from the nation's overall network of investment, we can notice the trend of expanding and complicating for the entire network from 2000 to 2015 (Fig. 8.3). In 2000, there is a pattern of core-city-driven investment network. From the graph, Beijing, Shanghai, Guangzhou and Chengdu are clearly recognized, forming the four vertexes of the diamond structure of the nation's investment network. In 2005, the trend still exists while Urumqi became a new polar in the entire network. At the same time, the tie between Beijing and Chengdu grew stronger than 2000. Nevertheless, the leading role of the four cities as regional investment cores, although still exists, becoming obscure in the following 2010 and 2015 investment network. The 2015 network map shows a more various investment activities among eastern coastal cities and central region cities. And the leading role of the four cities is difficult to identify from the graph. The change of national investment activity also reflects in the total amount of investment and city's node degree (Fig. 8.4).

Looking into the total amount of investment of the entire country, the network grows exponentially. In 2015, the total investment is more than 20 times to the

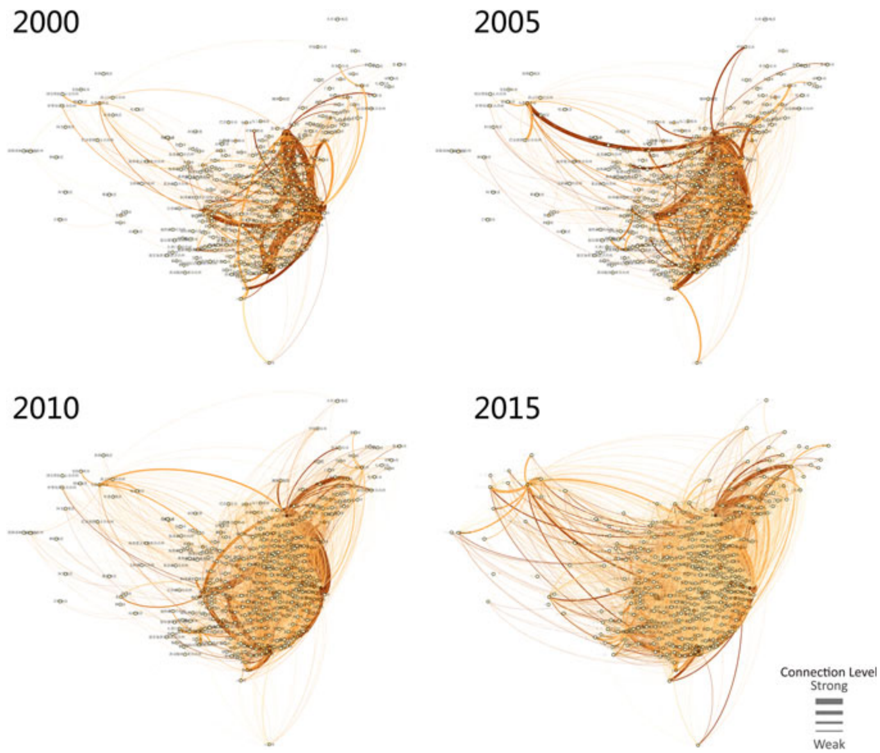

Fig. 8.3 China's investment network

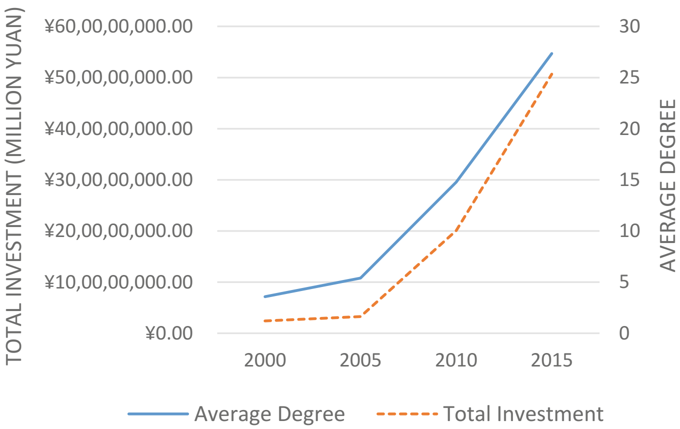

Fig. 8.4 The change of network features

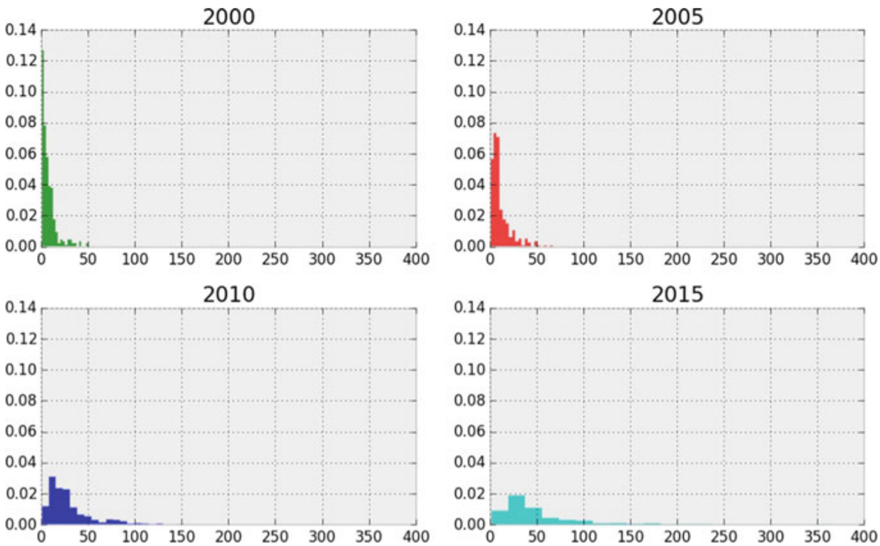

Fig. 8.5 Nodes degree distribution

amount in 2000. At the same time, the network average degree grows simultaneously, from only 3.58 in 2000 to 27.35 in 2015.

The entire network node degree distribution shifts from a polarized structure, with four leading cities as vertexes dominating the network, to a more balanced structure as shown in Fig. 8.5. In 2000, the nodes degree for most of the cities lies between 0 and 10. However, the nodes degrees for four leading cities are as high as 50. While in 2015, apart from some of the vertexes in 2000's diamond structure, such as Beijing and Shanghai, cities that have lower nodes degree in 2000 start to play more important roles, especially the second-tier regional centers in the mid-east. The nodes degree of some cities like Wuhan, Hangzhou and Nanjing have seen a sharp increase.

From the overall change of the nation's investment network in the past 15 years, it is obvious to recognize that the rapid increase in total investment brings a huge change in the overall structure of the nation's investment network. Core cities in the national network like Beijing and Shanghai, which used to play crucial roles, still maintained their advantages. But several new cities have shown up as regional core, promoting investment within regions. The national investment structure changes from the diamond-shaped investment network of four cities to a more complicated and complete structure.

By comparing the change in in-degree and out-degree for the top 10 cities in the past 15 years, we have a deeper insight for the change of the investment characteristic for cities in China (Fig. 8.6). In 2000, 7 out of the top 10 cities have a higher in-degree than out-degree, suggesting a more inward type of investment style with more investment received than made. All four of the vertexes cities in the diamond structure in this period have a higher in-degree than out-degree, revealing the fact that even the investment or financial center in this stage is built on an inward type of investment structure. Few cities ran against this trend. Only Zhanjiang and Wenzhou have an out-degree twice higher than their in-degree.

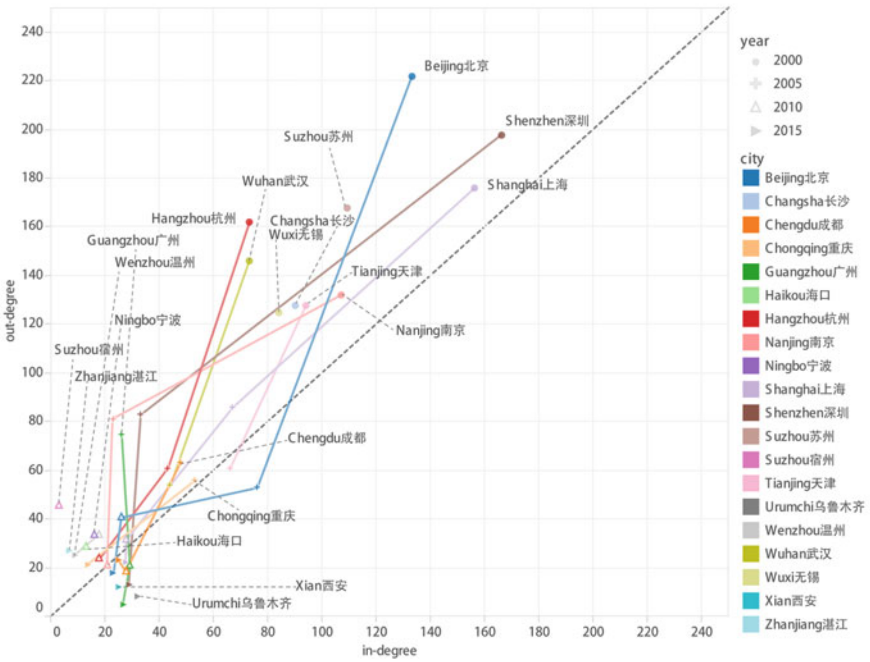

Fig. 8.6 Each year's top ten cities based on nodes degree

The change began at 2005, in this year, 8 cities' out-degree are higher than their in-degree, showing an approximation of the out-degree to in-degree, suggesting a transformation from investment receivers to comprehensive hub. During this time, more investment is made by these cities than they received. At the same time, 2 out of the top 4 cities' out-degree is higher than their in-degree, which are Beijing and Shanghai. While the only 2 cities that have a lower out-degree are Chengdu and Guangzhou, these two investment centers are still attracting more investment than they made. Also from the statistics perspective, during this time, the out-degree for most of the cities is higher than 20, as the number is only 2 in 2000, as mentioned above.

In 2010, the trend is still expanding for most of the cities in the top 10 by investment amount. More investment hubs appear during this period. Meanwhile, the out-degree for these cities is much higher than 5 years ago, as all the cities have an out-degree higher than 40, even for the cities that have a higher in-degree than the out-degree of their own.

In 2015, all the top 10 cities have a higher out-degree than in-degree, showing a much more outward investment structure in the entire country. The out-degree for these cities are all higher than 100. For investment center such as Beijing, Shenzhen and Shanghai, the out-degree are even higher. The function and status for these cities are no longer just investment hubs for investment transition, cities with higher total investment are both investment attractor and investment initiator in this period, stimulating the country's investment network in a more positive way, expanding the entire network into a complex agglomeration.

In order to better understand the hierarchical structure of the national investment network and each city's role within the investment network, a hierarchical clustering algorithm was applied, aiming to categorize all the cities based on their investment type revealed by indicators like total investment, in- and out-degree. The number of clusters, after the estimation by the elbow test generated from K-Means clustering, was set to 10. By looking into the character of each of the 10 clusters, we merged some of the clusters as they share the similar features in investment and out-degree (Table 8.2). As a result, the original 10 clusters are finally merged into 4, as four tiers of cities based on investment type are recognized. The result depicts a broader but insight view for the country's investment network.

The distribution of different category results (Fig. 8.7) can be explained by the Core-Periphery Paradigm. According to the Core-Periphery Paradigm proposed by A. J. Friedmann, any region is consists of its own core area and periphery area. Due to the difference in resource, market and space, certain areas, which are the core areas, will have a faster pace of development than those areas in the periphery status. Thus, these areas hold a stronger competitiveness, forming the core of the region. Eventually, radiating its influence to the periphery areas.

In our case, the cores, which are the political and financial center for either city clusters or geographical regions, have a better ability to attract investment and then radiating its influence outwards by making investment to the surrounding periphery areas.

Table 8.2 Cluster model's result category

Category	Investment level	Number of cities	Average total investment (million yuan)	Average total out-degree
1	National center	1	1,462,647	331
2		1	785,215	293
3		1	664,047	292
4	Regional center	1	107,582	195
5		1	107,453	120
6		4	69,605	191
7		1	67,104	158
8	Sub-regional center	1	32,589	78
9		29	29,532	98
10	Periphery city	296	2388	23

Fig. 8.7 Spatial distribution of cities in different investment level

From the result, category 1, 2, 3 are identified as national cores or centers, which are Beijing, Shanghai and Shenzhen. These three cities are establishing their influence on a national scale, with extremely high out-degree and total investment amount as they are playing crucial roles in the entire national investment network.

Category 4, 5, 6, 7 are recognized as regional centers, which are mainly consist of the second-tier cities in the mid-east. There are 7 cities fall in these four categories. Though these cities share a relative lower total investment and out-degree than the national cores, the amount is still very high, compared to major body of the dataset. This type of cities is more like a hub in certain region of the national network. Although they are not as influential as the national cores, they are radiating their impact in the certain region or regions.

The third level of the nation's investment network contains category 8 and 9. These cities are identified as sub-regional centers and important third-level nodes, as their out-degree is much lower than the regional centers. Compared with category 10, these cities are still standing out in the perspective of both total investment amount and out-degree. The third level cities act as hubs between regional centers and periphery cities. The typical investment type of these cities is receiving investment from cities in upper level of the network and delivering investment to peripheries.

The rest cities are clustered into one group, which is category 10. There are 296 cities in this group, which forms the majority of the network, the periphery in the hierarchical investment network. The out-degree for these cities are the lowest in the entire system, showing an investment type of more receiving than giving.

8.4 Evaluation of Mega-regions' Development

8.4.1 Mega-regions' Investment Activities in the Country's Investment Network

From Fig. 8.8 and Table 8.3, we can see mega-regions, as important components of the national investment network, have played an irreplaceable role. The percentage of investment within mega-regions counts for more than 50% of the total national investment in 2000, 2005 and 2015. In these years, the percentage of investment involving cities within mega-regions count for more than 90% of the amount of total national investments. Mega-regions investment activities deeply influenced the national investment network.

Since mega-regions only counts for 1/4 of the total numbers of cities taken into study, from Table 8.4 we can see all mega-regions invested more to cities outside the mega-region. But compare to other mega-regions, CEZ tend to invest more to other cities outside CEZ, but YRD tend to invest more to cities inside YRD. In order to compare mega-regions' attitude towards inside and outside investments, we use two indicators: "difference of inside investment (DII)" and "difference of outside investment(DOI)". Both two indicators are relative values used to compare the investment activity amount these ten mega-regions.

$$\mathrm{DII}_k = \left\{ \left[\frac{II_k}{II_k + IO_k} \right] - \left[\sum_{i=1}^{10} II_i/(II_i + IO_i) \right] /10 \right\} * 100$$

$$\mathrm{DOI}_k = \left\{ \left[\frac{IO_k}{II_k + IO_k} \right] - \left[\sum_{i=1}^{10} IO_i/(II_i + IO_i) \right] /10 \right\} * 100$$

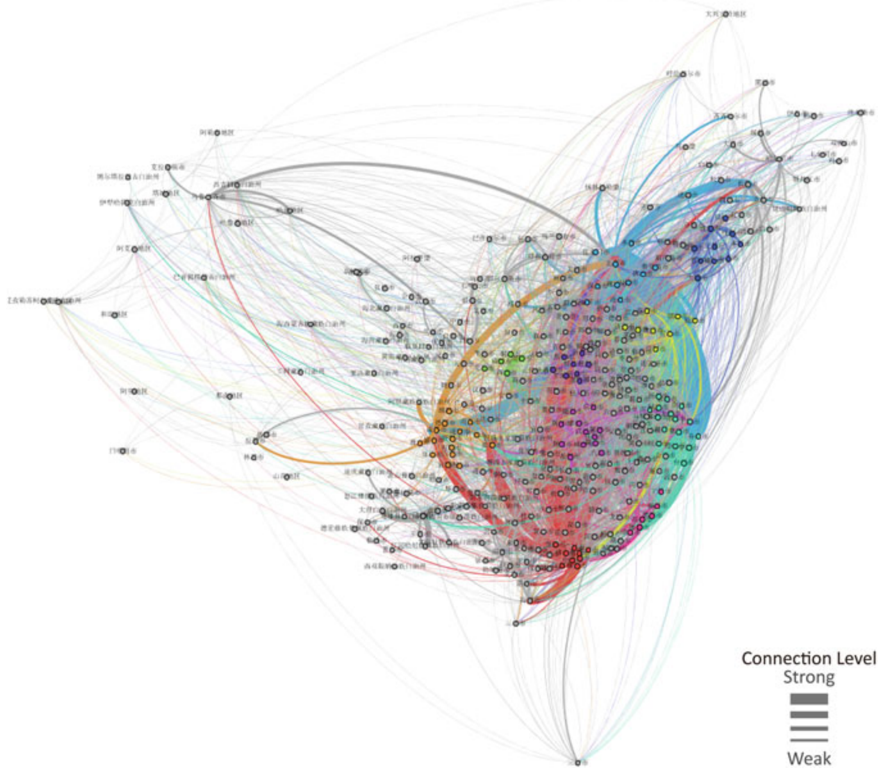

Fig. 8.8 Mega-region involved national investment network-2015

Table 8.3 Mega-regions' investment by year

Year	Investment within mega-regions (million yuan)	Investment involve mega-regions (million yuan)	Percentage of investment within mega-regions (%)	Percentage of investment involve mega-regions (%)
2000	¥135,400	¥224,706	56	92
2005	¥179,230	¥294,553	55	90
2010	¥770,292	¥1,287,287	38	64
2015	¥2,885,186	¥4,748,143	57	94

where

II_k is the k mega-region's investment inside.
IO_k is the k mega-region's investment outside.

From Fig. 8.9 we can see, as shown from Table 8.4, CEZ shows a strong preference for outside investment compare to other mega-regions. YRD has a

Table 8.4 Mega-regions' investment activity

	Investment inside (million yuan)	Investment outside (million yuan)	External investment[a] (million yuan)
CMR	¥18,704	¥115,689	¥13,207
HWM	¥28,586	¥130,764	¥10,980
CEZ	¥171,520	¥1,408,742	¥67,880
LMR	¥9177	¥42,636	¥6016
SMR	¥31,081	¥78,645	¥17,323
GMR	¥14,766	¥55,566	¥12,283
YRD	¥444,546	¥784,779	¥182,401
WMR	¥11,579	¥68,899	¥15,645
ZMR	¥4503	¥40,235	¥1425
PRD	¥158,287	¥703,543	¥98,735

[a]Other city's investment to the mega-region

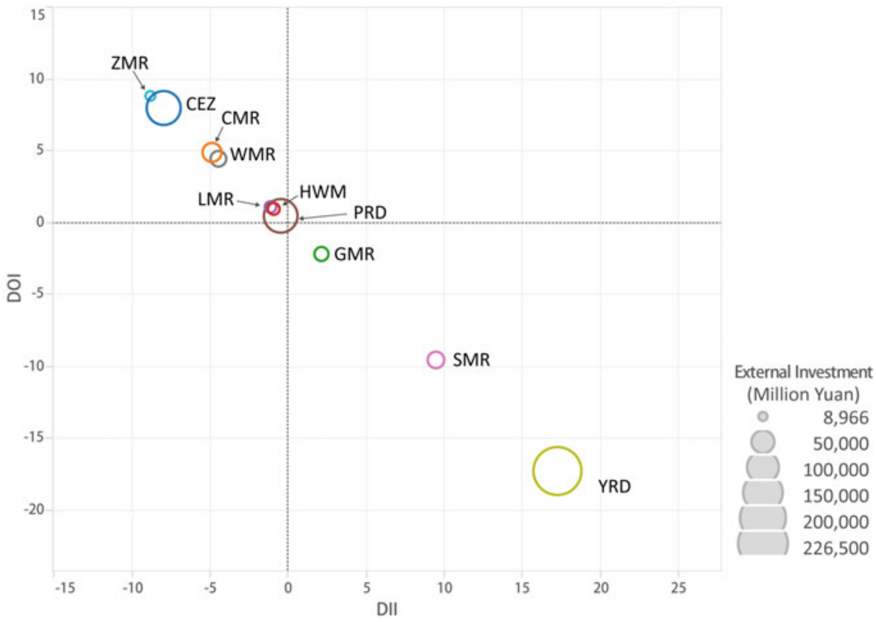

Fig. 8.9 Mega-regions' preference on inside and outside investment

relatively more intense interests in inside investment. ZMR, CEZ, CMR, WMR are all high outward investment propensity regions. SMR is a high inward investment propensity region. HWM, LMR, PRD and GMR have minor difference on their internal and external investment, and are balanced investment regions.

Since mega-region is a group of cities that have strong economic connection and industry collaboration, its attitude towards inside and outside investment might reveal the different development stages that a mega-regions is in.

8.4.2 The Strength of Economic Activities Within and Outside Mega-region

In order to evaluate the strength of connection within mega-regions and identify those mega-regions development stage, we use fast modularity optimization method to test the national investment network. This algorism separates the whole investment network into 10 cohesive subgroups with a modularity value of 0.310. Cities inside one subgroup have stronger connection to group members than to cities outside the subgroup. The result takes both the weight and the direction of the national investment network into consideration.

From the result we can see cities within HWM, CMR, YRD, GMR has all been separated into 4 different subgroups (Fig. 8.10). This shows those four mega-regions have strong internal investment connections and stabled structure.

All cities within PRD have been grouped to one cohesive subgroup. This shows PRD is also a mega-region with strong internal connections. But besides PRD cities, cohesive subgroup 6 also contains almost all cities within WMR. Only Xinyang been separated into subgroup 8. The result shows, compare to other cities, there is a strong connection between cities in these two mega-regions.

WMR and SMR both have one city not included in cohesive subgroup 6 and cohesive subgroup 9. Since cities within mega-regions are expected to have stronger connections, the result shows both Xinyang and Dongying are not strongly connected to the designated mega-region. Both two mega-regions structure are not stable.

All cities within CEZ, LMR, several cities within ZMR and one city within SMR have been grouped to subgroup 4. The result shows those cities have stronger internal connections. But compare the amount of money invest inside and outside mega-regions, as show in Table 8.4, we can see LMR and ZMR are substantially behind other mega-regions. These two mega-regions are still in embryonic form. CEZ as a mega-region with large amount of financial flows, its preference to outside investment is probably due to the economic connections it have with LMR and ZMR.

Studying the distribution of cohesive subgroups at a national scale we can see it has a high degree of coincidence with the mega-region distribution map. Subgroup 4, which includes CEZ, LMR and part of ZMR, does not have a strong spatial cohesion. Subgroup 3, subgroup 1, subgroup 9 and subgroup 2 have better spatial cohesion. They are similar to the distribution of PRD, SMR, HWM and GMR. Subgroup 1 for example, includes the whole HWM and 3 cities geographically

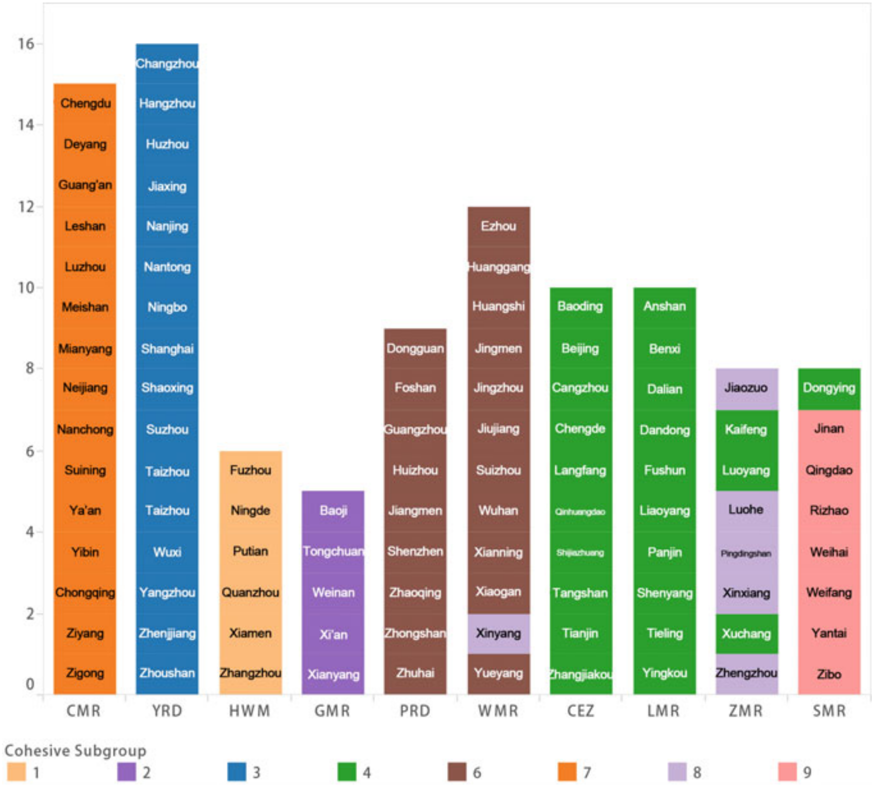

Fig. 8.10 The distribution of mega-regions in cohesive subgroups (cohesive subgroup 0 contains no city from these 10 mega-regions and is not show on this figure)

adjacent to the mega-region. Subgroup 7 and subgroup 6 where CMR, PRD and part of WMR are in reveal a trend of expansion.

Combining with the result we get from Fig. 8.9, we can see YRD and SMR are in a steady status, focusing more on internal development. CMR is now in a trend to extended. Its connection to southwest cities is much more stronger than other mega-regions (Fig. 8.11). HWM and GMR are still keeping their balanced inside and outside investment, lack of the motivation of outward expansion. CEZ and LMR are still in the process of dynamic development. CEZ has a strong preference for outside investment. Using investment to strength the mega-region's connections to special cities outside the mega-regions. LMR does not have a strong economy and is still under the influence of CEZ. PRD shows a clear sign of expansion. It maintains a strong economic connection with WMR cities. Its inside investment and outside investment are both kept at a quite high level. WMR is still not in a steady status.

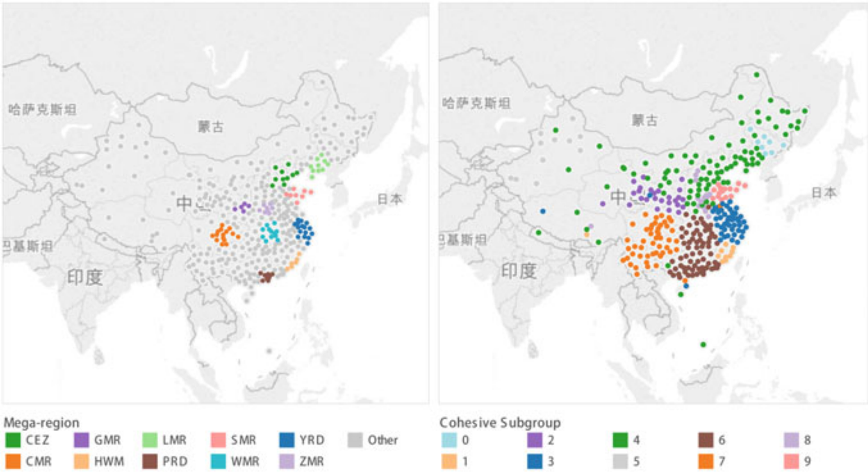

Fig. 8.11 Compare the spatial distribution of mega-regions and cohesive subgroups

8.4.3 Investigate the Mechanism Behind the Development of Mega-regions

Proposed by Francois Perrous in growth pole theory, the growth poles cities are engines for economic growth and economic activity agglomeration (An 1997). Based on this theory, Zhang and Pu studied the economic network of China's western cities and recommends a Gradation Growth Poles Network Development Model for regional development. (Zhang and Pu 2006) The advantage of these model is, on the basis of polarized distribution of population and production, giving full play to all levels of the growth poles. Different levels of growth poles holds different core competencies and will play a different role in regional development. Through the construction of Gradation Growth Poles Network, regions can strength vertical cooperation and weaken the competition among same level cities.

Combining with results get from hierarchical cluster analysis and fast modularity optimization analysis, we can evaluate these mega-regions through studying their internal mechanism. The cluster analysis on national investment network exhibits a clear hierarchical structure. The roles each city within mega-region plays could be explained through this structure. In this section, we choose four typical mega-regions YRD, CEZ, PRD and WMR for more in-depth analysis.

From previous analysis we can see YRD is a stabled, well-developed mega-region. There is a vibrant high-frequency internal economic exchange between cities within the region. Compare to other mega-regions, YRD has a strong preference in inside investment, which also exhibit its powerful internal cooperation mechanism. From YRD's hierarchical structure we can see its internal structure is very stable (Fig. 8.12). Shanghai, the national core level city is located on the top of

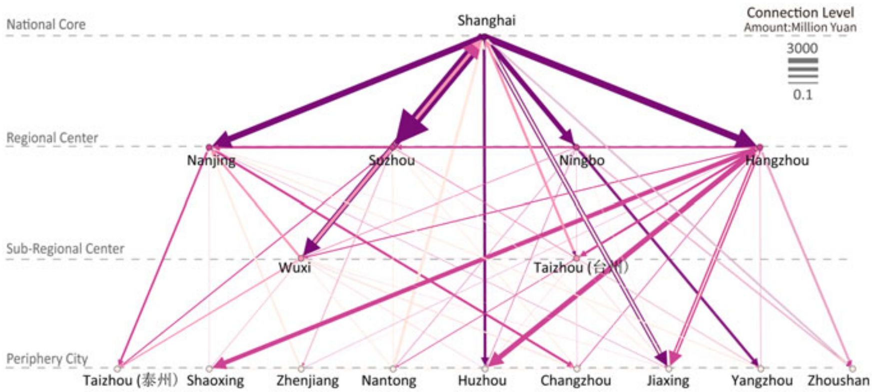

Fig. 8.12 The hierarchical structure of YRD

the pyramid-shaped structure. Under it, four regional centers, Nanjing, Suzhou, Ningbo and Hangzhou takes the majority of the investment national core level city invested to the mega-region and invest to the third and fourth level cities. Investment flows smoothly through the network, crossing the node in each level, from top to bottom then back to the top.

This structure also exhibits a well-arranged regional industrial division. Shanghai as a well-known financial service center works as a hub attracting external investment and distribute investment to second level cities. Nanjing, Suzhou, Ningbo and Hangzhou are also cities with strong financial industry but also have strong high-tech manufacturing industry. Wuxi and Taizhou[1] are also strong in manufacturing industry. The fourth level cities with a relative low industrial scale provide space and cheap labor resource for labor-intensive industry. High quality transportation infrastructure is a strong support for the industrial cooperation among those cities.

Compare to YRD, CEZ has a much weaker hierarchical structure. The majority of cities within this mega-region are fourth level cities. Tianjing is a sub-regional center city while Beijing is a national core. As can be seen from Fig. 8.13, Beijing invests heavily to the third level city but also invests directly to those fourth level cities. Within this region, Beijing is the irreplaceable center while the interaction among other cities are quite weak. Looking back to the hierarchical structure of YRD, the lack of internal economic interaction in CEZ could be caused by the absence of second level and even third level cities. While under strong policy implications, Beijing distributes its investment to fourth level cities, there is no good economic basis for the industrial cooperation among nation core level city and periphery city. In order to achieve industrial cooperation, nation core level city has to invest in

[1]台州市

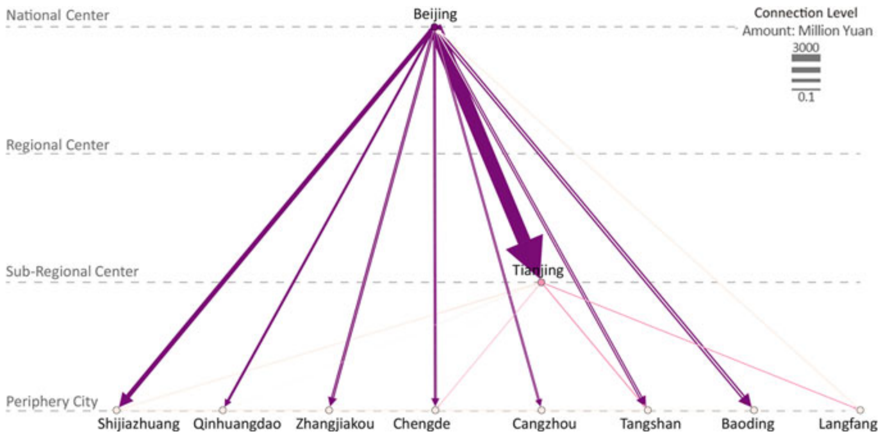

Fig. 8.13 The hierarchical structure of CEZ

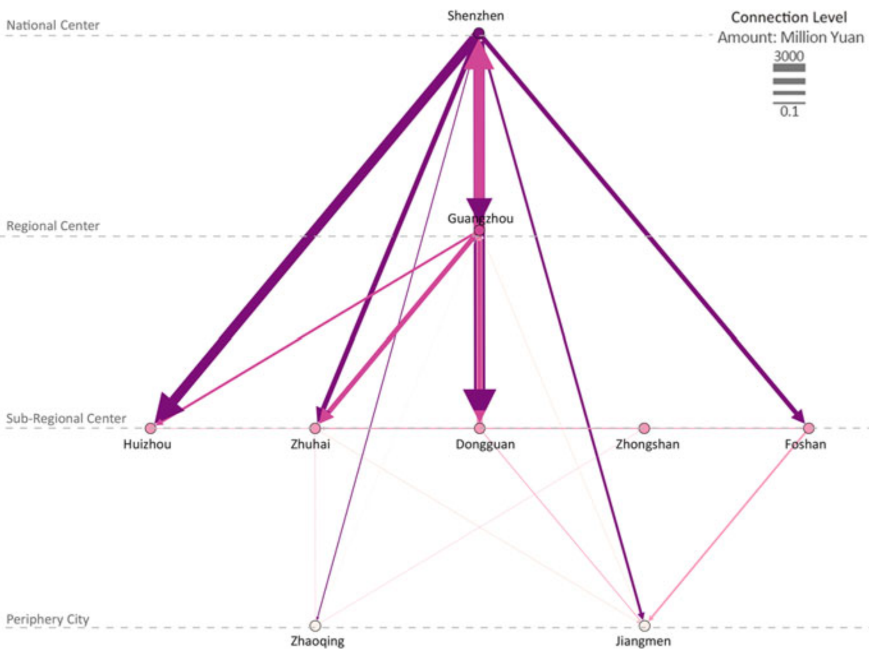

Fig. 8.14 The hierarchical structure of PRD

second level and third level cities, like Dalian and Harbin, outside the mega-region. As a result the whole CEZ shows a strong preference for investment outside.

From Fig. 8.14 we can see as a well-known mega-region. PRD also has a four-layer structure. Shenzhen is the mega-region's national core level city.

Guangzhou is the second level city. Underneath them are five sub-regional center cities: Huizhou, Zhuhai, Dongguan, Zhongshan and Foshan. Zhaoqing and Jiangmen are the only fourth level cities this mega-region has. As can be seen from Table 8.4, although PRD keeps a balanced inside and outside investments, the total amount of money it spends is just slightly smaller than CEZ and YRD. On one hand, PRD keeps strength the connection within mega-regions. On the other hand, it also invests heavily to cities outside the region. In recent years, PRD is facing a skyrocket of labor cost and business management cost. Large amounts of labor intensive and low-value-added companies move out to surrounding inland areas. This could be the explanation to the heavy investment PRD put on cities outside the mega-region. A well-developed mega-region structure needs the strong support of fourth level cities.

In WMR, the region still keeps a flat structure. Wuhan is the mega-region's only third level city. All other cities in this mega-region are located on the fourth level. Since most cities are located on the same level, there exists a intense homogeneous competition. As can be seen from Fig. 8.15, not all fourth level cities choose to keep a strong connection to Wuhan. Since WMR includes cities from three provinces and does not have a stabled multi-layer structure, multiple cities choose to strength the connection to higher level cities outside the mega-region. Wuhan also keeps a strong connection with other external second level cities. The whole mega-region thus exhibits a strong preference for outside investment.

From the modularity analysis result, we can see PRD and WMR are been grouped to one cohesive subgroup. This shows there is a strong connection between these two mega-regions. As mentioned, PRD is a well-developed mega-region with plenty of top-level cities, but lack of bottom level cities. WMR is still a developing mega-region with only one high-level city. The cooperation of these two mega-regions improves the hierarchical structure (Fig. 8.16). From the result we can see CMR also has a plenty of fourth level cities. But the construction of major infrastructures like Beijing-Guangzhou high-speed railway strengthened the connection between these two mega-regions, enhancing the industrial cooperation across mega-regions.

Fig. 8.15 The hierarchical structure of WMR

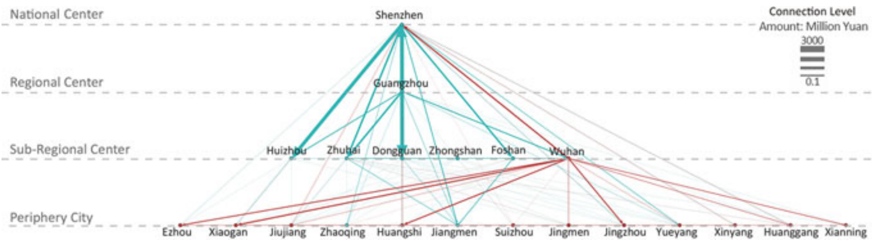

Fig. 8.16 The hierarchical structure of combined PRD and WMR cluster

8.5 Conclusion

The whole analysis starts at a national level. Through studying the distribution of node degree and top ten degree cities' in-degrees and out-degrees, we can see China's investment network has developed to a matured status. By using hierarchical cluster analysis method, we divide cities into four stages: national core, regional center, sub-regional center and periphery city. Mega-regions play an important role in the national investment network. From studying their preference on inside investment and outside investment, 10 mega-regions can be categorized into different groups. Through fast modularity optimization method, the whole national investment network are been divided to 10 cohesive subgroups. From the result we can see HWM, CMR, YRD, GMR are stabilized mega-regions. WMR's internal connection and SMR's internal connection are not quite strong. CEZ, LMR and ZMR are still in embryonic form. And PRD as a stabilized mega-region is now strongly connected to WMR.

Connected with hierarchical cluster analysis result, based on Gradation Growth Poles Network Development Model, we can explain the mechanism behind different investment preference and mega-regions' cities' distribution in cohesive subgroups. A well-developed mega-region structure, as displayed in YRD, is a multi-level hierarchical structure, attracting the mega-regions to invest more to strengthen its regional cooperation. In order to achieve this structure, PRD strengthened its connection with WMR. CEZ choose to invest more to cities outside regions. For the future development of China's mega-regions we should focusing on cultivating these multi-layer structure. The structure of YRD could be a regional cooperation paradigm, providing some guidance to other mega-regions development.

Acknowledgements This work was funded by Demarcation of Urban Agglomeration Boundary from the Perspective of Complex Networks and Multi-source Flow Data, Institute for China Sustainable Urbanization, Tsinghua University (K-17005-01).

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Chapter 9
Exploring Spatial Relationships in the Pearl River Delta

Liang Xiong and Steffen Nijhuis

9.1 Introduction

Urban deltas belong to the most promising regions considering their population concentrations, ecosystems service and economy significance. Meanwhile these regions are facing multiple threats and are extreme vulnerable for increasing flood risk, damage of social and ecological values and substantial economic losses. These challenges are demanding a fundamental review of the planning and design of urban delta landscapes and infrastructures, in particular in relation to environmental issues and sustainability. Systematic study of urbanized delta landscapes is essential as a basis for future-oriented action and thinking for the sustainable development of these rapidly changing landscapes (Meyer and Nijhuis 2016). Key in this perspective is to understand urbanizing delta landscapes as complex systems composed of subsystems, each with their own dynamics and speed of change (Meyer and Nijhuis 2013; Dammers et al. 2014; Meyer and Nijhuis 2016). As a system the urbanized delta landscape is a material space that is structured as a constellation of networks and locations with multiple levels of organization at different spatial and temporal dimensions. Mapping the peculiar form of these systems provides insight into the complexity of the built environment and the related spatial networks—and with that, understanding in important social and ecological relationships. Insight into the morphology of the natural landscape, networks and urban pattern provides not only a window to the complex tangible relationships between them, but offers also important clues to get a grip on intangible relationships and driving forces, such as social networks, knowledge exchange, governance structure, tax systems

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X. Ye and X. Liu (eds.), *Cities as Spatial and Social Networks*, Human Dynamics in Smart Cities, https://doi.org/10.1007/978-3-319-95351-9_9

etc., that shape the urban landscape. Urban delta landscapes as such can be defined as an area, as perceived by people, whose character is the result of the action and interaction of natural and/or human factors (cf. Council of Europe 2000).

This chapter aims to introduce a multiscale mapping approach to understand and represent urbanizing delta landscapes while addressing different spatial and temporal dimensions of the involved natural and urban systems, and their roots in social network changes. Subject of this study is the Pearl River Delta (PRD), one of the quickest and most densified large scale urbanizing deltas of the world for the past four decades, to gain insights in the spatial mechanism of urbanization in deltaic circumstances and the problems it causes. It will serve as a case study to exemplify how mapping can be used for constructing and communicating knowledge on tangible and intangible aspects as a basis for sustainable urban regional urban landscape design and planning throughout the scales.

The first section elaborates on the theoretical and methodical backgrounds of the study. Next the PRD is introduced, followed by a cartographic exploration of the landscape, networks and urban patterns in the PRD. The chapter closes with a discussion of the findings and conclusions.

9.2 Theoretical Framework

9.2.1 Urbanized Delta Landscapes as Systems

The urbanized delta landscape can be regarded as a result of both natural and artificial processes (Meyer and Nijhuis 2016). In this perspective the urban landscape is considered a system where different processes and systems influence each other and have a different dynamic of change (Braudel 1966). The landscape is thus a mediator between nature and society, based on a material space that exists as a structure as well as a social and ecological system, which is independent of perception; landscape is a level of organisation of systems (Burel and Baudry 2003).

Systems are organised entities that are composed of elements and their interaction, and consist of structures and processes (Batty 2013). The urban delta as system is a constellation of networks and locations with multiple levels of organisation (Doxiadis 1968; Otto 2011). Networks are important for social and ecological interactions, communications and relationships. Locations are the result of the synthesis of interactions. The networks can be defined as the formal expression of structures for the (1) provision of food, energy, and fresh water; (2) support for transportation, production, nutrient cycling; (3) social services such as recreation, health, arts; and (4) regulation of climate, floods and waste water. Locations are the spatial expression of a locale whose form, function, and meaning are a result of social, ecological and economical processes (Nijhuis and Jauslin 2015).

Though the relationship between networks and locations is not pre-determined in its outcome, networks are becoming more dominant as a spatial manifestation of power and function in society (Castells 2000). This shift implies that design disciplines should not only focus on locations but also on the networks because they have the potential to gain operative force in territorial transformation processes (Nijhuis and Jauslin 2015).

9.2.2 Mapping Urbanized Deltas

Mapping serves as an important tool for the systematic study of urbanized delta landscape in knowledge generating, visualizing, experimental design and decision making. It is a means to generate knowledge from the complex interactions and networks. Maps as a product and the process of mapping are both important means for visual thinking and visual communication in order to understand delta landscapes. Maps help us to reflect upon emerging insights, appraise the landscape in its totality, and observe the relationships between the parts and the whole (Nijhuis and Pouderoijen 2014).

Map dissection and map comparison are useful analytical operations in order to understand urban delta landscapes as systems. Map dissection is about discovering spatial patterns by selection and reduction, and often serves as the basis for spatial association analysis, which explores the relation between different patterns. Techniques for spatial association analysis are overlay analysis and cross-reference mapping. Overlay analysis is employed to derive relationships by applying thematic overlays to geographic location. Map comparison is about finding similarities and dissimilarities in space, time, and theme between the different urbanized deltas, as well as within the individual delta. Since spatial dynamics and changes over time are hard to express in a static map, different time-slice snapshots need to be mapped in order to delineate the development of a delta landscape (Nijhuis and Pouderoijen 2014).

9.2.3 Spatial and Temporal Scale

From the systems perspective, the urbanized delta landscapes comprises of functions with spatial and temporal dimensions (Nijhuis and Pouderoijen 2014). In order to comprehend the heterogeneity of this composition in space and time should be viewed as a scale-continuum (Nijhuis 2013). Therefore, temporal and spatial scale is essential to understand the dynamic of a system, its elements and interaction with other systems and implies that a particular location is always part of the larger context. Spatial scale is related to grain, resolution and extent (De Jong 2012). Grain refers to the finest resolution of a phenomenon or a data set in space or time within which homogeneity is assumed, while extent refers to the expanse in space or time of a study (Turner et al. 1989). Temporal scale refers to the dynamics of development and change in time. Natural landscapes take much longer to develop than infrastructure networks and urban extensions.

Through mapping different spatial and temporal scale urbanized deltas can be explored by changing one of the three parameters: grain, extent and resolution. This offers possibilities to link the different scale levels and to consider the urban delta landscape as a scale-continuum (see Figs. 9.1 and 9.2). By studying the scale change, different systems and elements within them are possible to be composed, linked and understood under the same temporal and spatial scale.

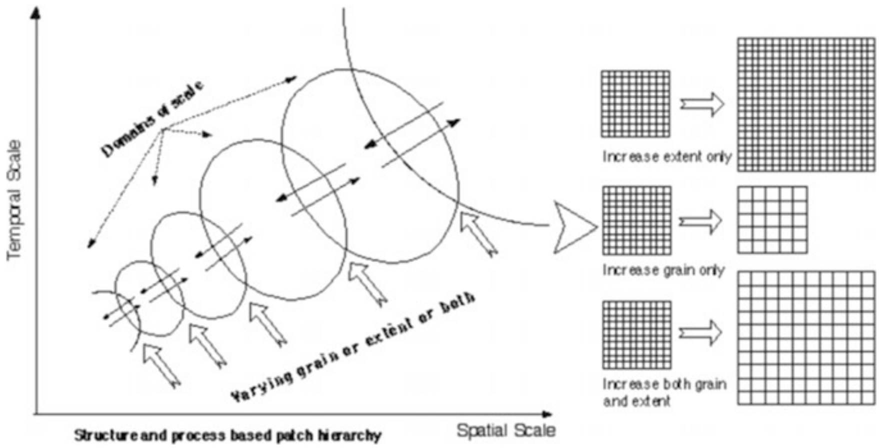

Fig. 9.1 The three ways of information scaling in a temporal—spatial scale system: extent scaling, grain scaling and resolution scaling (Wu 1999)

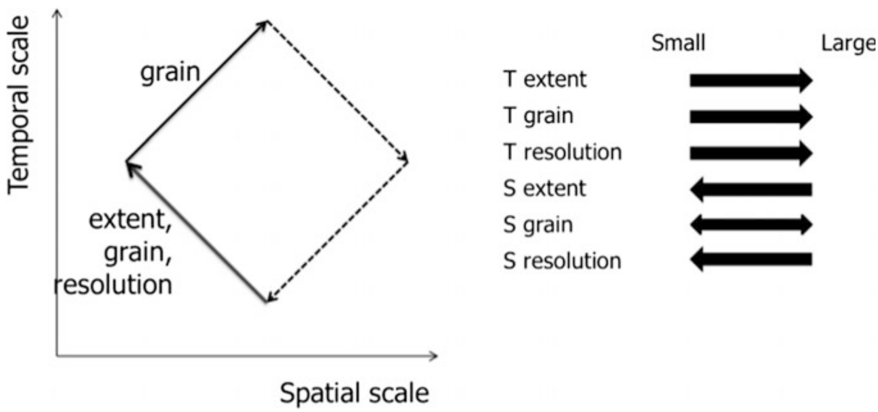

Fig. 9.2 The spatial and temporal scaling possibilities in the cartographic exploration of urbanized deltas. The temporal extent, grain, and resolution can be scaling upwards; the spatial extent and resolution can be scaling downwards; while the spatial grain can be scaling both upwards and downwards

9.3 PRD as a Case Study

9.3.1 Introduction to PRD

Being the quickest developing and most densified urbanizing deltas in the world for the past four decades, the PRD has surpassed Tokyo to be the world's largest urban area in both size and population in 2014 (World Bank 2015). This area has lead the Chinese urbanization and socioeconomic transformation with ground breaking changes since 1980s (Lo 1989; Yeh and Li 1999). Speaking of the speed, its GDP has increased more than 400 folds from 1980 to 2013 (see Table 9.1), while the population rocketed from 20.1 million to 47.9 million between 1982 and 2000 (Tang 2008). The PRD has also ranked as one of the most quickly developing regions in term of urban expansion (Wang et al. 2012). The built-up area emerged at an average speed of 82.1 km^2/year between 1989 and 1997 (Weng 2002). Urban areas have increased by more than 300% between 1988 and 1996 (Seto et al. 2002). Considering the size, Over 56 million permanent residents lives in the delta area (Li 2011), including the world's two urban agglomerations with highest population growth since 1970 (United Nations 2012). Besides the quick developing urban system, the PRD is the most diverse delta in water ecosystem of China. With 383 Phytoplankton species, 410 Zooplankton species and more than 450 fish species, the Pearl River ranks first in the freshwater biodiversity of China (Cui et al. 2005; Wang et al. 2013).

The delta can be divided into two parts with different types of geomorphology. A strong fluvial-dominated characteristic showed in its main part, while tide-dominated characteristic were mainly recognized in the east wing (Li et al. 2001). 80.6% of the land in the delta is flat terrain with about 160 hills and 187 islands spreading around the coast (Huang and Zhang 2004). It starts from the joined point of *Xijiang* (West River) and *Beijiang* (North River) in *Sansui* (Three Rivers), and Shilong in the *Dongjiang* (East River). These three major tributaries (see Fig. 9.3) have contributed the drainage area of the Pearl River in 77.8, 10.5, and 6.6% respectively (Chen et al. 2010), and the sediments of 86.9, 6.2 and 3.7% (Liu et al. 1998). 20% of the sediments settled inside the delta and the rest spread around the estuaries (Wang et al. 2005). The Pearl River is the second largest river in terms of stream flow in China after Yangtze River featuring a drainage area of

Table 9.1 GDP growth in Pearl River Delta 1980–2013

Year	1980	1990	2000	2010	2013
GDP (Billion CNY)	0.12	0.87	7.37	37.39	53.06

Data from 1980–2000: (International Statistics Information Center of National Statistics Bureau 2009), 2010 & 2013: (Statistics Bureau of Guangdong Province and Survey Office of the National Bureau of Statistics in Guangdong 2011; Statistics Bureau of Guangdong Province and Survey Office of the National Bureau of Statistics in Guangdong 2014)

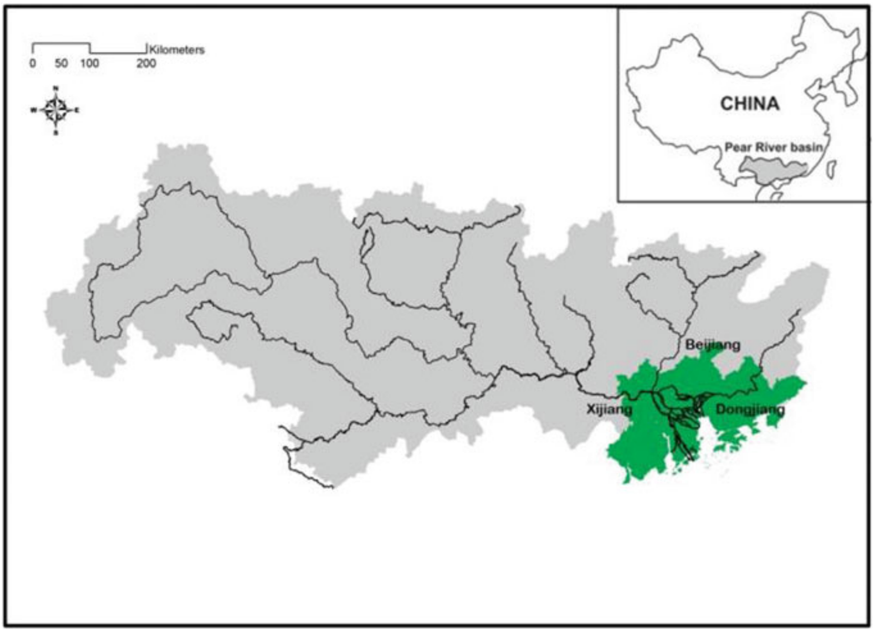

Fig. 9.3 Main tributaries in the Pearl River Basin and the PRD. The delta landscape is complex because of river network formed by the three main rivers Xijiang, Beijiang and Dongjiang, which joined in the delta and formed eight estuaries (mapped by author)

453,690 km^2 and a length of 2200 km. 80% of the total stream flow of the river occurs in the flooding season from April to September (Zhang et al. 2008). Both the urban and natural systems are highly dynamic, while its challenges are in highly dynamic as well.

The 4000 years of extensive agriculture activities in the PRD have proved a sustainable human-environment relationship in this ever-changing wetland environment resulted from frequent flooding and continual seaward extension (Weng 2000). However, its sustainability is in doubt with the new circumstances. In 2016 the PRD could have faced massive floods due to the worst El Nino since the 1997/98 weather pattern, which lead to havoc flood of once in a hundred year, stated by the Pearl River Flood Control and Drought Relief Headquarters Office (Xinhua News Agency 2016). Besides flood, the delta also suffered from the threat such as mangrove disappearance (Zhao 2010), saline (Xu and Luo 2005), agriculture land loss (Hu et al. 2002; Hu and He 2003), air and water pollution (Chau and Jiang 2003; Ouyang et al. 2006), water shortage (Li 1998; Chen and Chen 2004), and decreasing social security (Huang 2003). Despite the increasing awareness of the necessary of integral planning and design approaches, there is evidence that the potential of such approaches has not been fully exploited in urban landscape development. An attempts of the sponge city planning, one of the latest integration initiative of storm water management promoted by the national government, usually found stuck in approaching two to four plans made by different sectors (Che 2016). Such sectoral segregation blocks the integral planning (Yu 2016). Therefore, the lack of knowledge of framework and approaches in integral planning appears to be a significant barrier preventing a sustainable and adaptive urban landscape development in PRD.

9.3.2 Data Availability

The main data used in this study is the morphological information deriving from the delta's natural and human dynamic. The studied time period covers from 4000 BC to 2016 AD, in which all the major natural and human dynamic of PRD involved until recently. On one hand, sedimentation, river channel change and coastal line development are considered to be the major natural dynamic. On the other hand, dike construction, land reclamation, farming, fishpond construction, main road construction, and settlement development has been identified as the major human dynamic. The morphological data are collected from geological studies, historical maps, master plans, archives and GPS assisted field trips (Table 9.2). All data are converted into digital form, rectified with projection of WGS84 with Google map as base map. The data then has been organized with the help of software environment in ArcGIS 10 and Illustrator CS 6.

We apply two steps of data validation, both accountability and validity, towards the morphological data. The accountability of the data has been validated by comparing maps of different sources, while the validity check has been done by other types of data. We deployed both visual and metadata check to evaluate the accountability of the maps during the digitalization process (evaluating map quality, coordination system, time frame, and resolution). In the validity check process,

Table 9.2 Morphological data acquiring time range and sources

Time range	Type of sources	Sources
4000 BC–1980 AD	Geological studies	Zeng et al. (1982), Zeng and Huang (1987) and Li et al. (1991)
600 AD–1950 AD	Historical maps	U.S. Army Map Service (1954), Tan (1982) and Guangdong Historical Atlas Board (1995)
1900 AD–2000 AD	Archives	Board of Pearl River Delta Agriculture Gazetteer in Foshan Revolutionary Committee (1976), Feng (1990), Wu et al. (1990), Chen et al. (1995), Liu et al. (2001) and Mao (2002)
2000 AD–2015 AD	Master plans	Guangdong Provincial Department of Land and Resources (2009)
2010, 2011 and 2016 AD	Field trips	

we derived numeric and descriptive data from different sources of literature to verify the validity of the morphological data. After the two steps of check, the verified information has been sorted by time for exploration later.

9.4 Mapping the PRD

During the mapping exploration, we generate three set of maps based on the: landscape formation, water infrastructure network and urbanization. Nine temporal stages have been identified. According to the data availability, the maps of landscape can date back to 4000 BC, water infrastructure 1000 AD, and urbanization 1950 AD. Each set of maps are being studied separately, then their relationship has been linked.

9.4.1 Landscape, Networks and Urbanization

The maps of the natural landscape (see Fig. 9.4) indicate a series of speed acceleration in the delta formation process. There are three steps in the formation of the delta. The first change starts at around 1000 AD, second times from 1300 AD and the third times around 1950 AD. Because of such differences in change of speed, we adjusted the temporal scale for representation. Temporal grain has been changed from 2000 years to 1000 years since 1000 AD, and then from 1000 years to 300 years since 1300 AD, and finally refined into 50 years since 1950 AD.

We organized the maps of water infrastructure networks (see Fig. 9.5) based on the same temporal grains used in the maps of landscape. This series of map suggest the change of dike system. To be more specific, from 1000 AD to 1300 AD, only in the most dynamic section of the river the land owners did enforce the natural levee jointly to protect their farmland. Here also affected villagers cooperated in dike construction. Most dikes built at this time are semi open. From 1300 AD to 1600 AD, the local scaled dike system began to extend its length and height. Especially in the north of the delta region, the dike system started to link with each other and upscaling from local homogeneity to sub-regional homogeneity. From 1600 AD to 1900 AD, the dike system developed towards the newly formed part of the delta region in the south with the similar sub-regional spatial scale as it is in the last period. However, a huge change started since 1950 AD, when the dike system has been scaling up towards a regional level. Such spatial scaling resulted in an integrated regional dike system in 2015 AD.

Maps of urbanization (see Fig. 9.6) have also been arranged according to similar temporal grains. The two maps show the spatial development between 1950 AD and 2010 AD. Comparing to the former two sets of maps, we witnessed a far more

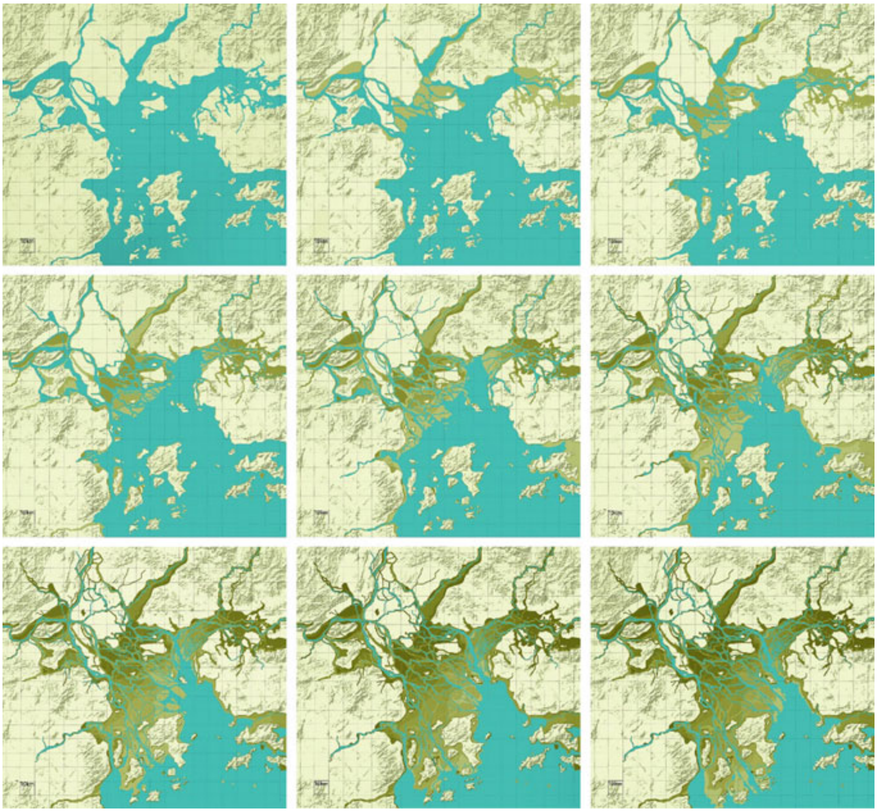

Fig. 9.4 Landscape series (4000 BC–2015 AD) featuring the landscape formation in 4000 BC, 2000 BC, 200 AD, 1000 AD, 1300 AD, 1600 AD, 1900 AD, 1950 AD, and 2015 AD

significant spatial change in a shorter temporal grain in the maps of urbanization. The maps in landscape, water infrastructure and urbanization reveal the spatial and temporal changes respectively. Insight of spatial mechanism is going to be discussed by linking and comparing these layers in the next section.

9.4.2 Link the Rhythms

After the completion of map series, we discover that the water infrastructure networks play an essential role in understanding of both the physical structure and social relationships in the delta. The dikes create important conditions for agricultural land-use and housing. By comparing the maps a change in the morphological co-relationship among three layers is visible. As indicated by the maps, the delta landscape is mainly formed by natural forces in the period from 4000 BC to

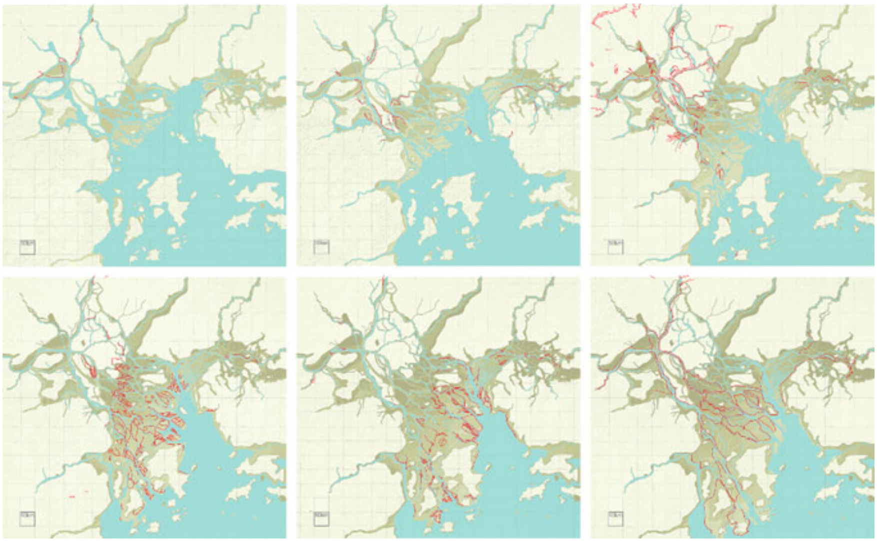

Fig. 9.5 Water infrastructure series (1000 AD–2015 AD) featuring the main dike morphology in 1000 AD, 1300 AD, 1600 AD, 1900 AD, 1950 AD, and 2015 AD

Fig. 9.6 Urbanization series (1950 AD–2015 AD) features the built up area in 1950 AD and 2015 AD

1600 AD. From 1600 onwards the dike system as important water infrastructure network exerted great influence on the formation of the land. The key to understand the territorial change is the social network that is related to the development of water infrastructure. Based on the availability of the maps and the literatures, we examined the social network changes in the period from 1950 AD to 2015 AD (see Fig. 9.7).

The number of dike rings shrink from over 1000 in the beginning of the 20th century to 218 in 1982 (Huang and Zhang 2004). The Nationalist Government of the Republic of China (ROC) started the large scale dike ring integration plan in PRD with the help of United State in 1928 (Archive Bureau of Guangdong Province 1928). Thirteen dike rings were identified as the most vulnerable. Integration and enhancement projects were planned. However, due to The Second

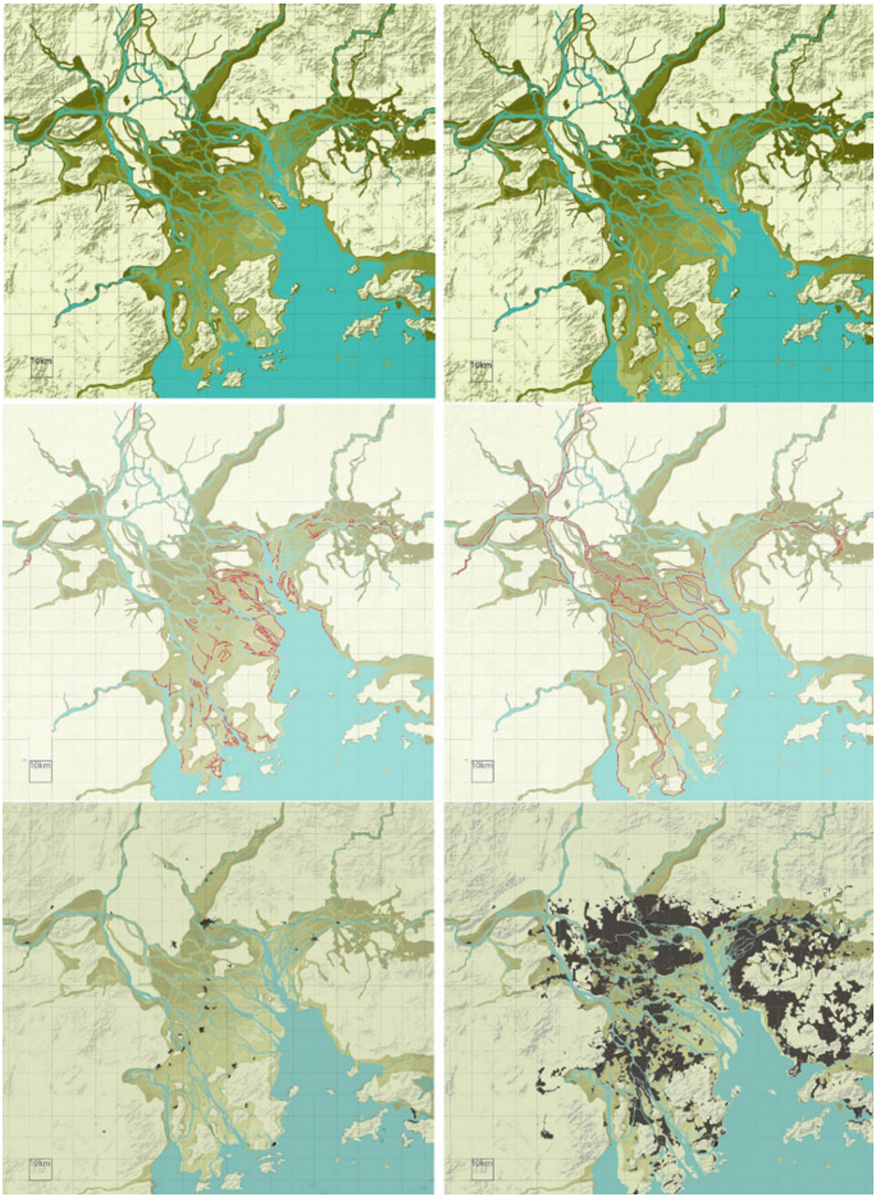

Fig. 9.7 Compare of maps between 1950 AD and 2015 AD in landscape, water infrastructure and urbanization

Sino-Japan War and Civil War from 1927 to 1950, the ROC government hardly had advanced to implement the plan before it was replaced by the Government of People's Republic of China (PRC) in 1949.

Since 1950, the change of land ownership from private to state owned has enabled the large scale infrastructure management in the delta. The integration of Dike system had significantly reduced the number of the dike rings from 2950 to 218 during 1949–1982 (Huang and Zhang 2004). Soon after the new government formed, two floods submerged an area of 3233 km^2 of farmland in the delta in 1947 and 1949 (Guangdong Province Planning Commission 1964). The Guangdong provincial government started the dike construction and integration project to control the flood and promote agriculture in the delta area. Before the project stared, there were 2950 dike rings. In 1961, the number of dike rings decreased to 530 with a total length of 3978 km. the dike rings protected population of 2.86 million farmland of 4160 km^2. Dike construction and management was no longer a Sub-region scale issue for villages or families. Instead, the Guangdong Province has taken the charge of the dike system management. The first application of this management switch is the large scale dike integration. This project aimed to shorten the length of dikes and to better protect the cities within the separated small and relatively weak dike rings. Small dikes are integrated into larger, higher dike rings. The dike systems in the Sub-region scale has been connected and upscaled into a more connected delta-scale dike system, which means better protection against flood. However, this upscale lead to a ignoring situation for long times. Besides enabling the cities originated from high lands and theirs suburban along the river a better protection against flood, the delta-scaled dike system also offered a much better protection for the farmland originated from reclaimed lowland. The hydrologic condition change among those farmland has enabled the fast rural urbanization without threatening from the flood.

Thanks to the delta-scaled dike system, a noticeable rural urbanization has had a better chance to spread throughout the Pearl River Delta in the reclaimed area since 1979. At this time the large scale dike system continued to grow with the process of downscaling of the urban system. The number of dike ring decreased from 218 to 53 in 2000 (Huang et al. 2000) During the urbanization, large areas inside the polders had been transfer from farmland into urbanized area. This means the tradition settlement pattern had switched. In the past, people lived in the high ground or elevated dike, using the polders for agriculture. Now they stepped down from the highlands to build cities on those lowlands, with the wish to use dike to protect all their belongings against water. The large-scaled dike system has hidden the flood threaten to most people: when they decided to convert their farmland into manufactory, and later when this manufactory became their main business, and finally all this individual business gathered into a new town. During the process, it is hard for the local citizen to realize their change in their farmland can lead to a totally change of urban pattern in the delta scale. It is an urban pattern that heavily dependent on the delta-scaled dike system, instead of the long tradition of landscape dependent in the Pearl River Delta. The local influence of the delta-scaled dike has changed the local recognition of the territory and their behavior, which lead to a more infrastructure-depended urbanization pattern in the delta scales. The current unawareness of the delta landscape has led to planning principles and approaches that are less likely to meet the increasing challenges of flood risk.

9.5 Discussion and Conclusion

The study shows that the multiple scales mapping approach can effectively address the different dynamics of the delta, especially in the need to understand the interaction among the tangible and intangible components of the delta system. Such exploration generates knowledge that helps to overcome the scale obstacle. In short, mapping is a helpful instrument for urban landscape study, especially in the study of urbanized deltas. We see the possibilities to generate more understanding from comparing more levels of spatial extent within each temporal stage. However, data acquisition becomes harder when we scale down in space and need high resolution data. We also found out that it is extremely hard to get valid morphological data of the past four decades urbanization. Possible reasons are (1) the national data security policy towards spatial information prohibits data acquisition from a foreign university, (2) sector segregation and local protectionism because of the governance among provincial and local governments, and (3) lack of awareness of the power of morphological knowledge sharing and exploration. Since such cartographic exploration can effectively organize, understand, analyze and design the different types of dynamic in urban region and its connected landscape, we plea for a more open data access and sharing from the authorities. Mapping activities would provide possibilities for better decision making and planning in the long run. Spatial information proofs to be important for decision makers and specialists from different disciplines to communicate effectively for urban landscape planning.

In PRD, three types of process are identified according to their speed: landscape formation, infrastructure extension and urbanization. We explained the spatial interaction from delta scale with a time extent ranging from two thousand years to fifty years employing the power of maps. We laid bare a transition from a water-based attitude to a land-based one, during which an unawareness of the underlying landscape and a detached urban pattern was developed. Such trends increased the flood risk in the new urban areas in the region at several scales.

The change of the social network plays an important role in shaping the physical environment in the PRD, especially in shaping the water infrastructure networks. The governance and available knowledge has led to an upscaling of the water infrastructure since 19th century. In turn this large scale water infrastructure shapes our knowledge and understanding of the delta into an unawareness of its increasing flood risk in the large scale. Such change results in a society with increasing dependence on the artificial flood defense system, in which an unlimited capacity could not be achieved. On the contrary, we see possibilities of a more sustainable future lies in the awareness of the flood risk in all levels of scale, and a more resilience physical structure of delta system. The mapping exploration in this study would serve well in constructing both the social awareness and the physical structure of the delta regions in this purpose.

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Chapter 10
Urban Networks of Leisure Activities: Using Douban Event to Measure Interaction in the Megacity Region of the Pearl River Delta

Miaoxi Zhao, Wenmin Liang, Gaofeng Xu and Zhifeng Li

10.1 Introduction

The spatial organization patterns of a monocentric city can lead to many urban problems, such as overpopulation, traffic congestion, and environmental degradation, making the transition to polycentric city regions attractive for further economic development and a realistic choice for urban development (Meijer et al. 2016; Hall and Pain 2006; Neal 2012a, b; Glaeser et al. 2016; Zhao et al. 2016). In China, excessive population agglomeration has negatively affected the built environment, resulting in rising demand to establish polycentric urban regions in place of single super-cities. Thus, in the recent planning document known as the 'New Path of Urbanization (2015–2020)', the central government anticipates that mega-city regions will, in the future, accommodate more people from rural areas. Thus, Zhou (2016) has argued that finer-grained analyses of small or medium-size cities might enhance our understanding of the paths to future urbanization in China's mega-city regions.

It is widely known that the increasing returns of urban size resulting from spatial agglomeration contribute impressively to economic growth (Fujita et al. 1999), thus emphasizing the sustainable and cumulative nature of spatial agglomeration.

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X. Ye and X. Liu (eds.), *Cities as Spatial and Social Networks*, Human Dynamics in Smart Cities, https://doi.org/10.1007/978-3-319-95351-9_10

However, Johansson and Quigley (2004) have argued that the economics of network externalities may represent an alternative structure for the regional development of agglomeration economies (Derudder et al. 2003; Bel and Fageda 2008; Neal 2012a, b; Glaeser et al. 2016). Meijer et al. (2016) explored the impact of city size and network connectivity across Western European cities on two levels—borrowed size and agglomeration shadows—and showed that network connectivity positively enhanced metropolitan functions. In other words, network externality and borrowed size are conducive to the overall development of city regions. Accordingly, examining urban functional connectivity at the scale of city regions has practical significance.

'*The polycentric metropolis: learning from mega-city regions in Europe*', co-authored by Pain and Hall in 2006, reveals the characteristics of functional connectivity across eight European mega-city regions, highlighting the trend of city network research within mega-city regions (Hall and Pain 2006). In China, urban studies research has produced materials supporting spatial planning documents, e.g., the recent 'Thirteenth economic and social planning of Shunde (2016–2020)'. In addition, Prof. Cui (2015) and Tang (2013) explored functional links for the Strategic Planning of Huangshi and Wuhan, for which Saskia Sassen was invited to join the forum on the development of megacities in 2014. These planning documents reflect the importance of functional links for the planning practice of city regions in China. In terms of regional planning in Guangdong Province, policymakers have notably always been interested in the functional linkages among cities in the Pearl River Delta (PRD). Urban networks in the PRD have been outlined at the scale of prefecture regions in the documents, '*Planning for a new path of urbanization in Guangdong province (2014–2020)*' and '*Planning for the whole territory of the Pearl River Delta (2015–2020)*'. These two documents have evaluated and verified the functions of Shenzhen, Guangzhou, Dongguan, and other cities. It has been determined that Shenzhen had the highest centrality of headquarters in the networks, a finding that has been noted in other studies as well (Zhao and Liu 2012; Zhou et al. 2015a, b, 2016; Zhu and Li 2015; Yeh et al. 2014). However, functional links among leisure activities in the cities of the PRD have not yet been extensively researched.

According to the concept of post-industrial society proposed by Bell (1974), continuous concern for and pursuit of efficient social production and increased leisure time have accompanied the transformation of the global economic structure and deepening divisions of production. Thus, lives of leisure, non-mass consumption and diversified demands are gradually becoming universal characteristics of a society in which citizens pursue their own individual social lives. In related studies, Francisco et al. (2016) conducted in-depth and meticulous research into social leisure in the digital age. Regarding economic property, Min et al. (2016) explored the correlation between leisure events and economic development using mathematical models. Other scholars have studied the spatial structure of regional tourism and planning layouts from the perspective of tourism geography, emphasizing the impact of urban scale on tourism (Tang et al. 2014; Chen et al. 2011; Miguéns & Mendes 2008). Basic research performed by Kowald (2011) on the social networks of leisure activities (including network sizes, network densities, communication frequency mode, etc.) surveyed the effects of urban leisure network structures upon individual leisure behavior. In China, the *Government Work Report in 2016* clearly proposed the active cultivation of leisure as a consumption hot spot, factoring leisure into economic and social development for the first time. However, research on urban leisure networks in cyberspace has rarely been included in these studies. Therefore, we believe that it is rational and significant to characterize social networks as they relate to leisure activities and also helpful as further explorations of functional linkages under the influence of urban scale in region planning.

10.2 Literature Review

10.2.1 City Connections in the Network Society

Many urban scholars have observed that as globalization and information have progressed, an extensive archipelago of large city regions has arisen (e.g., Petrella 1995; Veltz 1996; Sassen 2001; Newman and Thornley 2011). For instance, Scott (2001) coined the term 'global city regions' (GCRs) to indicate that many large metropolitan areas are increasingly functioning as the spatial foundations of the global economy that has been taking shape since the end of the 1970s. The ensuing challenge of describing and analyzing the shifting spatial organization of GCRs has led to a rapidly evolving urban-regional literature. A plethora of concepts has emerged from this literature, among which 'polycentric mega-city regions' (PMCRs, see Hall and Pain 2006) and 'polynuclear urban regions' (PURs, see Turok and Bailey 2004) are favored terms. The key emphasis of this literature is the observation that heavily urbanized regions are made up of a conglomeration of cities of varying sizes that are important in the network society (Castells 2011; Hall and Pain 2006).

Advances in information technology have greatly weakened the importance of geographical proximity. Meanwhile, the scope of human activities has extended beyond urban space, as it is easier and more convenient to pursue cross-city activities in megalopolitan regions. As suggested by Castells (2011), network society has lent an important theoretical framework to urban network analysis, in the context of which Hall and Pain (2006) determined the functional connectivity between mega-city regions by employing the lens of business mail. Castells (2011) also proposed a 'sandwich' model in his theory of "Space of flow", confirming cities as nodes and hubs and emphasizing the external relations of world cities. There are diverse types of flows between cities: actual connections, such as airline networks (Smith and Timberlake 2001); virtual connections, such as Internet backbone networks (Zook 2001; Townsend 2001); and indirect connections, in the form of spatial corporate organizations (Taylor 2009; Alderson and Beckfield 2004; Parnreiter 2015). Urban networks should be understood as the frameworks for the interaction of agents' activities among cities. In a related study, Taylor et al. (2008) has equipped the urban network with a more powerful quantitative analysis tool by proposing an interlocking network model algorithm, which has been incorporated by varying studies on corporate spatial organization in recent years (Neal 2012b; Liu and Derudder 2012; Hennemann and Derudder 2014; Zhao et al. 2014; Järv et al. 2015; Sanderson et al. 2015). However, little attention has been paid to the integrated networks of leisure activities in megacity regions.

In leisure studies, those network analysis tools are used to study tourism (Tang et al. 2014; Gan et al. 2016; Sun et al. 2016; Baggio and Sainaghi 2016; Casanueva et al. 2016). In particular, Tang et al. (2014) have undertaken complex network analyses of regional tourist routes by using degree distribution, assortativity, robustness and other multi-dimensional statistical tools. These studies have shown the usefulness of performing network analyses of leisure connections in Chinese cities using the tools of complex network analysis.

10.2.2 Research Approach

Internet-based social links have become an important field in the context of research into city networks. Because more and more people are today sharing their leisure activities online, the data on virtual cyberspace revealingly mirror social activities —as well as reality—to some extent (Lin and Wang 2014; Qi and Wang 2016). Boulton et al. (2011) focused on the global economic and environmental crisis in 51 cities in the United States using Google hyperlinks. Zook (2001) analyzed the dynamic mechanisms of production and consumption in cities' networks across the globe by illustrating the connections of Internet domain names around the world's major cities. Chinese scholars have also examined various forms of urban networks, including the corporation network (Zhao and Tang 2010; Lu et al. 2012; Zhang and Kloosterman 2016), the traffic network (Chen et al. 2013), the infrastructure network (Wang and Ning 2006) and the scientific citation network (Hu et al. 2012). In addition, Zhen et al. (2012) depicted the social characteristics of Chinese urban networks using Sina Weibo, and Liu et al. (2013) described the city networks of 36 provincial cities in China employing the Baidu Index. Therefore, considering the strength and nature of information linkages within mega-city regions, this article uses netizens' Douban-Event activities as a sample in conducting a positive analysis of the relationship between leisure function and city size from the perspective of cyberspace.

In the basic analysis of urban systems, we can learn about the concept of polycentricity from Hall and Pain (2006) and explore the functional linkages between cities. For example, we can measure the strength of functional linkages using the lens of attention paid by residents to activities taking place in another city. We assume that features of urban networks will be reflected in the individual microscopic features of preferences between different-sized cities. If residents in city A pay more attention to activities organized by city B, it might be that residents in city A are more willing to accept information from city B because it is more attractive to them, and vice versa. In this manner, asymmetric links between different-sized cities can result, which might be measured by out-degrees and in-degrees, as proposed by Limtanakool et al. (2009), that reflect the differences in inflow and outflow between different-sized cities (Zhao et al. 2016).

In addition, the extent of the interaction of micro-individual activities in cities can respond to the degree of individual participation in the network of mega-city regions as determined by the index of self-compatibility proposed by Hall and Pain (2006), which can also be used to test the level of connection among different-sized cities (Zhao et al. 2016). For instance, the lower the proportion of attention paid by users in city A to activities happening in city A (suggesting that residents are more likely to have cross-regional interactive behavior), the lower the degree of connectivity of city A to other cities.

Moreover, the network aggregation proposed by Watts and Strogatz (1998), in which the number of triangles between any three cities (nodes) can measure the contact strength of city networks in terms of topology, is another important indicator used to measure social networks. In the case of cross-regional activities in the PRD, it is clear that the more triplet combinations made up of cities in the PRD, the more important the balanced characteristics are in the urban scale. Thus, we can say that network aggregation is another statistical tool that can be used to measure the polycentric structure.

10.3 Research Methods and Data

10.3.1 Data Acquisition

This paper selects 9 cities in the PRD to analyze the network characteristics of city regions in Cyberspace. Douban is a well-known WEB 2.0 social networking site. Although it cannot be compared with Weibo, WeChat and other major social platforms in terms of total number of users, its Douban Event (http://www.douban.com/location/world/) is a mature and major platform for urban activities on which residents can post and participate in online and offline activities. Douban Event originally provided activity information for residents in the same city, but due to closer links within the mega-city regions, events on the platform attract users across regions. To demonstrate the strength of cross-regional connections, this paper first tested the correlation between the number of both Douban Event users and Internet users using SPSS. The results showed that they are significantly related, with a Pearson correlation coefficient of 0.928, which indicates that the number of Douban Event users can represent residents' active participation in cyberspace.

To clearly reveal the activity characteristics of various cities, activities are categorized into the following six groups, based on original activity classifications and their sample size on Douban Event: leisure recreation, outdoor activity, lecture, party, exhibition and other. It should be noted that leisure recreation includes music, movies and drama, while outdoor activity includes sports and tourism. In addition, the above six types of activities can also be combined into the following two types, based on the extent of the user's participation: ornamental activities and interactive activities. Ornamental activities mainly refers to performances such as leisure recreation and exhibition activities, while interactive activities are those in which users interact with one another as the main event, emphasizing face-to-face exchanges, such as outdoor activities, parties and lectures.

Data collection was completed on January 15, 2016. This paper takes 9 cities in the PRD as its study area. We collect and then select the geographic information of users who participate in or have interests in online activities. Then, we produce a series of separate data matrixes based on the city region and classified in accordance with the above typology. With the help of Locomotive Data Collector, a common data acquisition tool, we read and parse the source code of the website to gather the information we need. Ultimately, we collected 1926 activities from October 15, 2015 to November 17, 2016 occurring in the Pearl River Delta region, with 36,575 pieces of user information. Among these activities, 26,308 users are from activities in the PRD. This paper takes activities occurring in the PRD as its research object.

10.3.2 Measurement Method

Degree centrality

For the directed network, the basic unit of connection, T, is defined as the actual interaction between the two cities.T_{ij} represents the number of residents living in city i and participating in events in city j(i $\neq$ j). $\sum_i \sum_j T_{ij}$ indicates the sum of cross-regional connectivity throughout the entire network. L_{ij} represents the relative strength of the directional links from city i to city j compared with the total links in the network. This ratio characterizes the basic links between any pair of cities. For a certain city i, the sum of its inflow is defined as the in-degree centrality S_i^{In}, while the sum of its outflow is the out-degree centrality S_i^{Out}. These degrees can be calculated by the following formula.

$$L_{ij} = \frac{T_{ij}}{\sum_i \sum_j T_{ij}}; \quad S_i^{in} = \sum_j L_{ji}; \quad S_i^{out} = \sum_j L_{ij} \tag{10.1}$$

Distribution of degree

When in-degrees or out-degrees are 0, it is difficult to describe the distribution of the nodes using the traditional rank-size method. Drawing on Zhao et al. (2016), the paper first optimizes the calculation of the Gini coefficient (G) by introducing the analysis method of node hierarchy to describe the aggregation and dispersion of degree centrality. By summing cumulative differences of degree and rank, our analysis depicts different agglomeration types of activities in cyberspace. If G equals 1, it indicates that the Douban activities in cyberspace show absolute

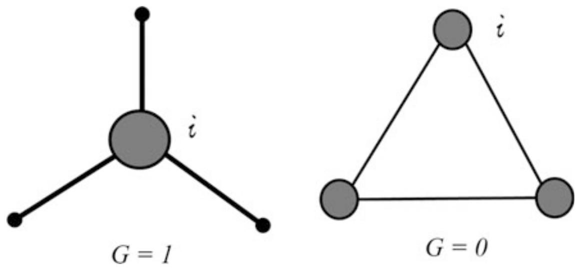


Fig. 10.1 Node hierarchy schematic diagram

agglomeration in the network. If G is equal to 0, then those activities in cyberspace indicate absolute dispersion (Fig. 10.1).

$$S_I = S_i^{in} + S_i^{\text{out}}; \quad G = \frac{1}{n-1}\sum\sum\left|\frac{S_i}{\sum S_i} - \frac{S_j}{\sum S_j}\right| \tag{10.2}$$

Asymmetry

Limtanakool et al. (2009) proposed that asymmetry reflects the differences between inflow and outflow for each node, and this formula is defined as (3). The NSI ranges from −1 to 1, and when NSI is greater than 0, it indicates that the city belongs to incoming nodes in the network and also suggests that the city is more attractive to people—otherwise it is an outgoing city. If NSI is equal to 1 or −1, then it shows that the city is an absolute incoming or outgoing city, respectively. When the NSI value is near 0, it indicates that the city's inflow and outflow tend to be in a dynamic balance (Fig. 10.2).

$$NSI_I = \frac{S_i^{in} - S_i^{out}}{S_i^{in} + S_i^{out}} \tag{10.3}$$

Self-compatibility

Referring to the concept of self-compatibility proposed by Hall and Pain (2006), our analysis seeks to assess the interaction network degree of different urban residents in the city region. Our analysis defines T_{ii} as the functional links of community residents following activities in their own city. $\sum_j T_{ji}$ represents people concerned from city j to city i for activities. $\sum_j T_{ij}$ represents people concerned

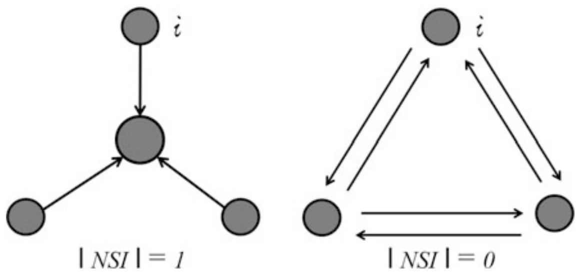


Fig. 10.2 Network symmetry schematic diagram

from city i to city j for activities. The self-compatibility (SC) of city i is shown in formula (10.4).

$$SC_i = \frac{T_{ii}}{\left(\sum_j T_{ji} + \sum_j T_{ij} + T_{ii}\right)} \tag{10.4}$$

In the formula, self-compatibility SC_i ranges from 0 to 1 and reflects the level at which a city participates in an interaction network. The higher the self-compatibility, the lower the level of a city's interaction in the network.

Clustering coefficient

In graph theory, the clustering coefficient measures the degree to which nodes in a graph tend to cluster together. This approach is a type of quantitative statistics for the number of triangular links in the network, following Watts and Strogatz (1998). On this basis, Zhao et al. (2015a, b) optimized it and used clustering coefficient C_i to derive a weighted network based on the characteristics of the mega-city region. Wu et al. (2015) proposed the average cluster coefficient C of the network as formula (10.5).

$$C_i = \frac{1}{k_i \times (k_i - 1)} \sum_{\mathrm{j,h}} \sqrt[3]{L_{ij} \times L_{ih} \times L_{jh}}; \quad \mathrm{C} = \frac{1}{\mathrm{N}} \sum_{\mathrm{i}=1}^{\mathrm{N}} \mathrm{C_i} \tag{10.5}$$

In formula (10.5), k_i is the number of nodes. Notably, this metric weights the low degree nodes more, whereas the transitivity ratio places more weight on the high degree nodes. When C is higher, then each node is more likely to connect equally to the entire network (Fig. 10.3).

10.4 Results

10.4.1 Network Features

In this study, there are 1719 cross-regional connections among all 26,308 activities, which indicates that 6.53% of the urban activities take place in a different city.

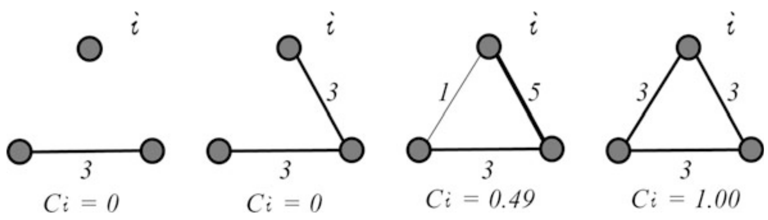


Fig. 10.3 Clustering coefficient schematic diagram

The cross-regional flow might therefore be represented by the attractions on Douban Event.

The characteristics of an urban network with a multi-core network and distinct hierarchy.

Our analysis describes cross-regional activity from the perspective of degree centrality. Then, we classify the undirected connections into 3 categories based on the former 5, 5–25 and greater than 25% categories, and we also classify the cities into core cities, secondary cities and other cities based on their degree centrality. As Fig. 10.4 indicates, the mega-city region of the PRD presents a "polycentric network organization", where Shenzhen and Guangzhou predominate in the PRD, accounting for 72% of all activities, thus making them the two core cities in the network.

Regardless of the type of activity, Guangzhou-Shenzhen always presents the strongest bilateral links in the regional network, occupying 40–60% of total connectivity in the city region. Among the six types of connections, outdoor activities show the most significant dominance in Guangzhou and Shenzhen, occupying 60.49% of the links in the PRD (see Fig. 10.4). Concurrently, the cross-regional links of Foshan, Zhuhai and Dongguan are relatively higher than the other four cities in the PRD among all types of activities, and they are thus classified as secondary cities in the networks. In particular, we see at this juncture that cross-regional links are also active from high-grade cities to low-grade cities, as well as between same-grade cities; thus, these links are not just active from low-grade cities to high-grade cities. The city region of the PRD is represented by a

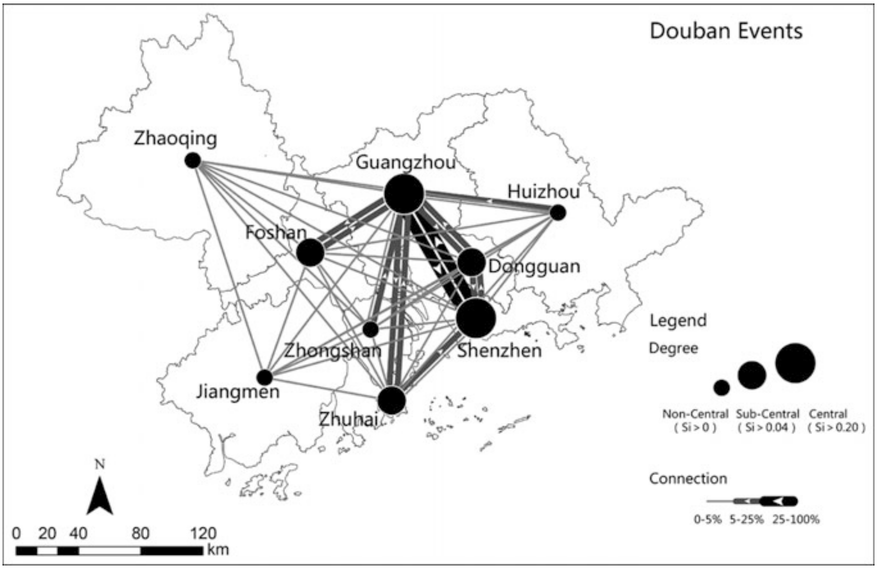


Fig. 10.4 Cross-regional connections in Douban event within PRD

complex network organization among the core cities of Guangzhou and Shenzhen and among the secondary centers of Dongguan, Foshan and Zhuhai, exhibiting a clear network hierarchy (see Fig. 10.5). This tendency is consistent with previous research, such as Mei et al. (2012), Cai (2013) and Zhao et al. (2016).

Core cities are important hubs in cyberspace and constitute the basic framework of the city network with secondary cities.

Our research also describes the primary and secondary cities in this region by comparing in- and out-degrees. We conclude that Guangzhou has the largest—and Shenzhen has the second largest—node degree among all the cities in the PRD. This finding suggests that the regional core cities not only agglomerate cross-regional attention but also strongly attract attention from the surrounding cities (see Table 10.1).

The connection between Guangzhou and Shenzhen is the largest city-dyad and accounts for 46.83% of the total links in the PRD. Moreover, the city-dyads of Foshan-Guangzhou, Dongguan-Guangzhou, Zhuhai-Guangzhou and Dongguan-Shenzhen remain in the range of 5–25%, and the combination of these characteristics occupy one-third (34.5%) of the total number. This result suggests that the connections between the secondary city and the two core cities are significant in the PRD; moreover, there is connectivity of 75% between the two core cities and less than 20% between other cities, indicating that the relationships between core cities and secondary cities constitute the main nodes in urban networks (see Fig. 10.6).

10.4.2 Cross-Regional Characteristics

Our analysis is based on 26,308 cases of urban Douban events. The types of activities include leisure and recreation, outdoor activities, lectures, gatherings, exhibitions and others. Parties account for 39.33% of cross-city activities, the highest among all activity types. Meanwhile, interactive activities (outdoor activities, gatherings and lectures) contribute much more than ornamental activities (leisure recreation and exhibition), at 56.40 and 34.01%, respectively (see Table 10.2). In secondary cities, compared with ornamental activities, interactive activities are more popular, and the development of information and communication technology makes cross-regional activities much easier.

(1) **In cyberspace, various activities are distributed in clusters and present network characteristics**.

Our analysis describes the agglomeration characteristics of various types of cross-regional activities in cyberspace using an approach based on Gini coefficients. The Gini coefficients of ornamental and interactive activities in the PRD are 0.759 and 0.682, respectively, which indicates that the two core cities, Guangzhou and Shenzhen, agglomerate the majority of regional activity enthusiasts for whom ornamental activities are preferable. Our analysis compares different activities using

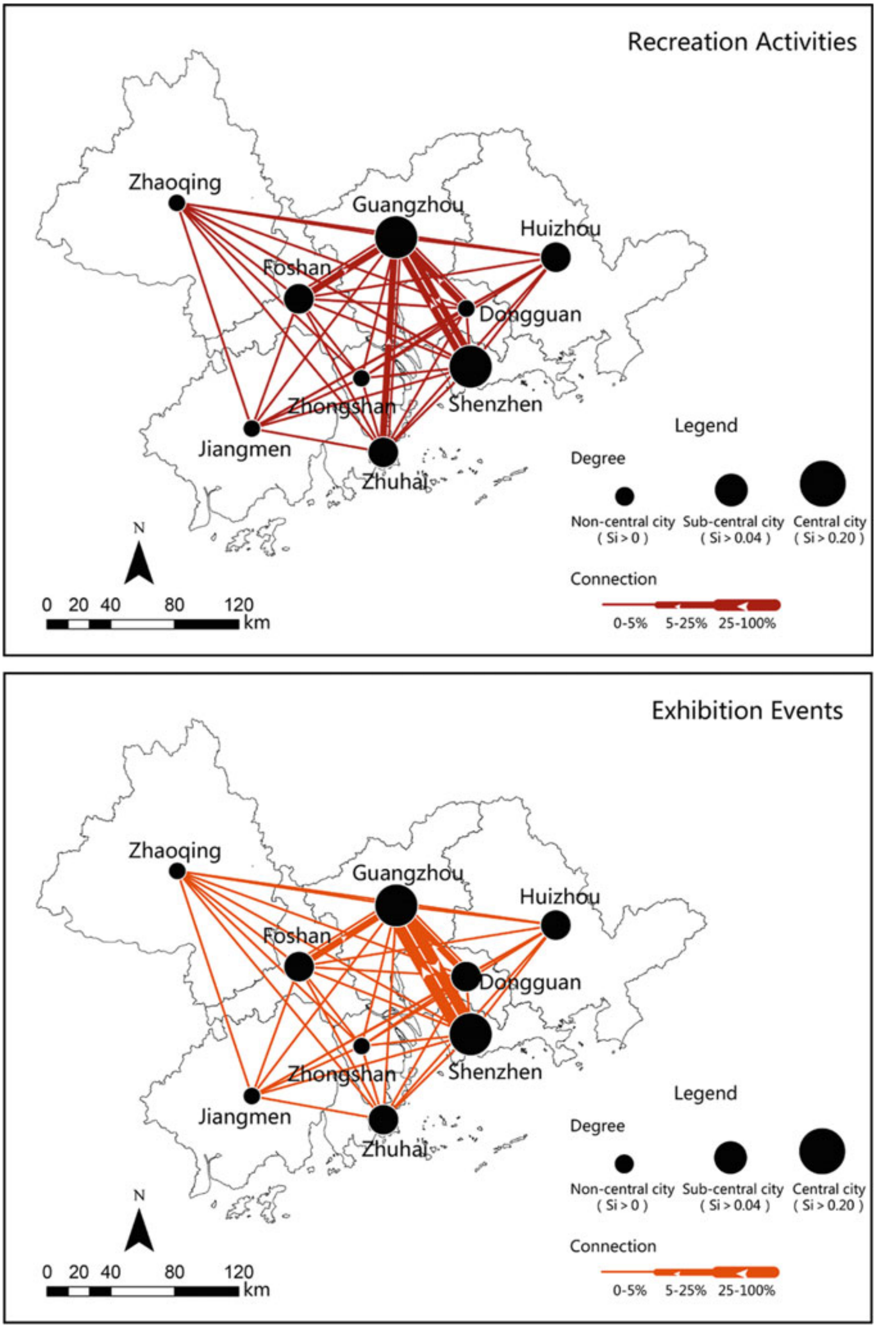
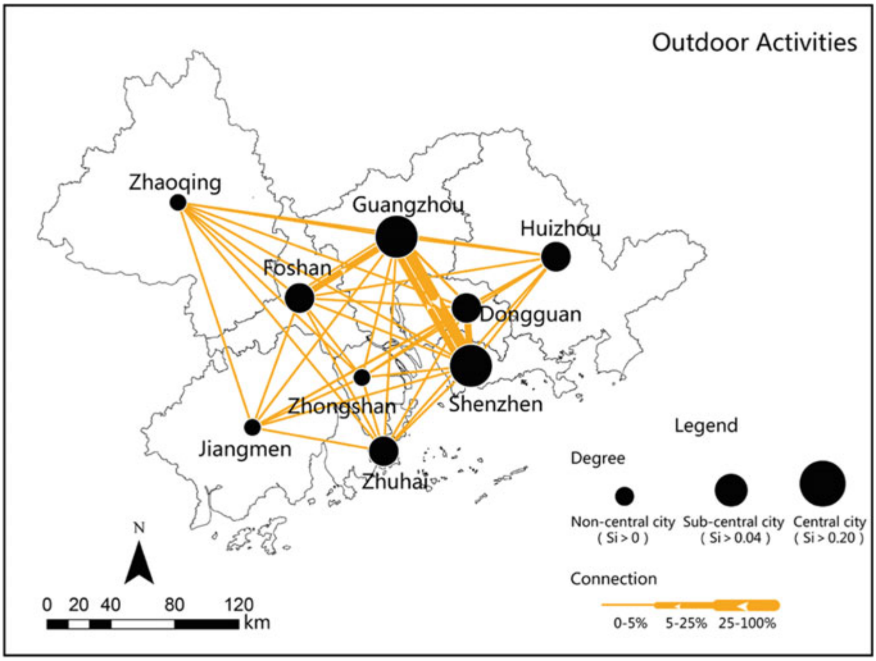


Fig. 10.5 Cross-regional connections of diversified activities in the Douban event within the PRD



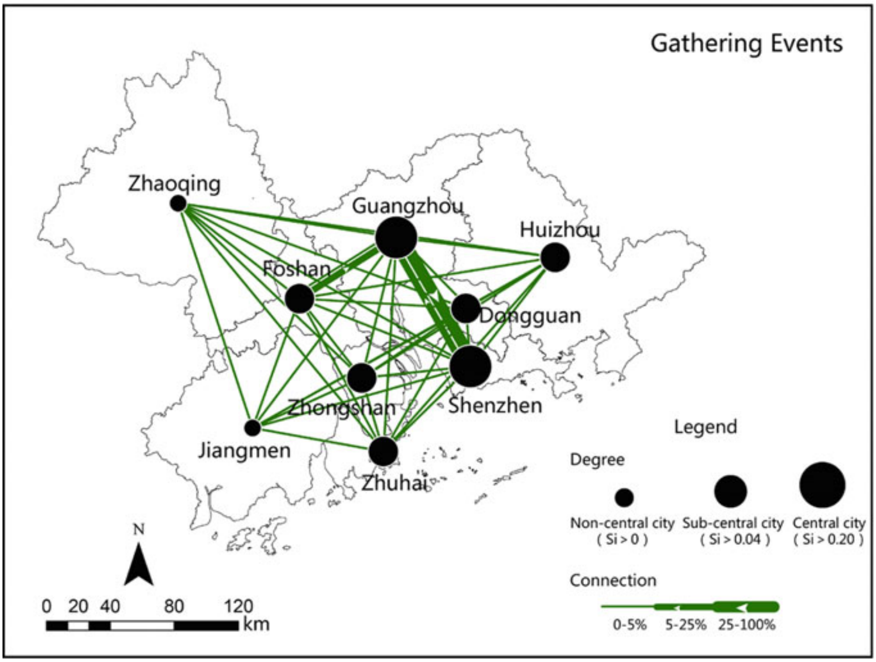
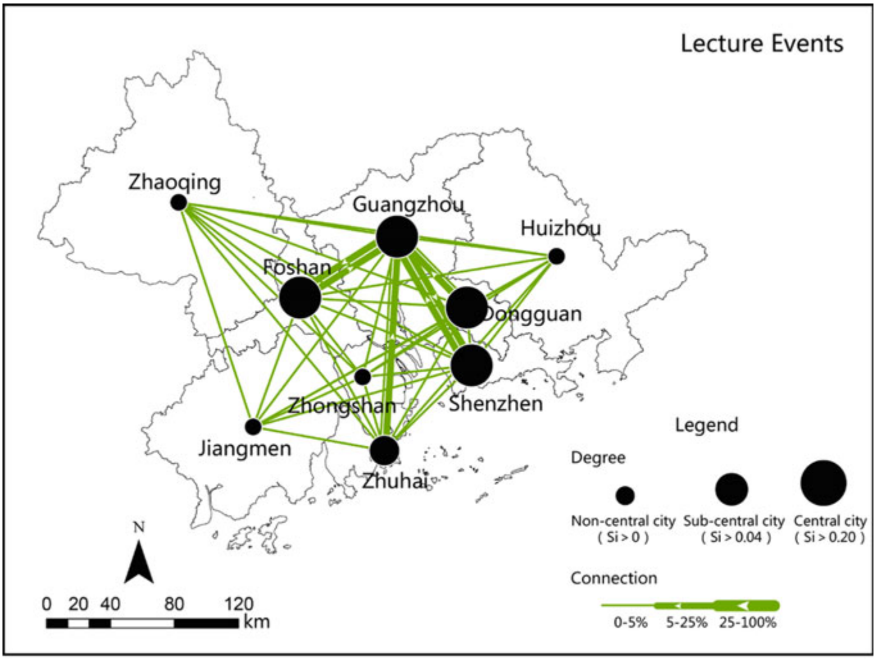


Fig. 10.5 (continued)



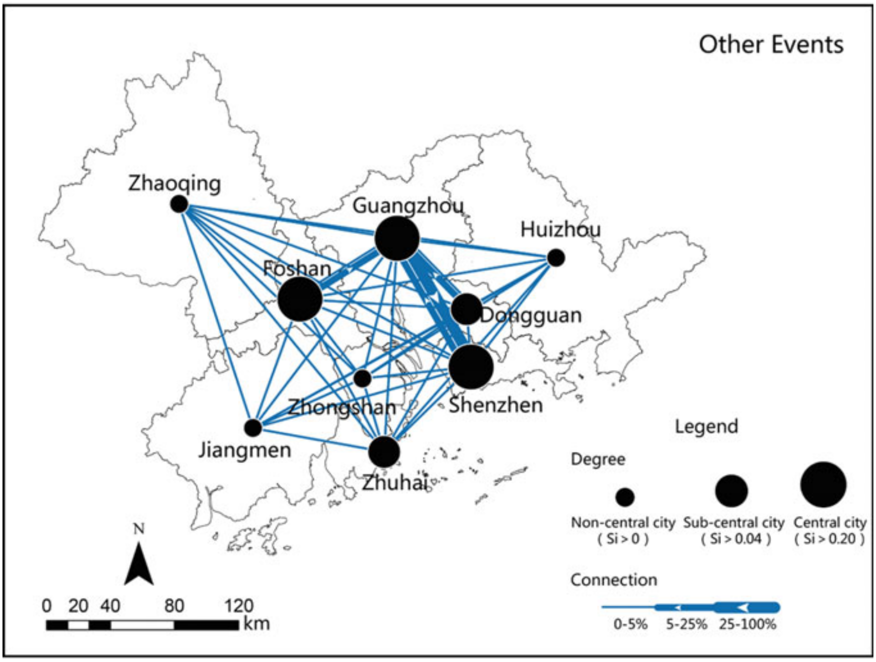


Fig. 10.5 (continued)

Table 10.1 The out-degree and in-degree of each city within the PRD

	Guangzhou	Shenzhen	Foshan	Zhuhai	Dongguan	Zhongshan	Jiangmen	Huizhou	Zhaoqing
Out-degree (S_i^{out})	0.393	0.218	0.134	0.076	0.084	0.032	0.010	0.040	0.013
Out-degree (S_i^{in})	0.447	0.389	0.056	0.031	0.049	0.011	0.008	0.009	0.000
Node degree (S_I)	0.843	0.598	0.194	0.106	0.134	0.042	0.020	0.050	0.013

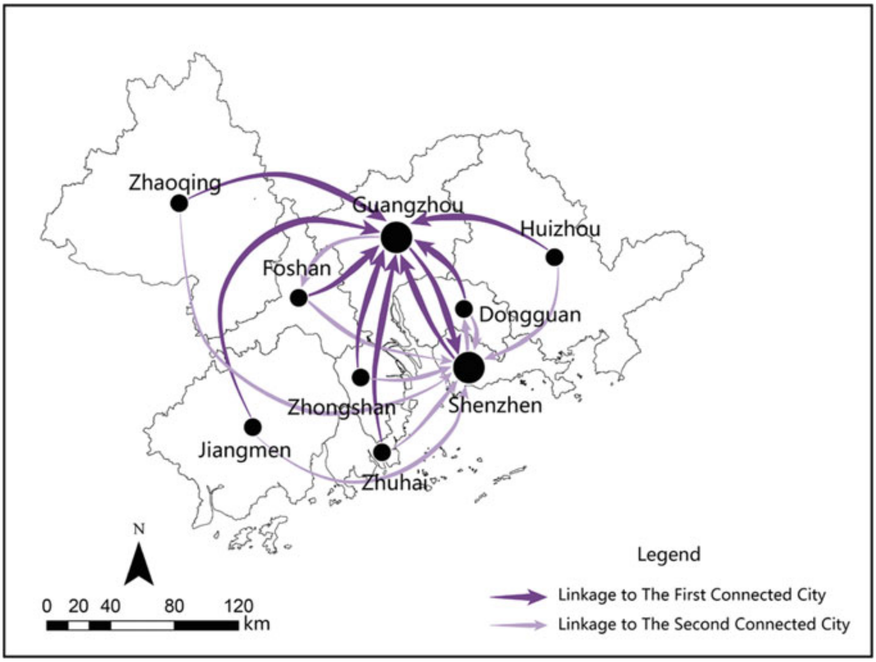


Fig. 10.6 The first and second connected cities' linkage in PRD

Table 10.2 Percentage of connections in cross-regional activities within the PRD

	Ornamental activities		Interactive activities			Other activities
People concerned	Leisure and recreation	Exhibition	Outdoor activity	Gathering	Lecture	other
	4208	4740	1553	10,346	2938	2523
Percentage (%)	16.00	18.02	5.90	39.33	11.17	9.59
	34.01		56.40			9.59

Table 10.3 The Gini coefficient and the clustering index in cross-regional activities within the PRD

	Ornamental activity	Interactive activity
Gini coefficient	0.759	0.682
Clustering index	0.013	0.029

the average clustering index, C. We find that the C values for ornamental and interactive activities are 0.013 and 0.029, respectively (see Table 10.3). The C value for interactive activity is higher than that of ornamental activity, and it correlates with low spatial agglomeration. This result reflects the relatively balanced

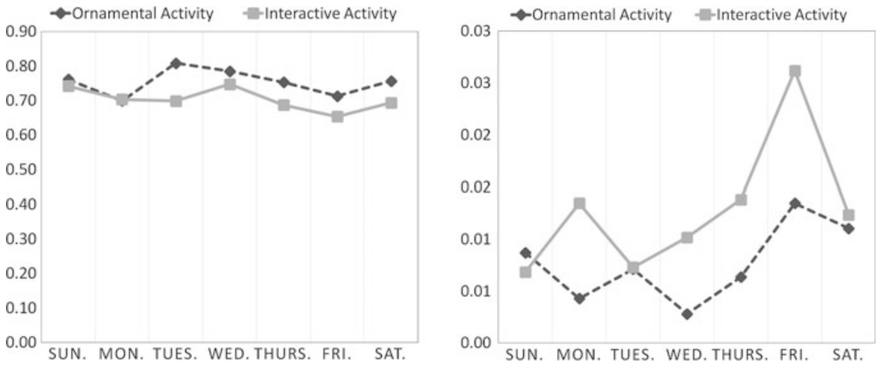


Fig. 10.7 The Gini coefficient and the clustering index in the cross-regional activities at different times of the week within the PRD

distribution of interactive activity facilities, whereas the distribution of ornamental activities in the network reveals less balance (see Fig. 10.7).

In addition, the empirical research similarly shows that interactive activity is slightly inferior to ornamental activity with regard to the spatial agglomeration characteristics based on the time dimension. Notably, the peaks of the network-clustering index of the two types of activities both occurred on Friday. To some extent, this result suggests that people are likely to choose the end of the work week to go out to activities, particularly interactive activities, in low-grade cities.

(2) **In cyberspace, cross-regional interaction is taking place**.

Next, the study analyzes the incoming and outgoing degrees of the cities in the PRD using NSI, as indicated by the various types of activities. We also analyze cross-regional interactive connections by examining self-compatibility for each city in the PRD. Generally speaking, the NSI values for Guangzhou and Shenzhen are positive, with SC values above 0.8, which shows that the two central cities have great appeal for the other cities in the PRD. However, the NSI values for the other cities are all negative, and their SC values are generally low (see Table 10.4).

In particular, the NSI and SC values of Guangzhou are both highest in terms of ornamental activity, but with regard to interactive activity, the highest value is found in Shenzhen. This result indicates that even if both are agglomerative central cities with cross-regional activities, their external functions for other cities in the PRD are different. Guangzhou provides large-scale public service facilities to attract surrounding cities to participate in its ornamental activities, whereas Shenzhen provides special service facilities to attract surrounding cities to its attractive interactive activities. This result indicates that the two central cities, which serve as hubs, have both complementary functions and enjoy collaborative development simultaneously (see Table 10.5).

Table 10.4 NSI in cross-regional activities within the PRD

	Guangzhou	Shenzhen	Foshan	Zhuhai	Dongguan	Zhongshan	Jiangmen	Huizhou	Zhaoqing
NSI	0.064	0.281	−0.411	−0.416	−0.263	−0.486	−0.133	−0.624	−1.000
interactive activity	−0.195	0.418	−0.226	−0.097	−0.046	−0.234	0.130	−0.289	−1.000
Ornamental activity	0.524	0.226	−0.473	−0.962	−0.695	−1.000	−1.000	−1.000	−1.000

Table 10.5 SC in cross-regional activities within the PRD

	Guangzhou	Shenzhen	Foshan	Zhuhai	Dongguan	Zhongshan	Jiangmen	Huizhou	Zhaoqing
SC	0.893	0.913	0.321	0.388	0.382	0.319	0.385	0.311	0.231
Interactive activity	0.894	0.934	0.342	0.416	0.405	0.359	0.398	0.373	0.310
Ornamental activity	0.891	0.859	0.291	0.218	0.215	0.042	0.000	0.000	0.000

Regarding the interactive activities of secondary cities and other small cities, the difference between NSI and SC is slight. This result indicates a greater degree of interactive activities network within the city region. For ornamental activities, the NSI value for small cities is −1, and the SC value is 0, which shows that users living in small cities are attracted to the ornamental activities organized in larger cities. The hierarchy characteristic is prominent in the ornamental activity distribution. Likewise, it seems that interactive activities, with their pronounced inflow characteristics—particularly on weekdays—are more appealing than ornamental activities over time. Moreover, the core city appears to be a near-monopoly inflow-type city on weekends, whereas secondary cities have an attraction to other cities that cannot be ignored.

Notably, there are some higher NSI values for secondary and small cities than for central cities in terms of interactive activity, which may result from the small quantities of inflow and outflow. Thus, the interactive activities in secondary and small cities can attract users from other cities, including large cities in the PRD.

10.5 Conclusion and Discussion

10.5.1 The Polycentric Structure of Urban Networks in the Pearl River Delta in Cyberspace

Driven by informationization and globalization, new geographical phenomena known as mega-city regions have emerged. The impact of these regions on the traditional structures of urban systems, also known as vertical regional structures, has been recognized by many scholars (Taylor 2009; Shen and Gu 2009) and has (conversely) brought the horizontally complementary regional structure of polycentric networks into being.

It has been found that the horizontal network structure of the PRD is present in the virtual world as well, which does not imply that the multi-centered network structure of the PRD might lead to absolute dispersion of population or economic activities, as ornamental activities still tend to cluster in the highly graded cities of Guangzhou and Shenzhen in virtual space. Meanwhile, there are stable and high-quality links between core cities and secondary cities because residents living in megacities are also attracted to the secondary cities for consumption and leisure, particularly for interactive activities. In addition to being attracted by Guangzhou and Shenzhen, the two largest cities, the secondary cities also show some contact with cities of similar size, forming a special network that is characteristic of the mega-city region.

10.5.2 Clusters of Cross-Regional Activities in Cyberspace and a Significant Urban Hierarchy

The degree of influence of distance on urban linkages appears to be somewhat muted in the virtual world, which means geographical proximity is no longer an essential prerequisite for urban linkages. Because the larger cities have better public service facilities and personnel, high quality services and urban activities can rapidly spill over into areas outside the cities because distance is no longer a major problem. This spillover promotes the additional accumulation of cross-regional activities in these large cities and indicates that the weekend is a peak time period for inflow in high-grade cities. With the advent of cyberspace, the urban hierarchy structure is becoming more and more significant.

10.5.3 Improvement of Urban Functional Linkages at All Levels of Cyberspace

The network-shaped and horizontal functional linkages of the corporation networks and traffic networks of the PRD are embodied in cyberspace as well (Zhao and Tang 2010; Tang et al. 2014; Zhao et al. 2015a, b, 2016; Lu et al. 2012; Chen et al. 2013). As a result of the accessibility of information in cyberspace, there is ample supply of activities that are rarely observed in normal high-grade cities, attracting great cross-regional interest from other cities to engage in trekking, hiking and other interactive activities, even on workdays with commuting demands, which is another indication of the weakening of distance effects. Interactive activities in cities with attractive ecologically appealing environments as well as their own distinguishing features, such as Zhaoqing and Huizhou, are brought to the attention of the nearby high-grade cities, enhancing horizontal contacts between cities of different grades. Concurrently, such functional linkages can be observed in the primary cities. With regard to Guangzhou and Shenzhen, for example, the former tends to provide large-scale public services, whereas the latter offers special facilities, services and resources. Thus, they have complementary advantages with different functions and together play a pivotal role in the entire region.

10.5.4 Planning Matters

As the subject of the study, the urban networks of mega-city regions in cyberspace are also mapped by means of the leisure activities in real life. The important differences between the Internet and reality are those of time and transportation costs; any city is easily reachable in cyberspace. High-speed railways and highways in mega-city regions substantially reduce travel time between cities, which makes meeting the demands of cyberspace much more achievable in the real world.

With regard to these demands, along with China's rising national income and booming leisure industry, inter-city interactive consumption is becoming increasingly common, which means that interactive activities are more popular than ornamental activities in the PRD. From this result, we discern that people are more inclined to pursue personalized, experiential and self-identified consumption patterns than traditional single and static patterns, while activity providers need no longer be confined to materiality and closed spaces but instead have the option of virtualization and open interactive space. Thus, it appears that consumers' demands are becoming more and more diversified.

In the past two years, Guangdong has introduced a sequence of documents regarding leisure, including *Opinions on the implementation of national tourism and leisure outline from General Office of Guangdong Municipal Government (2013–2020) (2014)*, and *Opinions on the implementation of promoting tourism reform and development from Guangdong Provincial People's Government (2015).* Guangdong is the only province to have implemented *the scheme of national tourism and leisure,* and it is the first to have enacted a comprehensive reform focused on provincial tourism demonstration areas on a national scale. From the perspective of the national economy, it might be a new attempt to develop leisure-related industries and to ease the structural contradictions between supply and demand. To this end, network-shaped and diversified supply might provide a new outlet for national supply-side reforms. The empirical results show that the uneven supply of activity facilities resulted in the insignificant network characteristics of the PRD, thus adversely affecting the balance of urban functional linkages.

Based on the above analysis, this paper suggests that differentiated and diversified space construction should be a major direction for urban development in the future. Within the mega-city region, the key to coordination between cities is to combine urban spaces with complementary functions. There ought not be too much emphasis on competition between cities; instead, functional complementarity should be emphasized. Thus, for instance, a city cannot prove its economic strength simply by building an opera house. These results demonstrate that ornamental activities rather than interactive activities will continue to cluster in core cities, such that the design, location and layout of large-scale public services should provide more consideration to the needs of surrounding cities, particularly secondary cities. As for secondary cities, there is no need to blindly build large-scale regional public services. Instead, it is essential to carefully consider these cities' relationships with core cities when planning public services. For example, the *Into Guangzhou* project in North Shunde (rather than *Into Foshan*, which is the regional central city in the traditional sense) clearly accounted for functional complementarity with primary cities during local planning and city positioning. By strengthening their regional characteristics and ecological bases, by promoting their interactive activities to people from hub cities, and by encouraging staggered shifts to pick up the slack with interactive activities on weekdays, normal cities might accommodate the demands of residents in large-scale cities for 'face-to-face' communication with their wonderful ecologically appealing environments, ultimately enhancing connections at all levels of the mega-city region. Notably, only when a constant characterizes its scarce regional resources—whether these activities are based on the urban living environment and special recreational resources or rooted in urban activities and events with unique themes and rich real-life experiences—can a city establish itself and compete for capital, talent and technology from around the world, thus becoming a more attractive city with rising international status.

Acknowledgements This work was funded by the Natural Science Foundation of Guangdong [grant number 2016A040403041].

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Chapter 11
Reorganisation of the Spatial Economic System in a Population Decreasing Region

Daisuke Nakamura

11.1 Introduction

A self-sustaining regional economy is achieved where there are constant levels of local population and economic activity. To keep such situations, the consideration of the long-run attractiveness of region is an essential factor. The long-run attractiveness can be closely connected with the standard of living as residents of that region (such as the availability of high quality of life). In addition, the arrangement of exclusive cost-saving opportunities for local firms is also important. These opportunities include the notion of external economies. External economies are caused by external effects to an economic agent from the action of others (c.f., Mas-Colell et al. (1995)). These may vary with the type of region. The type of region can be classified by means of hierarchical central place system. The hierarchical central place system is a basic framework of central place theory.

Central place theory was preliminarily addressed by Christaller (1933 [1966]), and this was investigated by spatial competition of the economic activity by Lösch (1944 [1954]) as market-area analysis. The market area of a firm represents the territory of that firm to distribute its final goods. The progress of central place theory up to now can be referred to Mulligan et al. (2012). As another aspect of central place system, Parr (2008) reveals that the central place system can be divided into two parts; namely, the administrative structure and the functional structure. For instance, the centre of administrative structure can be the centre of a municipal service, such as the location of the local authorities, whereas the centre of functional structure is the centre of an economic system or the centre of a market area as conventional central place theory.

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X. Ye and X. Liu (eds.), *Cities as Spatial and Social Networks*, Human Dynamics
in Smart Cities, https://doi.org/10.1007/978-3-319-95351-9_11

While conventional central place theory does not directly investigate accessibility for consuming goods and services, it is important to reveal the difficulty of access for regional planning and design from the standpoint of the social dimension in addition to the economic dimension. The reason is that the social dimension involves regional benefits on households, whereas the economic dimension is mainly relevant to individual firm's profit-maximising behaviour. Nakamura (2010) demonstrated the difficulty of access for particular consumers as spatial consumer exclusion, which explains the presence of consumers who are not able to reach goods and services due to the problem of limited access. There is also a remaining issue for improving the attractiveness of region as a result of limited budget constraints of regional governments for providing sufficient public services. The problem can be particularly severe in rural areas with decreasing populations as revealed by Nakamura (2016).

This chapter examines spatial reorganisation scenarios that may enhance the utilisation of the spatial economic structure. Since the reorganisation involves a trade-off between agglomeration economies and transportation costs as originally addressed by Weber (1909 [1928]), the application needs to include both externalities and the costs of access. This conceptual framework was expanded by Isard (1956), Khalili et al. (1974), and Mai and Hwang (1992) on the location-triangle model. Regarding externalities or external economies, both positive and negative terms exist. These refer to localisation economies, urbanisation economies, urbanisation diseconomies, and active-complex economies, as long as they are spatially constrained factors (Parr 2002, 2015).

Each definition of agglomeration economies were summarised by Nakamura (2015) as follows. First, localisation economies are observed when there are possibilities for firms to attain labour cost savings, to act joint input extraction among different local firms, and to share specialised services such as repairing of machinery. Second, urbanisation economies are commonly found in large metropolitan areas as a result of the various cost-saving benefits such as better administrative accessibility, well-organised infrastructure, varieties of labour supply, and highly advanced network of transportation and communication. Finally, activity-complex economies are observed when local industries rely on trade between different local firms in a production chain.

Together with the notion of agglomeration economies, aggregate access costs play important roles in this chapter. The aggregate access costs include not only transportation costs as the actual expenses of travel and time consumption but also involve other factors, such as the cost at connection nodes. For instance, connection nodes are short- and long-haul bus centres, transit centres, park and ride centres and other sites to transit unless a trip completes by a door-to-door method. In the later part of the chapter, this notion is interpreted as terminal nodes.

Following sections apply these terms to a location model which may lead regional policies to establish more effective regional planning and design by better utilising physical economic space.

11.2 Location Model

This section introduces a simple location model to understand the spatial economic mechanism of distributing goods and services within the framework of central place system. First, goods and services can be categorised into three groups: essential, semi-essential, and luxury types. For instance, essential types are daily foods, luxury types are commodities which need to obtain once a month or less frequently, and semi-essential types are goods and services which have frequencies of access between essential and luxury types. Following the hierarchical urban system in central place theory in Lösch (1944 [1954]), essential goods and services can be distributed across the physical economic plain, while luxury goods and services are exclusively distributed from the centre of the large market area. Semi-essential goods and services would be somewhere between them. Even though the recent technological innovation on transportation has been well-developed, there are still limitations to deliver daily goods such as fresh milk, vegetable, and fruit within a physically close distance to the locations of households.

Regarding the cost of transportation, it is common in spatial economic analysis that the cost of access both for producers and for households is usually assumed as a constant parameter. In other words, such cost is simply multiplied by the physical distance for reasons of simplicity. However, the location model of this section will introduce an alternative structure of transportation cost, and present a method for maintaining accessibility to goods and services in a lower hierarchically-ordered region.

The model assumes the following situation. First, three different types of hierarchical region exist; namely, the lowest hierarchically-ordered area, which has the centre *S*, an intermediate hierarchically-ordered area, which has the centre *M*, and the highest hierarchically-ordered area, which has the centre *L*. Second, a representative household lives at a specific location, *A*, as indicated in Fig. 11.1. The figure shows the central places of *S*, *M*, and *L*, which are respectively the nearest centres for this household. According to the hierarchical central place system, the variety of goods and services is the smallest at the lowest hierarchically-ordered region, which has the centre *S*, is the largest at the highest hierarchically-ordered region, which has the centre *L*, and is somewhere between *S* and *L* at the intermediately hierarchically-ordered region that has the centre *M*.

The corresponding transportation network of this household can be illustrated as in Fig. 11.2. In the figure, the transportation network is divided into three parts; namely, the part between location *A* and the centre *S*, the part between centre *S* and centre *M*, and the part between centre *M* and centre *L*. For instance, a person needs only to travel between her location, *A*, and the centre *S* in order to obtain essential goods and services, while she needs access between *A* and the centre *M* via centre *S* in order to consume semi-essential types, and access between *A* and the centre *L* to purchase luxury goods and services.

While spatial analysis commonly sets the unit fixed constant transportation rate as noted earlier in this chapter, a more complex structure is now introduced.

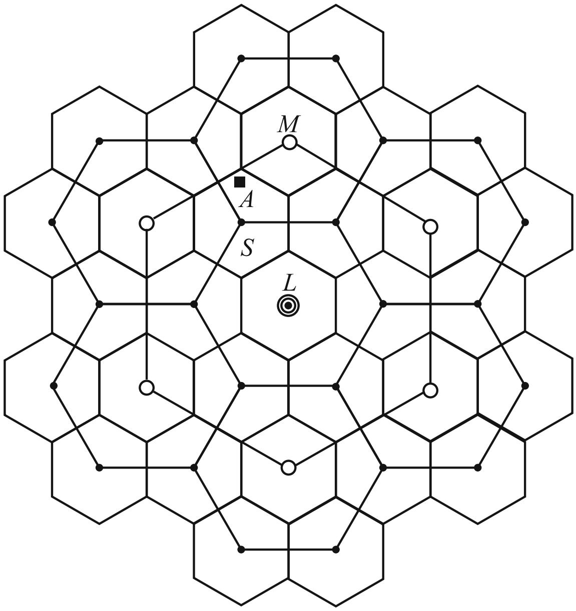

Fig. 11.1 Hierarchical central place system

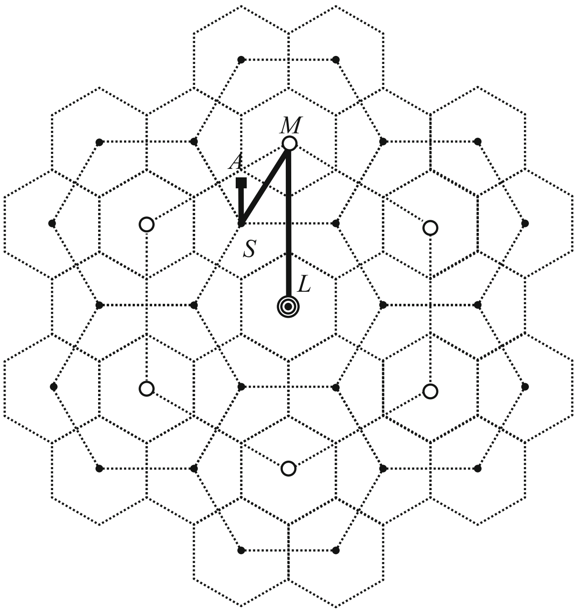

Fig. 11.2 Hierarchical spatial and transportation system

In Fig. 11.3, the unit transportation cost for each segment is denoted by t_S, t_M, and t_L. More precisely, t_S $(t_S > 0)$ is the unit transportation cost between the individual's location, A, and centre S; t_M $(t_M > 0)$ is the unit transportation cost between

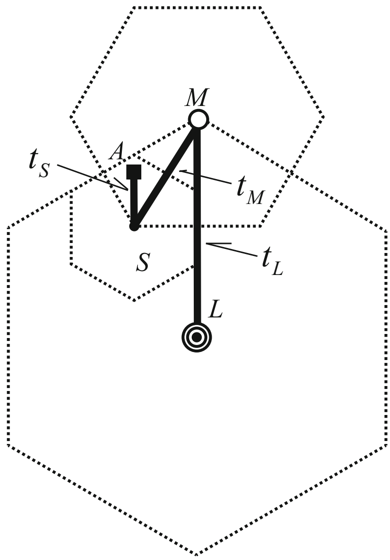

Fig. 11.3 The network of transportation

centre S and centre M; and t_L $(t_L > 0)$ is the unit transportation cost between centre M and centre L.

Transportation costs generally form a taper shape, which can be drawn as the curve TrC_0 in Fig. 11.4. In the figure, the horizontal axis and vertical axis plot distance, d, and cost, C, respectively. Additionally, F_0 $(F_0 > 0)$ is the fixed cost element in the sense of location economies. Hence, we have the following condition: $t_S > t_M > t_L$.

The aggregate transportation cost, TrC, can be expressed as Eq. (11.1) by applying the notion of total transportation costs in Fig. 11.4.

$$TrC = F_S + t_S d_S + F_M + t_M d_M + F_L + t_L d_L \tag{11.1}$$

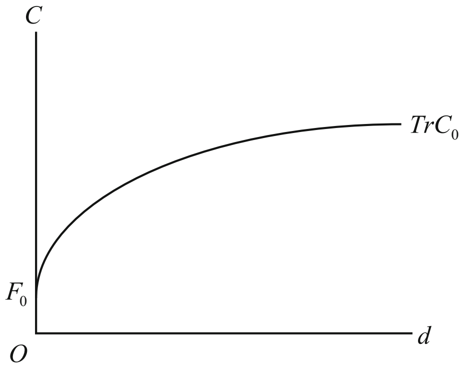

Fig. 11.4 Taper-form total transportation costs

In the equation, F_z $(z = S, M, L)$ = terminal cost in order to use the transportation network z; t_z = unit transportation cost to use the transportation network z; and d_z = physical distance of travel for z. The terminal cost is the cost, which has to bear at every connection node. This specific cost is the same meaning of fixed cost in conventional economic theory as indicated by Brueckner (2011). The terminal cost incorporates several factors such as the transit time, parking fees, accessibility, and convenience. There, accessibility can be whether the place has universal access for elderly people or families who are travelling with small children, for instance. Also, convenience may be exemplified as whether there is a food court, and if so, whether it only serves heated meals during the daytime on weekdays and is completely closed during the weekend. Terminal nodes of transportation include short- and long-haul bus centres, transit centres, park and ride centres, and so on. However, these are difficult to convert directly into monetary terms. Hence, terms that are directly visible, such as parking fees, would be more applicable here for Eq. (11.1).

Regarding other excluded factors, they are still unavoidable and these elements are included in a part of external elements in Eq. (11.2).

$$\max U = U_A(x_1, \ldots, x_n;\ y_1, \ldots, y_m) \tag{11.2}$$

$$\begin{aligned} s.t. \quad & \sum_{i=1}^{n-a} p_i x_i + \sum_{j=n-a+1}^{n-b} p_j x_j + \sum_{k=n-b+1}^{n} p_k x_k + \left[\left(\sum_{i=1}^{n-a} x_i t_S d_S v(x_{i-1})\right) + F_S\right]\sigma \\ & + \left[\left(\sum_{j=n-a+1}^{n-b} x_j t_M d_M v(x_{j-1})\right) + F_M\right]\delta \\ & + \left[\left(\sum_{k=n-b+1}^{n} x_k t_L d_L v(x_{k-1})\right) + F_L\right](1 - \sigma - \delta) = B \end{aligned} \tag{11.3}$$

Equation (11.2) shows an expanded utility maximisation of the representative household A. This function contains n different types of goods and services $X\,(X = x_1, \ldots, x_n)$ in addition to external elements y_h $(h = 1, \ldots, m)$ as can be referring to Hanley et al. (2007). External elements will be argued later in this section. Equation (11.3) shows the budget constraint, B, of this household where σ $(0 \le \sigma \le 1)$ represents the frequency of access to the centre S, and δ $(0 \le \delta \le 1)$ is the frequency of access to the centre M, respectively. To be precise, it can be shown that $\sigma + \delta \le 1$ in order to satisfy the condition where other remaining goods and services are exclusively available at the centre L. Moreover, the order of frequency of access to goods and services can be illustrated as in the stepwise line in Fig. 11.5. This interpretation is determined by the parameter $(0 \le v < 1)$, which represents a higher frequency of demand as the subscript number becomes smaller.

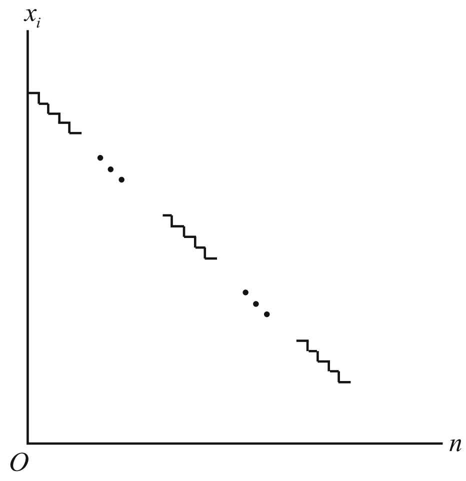

Fig. 11.5 Commodity hierarchical order

Regarding external factors, y_h $(h = 1, \ldots, m)$, in Eq. (11.2), these can be interpreted as follows. For instance, urban areas need to consider negative externalities as urbanisation diseconomies due to excess population and land use in those areas. By contrast, rural areas may not be able to observe such negative elements as there are not enough level to create urbanisation diseconomies so that:

$$\frac{\partial U_A}{\partial y_h} > 0. \tag{11.4}$$

The series y_h may also contain the notion of social participation, such as job opportunities at closer and more accessible distances for various generations, including them for elderly people who are willing to keep social participation: $\frac{\partial y_h}{\partial d_S} < 0$. Regarding agglomeration economies in external terms, social participation in rural areas can relate to localisation economies and activity-complex economies. In general, there are many unsuccessful cases in rural areas, in which the industrial hollowing-out of local firms to other cost-saving countries takes place. In addition, an important factor is whether the regional economy is capable of continuing long-run export for enabling the region to be self-sufficient. The importance of export industry for regional economy can be found in the literature of basic industries (i.e., Capello 2007).

Without industry-relevant types of agglomeration economies, it is still valid to apply this framework to urbanisation economies. While it is conceptually not valid for non-metropolitan areas to apply urbanisation economies, there is a possibility to employ this scenario by means of an arrangement of wider-regional coordination. Also, it should be noted that the relationship between 'less-frequently demanded goods and services' and 'accessibility' is important for the attractiveness of a region, since households maximise their satisfactions by a love of variety (see Dixit and Stiglitz (1977)). This can relate to leisure activities, such as visiting concert halls, museums, art galleries, or beautiful national parks. If leisure activities are easily accessible, the attractiveness of a region will also be high as represented in Silicon Valley (c.f., Glaeser et al. 2001), which is one of the key elements for sustainable regional economic growth that have centripetal force of local population and economic activity.

Furthermore, environmental advantages in rural areas are inclusive in this force against large metropolitan areas, where urbanisation diseconomies, such as pollution, typically exist. This would attract more firms that require clean air, water, or quiet areas for processing to engage in production. For households, these environmental benefits should be reflected in higher levels of quality of life, as one of components of y_h in Eq. (11.2) (see Hanley et al. (2007)). Also, local households can take advantage of the decisions of firms to locate in rural areas, which may improve spatial vicinity to job opportunities as long as firms open their job markets to local residents as well as the production activity of new firms does not exceed a critical level of environmental pollution. Also, it should be noted that the extent of economic contribution depends on the type of contract in the job market whether firms need high-skilled labours or not.

11.3 An Application

Applying the framework in the previous section, the analysis will now demonstrate a system-wide planning beyond the scope of the established administrative boundary under the circumstance that regions face a constant population decline. In such a case, the hierarchical spatial structure has methodologically two options if the economy is a physically isolated or completely closed space. One option is to merge the lowest hierarchically-ordered region, which has the centre *S*, with the higher hierarchically-ordered region, which has the centre *M*. The other option is to keep the regional system, and the choice of option depends on given economic and spatial settings. Figure 11.6 introduces two types of hypothetical scenario; namely, the *LM* and *LS* structures.

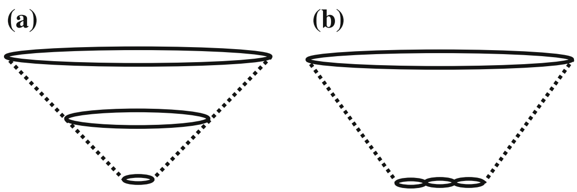

Fig. 11.6 The *LM* central place system (**a**), and *LS* (**b**) central place system (**b**)

11.3.1 The LM Structure

When a constant population decline is observed, the compact city scheme is an effective spatial policy. Here, the compact city scheme is one of representative spatial planning systems that enhances concentrations of population and economic activity within the physically limited distance from the central place. Detailed analysis was found in Burton (2000), for instance. Applying this scheme to the hierarchical central place system, the structure eliminates the lowest hierarchically-ordered area with centre *S*, and becomes the *LM* (*L*&*M*) structure, as illustrated in Fig. 11.7.

The *LM* scenario assumes that all households migrate close to the centre *M* or to the centre *L*. Households who do not desire to migrate from the area with the centre *S* face severe spatial consumer exclusion unless the optimal market-area radius for each distributing good or service exceeds the maximum size of the region which has the centre *M*. This is an actual problem on the compact city scheme (see the case of consumer exclusion in Nakamura (2010)). In particular, accessibility to essential goods and services such as supermarkets, pharmacies, clinics, and childcare services would be crucially important. In this scenario, a modified equation for the transportation system can be expressed as follows.

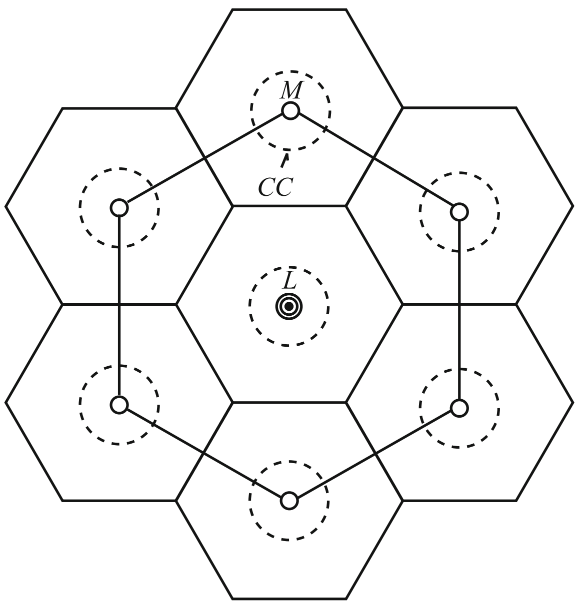

Fig. 11.7 The *LM* structure

$$\sum_{j=1}^{n-b} p_j x_j + \sum_{k=n-b+1}^{n} p_k x_k + \left[\left(\sum_{j=1}^{n-b} x_j t_M d_M v(x_{j-1})\right) + F_M\right]\delta + \left[\left(\sum_{k=n-b+1}^{n} x_k t_L d_L v(x_{k-1})\right) + F_L\right](1-\delta) = B \tag{11.5}$$

In this case, the centres of the administrative and functional structures may coincide. While urbanisation economies can be available at every central place, urbanisation diseconomies may also be observed due to spatial concentration of the economic activity when the areal population and economic activity exceed its physical capacity. This could include an increase in the price of land and congestion. If the extent is evident, declines in y_h in Eq. (11.2) will reduce the utility level of local households.

11.3.2 The LS Structure

Another spatial pattern can be illustrated as in Fig. 11.8, which represents the *LS* (*L*&*S*) structure. In this case, the role of the central place *M* becomes a transit node, connecting the centre *S* and the centre *L*, as well as connecting different *S* centres. Here, a difference to Fig. 11.2 is that the centre *M* does not have a function of the centre of market area so that the centre *M* has no circular symbol in Fig. 11.8.

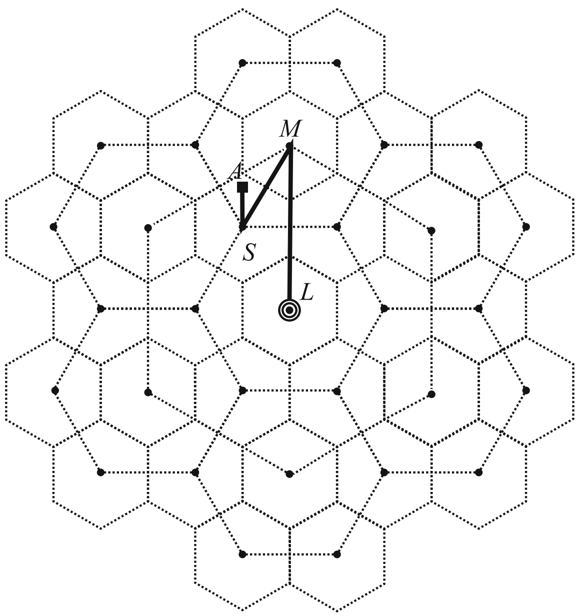

Fig. 11.8 The *LS* structure

The benefit of forming this specific system is that all households can minimise the cost of access to essential and semi-essential goods and services. The costs of transportation for this scenario can be expressed in the following equation.

$$\begin{aligned}&\sum_{i=1}^{n-b} p_i x_i + \sum_{k=n-b+1}^{n} p_k x_k + \left[\left(\sum_{i=1}^{n-b} x_i t_S d_S v(x_{i-1})\right) + F_S\right]\sigma \\ &+ \left[\left(\sum_{k=n-b+1}^{n} x_k t_L d_L v(x_{k-1})\right) + F_M + F_L\right](1-\sigma) = B\end{aligned} \tag{11.6}$$

The lowest hierarchically-ordered region, which has the centre S, does not need to change the formation of market area under the following structure of economic space.

$$\begin{aligned}&\sum_{i=1}^{n-a} p_i x_i + \sum_{k=n-a+1}^{n} p_k x_k + \left[\left(\sum_{i=1}^{n-a} x_i t_S d_S v(x_{i-1})\right) + F_S\right]\sigma \\ &+ \left[\left(\sum_{k=n-a+1}^{n} x_k t_L d_L v(x_{k-1})\right) + F_M + F_L\right](1-\sigma) = B\end{aligned} \tag{11.7}$$

These two patterns are a trade-off between minimising the access costs of households and minimising the operating costs of the region which has the centre S. To be precise, the former case, represented in Eq. (11.6), shows that the lowest hierarchically-ordered region which has the centre S handles up to the bth type of goods and services. This implies that the bth minus the ath type of goods and services, originally available at the region category M, can then be available at the nearest central place S for a household who locates at A. This scenario is feasible as long as the lowest hierarchically-ordered region which has the centre S has a sufficient demand of the bth minus the ath types of goods and services, while it is actually difficult to arrange.

By contrast, the latter pattern illustrated in Eq. (11.7), which is the second case, represents the lowest hierarchically-ordered region that has the centre S, and does not change the handling of any goods or services. This implies that the bth minus the ath types of goods and services are exclusively available at the highest hierarchically-ordered region which has the centre L. In order to keep the local households' welfare level, a better network of interregional transportation is needed between the centre S and the centre L.

In both structures, the central place M can be not only a transit node but, perhaps more importantly, a central regional administrative system to maintain the security and safety of regional activities. It is possible to have the case where the centres of the administrative (*AS*) and functional (*FS*) systems do not coincide. In other words, an alternating structure, "*FS*/*AS*/*FS*" (namely, centres of *FS* exist at L and S, and centres of *AS* locate at M), can be formed. This could contribute to dispersing the potential problematic issues of risk and uncertainty of natural disasters, for instance, massive earthquake and flood. There are cases where spatial concentration causes temporal disruption of the economic activity by natural disasters such as the case of serious flood at Bangkok in 2008 which suspended the supply-chain system of laptop computers for a couple of months all over the world.

11.4 Spatial Rural Policy

Hitherto, hypothetical analysis has been presented as the scenario of self-sustaining regional economic growth through two types of alternative spatial structure, *LM* and *LS*, when a regional population gradually declines. This section discusses policy implications, since the alternative spatial structure varies with the location attributes according to the following observations. First, both types of alternative structure require well-organised infrastructure for interregional transportation to the centre *L*, as long as some goods and services that are exclusively available at *L*. There, directly relevant variables are t_L, d_L, and F_L in Eqs. (11.5), (11.6), and (11.7), while the indirectly relevant variables are b and σ or δ. From the standpoint not only of households but also of firms, a well-organised interregional transportation network is important in particular for producing market-oriented goods and services which are distributed from the centre *L*. If such a network is unavailable, they will relocate nearby the centre *L* unless the cost of urbanisation diseconomies is remarkably high level. Such relocating behaviour may negatively affect the utility level of households in Eq. (11.2) through the reduction in y_h.

The *LM* structure is advantageous for saving costs not only through the intraregional transportation network but also through the facility operating costs of public services. If the migration of local residents towards the centre *M* is feasible, the *LM* structure can be the optimal policy. In contrast, the *LS* structure is more effective if essential and semi-essential goods and services can be arranged among neighbouring centres of *S*. This can be considered as a case between the patterns in Eqs. (11.6) and (11.7). In other words, consumers who have difficulty in accessing the largest centre *L* can avoid spatial consumer exclusion for semi-essential goods and services, if some neighbouring lowest hierarchically-ordered centres of *S* share in supplying semi-essential goods and services. However, it should be noted that such a scenario is only possible if the network of transportation between neighbouring centres is well-organised. If these conditions are satisfied, the *LS* structure is beneficial for utilising existing facilities in the community-level central place system.

Such area not only supplies essential and semi-essential goods and services but also provides opportunities for work for people who are willing to work, but have difficulty in long-distance commuting: $\frac{\partial y_h}{\partial d_S} < 0$ as indicated in previous sections in this chapter. This can be important for solving several problems caused by a severe dependence on the economic system in a society. More precisely, in many developed countries, more increased economy reduces the weight on the social system (i.e., non-pecuniary activities of households, such as taking care of children). If the *LS* structure is properly established as one of methodological outcomes, local participants can fulfil the shortage of supply of the social system without relying on governmental support, which would require certain amounts of public finance under the severely limited budget constraint.

In addition, this fulfilment can be easier than in the *LM* structure, since larger regions tend to be far away from localised community-level activities. In other words, a small region that can be categorised as the lowest hierarchically-ordered region would have an important role in capturing the demand of local economic agents, such as through coordinating well-organised universal access and community support. From the perspective of the built environment, the coordination of alternative spatial structure of regional economic system may adjust the emerged gap between the organised infrastructure and the actual usage of these elements, which is caused by demographic changes and other factors. The adjustment can be made by coordinating better arrangement of physical accessibility to the market and to the society.

11.5 Further Avenues

While this analysis examines limited conceptual scenarios, the following arguments may be expanded. First, it is important to consider the availability of facility operating costs for infrastructure in detail. Here, facility operating cost includes repairs, fulfilling labour supply, replacement of machinery, and so on. From the standpoint of the expected regional fiscal revenue of the local government, it would be a problematic issue under the tight-budget operating requirements for population decreasing regions. Second, a detailed investigation requires inclusion of a variable for the density of demand for each area under examination. There, the density of demand can be interpreted that lower density areas would have a plenty of available space, while higher density areas may be able to receive advantages on the scale merit of the economic system. This is because spatial analysis needs to consider the density of demand in addition to the costs for access to economic activities and other spatial factors.

Third, in addition to physical retail stores, delivery services (i.e., online shopping) can now cover wide areas. However, such services have not yet completely replaced physical retail stores. The extent to which future delivery services may reduce spatial consumer exclusion in rural areas should be examined, although it is necessary to consider the problem of digital exclusion such as a very limited options of the payment method, for instance. In addition, the hierarchical urban system has been involved in several market-area laws, such as the economic law of market areas (Fetter 1924; Hyson and Hyson 1950), and the law of retail gravitation (Reilly 1929, 1953). The economic law of market area clarifies the spatial territories of economic activity on firms under given competitive conditions of price and transportation cost. The law of retail gravitation analyses spatial economic competition of market shares between two cities at a third location under given condition of the ratio of the two city populations and the distance to the third location. These are useful to consider in the hypothetical framework in this chapter. While these are not applicable in a straightforward manner, it would be necessary to employ when the analysis solely focuses on the structure of market areas.

11.6 Concluding Comments

This chapter has discussed the hierarchical urban system and the structure of the market areas of goods and services. The conceptual framework integrated spatial elements such as accessibility, externalities, and utility levels of regional households. Also, an extended framework revealed that the self-sustaining regional system in population decreasing areas can adopt the *LM* and *LS* structures. There, it has argued that the *LS* structure is more feasible for creating social participation among people who are willing to work but have difficulty in commuting long distances, for instance. This may contribute to support the function of the social system, and avoid further burdens on the public finances of local governments, although the outcome was derived by the limited conceptual framework.

Acknowledgements A preliminary version of this article was partly presented at the Autumn Meeting of the Japan Association for Applied Economics in Saitama, November 2015, and was partially supported by Japan Society for the Promotion of Science (JSPS) KAKENHI, Grant Number 25780179, and the final version was supported by the Grant Number 16K03643.

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Chapter 12
Socio-spatial Network Structures in Border Regions: West and East Borders of Turkey

Cigdem Varol and Emrah Soylemez

12.1 Introduction

Globalization defined as "the widening, deepening, and speeding up of worldwide interconnectedness in all aspects of contemporary social life" (Held et al. 1999:15) has facilitated the free flow of capital, commodities, information as well as people. The increasing flows have brought the discussions of relationality in which researchers tend to place their analytical focus on complex links of relations among actors and structures (Yeung 2005).

Relational approach conceptualizes the relations in a broad perspective. It includes social, economic, political actors and their network relations at different spatial scales. 'Spatial' includes the interrelations between different activities and networks in an area, and the significant intersections and nodes within an area which are physically co-located (Healey 2004:46). Research on the relational approach in various social-scientific fields has contributed to theoretical debates on the conceptualization of network geographies and their relation to territorial, place-based and scalar formations (Amin 2004; Marston et al. 2005; Jessop et al. 2008). Although relations affecting the territories are theorized to be embedded in networks of relational assets and spatial proximity, particularly at the local and regional scales, they may enlarge in many directions and link to different scales. The scale from global to local may connect many discontinuous sites or may bring together intense interactions with a global range (Healey 2004). The coexistence of multiple economic, socio-cultural and political layers of relations within multiple

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X. Ye and X. Liu (eds.), *Cities as Spatial and Social Networks*, Human Dynamics in Smart Cities, https://doi.org/10.1007/978-3-319-95351-9_12

spatial scales (Brenner 1999) forms the basis for socio-spatial organization. Socio-spatial relations of actors are intertwined with broader structures of processes of social and economic change at various geographical scales.

In this study, socio-spatial relations are analysed over a specialized geography of networks; the border regions. Borders are defined as "the dividing line or frontier between different political or geographic regions" and the border space is conceived as a shift from one system to another. Furthermore, border regions are socially and economically marginalized (Paasi 1996) areas and the evaluation of these areas within socio-spatial dialectic brings out the research agenda of social relations, policies and institutions functioning in the economic structure. As different types of relationships across different countries appear, border regions become spaces of flows. Formal and informal flows in border regions create multi-dimensional and complex structures. These structures necessitates the social, economic, political and spatial analysis and the evaluation of actors in the region.

As a spatial component, though border contributes to the differentiation of territories at different scales, they can become bridges between the two societies or the two countries they split. Geographers consider borders according to two complementary aspects that equally integrate the human dimension of space (Bioteau 2007). One is related with political geography and geopolitics, concerned with the role of state borders in the construction of national territories and territorial identities. The other is more economically oriented whereby the regional dimension of cross-borders cooperation prevails. By the increasing economic, social and political relations all over the world, borders become more permeable, where geopolitical approach stays at back and economic and social oriented approaches come to the fore making the border regions more interrelated with the other side.

This study aims to analyse social, economic, political and spatial dimensions of multicultural, multi-layered, multi-actor decision making in complex structures of the border regions. Social dimension in cross-border relations includes formal and informal relations and level of these relations, structural similarities/differences and mutual trust. Economic dimension includes economic volume and activity of both sides in the border region and economic relations between each side. Political dimension includes level of decision making, border crossing conditions and bureaucratic facilities and obstacles. Spatial dimension analyses the locations of the settlements in the border region and the interaction of these settlements with each other. Integrated analysis of all these dimensions is critical in putting the socio-spatial interaction in the border region as a whole.

Regarding these dimensions, the study tries to explore the complex relationships occurring in the border regions by analysing social and spatial network structures. In doing this, the tool of social network analysis is utilized and spatial inferences are made by the help of social network measures. Analysing the border region in terms of its social and spatial networks will help to understand socio-spatial dimensions of the relations and to visualize the relational border space. The study consists of three parts. The introduction constitutes the first part. The second part tries to understand the changing characteristics of borders and border regions where social and spatial dynamics define the relationality. The third part explores the methods and approaches of network analysis that are used to examine the spatiality of social relations among the settlements of the west and east border regions of Turkey. The fourth part exhibits the findings of the social and spatial network analysis in the west and east border regions of Turkey, including the relations across Bulgaria-Turkey and Greece-Turkey border in the West, and Georgia-Turkey border in the East. The main problem here is to understand how social relationships shape the border space and how the spatial structures are formed by the interaction of social and spatial networks. Finally the fifth part draws out conclusions from the findings of the study.

12.2 From Borders to Border Regions

While it is evident that globalization has facilitated the free flow of capital, commodities and information, when it comes to regulating the movement of people, it is constrained by territorialized national borders which are built by states. Although national borders are slowly losing their functions with the effect of globalization and with the construction of supranational communities like EU, it still remains as a breaking line in the national space. Borders are still shaping the space as bounded regions, places and territories and they remain as boundaries of the legitimacy of the state and its power (Bioteau 2007). Even if the borders become blurred, they will still act as crossings between two worlds or two distinct state societies that have been parted for a long time. Thus, rather than fixed lines, rethinking the notion of "border" as a region in a relational context and taking the increasing permeability across the borders into consideration attract the attention of researchers in the social-scientific fields.

Theoretical studies about transformation of a border line to a relational border region came into the agenda during the 1990s. In these studies, mostly regional economic relations and prohibitory effects of boundaries were studied and modelled (Ratti 1993). In the relational approach, border areas are not considered as clear-cut as the metaphor of the linear boundary suggests, but as regions shaped and negotiated through various social practices and discourses. Border regions are perceived as socially constructed spaces, mediating and negotiating the existence of linear demarcations between territorial units (Paasi 1996). In other words, they are conceived as spatially extended frontiers, in which people have recognizable configurations of relationships with other people inside or on both sides of the borderline.

The transitional character of border regions as being "in-between" spaces was considered as a disadvantage until recently. However, these regions become a potential for the construction of new attraction points when borders become more permeable in terms of social, economic and spatial dimensions. The notion of transitional space, which crosses the boundaries and takes in areas and people on both sides of the formal line of divide, causes the social and cultural groups increasingly become hybrid. In contrast to their traditional role of barriers, the nature of borders becomes bridges and points of interaction where people or groups contact and interact (O'Dowd and Corrigan 1995; Newman 2003).

From the spatial dimension, border regions include many settlements, towns and cities, which are located along the national borders and normally perceived as constituting single functional entities. The question of the relationship between settlements and borders has long promoted the notion of border cities (Nugent 2012). In the light of the emergence of new economic, political and cultural relationships between cities separated by a state border that has become permeable, new spatial arrangements of cross-border settlement spaces come into the agenda. Using different methods, such as analysing the social relations among the settlements in the border space and integrating this analysis with spatial network structures in different scales will help to explain these new spatial arrangements in the border regions.

12.3 Research Methodology

In the recent years, the spatiality of social relations has become a popular debate in the social sciences. In geographical thought, it reflects the shift to a dynamic and relational conceptualization of spatiality, and this new approach has revolutionized the way of analysing social-spatial interactions. In the analysis of socio-spatial interactions, different methods of social and spatial sciences have been used to model the interaction. In socio-spatial studies, social network analysis (SNA) becomes a strong tool for representing the spatiality as well. Here, social networks can be represented in space by connecting the users of the network to geographic entities and routes.

The core concept of the 'social network' can basically be defined as a set of social actors over whom one (or more) social relation(s) are defined (Wasserman and Faust 1994) and the 'spatial structure' consists of specific features of a context that are located explicitly in geographic space and analyses the way of relations embedded in space. The contextual features of both social and spatial can have impacts on the networks formed within them. Although social networks at first seem to be not directly embedded in space, it is important to notice that space intervenes the social connection probability between two actors usually related with the distance between them.

SNA and data visualizations offer a complementary dimension compared to the traditional approaches. Multi-dimensionality and complexity of the relations in the network are generally measured by social, economic, spatial and political data and analysing relational patterns and morphological properties of the actors on the border region reveal the dimension of interaction in the network and thus the relational character of the border regions.

In this study, socio-spatial relations are analysed in the west and east border regions of Turkey: Bulgaria-Turkey, Greece-Turkey border region in the west and Georgia-Turkey border region in the east. In the study, characterizing and understanding the social and spatial network structure of the relationships among the actors of the neighbouring countries are the main intention. The network data were collected by a questionnaire, applied to the citizens living in the buffer zone of 50 km from the borderline and having cross-border relations. The data was collected in July and August 2016 in the two border regions of the West and East. Totally 800 questionnaires were applied to the citizens on both sides of the border; Turkey, Greece, Bulgaria and Georgia. Questionnaires mainly aimed to explore the interrelationships between actors in order to identify the network characteristics and spatial effects in the network of border regions. From the questionnaires, a better understanding of the relationships among the actors on both sides of the border was explored by the help of a detailed social network analysis that gave the opportunity for spatial analyses afterwards. The social network analyses that were used in the study are the following: (i) macro level network analysis (node and edge size, modularity, average/weighted average degree and network diameter) (ii) micro level analysis (closeness, degree, betweenness centrality (Freeman 1979) and eigenvector centrality (Bonacich 1972)) and (iii) visualization of networks on border regions. Gephi and NetDraw programs were used for analysis and visualizations.

12.4 Socio-economic and Spatial Network Structures in the West and East Borders of Turkey

The most interactive/permeable border regions of Bulgaria-Turkey border and Greece-Turkey border in the west and Georgia-Turkey border in the east of Turkey were chosen as the study area (Fig. 12.1). The entire length of the Turkey's west border is nearly 465 km. Geostrategic and geomorphologic characteristics result in

Fig. 12.1 West and east border regions of Turkey and neighbour countries

a rather specific regional structure for the west of the Turkey, where the border line dividing the territory transforms into the borderland. Related with the physical thresholds and the transportation infrastructure, border crossings are distributed unevenly along the borderline. Border crossings generally determine the characteristics of the borderline as a barrier or as a potential of contacts and cooperation among border regions. In the West border, a developed transport interconnection and the close location of a regional centre; Edirne carries the potential of an accessible border region for the border actors. On the other side, the east border of Turkey with Georgia is nearly 252 km length. Geomorphologic characteristic of this border is quite tough, as behind the coastline a steep topography begins. The easiest passage to the other side is through the coastline, where the technical infrastructure is relatively developed.

In the Western region, the borderland at the Turkish side is formed by the cities of Edirne and Kirklareli. Although these cities locate at the periphery of the country, they are economically more developed compared to the other border regions in the country. The northern part of the borderland is formed by sparsely populated area covered with forests. The southern part is a part of the Maritza Basin and is characterized by agricultural lands. The borderland in Bulgaria is formed by Yambol, Haskovo and Burgas cities/regions, while the Greece borderland includes Western Thrace region (Alexandroupoli, Komotini, Xanthi, Orestiada, Didymoteicho). These border regions of Bulgaria and Greece are relatively less developed areas in social and economic bases when compared to the whole of the countries. These areas are sparsely populated and do not have important industrial investments. The borderland of Eastern region is formed by Batumi city of Georgia; and Artvin, Hopa and Kemalpaşa cities of Turkey. Eastern border region is less populated than Western border region. Economic relations between two countries have helped the growth and development of cities on both sides of the border like Batumi and Artvin.

In border studies, permeability concept is used to emphasize the intensity of the flows among countries. Border permeability is defined as the ease of interaction in the geopolitical level (Starr 2002; Stephenie and Pessaresi 2006) where border is conceptualized as a product of restriction created by the goods, capital and thoughts on legal, geographical, historical and social identity (Stephenie and Pessaresi 2006). The degree of border permeability, varying from closeness to full openness, is defined according to the size, shape and direction of the flows. The mean permeability index values (Fig. 12.2) for the borders of Turkey were calculated from totally 23 variables of social, political, economic and spatial data on 10 * 10 km raster grids (Varol and Söylemez 2016). When the permeability levels of west and northeast border regions of Turkey are analysed, though there are differences in socio-spatial structures between the two regions, the levels of mean permeability index values look similar to each other.

The comparison of the characteristics of the west and east border regions of Turkey and neighbouring countries is given in Table 12.1.

Fig. 12.2 Permeability index of Turkish borders (Varol and Söylemez 2016)

Table 12.1 Comparison of characteristics of west and east border regions of Turkey

	West border region	East border region
Neighbour countries	Greece and Bulgaria (EU)	Georgia
Active land border crossings	Kapıkule Pazarkule İpsala Hamzabeyli	Sarp, Posof-Türkgözü
Length of borderline	465 km	252 km
Population living within the first 0–100 km from the borderline	1.250.000	550.000
Macro level mean permeability levels	0.23	0.27
Settlement morphology	Dispersed in plain and rugged terrain	Linear to coastline because of rugged/hilly backside

12.4.1 Development of Border Relations in West and East Borders

Current borders of Turkish Republic were drawn by Treaty of Lausanne in 1923 after the Independence War. During the Ottoman Empire, just before the establishment of Turkish Republic border lines were more permeable and changeable due to the nature of war environment. These boundaries were psychological barriers that keep ethnic and religious characteristics (Gavirillis 2008). After the establishment of Turkish Republic and the formation of current boundaries, the borders strictly separated the neighbour countries from each other. The permeability of the borderlines between the countries had been shaped by security based national policies until the 1990s. During this period, border was characterized by a single line that permitted very limited number of flows of the inhabitants on the other side of the borderland. Cross-border contacts were only established to meet the basic and practical mutual needs of both sides. The main activities between countries were generally the administrative issues such as transnational road infrastructure or flood prevention policies and activities etc. Due to the low permeability levels between the countries, border regions were spatially and economically at the peripheries during this time for West and East border regions.

There were several breaking points of border relations, related with economic, social and spatial issues. These breaking points mainly occurred in the context of changing regimes, either by becoming a member of a supranational entity or by transition to an open economy. For Bulgaria and Greece, the EU membership and the common use of the structural funds related with cross-border cooperation, have increased the permeability between Turkey both in economic and social bases. On the other side for Georgia, transition to an open economy affected the relations with Turkey positively and enabled thousands of people to overcome economic difficulties by crossing to the other side of the border. Turkish-Georgian economic, commercial and cultural ties have boosted since the 1990s and Turkey has become a place, where Georgians looked for jobs (Kononczuk 2008; Modebadze et al. 2014).

12.4.2 Analysis of Socio-spatial Networks of Border Settlements

In the analysis of socio-spatial networks among the actors of the neighbouring countries, social network analysis was used. In the analysis, nodes refer to inhabitants living within the limits of the first 50 km from the borderline and crossing the border for some reasons. Ties refer to the links that connect pairs of actors living in the border settlements. Ties are directed and weighted, which shows the way of flows and the intensity of relations among the settlements (Fig. 12.3).

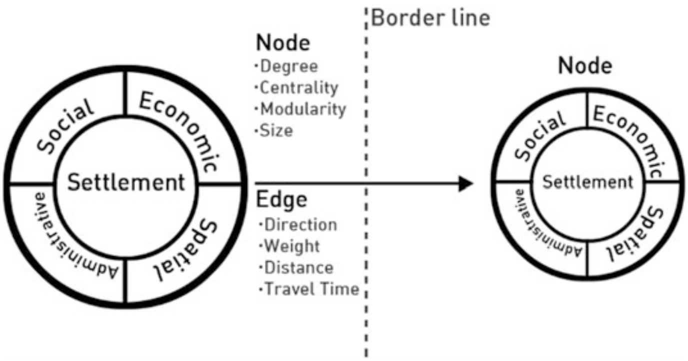

Fig. 12.3 Nodes and edges in the network of a border region

Table 12.2 Network metrics

Networks	Size (node/edge)	Modularity (clustering)	Average degree/average weighted degree	Network diameter
West border (Turkey-EU)	69/98	0.281	2.841/11.478	6
East border (Turkey-Georgia)	48/66	0.02	2.75/16.583	5
West and east borders-Turkey	117/164	0,513	2.964/14.232	8

Depending on the characteristics of the actors at different borderlands, types of interactions between the actors differ. Therefore, relations can change according to the type of interaction, the intensity of the interaction and the content of the interaction. In this study, the data about actors and their relations collected by the questionnaire was used to display the characteristics of social and economic relationships and to analyse macro and micro level network structures of border region settlements. Macro level network analyses reveal network metrics like network size, modularity and network diameter. Micro level network analyses include centralities like; degree centrality-hub and authority (Kleinberg 1999), closeness centrality, betweenness centrality.

From the data collected by the questionnaire applied to 400 inhabitants in the Thrace border region and 400 inhabitants in Hopa-Batumi border region, macro network characteristics were explored as in Table 12.2.

Among the macro level analysis of the networks, modularity (clustering) feature stands out as the main feature of networks. Modularity is defined as the separation of the clusters on the network and plays a key role in social behaviour of nodes on the network (Reichardt and Bornholdt 2007). It is estimated by the degree of interaction. Modularity coefficient can take values between 0 and 1 and values close to 1 have higher modularity (Newman 2006). Marcoux and Lussea (2013) argue that if modularity increases, the possibility of cooperation in the network will increase. However, while high modularity shows a strong interaction in the cluster, it can at the same time be the indicator of weak interaction between the clusters. In this perspective, considering the modularity values of the border regions, interactions between Turkey-EU borders (0.281) seem more directly and heterogeneous compared to the east border (0.02) of Turkey. The analysis explores that in the west and east border regions, there are three main clusters based on the relations of the settlements (Fig. 12.4).

Degree is the simplest macro level network measure. It analyses the local structure around nodes considering the number of ties that a node has. In a directed network, a node may have a different number of outgoing and incoming ties, and therefore, the degree measure is defined as out-degree or in-degree, respectively (Opsahl et al. 2010). The weighted degree of a node is based on the number of edges for a node and summed by the weight of each edge. In the border region

Fig. 12.4 Modularity of the total network

context, the edge's weight represents the level of relations among settlements. Thus, the average weighted degree here is equivalent to the average number of relations between settlements.

In the micro levels analysis of networks, the main measuring tool is centrality. Centrality indicates critical positions that are often seen as leadership or popularity in the network (Valente et al. 1997). It describes the relation of a specific node to the overall network in a given framework. In addition centrality is interested in how a node is connected, how easily a node can reach to other nodes, how important a node is in terms of connecting other nodes and how important, central or influential a node's neighbours are (Borgatti 2005).

Centrality measures delineate the position of actors relative to other actors in the network. Importance of vertices in a network can be revealed by centrality measures. Several centrality measures are used to measure an actor's position (Wasserman and Faust 1994) and the actor's influential effects in the network. Four of them; closeness, degree, betweenness and eigenvector are the ones to measure different and distinct characteristics of the network more effectively (Valente et al. 2008). Closeness, degree and betweenness were proposed by Freeman (1979) and eigenvector was proposed by Bonacich (1972). In the context of the border region, these measures can be used to investigate the spatial dynamics of the border regions. Centrality helps to find out which settlement is most likely to get affected and which settlement is most likely to affect the other settlements. Centrality measures, which are dependent or independent from geodesic distance reveal different characteristics of networks. In terms of the degree of social and spatial relations in the border region, the influence of geodesic distance can increase or decrease. For this reason, the border line can change the perception of proximity measured by the centrality. Evaluating four of the centrality measures together in this study is to compare the results of each and to interpret different meanings they bring out in the border regions.

A node's closeness centrality gives the sum of geodesic distances from all other nodes, where the distance from a node to another is defined as the length of the shortest path from one to the other (Freeman 1979). Closeness measures are based on the ideas of efficiency and independence (Freidkin 1991). As a result of being situated close to the others in the network, actors with high closeness measures are able to transmit the information efficiently and have the independence that they do not need to seek information from other more peripheral actors. In the border region context, closeness gives some perspectives about locations. However, as the geodesic characteristics of closeness ignore the geographic distances, the results generally appear as independent from the spatial context. Although it does not directly evaluate the spatial pattern, high closeness scores of the settlements like Edirne (0.70), Alexandroupoli (0.47) in the west and Batumi (0.36) in the east seem to define the central or sub central role of the settlements in the region. On the other side, from the closeness analysis, it is found out that as the number of border crossings increases, the closeness centrality of the settlements increases, as well.

The degree centrality of a node indicates how well a node is connected to the others in terms of direct connections, but it does not measure how well located is a node in a network (Jackson 2008). It ranges from 0 to 1. Actors who have more ties can be in advantageous positions, as they may have alternative ways to link and be able to call on more of the resources of the network as a whole (Hanneman and Riddle 2005). Using the directed data, it is possible to distinguish the characteristics of the link, in terms of in-degree centrality or out-degree centrality. If an actor receives many ties, then it is often said to be the authority. That is, many other actors seek to direct their ties to that actor. Besides, actors who display high out-degree centrality are often said to be the hub actors. For the west and east borders of Turkey, it is seen that in the total network, Edirne has the highest authority value and Istanbul follows it. From these values it is seen that although Edirne seems as the only authority in the border region, another settlement out of the border region; Istanbul, has a high value of authority as well. Istanbul having a high value of authority shows the solid impact of the greatest city of Turkey on the cross-border relations. Regarding the other settlements, it is interesting to observe that in the East Border, there is a balanced degree centrality value of Artvin from the Turkish side and Batumi from the Georgian side; but in the West Border, there is the dominance of one settlement Edirne in the region. From the hub analysis, it is observed that Edirne, Istanbul and Batumi settlements have the highest values (Fig. 12.5). It is also interesting to see that although some of the settlements have lower authority values, they get higher scores in hub values like Kobuleti, Orestiada and Rize. This can be interpreted by the relatively high out-degree centrality values of these settlements in the east border region.

In addition, although the cities with high authority and hub values for both border regions appear as the centre of the border region, actually they are geographically located on the periphery of the nation states. Edirne, for example, in the western border region, is located at the centre of the border region while being at the periphery of Turkey. Contradictory to this is Istanbul, which is not located

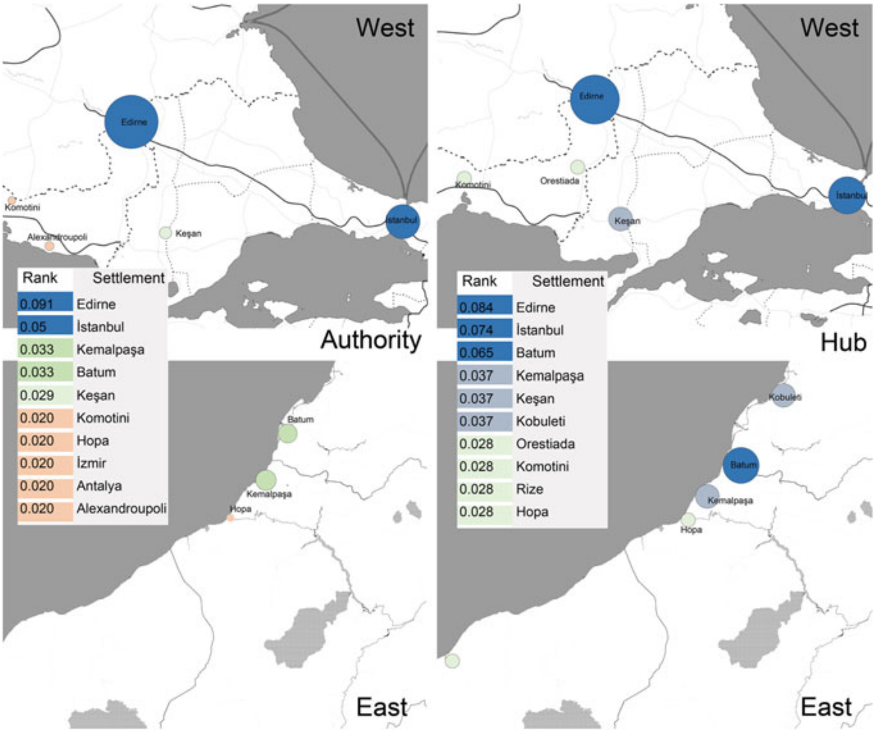

Fig. 12.5 Authority and hub analysis of the west and east border regions of Turkey

geographically in the border region, but has a high authority value due to the social, economic and political relationships that exist beyond spatial proximity.

The evaluation of hub and authority values together gives clues about reciprocal relations among settlements. Reciprocity in a network is defined as the tendency towards forming mutual links with each other. In a highly reciprocal relationship, both parties share equal interest in keeping up their relationship, while in a relationship with low reciprocity, one person is much more dominant than the other (Akoglu and Pedro 2005). Reciprocal relationships in the network are strongly associated with authority and hub value correlations. The correlation between authority and hub gives the degree of symmetry of the network. According to results of correlation between the authority and hub values, relations in the west border regions ($\beta = 0.695$, $p < 0.01$) is more symmetric than the east border region ($\beta = 0.519$, $p < 0.01$) of Turkey. Table 12.3 shows that there is a moderate symmetrical network for eastern and western border regions. When the total reciprocity of the relationships among all settlements is analysed, the reciprocity between Turkey and EU border appears higher than Turkey-Georgia border.

Another centrality measure, the betweenness centrality, describes the actor's position on the shortest paths between other actors. Settlements which have high

Table 12.3 Correlations between authority and hub

West and east border regions		Authority	Hub
Authority	Pearson correlation	1	0.657
	N	111	111
Hub	Pearson correlation	0.657**	1
	N	111	111
West border region		Authority	Hub
Authority	Pearson correlation	1	0.695
	N	63	63
Hub	Pearson correlation	0.695**	1
	N	63	63
East border region		Authority	Hub
Authority	Pearson correlation	1	0.519
	N	48	48
Hub	Pearson correlation	0.519**	1
	N	48	48

**Correlations are significant at the 0.01 level (2-tailed)

betweenness centrality, have the potential to influence other settlements near them in a network and can potentially influence social and economic flows through the network as a bridge. The concept of bridge is defined as the vertices that cross structural holes between discrete groups. Each settlement that connects to other settlements in the network can therefore be defined as a bridge. Also betweenness centrality identifies the position of an entity within a network in terms of the number of occurrences between the shortest paths with other pairs. A settlement with a high betweenness centrality generally holds powerful position in the network. In the west and east borders of Turkey, highest betweenness centrality values are numbered as Edirne (0.51), Istanbul (0.37) and Batumi (0.36) respectively. From these values it is seen that Edirne and Batumi seem critical settlements in order to connect actors for their border regions. Also Istanbul has a high value of betweenness centrality which shows that regardless of the distances Istanbul has potential to connect both two border regions (Fig. 12.6).

Eigenvector centrality weighs the links to other nodes, unlike other type of centrality measures including indirect connections (Bonacich 2007). Those with high eigenvector centrality are linked to well-connected actors and so may influence many others in the network directly or indirectly through their connections. Eigenvector centrality is more rigorous than closeness, degree and betweenness centrality measures. For the west and east borders of Turkey eigenvector centrality degrees have similar results. Edirne with its highest eigenvector centrality value (1.0) can be called a "centre of periphery" in the West. Batumi has similar characteristic for the East with a value of (0.46). Also Istanbul with its high eigenvector centrality value (0.41) has influence on both of the regions (Fig. 12.6).

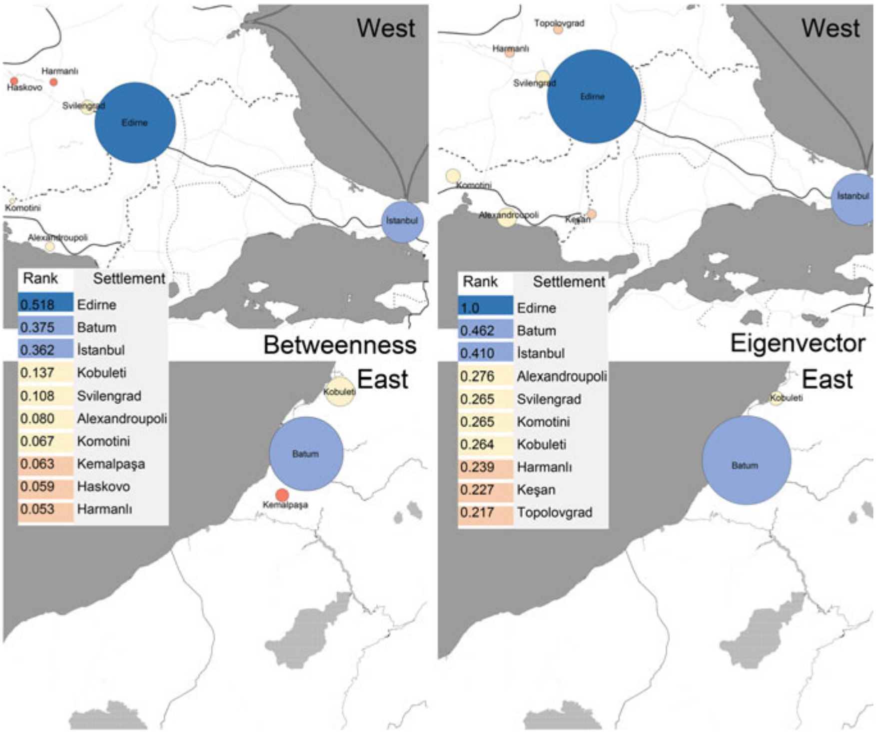

Fig. 12.6 Betweenness and eigenvector analysis of the west and east border regions of Turkey

For the western border network, Edirne with 0.51 value of betweenness centrality is the main and most important node in the network structure and appears as a regional hub for this border region. Istanbul, Svilengrad, Alexandroupoli and Komotini follow Edirne respectively. The population and distance from the border, socio-cultural relations and daily economic relations appear as important parameters for these findings. Edirne in Turkey is the biggest and nearest city for the three sides of the border and it has the hub position as Turkey's biggest regional centre. Svilengrad in Bulgaria is also the nearest settlement to the border and mostly popular with its casinos for Turkish tourists. In Greece part, Alexandroupoli follows Svilengrad which is biggest city nearest to the border.

In the eastern border network, Batumi is placed in the most central position through the network with the value of 0.37; Istanbul, Kobuleti and Kemalpaşa follow up Batumi. Batumi is in a central position in the eastern border region, hence socio cultural and economic relations become intense in Batumi. On the Turkish side, there is more than one node for daily economic and social relations. The most centrally positioned ones are Kemalpaşa 0.15, Hopa 0.15 and Sarp 0.14 respectively.

12.4.3 Spatial Extractions

The border space is affected by transnational flows of both local and national socio-economic functions. Szekely (2013) quotes from Renard and Picouet (1993) about the spatial organization of cross-border regions and classifies the urban settlements by evaluating the parameters such as border line, spatial development level, cross-border relations and population. The evaluation of these parameters brings out the spatial classifications like dynamic border region, border space undergoing metamorphosis and asymmetric/symmetric or cutting and filtering borders. This theoretical framework introduces urban typologies for border cities existing on both sides of the border in relationship with each other (Fig. 12.7).

In nation states despite the prohibitory effects of the boundary, border settlements can form different spatial typologies and relationships. In addition to Szeleky (2013) this study brings out an extended analysis by including the social networks to explain the spatial structure of the region which can contribute to the governance model for these regions. Defining the cross-border social, economic, political and spatial relations and measuring the level of relations among them may also help to go beyond the morphological and functional characteristics of settlements located along the border and help to explore the relational potentials of them. Regarding this, Fig. 12.8 displays the socio-spatial network structures in the west and east border regions of Turkey. From Fig. 12.8, it is possible to follow the centrality of settlements, closeness to border line and the structures of relations due to the direction of the flow among the settlements. While more symmetrical relations are observed in the west border, in the east border there are more asymmetric relations between the settlements. The density of flows is less but more homogenous among settlements in the West, but in the East, relations among some of the settlements are much denser relative to the other settlements.

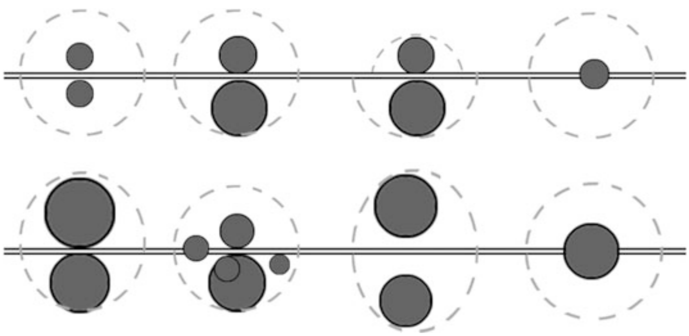

Fig. 12.7 Typology of settlements in cross-border areas (adapted from Szekely 2013)

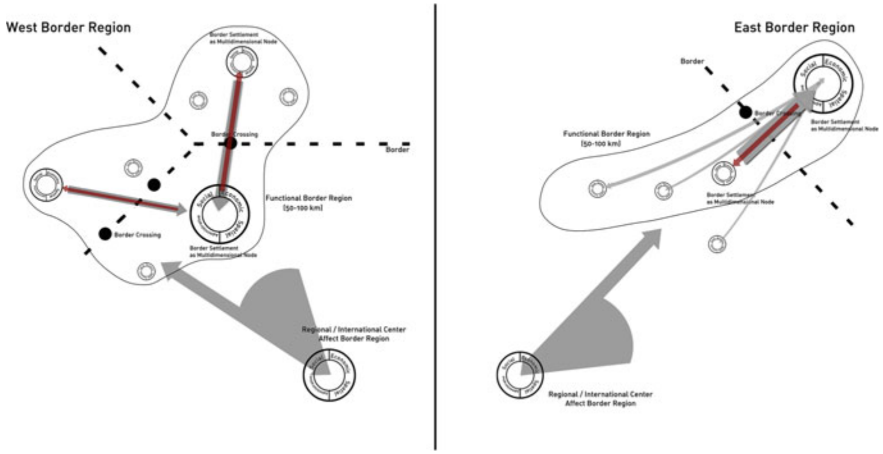

Fig. 12.8 Socio-spatial network structures of west and east border regions of Turkey

12.5 Conclusion

Social, economic and spatial relations coexisting within multiple scales have expanded their territorial boundaries for the last 30 years, thus it becomes important to address these places just as Massey (1993:66) does, i.e., "instead of thinking places as areas with boundaries around them, they can be imagined as articulated moments in networks of social relations and understanding". Regarding this, the study tries to figure out socio-spatial relationships in border regions, which appears as the meeting spaces of cross-national or supranational flows. It proceeds from the question of how social relations impact the spatial network structures and what are the characteristics of the socio-spatial networks among the settlements in the border regions of west and east of Turkey.

In the west and east border regions of Turkey with similar permeability levels, the socio-spatial networks analysis among the settlements of both sides exhibit somehow similar and somehow different functional and relational structures. The intensity of the flows is generally affected by the national level political decisions. This is interpreted from the findings that under the same umbrella of EU supranational structure, two different countries (Greece and Bulgaria) have different levels of relations and different socio-spatial network structures with Turkey. It shows that despite the efforts of the EU structural funds for increasing cross-border relationships among countries, the national border policies and the historical processes with neighbouring countries are the main determinants that affect the intensity of flows across the borders.

When the border region concept explored from the study is evaluated, it corresponds to an impact area with fuzzy boundaries, including intensity, reciprocity and dependency of relationships among the settlements, rather than a space with clear-cut boundaries. Being close to the borderline is a factor strengthening the position of the settlement in the socio-spatial network. However, other factors like being close to the border crossing, the population size of the settlement and the place of the settlement in the urban hierarchy affects the centrality of the settlement in the network. Regarding these, Edirne-Turkey in the west border and Batumi-Georgia in the east border of Turkey appear as the two central settlements in the network. On the other hand, disregardful to the distances, the dominance and the impact area of Istanbul is observed clearly in the network both for west and east borders. Within the framework of socio-spatial relations there is a moderate symmetrical network for eastern and western border regions. When the total reciprocal relationship of the all settlements is analysed, the reciprocity between Turkey and EU border appears higher than Turkey-Georgia border.

The analysis promotes two essential aspects of a border: while it acts as a social barrier between countries, it can at the same time be a bridge between the communities inside and outside the country. From this analysis on a regional scale, it is possible to assess the region as a whole regarding the spatial and social relations. Thus, in the spatial planning process, putting forward the spatial implications of social, economic and political relationships together may guide the decision makers for developing interaction and governance models that help the region to act as a centre rather than as an area isolated by a border line and located in the periphery. This may help to create a territory of diverse local identities around a sense of place, where all parts are encouraged to maximize their potentials.

Acknowledgements This research was financially supported by Scientific and Technological Research Council of Turkey (TUBİTAK), SOBAG-114K887.

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Chapter 13
Outlook and Next Steps: Integrating Social Network and Spatial Analyses for Urban Research in the New Data Environment

Xingjian Liu, Yang Xu and Xinyue Ye

13.1 Introduction

As illustrated by the previous chapters in this edited volume, the interactions between spatial and social dimensions of the built environment have both conceptual and practical significance. However, many previous studies have adopted social network and spatial analyses separately to understand the built environment. In this book, we hope to put forward a discussion regarding how social network and spatial analyses could be combined for a more refined understanding of the built environment.

The need for such an integration takes places in a new data environment. Urban studies and planning might be approaching a 'technological inflection point' with the rise of information and communications technologies (ICT), smart cities initiatives, and powerful computing devices (Batty 2013; Rabari and Storper 2014;

Xingjian Liu would like to thank the organizers and participants at the 'Future of Urban Network Research' symposium, Ghent, Belgium, 18–20 September 2017, for their illuminating discussions. Yang Xu is grateful for the financial support from The Hong Kong Polytechnic University Start-Up Grant (1-BE0J). Xinyue Ye would like to acknowledge the financial support from National Science Foundation (1416509, 1535031, 1637242, 1739491).

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X. Ye and X. Liu (eds.), *Cities as Spatial and Social Networks*, Human Dynamics in Smart Cities, https://doi.org/10.1007/978-3-319-95351-9_13

Ruths and Pfeffer 2014; Shaw and Sui 2018). The combination of smart cities, open data and open government initiatives, ubiquitous computing, broadband internet, linked sensors, location-based services, and digitally enabled devices has turned the city into a data pool, creating a new data environment for urban research (Offenhuber et al. 2012; Batty 2013; Liu et al. 2015; Shaw et al. 2016; Ye and Liu 2018). This new urban data environment includes open data, big data, as well as emerging data infrastructures (Kitchin 2014). Datasets about urban dynamics are being produced at very fine spatial and temporal scales, oftentimes as 'data exhaust' during the operation of websites (e.g., Internet search and online shopping records), social media applications (e.g., Facebook and Instagram), service providers (e.g., mobile phone data), government and non-government agencies (e.g., open government initiatives) (Shaw et al. 2016).

These new urban datasets provide us with useful information to better link urban dynamics in and across physical, social, and virtual spaces. This new urban data environment could provide alternative ways of characterizing theoretical constructs (e.g., urbanity, place, and community), enable new approaches to urban planning and management, and inform new pathways towards urban development and sustainability (Shaw et al. 2016). Although it will not solve all urban problems on its own, this new data environment would help characterize urban dynamics and inform policy and planning at finer spatiotemporal resolutions than before (Glaeser et al. 2016).

Furthermore, the promises and limitations of integrating social network and spatial analyses (with or without the new data environment) have been reflected in related fields, such as sociology (Adams et al. 2012), public health (Emch et al. 2012; Perez-Heydrich et al. 2013), GIScience (Andris 2016), and organization science (Wineman et al. 2009; Sailer and McCulloh 2012). In this short concluding piece, we attempt to discuss the potential for integrating spatial and social network analyses for urban research and try to cover the theoretical, methodological, data, and applied aspects. While we have offered some initial thoughts in a related editorial (Ye and Liu 2018), we would like to further elaborate here the potential and challenges for such integration in the new data environment.

13.2 Possibilities for Integration

13.2.1 Integration of Conceptualizations

A first step in integrating social network analysis and spatial analysis requires the conceptualization of the built environment in terms of nodes (vertices) and links (edges). Nodes and links are the most basic building blocks in network research (Andris et al. 2018; Ye and Liu 2018). As suggested by Poorthuis and Van Meeteren (2018), this entails a 'nodalization' process, whereby a complex built environment is rendered "a discrete set of nodes between which interactions are modelled as edges is crucial". For example, in the analysis of networks at the inter-city scale (e.g., the world city network (WCN) approach developed by the Globalization and World Cities Research Network; Taylor and Derudder 2016), individual cities are treated as 'nodes', where flows of goods, information, and people between cities are deemed 'links' between cities. Similarly, road junctions and segments are conceived as 'nodes' and 'links' in the study of street patterns, as evidenced in the Space Syntax literature (Hillier and Hanson 1984).

The key theoretical concern is therefore with the analytical unit, i.e., what are the 'nodes' in the network (van Meeteren et al. 2016; van Meeteren and Poorthuis 2017). More specifically, "the main debates … concerns the choice of 'appropriate' spatial units and the relevance of 'interaction' between these spatial units" (van Meeteren et al. 2016, p. 61). On the one hand, the integration of these two types of analyses needs to be conceptualized and performed on the same analytical units. Spatial analysis tends to focus more on what happens within these analytical units, whereas social network analysis can more aptly analyze the interactions between these units. If spatial and social network analyses are based on different analytical units, we are likely to encounter issues such as the uncertain geographic context and modifiable analytical unit problems (Kwan 2012). On the other hands, the interactions between 'analytical units' must be relevant. In other words, we need to be clear about what the 'network' is and should not use social network analysis for its own sake. Van Meeteren et al. (2016, p. 61) demonstrate these two conceptual issues within the context of urban economics, and post the question that "are cities, regions, or other types of agglomerations the crucial geographical units of analysis if we want to understand economic development or is it better to focus on the interactions between these units, that is, networks of regions, cities and agglomerations, to fathom this conundrum?" Relatedly, in line with the call for 'use-inspired basic research' (Stokes 1997), having analytical units that are commonly understood and used by researchers and practitioners/professionals may ease knowledge exchange and facilitate research impacts.

The discussion about analytical unit has significant theoretical implications, as different analytical units essentially speak to different bodies of theoretical literature (Burger and Meijers 2016). For example, in the discussion of urban systems, Poorthuis and Van Meeteren (2018) suggest that "what we nodalize as a 'city' in urban network models is in fact a complex field of nested and imbricated, yet relatively autonomous, urbanization processes", and that these different nodalizations are respectively in line with different classical theories about the organization of the urban space, such as the daily urban system (Coombes et al. 1979) and Central Place Theory (See also Derudder and Taylor 2017). By the same token, Space Syntax's conceptualization of streets and plans is closely related to the observation that urban form and activities tend to overlap, especially in 'old cities' (Hillier and Hanson 1984).

13.2.2 Integration of Analytics and Methods

With recent ICT advancements, new data sources emerge that are able to capture different types of interactions among people and places. These data sources (e.g., mobile phone and social media data) have provided new opportunities for integrating spatial and social network analyses. At the beginning of this century, debates have emerged regarding how information and communication technologies may (re)shape the relationship between geography and human interactions (Cairncross 2001; Xu et al. 2017). As a result, many studies have started to examine the geographic properties of different social networks. We will narrow our scope here and demonstrate several major empirical ways of combining spatial and social network information. Our examples will mainly be drawn from the emerging field of human dynamics (Shaw et al. 2016).

One common approach is associating individuals within a social network to locations in geographic space (Liben-Nowell et al. 2005; Andris 2016). These locations usually refer to places where individuals' daily activities occur (e.g., home). By doing so, different types of social relationships can be analyzed from a spatial point of view. For example, many studies have found that there are distance decay effects in friendship or the connection strength of members within a social network (Backstrom et al. 2010; Goldenberg and Levy 2009; Xu et al. 2017). By embedding social networks into physical space, these studies have provided empirical evidence regarding how geographic distance and proximity shape social network structures.

Human is the central element that connects spatial and social networks. The behavioral dynamics of human in one type of network is highly related to that of the other. This has inspired researchers to investigate the interaction between social relations and activities of individuals in physical space. By using mobile phone data, Toole et al. (2015) suggest that the visitation patterns of individuals are much more similar to those of their social acquaintances than those of strangers. In another mobile phone based research, Calabrese et al. (2011) find that people who contact each other frequently are more likely to co-locate in space at the same time. Given the strong connection between human mobility and social relations, new methods can be proposed to predict the structure of one network type based on that of the other. For example, relationships of social contacts are proved to provide additional capability of predicting human movements in physical space (Cho et al. 2011). On the other hand, human movements in spatial networks can be used to better predict the formation and evolution of social links (Wang et al. 2011). In other words, spatial and social networks are two interconnected components that continuously shape each other.

Recently, another strand of research has focused on using information in social networks to enrich the semantics of entities in spatial networks. For example, Hristova et al. (2016) propose a framework of interconnected geo-social networks to quantify individual urban locations' social diversity. The approach makes it possible to distinguish places that are attended by diverse groups of individuals from those are frequented by regulars. In another research, Xu et al. (2017) propose two metrics, namely bonding and bridging capabilities, to identify places in cities that bring friends together versus those that facilitate chance encounters among strangers. By integrating social network and spatial analyses, these studies have shed light on the social dimension and roles of places in cities, which will be useful to urban planning (e.g., evaluating people's use of public space) and management.

13.2.3 Integration of Software Environments

Our discussion differentiates several major types of software environments: (1) those developed to handle 'spatial networks' (Barthélemy 2011); (2) those designed for 'social network' analysis; and (3) those generally developed for handling spatial information (e.g., Geographical Information Systems; GIS). Unlike social networks, the nodes and/or links in spatial networks are geographically bounded (Barthélemy 2011). Consequently, there have been different software and tools that handle these two types of networks. Each set of software was developed to solve specific research questions. From the perspective of spatial networks, the theory of space syntax has inspired the development of software for analyzing urban networks (Hillier et al. 1976; Hillier and Hanson 1984; Sailer and McCulloh 2012). Tools such as Axwoman and AxialGen were developed to describe the spatial configuration of complex urban spaces. These tools are often used to assist particular applications in urban design and planning. On the other hand, software such as UCINET and Gephi have been widely applied to visualize and analyze social network structures. Through the usage of these tools, the networks and their structural properties (e.g., small-world and scale-free networks) can be effectively revealed. There are also tools that are capable of analyzing both types of networks. Tools such as igraph and NetworkX have been broadly adopted to analyze network properties at the nodal level (e.g., betweenness and centrality) and to uncover hidden interaction communities (i.e., community detection). Unfortunately, there have been a shortage of tools and research that couple spatial and social network analysis (Ye et al. 2018).

Furthermore, current GIS functions are limited in dealing with network analysis (Andris 2016). For example, ArcGIS—which is developed by ESRI—has been widely used in academia, industry, and government sectors. Although it has incorporated certain functions of network analysis, those functions are designed to solve typical GIS problems such as way finding and vehicle routing. The abilities to reveal properties and dynamics of spatial networks remain quite limited. It is therefore important to identify key research questions that would drive the development of network analysis functions. For example, many mobility datasets such as floating car data and smart card transactions have been used to better understand urban spatial structures (Li et al. 2017). How to effectively measure these urban spatial structures from a network perspective? How to properly represent the urban hierarchy? These are all questions worth investigating. Also, there is a need to incorporate functions into GIS systems that could spatialize different types of social networks (Andris 2016). The functions should also be determined based on critical research questions. For example, critical questions include but are not limited to: how could urban researchers become literate about these new tools and datasets? How are social connections of cities related to other spatial processes (e.g., migration)? In sum, much work remains to be done to define standards and key functions for spatial and social network analyses, and eventually, the integration of the two.

13.2.4 Integration Beyond Spatial and Social Network Analysis

Having highlighted new data and methods for integrating spatial and social network analysis, we want to emphasize that there are opportunities for the integration beyond these quantitative analyses (Ye and Liu 2018). This is most evident in the recent call for integrating quantitative and qualitative studies in the world city network research (Watson and Beaverstock 2014). World city network research concerns both processes within individual cities that have given rise to their world/global city status as well as the connections between key cities (Sassen 2001; Coe et al., 2010). WCN within the Globalization and World Cities research network (Taylor and Derudder 2016) have been adopting spatial and social network analytics, which range from geospatial visualization, network centrality measures, to generative network models (Liu et al. 2013; Hennemann et al. 2015; Martinus et al. 2015). Recent studies have argued that such 'top-down' and 'structural' approaches to modeling intercity relationships have reached their theoretical impasses (Watson and Beaverstock 2014). Consequently, Watson and Beaverstock (2014, p. 412) have suggested "a move away from structural approaches in which the firm is the main unit of analysis, towards qualitative approaches in which individual agency and practice are afforded greater importance". Although such critiques can be made about any type of quantitative study, they do highlight the importance and possibilities of combining both quantitative and qualitative approaches. That being said, we should be aware of the pros and cons of quantitative analysis of the built environment. Instead, mixed methods might be needed to characterize the complexity of our human-environment interactions.

13.3 A SWOT Analysis of Integration

Next, we would like to offer a SWOT analysis of the integration within the broader context of the new urban data environment. Strength: We may be gradually heading towards the post big data era (Shaw et al. 2016; Ye 2018). Datasets that used to be considered as "emerging" are nowadays available to many institutions and researchers. The volume and diversity of new data, especially produced in urban settings, are continuously enriched by ubiquitous sensing technologies (Xu et al. 2017; Zhang et al. 2018). The emergence of new data sources is also related to a new science of cities, which analyzes urban systems through the analytical lens of networks, interactions, and flows (Batty 2013). Various analytical methods, such as spatial interaction models, scaling, and machine learning, have been used to address questions in global migration (Simini et al. 2012), prediction of social interactions (Wang et al. 2011), and socioeconomic segregation (Le Roux et al. 2017). There have been increasing efforts across different fields (e.g., GIScience, computer science, and statistical physics) to couple big data and relevant techniques/theories for integrated social network and spatial analyses. The integration of the two, however, is still at an early stage and should be motivated by key questions and challenges that we need to address in the contemporary world (e.g., aging population, sustainable urban development, social stratification).

Weakness: While there are many insightful discussions about the consequences of emerging data sources, we would like to highlight that the rise of the new urban data environment is accompanied by an increasingly multi-disciplinary workforce in studying and transforming the built environment (Kitchin 2014; Ruths and Pfeffer 2014; Shelton et al. 2015). For example, major data and information technologies companies are devising 'smart city' toolkits for cities across the world. Internet giants are transforming urban landscape with driverless automobiles and super-fast Internet. Still, major international development agencies are promoting 'big and open data' as the frontier of urban planning and management. This is also related to the many research challenges and opportunities of conceptualizing, visualizing and analyzing new spatiotemporal data (Ye and Rey 2013). On the one hand, the new urban data environment and the increasingly multi-disciplinary workforce make it necessary to remind ourselves of some methodological issues that have be long-researched in urban studies and planning (e.g., bounded rationality, rational planning, and the use of models; Lee 1973; Wegener 1994). On the other hand, as implied above, the inter-disciplinary nature of urban research opens new opportunities for cross-fertilization. For example, O'Sullivan and Manson (2015) have reflected what geographers can learn from geographical research conducted by physicists, and how geographers can build upon the model- and data-driven approaches.

However, different research fields often entail different research methods and subsequent different required skill sets. Researchers in the urban discipline (e.g., urban geography, urban studies, urban planning, and urban design) may need to at least inform themselves about techniques to make use of the new urban data environment. However, critical questions include but are not limited to the following: how could urban researchers become literate about these new tools and datasets? How good a data analyst urban researchers need to become? How could urban researchers best use the new data sources and analytics (see for example, Shearmur, 2015)? How to balance the focus on domain knowledge on the one hand and new datasets and techniques on the other hand, considering the fact that the latter is evolving (Ye 2018)? As an anecdotal evidence, similar questions have raised much discussions at the first 'Future of Urban Network Research' Symposium that the first authors has attended.

Opportunity: As hinted above, free access to and wide distribution of the data and source codes facilitate the dialogue and cooperation among computational scientists, urban researchers and the general public, in order to coordinate innovative efforts and advances in theoretical perspectives, analytical approaches, and outreach (Ye 2018). The data-driven urban science's self-correction power largely rely on the ability of research outcome reproducibility based on the open data and codes of such integration (Ye et al. 2018). The capability of recording individual's digital footprints has been growing in the emerging open culture. With the growing popularity of smart phones, citizens are acting as 'sensors' to synthesize and interpret information from many layers and sources about both the spatial and social dimensions of the built environment (Goodchild 2007). For example, such human behavior can be used to demonstrate how a specific location at a given time period might be attractive and accessible to various groups of people, which is labelled as urban vibrancy (Wu et al. 2018). The relationships between urban vibrancy (through open data such as social media check-in records) and spatial network (such as land-use configurations) can support real-time urban decision making with fine-scale spatial and temporal resolutions. The combination of open data sources and open source codes will set up a rich empirical context in front of our eyes for urban research and policy interventions towards ever-increasing size and diversity of urban data (Ye and He 2016).

Threats: A major downfall of using big data and 'digital skins' (Rabari and Storper 2014) to study urban social space may be the over-representation of communities with a sophisticated infrastructure and financially well-off young people. It is noted that there exist many depressed neighborhoods with limited infrastructure and low-income population producing under-represented amounts of digital signals (Ye and He 2016; Ye 2018; Ye and Liu 2018). Hence, the spatial dynamics (ranging from daily to long-term activity) of such biased digital landscape might negatively affect the reliability of information and knowledge retrieved from the new (big) urban data. The integration also faces the challenges of the noise and uncertainty embedded in spatial social network data, which would even increase the chances of misusing or abusing such integration to address specific urban tasks (Shaw et al. 2016). Ye and He (2016) express the concerns towards blindly big-data-driven research, arguing that the embedded uneven local contexts must be considered. Because the integrated analysis of human activities, dynamics, and interactions across social, virtual and physical spaces will possibly raise many concerns in the data security and privacy issues, more ethnical, legal, and technological efforts are urgently needed to avoid a number of threats released by the power of such integration (Shaw et al. 2016). Still, there are legitimate concern regarding confidential information which might be revealed due to spatial and social network analysis integration, especially for those disadvantaged communities and populations (Curtis et al. 2006).

13.4 Conclusion

This century has experienced tremendous strides in physical and virtual interactions across spatial scales. At the same time, the world has been witnessing a growing population size in many urban areas at an unparalleled scale and speed. New theoretical arguments, data sources, and analytical approaches have shaped the restless landscape for bridging spatial and social network analyses of the urban environment in a transdisciplinary and cooperative manner. The research agenda has been markedly transformed and reshaped in light of the cutting-edge information technology and new (big) data. Tracking the dynamics and interactions of spatial system and social system in a joint fashion will facilitate the early detection of events and phenomena in and across the communities. A better understanding of such integrated systems can help predict possible events and their outcomes/impacts in the urban setting. It offers new insight into more meaningful and reasonable policy formation of a livable and sustainable city. For example, policy makers and urban professionals can be better informed about resource allocation and sustainable design of communities (Wu et al. 2018).

With the rise of the new urban data environment, many dimensions and scales of emerging spatial social network data present both challenges and opportunities for the design, implementation, and evaluation of urban policies. However, it is difficult for most urban researchers to use cutting-edge methods due to the lack of the ability to retrieve and process such unstructured large data, let alone being unfamiliar with the open source environment where various contributed toolkit codes can be collected and modified to reflect the need of integrating spatial and social network analytics. Such weakness could become obstacles for promoting spatial-social network thinking, collaboration, and education in respective contexts (Ye 2018). In addition, the changing urban contexts necessitates innovative spatial and network thinking to provide suggestions and strategies for sustainable development (Ye and Liu 2018; Ye 2018).

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