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A Theoretical Framework and Methodology for Urban Activity Spatial Structure in E-society: Empirical Evidence for Nanjing City, China

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Abstract: The existing researches on the influence of information and communication technology (ICT) are mainly focused on human activity, whilst with few efforts on urban space. In the e-society, the widespread adoption of ICT devices not only affects almost every aspect of people′s daily life and thereby reshapes the spatial development of regions and cities, but also generates a large amount of real-time activity data with location information. These georeferenced data, however, have relatively recently attracted attention from geographers. Adapted from Lynch′s framework based on people′s perceptions, this paper proposes a framework of urban spatial structure based on people′s actual activity, including five elements, namely activity path, activity node, central activity zone (CAZ), activity district, and activity edge. In the empirical study, by using one week′s check-in tweets (from February 25 to March 3 in 2013) collected in Nanjing City, the five elements are recognized and analyzed. Through the comparison between our results and urban spatial structure based on population (and land use), we argue that ICT uses: 1) lead to polarize, rather than to smooth, the urban structural hierarchy, due to the dual role of distance; 2) enable a partial decoupling of activity and activity space node, which challenges our conventional understanding of the role of home and the utility of travel; 3) blur the boundaries of activity districts and hence may play a positive role in enriching districts′ functions, which should not be overlooked in the current urban transformation in China.
Keywords: information and communication technology (ICT); tele-activities; activity space; big data; e-society; Nanjing City

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1 Introduction

Information and communication technology (ICT) has been considered as one of the most powerful forces in shaping the 21st century in the ′Okinawa Charter on Global Information Society′. Its rapid development not only affects almost every aspect of people′s daily life, but also reshapes spatial development of cities and regions (Graham and Marvin, 1996). The function and role of the existing nodes (i.e., city nodes in a worldwide, national, regional system, activity space nodes within a city) are experiencing dramatic changes. The widespread adoption of ICT devices in people′s life has witnessed the emergence of the e-society (Loo, 2012). Given the emergence of mobile communication devices such as smart phones, wireless portable computers, and wireless personal digital assistants, and the availability of wireless Internet services such as Wi-Fi, wireless wide area network, and mobile telephone service, mobile informatization has become the new trend (de Castro and Jensen-Butler, 2003). Through this new trend people are able to access information almost anytime

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anywhere using different devices. This theoretically enables people to conduct activities by alternative e-means (i.e., tele-activity) instead of the conventional physical means (i.e., physical activity). Compared with the physical activity, tele-activity usually has less time-space constraints. Therefore, activities no longer need to be performed at certain place/time as before (Kwan, 2007) and hence, enable a partial decoupling of activity and activity space node (Schwanen *et al*., 2008).

Albeit with adequate studies focused on the impacts of ICT on the organization of people′s activities (Salomon, 1986; Pendyala *et al*., 1991; Mokhtarian *et al*., 2006; Kenyon and Lyons, 2007; Kwan, 2007; Schwanen and Kwan, 2008; Zhen and Wei, 2008; Chai and Zhao, 2009), less knowledge is known with its further influence on spatial structure from empirical analyses (O′brien, 1992; Johnston *et al*., 2002; Zhen, 2004). Though China has experienced a skyrocketing penetration of ICT devices according to a survey by Mckinsey & Company (Atsmon and Magni, 2010), the influence of ICT on people′s activities and urban space has not been well studied in academia. Note that spatial and historical contingencies are highly emphasized among these studies of other countries: context always matters (Schwanen *et al*., 2008). As a developing country undergoing rapid urbanization and informatization, an empirical study in China is important for understanding new technologies′ influence on people′s activity as well as urban activity spatial structure.

Additionally, the improved capacity to communicate, store, and compute information has promoted the Big Data Era. According to Hilbert and López (2011), the global growth of data storage is four times faster than that of economy in 2007. Big data has received increasing attention from many academic fields (Lynch, 2008), such as business (Alter, 2012), medical (Ginsberg *et al*., 2008), and sociology (Barabási and Albert, 1999; Berk, 2009). In these abovementioned analyses, big data has shown its strength to detect and reflect the correlations of the existence which, however, might be lost in analyses based on samples of small size (Mayer-Schönberger and Cukier, 2013). Until recently, geographers start to pay attention to these online ′traces′ with location information like the geoweb, spatial/social media, user-generated content, and volunteered geographic information (Wilson and Graham, 2013).

The advent of Global Positioning System (GPS) and Location Aware Devices (LAD) enables people to use their mobile devices to identify their location information based on Location-Based Service (LBS). According to the report by Pew Internet & American Life Project (2012), 74% of smart phone owners use LBS to get real-time location information and among them, approximately 20% use LBS to check-in at certain locations or share their location information with online friends. ′Check-in′ has become a popular application in the online social networks such as Twitter, Flickr, as well as the Sina micro-blog in China. It is important to note that the enormous amount of check-in data in Twitter and Flickr have already been used in geographers′ recent researches (Krings *et al*., 2009; Graham *et al*., 2013; Hollenstein and Purves, 2013). Albeit with about 3.1×10^8 users (of which 2.1×10^8 use smart phones) in China by 2012 (CNNIC, 2013), the Sina micro-blog has attracted little interest (Zhen *et al*., 2012; Long and Liu, 2013; Wang *et al*., 2013) and its value has not yet been uncovered.

The major aim of this paper is to build a theoretical framework for analyzing urban activity spatial structure based on a comprehensive review of activity space in the e-society. Thereafter, the theoretical framework will be put into practice, using innumerable check-in tweets from Sina Micro-blog in Nanjing City. Through a comparison of urban spatial structure based on the actual activity and on population (and land use), the influence of ICT on urban spatial structure will be further discussed.

2 Activity Space in E-society

2.1 ICT and its influence on human behavior and activity space

The relationship between tele-activities and physical activities could be theoretically summarized as the following four forms: substitution, complementary, modification, and neutrality (Salomon, 1986; Mokhtarian, 1990). A substitution relationship means that physical activities will be substituted by tele-activities and thereby eliminate the corresponding travel, while in a complementary relationship tele-activities will lead to more physical activities and thus generate more corresponding travel. A modification relationship refers to that tele-activities will modify the organization of physical activity and then change people′s travel behavior (e.g., travel time, travel mode, travel chain), while in a neutral relationship tele-activities have no impacts on physical activities and people′s travel behavior.

Furthermore, the increasing tele-activities in people′s daily life decouple the correspondence between the activity and activity space node. The relaxation of space-time constraints increases the flexibility in terms of physical places and chronological time which might give the impression that our daily life is becoming ′footloose′ (Dijst, 2009). The use of ICT devices (or tele-activities) enables people to break down everyday activities into small tasks at different places and different time (i.e., activity fragmentation) (Couclelis, 2009) as well as to conduct several activities simultaneously (i.e., multi-tasking) (Kenyon and Lyons, 2007). Therefore, a growing number of activities are no longer linked to particular activity space node (or location), and thereby change people′s use of existing urban node. This change will transform the urban spatial systems and blur the boundary of urban functional zoning (Kwan, 2007), which even leads to the hail of ′end of place, city, and geography′ (O′brien, 1992; Cairncross, 2001).

However, due to the lack of available data, there are few empirical studies that could answer the question that to what extent ICT has influenced urban activity space. The early analysis of people′s activity space is mainly concentrated on the static simulation of population distribution (Clark, 1951). Until the emerging of time geography proposed by Hagerstrand (1970), both temporal and spatial dimensions have been emphasized in the research on people′s activity (Zhao and Chai, 2013). Though with plentiful findings on different types of activity space, systematic and dynamic studies are relatively insufficient (Wang, 2004; Wang *et al*., 2014).

2.2 Big data in e-society and its use in urban research

In addition to the impacts on people′s activity, ICT uses have also generated new data sources, especially the real-time data with location information. Compared with the traditional methods of data collection (i.e., questionnaire, activity diary) that usually depend on the cooperation of respondents and their memory of what they have already done (Chai and Zhao, 2009), the real-time information is automatically recorded by the new technologies (e.g., LAD, GPS). The improvement of the scale, promptness, and accuracy of the data in the e-society has been highly evaluated in recent analyses (Ahas *et al*., 2007; Shoval and Isaacson, 2007; Wilson and Graham, 2013; Wang *et al*., 2014).

Big data has already been used in a variety of urban researches varying from urban hierarchy, urban network, urban functional zoning, to information production. Krings *et al*. (2009) examines the Belgian urban system based on the gravity model, using the communication data of 2.5×10^7 phone users. From the perspective of online social relationships among micro-blog users, China′s urban system is elucidated (Zhen *et al*., 2012). In the explorative work of Wakamiya *et al*. (2011), urban functional zoning is divided according to the space-time variation of check-in tweets. By using 8×10^6 Flickr images to display how tourists name the city core areas, the downtown boundary could be well identified (Hollenstein and Purves, 2013). In terms of information production, Graham *et al*. (2013) demonstrate how Twitter′s check-in tweets are unevenly distributed and through this research, he appeals strongly to geographers to put online social networks into the study of cybergeography (or neogeography).

2.3 Summary

To reflect people′s space-time requirements, understanding urban activity spatial structure from the real-time activity data is necessary for urban planning and management. As Fig. 1 shows, residents, time and space are the three factors in analyzing urban activity space. As the executor of each activity, people have to coordinate both space and time when make their location and time choice to conduct a certain activity (Hagerstrand, 1970). However, the use of ICT devices (specifically, the mobile ICT devices) has increased the flexibility among activity, time and space. Meanwhile, the real-time data with spatial information are automatically recorded by the new technologies. In addition, the existing studies are mainly concerned with the influence of ICT on human activity, whilst with few efforts on its further influence on urban space. Among these fewer efforts, dynamic and systematical studies focused on residents′ actual activity are even scarce. This paper represents a modest attempt to fill such a gap. Specifically, what framework would be applicable to analyze the urban activity spatial structure based on people′s actual activity in the e-society? What are the differences between urban spatial structure based on the

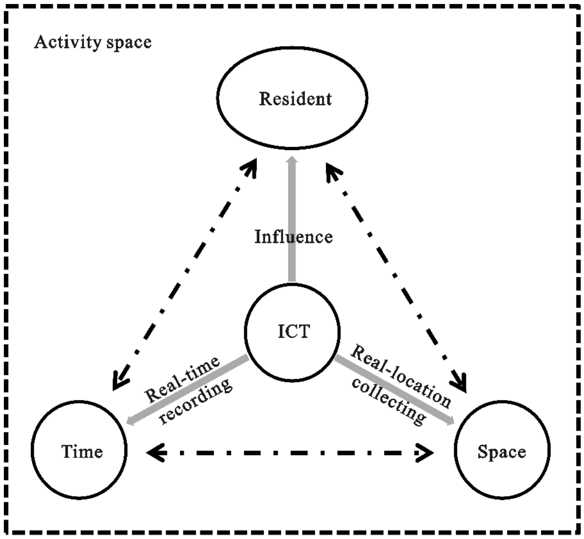

Fig. 1 Activity space in e-society

actual activity and on population (and land use), and what role does ICT play? Through an empirical study of Nanjing City, this paper wishes to shed some light on these important questions.

3 Research Design

In this section, this study first proposes a framework of urban activity spatial structure adapted from Lynch′s theory of ′the image of the city′ (Lynch, 1960). Then, the methodology will be elaborated to identify these elements of this framework by using the check-in tweets.

3.1 Framework of urban activity space

Generally speaking, urban spatial structure concerns about the distribution, combination, and evolution of different urban elements. Along with the humanist trend in social science field (Wolch and Dear, 1989), it becomes important for geographers and other social scientists to focus on people and their use of urban space. Based on people′s perception of the city, Lynch (1960) proposes a framework of the perceived spatial structure including elements of paths, edges, landmarks, nodes, and regions. In his milestone-style work, Lynch points out that the perception of the surrounding environment is built by both the stationary physical parts and the moving elements (in particular, people and their activities). In fact, people and their activities are highlighted in his definition of the five elements (Table 1). Though Lynch′s methodology has been questioned for the ignorance of differences between people′s intuitive perception and their actual activity, his work leaves an open framework that could be developed based on the actual activity. Adapted from Lynch′s framework, this paper proposes a framework of urban activity spatial structure focused on residents′ actual activity, made up of five elements as activity path, activity node, central activity zone (CAZ), activity district, and activity edge (Table 1).

3.2 Methodology

The methodology mainly focuses on: 1) how to collect check-in tweets and how to differentiate sub-districts (i.e., activity districts) reasonably; 2) how to identify activity node and CAZ; 3) how to characterize each activity district based on the temporal rhythm of check-in tweets. Details are as follows:

Table 1 Comparison of elements between urban activity space and urban perception space

Element	Urban activity space	Urban perception space (Lynch, 1960)
Activity path\path	Trajectory of people′s movement on the road and in the square (i.e., mainly refers to residents′ commuting space)	′The network of habitual or potential lines of movements through the urban complex′
Activity node\node	An area with a certain degree of activity concentration, including at least two types of activity; and thus shows a slighter variation of check-in tweets along time slice compared with usual activity districts	′Conceptual anchor points in the city′
Central activity zone (CAZ)① \ landmark	The most concentrated activity area all along the time slice; a comprehensive activity area with plentiful types of activity	′Singularity, contrast with its context or background; helps to identify direction and location′
Activity district\district	An area of homogenous activity and thus shows an apparent variation of check-in tweets along time slice	′An area of homogenous character, recognized by clues which are continuous throughout the district and discontinuous elsewhere′
Activity edge\edge	Boundaries between activity district including natural, artificial, and other ′flexible′ border	′A certain continuity of form throughout their length; boundaries between regions′

① In ′*The London Plan*: *Spatial Development Strategy for Greater London* (*since 2004*) ′, central activity zone (CAZ) as a concept was proposed for the first time. It is defined as a multi-activity area within the scope of the original CBD.

(1) Data collection. In this study, a week′s check-in tweets (from February 25 to March 3 in 2013 in Nanjing City①) were collected with the aid of open API (place/nearby_tmeline) of Sina Micro-blog. A total of 149, 178 check-in tweets② are collected. For each tweet, the space-time information is recorded for analysis. Longitude and latitude coordinates of each tweet are imported into ArcGIS, matching with the land use map of Nanjing. The temporal information is up-to-the second (like, 2013-02-28, 16:29:54), which is attached to each tweet in ArcGIS as well.

(2) Extracting check-in tweets on traffic route. Extract these check-in tweets posted on roads and squares to show people′s activity path.

(3) Division of urban activity districts. To characterize the activity district, we need to divide the whole city into sub-districts which will be then used as the unit in examining the temporal rhythm of the check-in tweets. K-means clustering method in ArcGIS is usually used to compute the geographical occurrences of a dataset and differentiate heterogeneous geographical regions. In this research, k-means clustering method is adopted to configure boundaries of sub-districts properly based on the geographical distribution of these check-in tweets. And 90 districts are finally differentiated with a significant correlation coefficient ($R^2 = 0.98$).

(4) Measuring the number of check-in tweets in each sub-district. First, count the number of check-in tweets in each sub-district to measure how people′s activity is concentrated. This number will be also used to identify and separate activity nodes and CAZ. Second, count the number of check-in tweets every 3-hour by splitting a day into eight equal time slices of morning (i.e., 6:00–9:00, 9:00–12:00), afternoon (i.e., 12:00–15:00, 15:00–18:00), evening (i.e., 18:00–21:00, 21:00–24:00), and night (i.e., 0:00–3:00, 3:00–6:00), which will be then used to examine the temporal rhythm pattern of each sub-district.

(5) Characterizing activity districts. The characteristic of each activity district will be revealed by its temporal rhythm pattern, measured by the variation of the number of check-in tweets in each 3-hour slice. The temporal rhythm pattern of a sub-district can be quite different, but some of them will show a remarkable similarity. For example, an increasing trend of check-in tweets from morning to afternoon and then stays steady during evening but finally decreases at night. To find the similarities, in each sub-district, let 6:00–9:00 as the starting point (usually, people get up and begin a new day during this period) and make the number of check-in tweets during this time slice as 100. Then, the number of check-in tweets during other time slice T_t is calculated as:

$$T'_{6:00-9:00} = 100$$

$$T'_t = T'_{6:00-9:00} \times \frac{T_t}{T_{6:00-9:00}} \times \frac{\sum_i^{90} T_{6:00-9:00}}{\sum_i^{90} T_t}$$

where $T'_{6:00-9:00} = 100$ is the standardized number of check-in tweets at the starting point. T'_t and T_t are the standardized number and the actual number of check-in tweets at other 3-hour slice t, respectively.

Then for each sub-district there is a changing pattern, $F_{(i)} = (T'_{6:00-9:00}, T'_{9:00-12:00}, T'_{12:00-15:00}, T'_{15:00-18:00}, T'_{18:00-21:00}, T'_{21:00-24:00}, T'_{0:00-3:00}, T'_{3:00-6:00})$. To make it simpler, we try to find common patterns from the temporal rhythm patterns of 90 sub-districts. In this experiment, six types of common patterns are finally extracted. And according to people′s usual activity regularity in a day, six activity districts based on the common patterns are defined as ′multifunctional area′, ′bedroom area′, ′office area′, ′dining area′, ′shopping and dining area′, and ′nightlife area′, respectively.

a. Office area. As Fig. 2 shows, the standardized number of tweets increases from 6:00 and stays above 100 till 18:00, while suddenly decreases from 18:00. In other words, more people occur and come to this district and keep slightly active there until the afternoon, and then leave the area in the evening.

b. Bedroom area. As Fig. 2 shows, the standardized number of tweets decreases from 6:00 and stays below 100 till 18:00, while suddenly increases from 18:00 and

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① The administrative division before 2013 is adopted, including *Xuanwu*, *Baixia*, *Qinhuai*, *Jianye*, *Gulou*, *Xiaguan*, *Qixia*, *Yuhuatai*, *Jiangning*, *Pukou* and *Luhe*. Meanwhile, according to the master plan in 2012, Nanjing City is divided into two parts: downtown surrounded by the belt of highways and Changjiang (Yangtze) River, and the outer as outskirts.

② Tweets in scientific and research institute are excluded because of the homogenous activity type.

then decreases from 24:00 and stays below 100 again. In short, most of people leave this district in the morning, but occur and come to this area in the evening and keep slightly active there. During the night, they do not keep active.

c. Leisure area (dining area, shopping and dining area, and nightlife area). As shown in Fig. 2, the standardized number of tweets in the dining area and the shopping and dining area all increases from 6:00 and stays above 100 till the evening and even the night. The difference is that in the dining area there are two distinct peaks at noon and dusk while in the shopping and dining area there is only one peak at 18:00–21:00. For nightlife area, the index increases from 6:00 till 24:00 and only decreases slightly after 24:00 but still staying above 100. In short, more people occur and come to the dining area at noon and dusk, and keep active; while more people occur and come to shopping and dining area in the evening and keep active; and enough people stay in the nightlife area until night and keep active.

d. Multifunctional area. As shown in Fig. 2, the standardized number of tweets in the multifunctional area jumps from 6:00 and stays above 100 during almost all the day. The index fluctuates at 18:00 when reaches the peak, while generally staying at a high level from 12:00 to 24:00. In short, this district attracts multitude number of people, and people keep active till the night. In other words, there are multiple types of activity happened there to keep the high level of check-in tweets.

4 Results

In this section, our empirical findings of urban activity space in Nanjing City are basically shown in Fig. 3. Then particular attention is devoted to the comparison between the urban spatial structure based on the actual

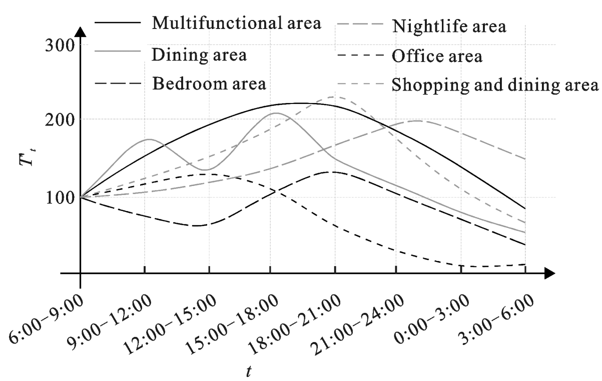

Fig. 2 Activity patterns and estimation of geographical regularity

activity and on population (and land use) to further discuss the influence of ICT on people′s use of urban space nodes, based on the supposition that people who frequently use online application usually have a high level of ICT use (Dijst, 2009).

4.1 Urban activity spatial structure

Following the framework of urban activity space, five elements are recognized. As shown in Fig. 3, the road system within the downtown and connecting the downtown and new urban areas (e.g., Jiangpu, Jiangning, Xianlin) in outskirts and the airport, and the regional highway connecting Nanjing and cities in Anhui and Northern Jiangsu have become the primary activity paths in Nanjing City. In the downtown, Jiangdong south road–Jiangdong north road, Zhongshan south road–Zhongshan north road, and Longpan road in the south-north direction; Beijing east street–Beijing west street, Zhongshan east street–Hanzhong street–Yunjin street, and Yingtian street in the east-west direction are the main activity paths. These abovementioned activity paths in fact constitute the commuting route of residents, connecting each activity district in Nanjing City.

Based on the number of check-in tweets in each activity district, the activity nodes consist of six activity districts including district in Hexi new town surrounding Wanda shopping mall, district in Xianlin surrounding Xianlin center, district in Jiangning surrounding Baijiahu and Dongshan, district in Jiangpu surrounding Hongyang shopping mall, district surrounding the high-speed railway station and airport. The district surrounding Xinjiekou which reaches as far as hu′nanlu in the north Confucius temple in the south and Daxinggong in the east, is the CAZ in Nanjing City.

Only 49 activity districts out of the 90 ones, with a high level of activity occurrence (more than 50 check-in tweets/km^2), are selected in the analysis. Based on their temporal rhythm patterns, only 14 districts could be categorized into separate office areas or bedroom areas, while the majorities are multifunctional areas or areas with combined temporal rhythm patterns of both leisure area and office (bedroom) area. Besides, in the fringes between downtown and outskirts there are some unknown areas which have quite chaotic temporal rhythm patterns out of the six common patterns. This may result from the disequilibrium development of these districts and the complicated mix of different social groups in these districts with the rapid urbanization and urban

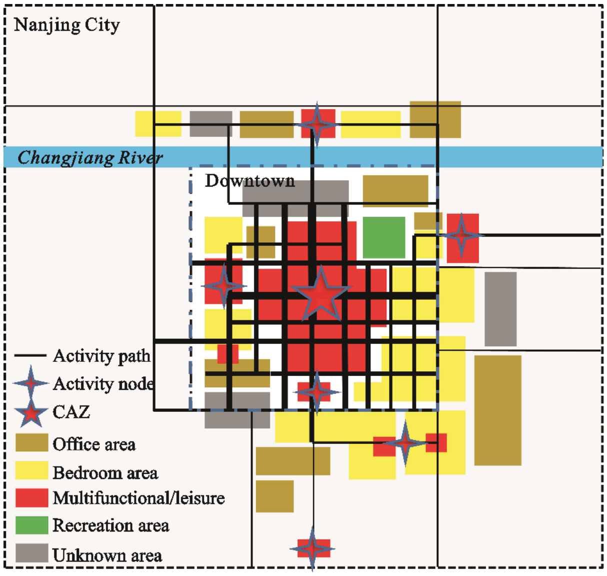

Fig. 3 Activity spatial structure in Nanjing City

growth in China (Cui and Wu, 1990). Moreover, by the comparison of check-in tweets of weekdays and weekends, recreation areas are also recognized.

Compared with the usual types of edge (Lynch, 1960), first, physical features such as mountains and rivers still play an important role in the differentiation of activity districts, especially given the fact that the Yangtze River bisects the activity district along the river. However, the role of physical features almost disappears in the downtown while being important in the outskirts. Because even these mountains and rivers in the downtown have already become people′s important activity space, especially as recreational areas. Second, neither roads (in addition to some regional highway) nor administrative boundaries play obvious roles in the differentiation of activity districts. The reason is that with the aid of mobile ICT devices, a lot of tele-activities can be conducted during the travel, which enables the trains, buses, and cars to become a moving space for conducting other activities. Third, it is important to point out that the activity districts nearby do not necessarily have different temporal rhythm patterns.

4.2 Influence of ICT on people′s daily use of urban space nodes

By the comparison between the abovementioned results and the traditional urban spatial structure based on population (and land use), this study further discusses the influence of ICT on people′s daily use of urban space nodes, from the perspective of the structural hierarchy, the correspondence of activity and activity space node, and the boundary between activity districts.

(1) Polarizing urban structural hierarchy. Geographers have long suggested that the frequent use of mobile ICT devices will lead to the flexible use of urban space nodes and thereby alter the traditional spatial division of urban hierarchy made up of centers and peripheries (Graham and Marvin, 1996; Kwan, 2006). Because of the changing principle of distance decay mechanism in the virtual world, Zook (2001) proposed the discussion of ′old hierarchies or new networks of centrality′. As shown in Table 2, our study indicates that people′s daily use of urban space nodes not only follows but also polarizes the traditional urban hierarchy based

Table 2 Comparison of hierarchy based on population and check-in tweets

Hierarchy	Name	Percentage of population in 2010 (%)①	Percentage of check-in tweets (%)
Downtown	Downtown	58.9	69.5
New urban area	Jiangpu	7.2	4.5
	Jiangning	9.1	5.6
	Xianlin	3.9	4.0
	Sum	20.1	14.1
New town	Xiongzhou	2.3	1.1
	Dachang	3.2	1.7
	Xinyao	1.0	0.6
	Longtan	0.7	0.1
	Banqiao	1.3	0.5
	Sum	8.5	4.1

① Data are acquired from *Nanjing Master Planning (2010–2020)*.

on population. However, compared with the traditional urban hierarchy, it is important to note that some key regional transport hubs (e.g., high-speed railway station, airport) which play key roles in 'the space of flows' have also become important nodes in urban activity spatial structure.

As shown in our findings of the urban activity spatial structure, the leisure activity has become an important part in people's daily life and also the main part that people are willing to do in the physical world and share in the virtual world. Therefore, the polarization of urban activity spatial structure first reflects the importance of leisure areas in the consumption economy. Second it is important to note that on one hand, the distance decay mechanism still exists in the physical world influencing people's choice (because of the uneven distribution of leisure places and the complex which usually follows the traditional urban hierarchy, and uses of leisure areas (because of the importance of face-to-face meetings) (Storper and Venables, 2004; Aguilera, 2008) and the irreplaceable of field experience (Mokhtarian, 2004; Hsiao, 2009). Consequently, in the real world the uneven distributing leisure places generate the concentration of leisure activity and hence, promote the hierarchy of these areas. On the other hand, the weakening of distance decay in the virtual world has blown up instead of flatten out the traditional urban hierarchy. To begin with, online social networking has already become an important Internet marketing strategy for both physical shops and online stores to attract consumers (e.g., I2C: information to consumer; B2C: business to consumer; C2B: consumer to business; C2C: consumer to consumer) (Fig. 4). In addition, the information of people's leisure experience shared by the tweets will attract others from their online social network to use the leisure areas. Moreover, the information diffusion with almost no distance friction strengthens the attraction of these existing activity space nodes and concentrates more activities, thereby polarizing the traditional urban hierarchy.

(2) A partial decoupling of activity and activity space node. Regardless of the disputes in terms of the interactions between tele-activity and physical activities from the very different empirical results over the world (cf Andreev *et al*., 2010), there is little doubt that multitasking and fragmentation have mediated people's everyday life (Dijst, 2009). We find in this case study that activities, to some extent, can be decoupled from physical places. First from activity districts' constitution of land use, each type of activity districts is, in general, bound to particular constitution of land use. In other

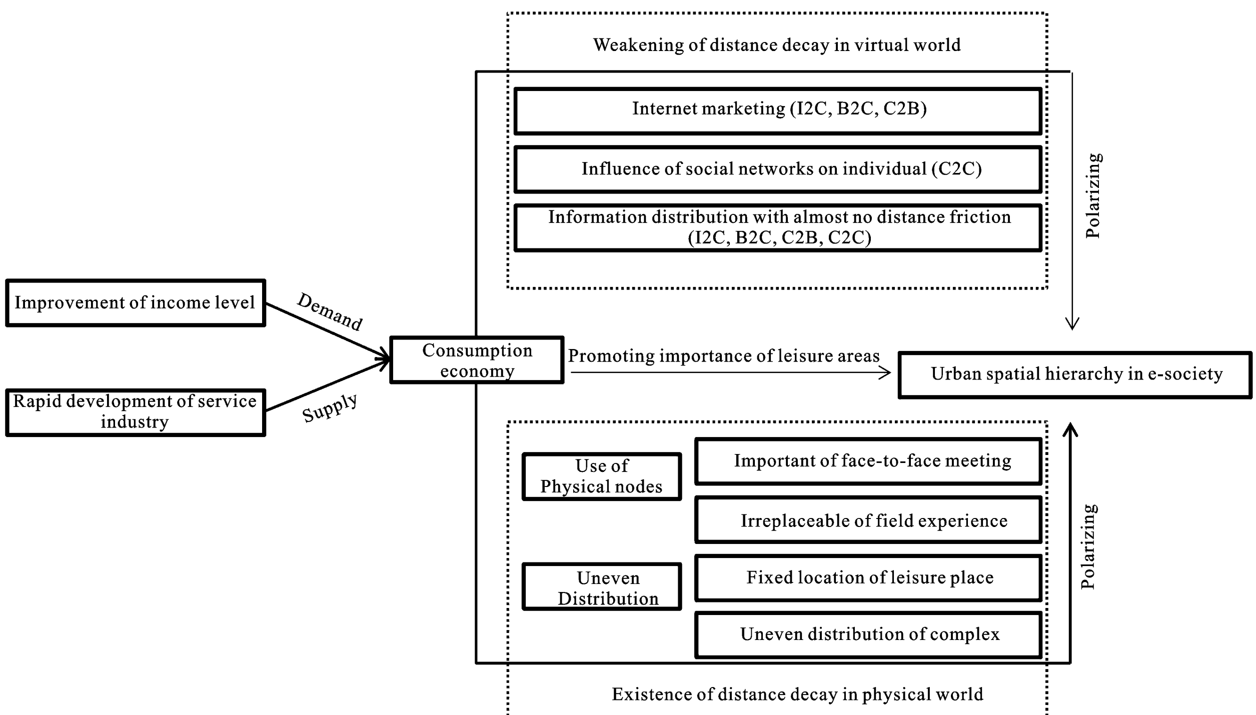

Fig. 4 Dual role of distance in e-society. I2C: information to consumer; B2C: business to consumer; C2B: consumer to business; C2C: consumer to consumer

words, office areas are mainly composed of industrial land and public services land, while bedroom areas are mainly composed of residential land. And multifunctional/leisure areas are mainly composed of public services, especially commercial land. Second from the comparison of check-in tweets happened among different land use (Table 3), it is very interesting that, slightly following pubic services, residential land[①] and street and transportation land in downtown have a quite high level of check-in density (1043.2 and 1022.2 tweets per square kilometers, respectively).

This suggests that various activities are conducted at home and during trips, which challenges our conventional thinking of the home and the travel. To begin with, it seems that home is no longer a living space with the aid of tele-activities, but a place to work, shop, and entertain (de Castro and Jensen-Butler, 2003; Mokhtarian *et al*., 2006). In the e-society, home has the potential to become a multifunctional hub, such as an alternative workplace or a shopping site. However, this does not imply that the changing function of home could definitely reduce travel demand and thus reduce travel-induced congestion and air pollution to promote a sustainable development, which still need more future empirical work. Moreover, tele-activities conducted during trips will more or less influence people′s evaluation of travel time which has long been perceived as ′wasteful′ or ′unproductive′ (Lyons and Urry, 2005; Lyons *et al*., 2007). Given the increase of commuting within the city in China because of the urban sprawl and the spatial mismatch of jobs and residences (Zhou and Yan, 2005) and the growth of travel between cities driven by intercity networking, it is necessary to discuss the influence of this utility change on people′s spatial organization of their activities within (or across) cities (Fig. 5).

(3) Blurring boundaries between activity districts. In the Athens Charter (Corbusier, 1973), living, working, recreation, and circulation have been regarded as the four basic activities within cities. For urban planners, it is critical to organize these related activity space (i.e., habitation, work, leisure, and traffic) to reduce the interference among different activities. The conventional thinking is that activities are imperatively bound to particular places; and to reduce the interference among different activities, the corresponding activity districts should be separated. Though this idea has been criticized

Table 3 Check-in tweets happened on different land use (Unit: times/km^2)

	Public services (administration and public, commercial and business land)	Residential land	Industrial land	Street and transportation	Green space
Downtown	1336.5	1043.2	315.6	1022.2	124.7
Outskirts	256.8	217.0	39.8	100.5	3.5
Nanjing City	691.2	539.4	87.1	285.7	16.7

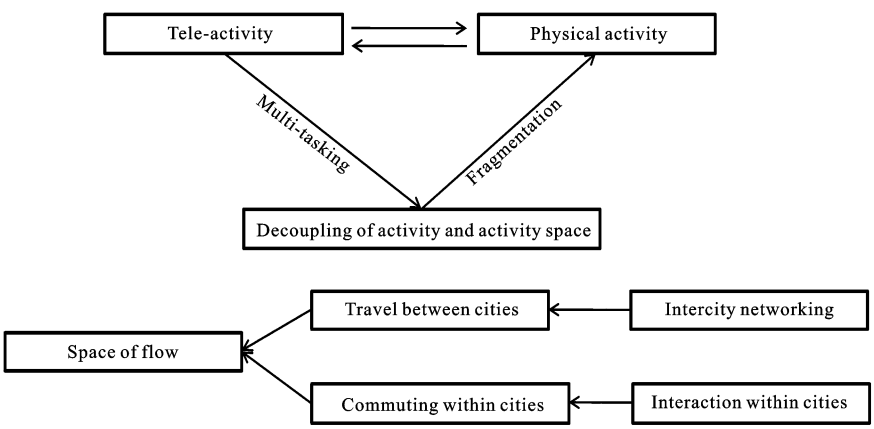

Fig. 5 Decoupling of activities and activity space nodes

① Because of the land use classification in master planning, the high level might partly be related to the other land use as commercial and business land in residential district which have been categorized into residential land.

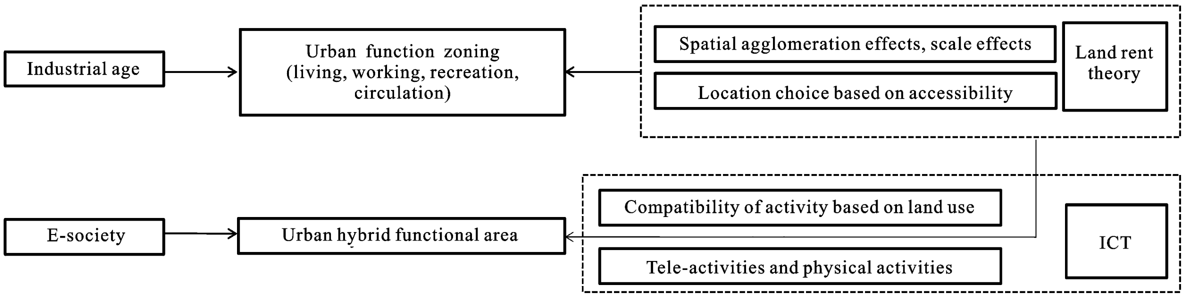

Fig. 6 Influence of ICT on urban function zoning in e-society

for the ignorance of the necessity of interaction between activities, the conventional thinking remains the key point in modern urban planning. From the perspective of land use, spatial agglomeration, and location based on accessibility are the main considering factors in the spatial organization of the activity space (Fig. 6).

However, from the perspective of activities, the increasing tele-activities in people′s daily life have weakened the correspondence of activity and activity space node and thereby blurred the boundaries between activity districts (as shown in our analysis of activity edge in this case study). Therefore, the conduct of tele-activities will increase the compatibility of land use and thus provide opportunities for developing areas with a hybrid function instead of a sole function. In other words, ICT can play a positive role in enriching districts′ functions, which will be useful and should be emphasized in the current urban reconstruction (such as city renewal) in China. However, ICT has not eliminated the important role of location because of the existence of distance decay in the physical world. In fact, district with a better location (i.e., higher level of accessibility) usually also have a higher level of compatibility of land use in this study. This is in line with the differences of activity districts between downtown and outskirts, in which downtown concentrates more multifunctional districts while outskirts have more sole activity districts (i.e., office area, bedroom area) as shown in Fig. 3. Therefore, it will be important to figure out how to use ICT to promote the hybrid functional development and to what extent activities could be decoupled from physical space and chronological time in the future empirical studies.

5 Conclusions and Discussion

In the e-society, the new technologies provide a big data source and open the Pandora′s Box for geographers. In terms of research on human behaviour and activity space, questionnaires and activity diaries are the main traditional data source in the existing methodologies (Chai and Zhao, 2009). However, not only are these data difficult to cover a large number of people, but also difficult to grasp their real-time activity. In this paper, one week′s check-in tweets in Nanjing City are collected. The real-time data with location information enable us to conduct a dynamic and systematic analysis of urban activity space. The strengths of big data to reflect the existence of correlations are confirmed through this study, particularly in dividing activity districts, revealing the characteristics of activity districts as well as exploring the influencing of ICT on urban activity space. In the future studies, there are a host of important questions for geographers or other social scientists to challenge, analyze, and contest, using enormous amounts of online traces, for example. However, these traditional data source from questionnaires, interviews, and dairies should not be overlooked. The value of small data in depicting characters of individuals should be emphasized. Instead, the choice of big data or small data will finally depend on the specific research question.

Urban space is always the main study area of geographic students from the perspective of physical sphere. Compared with physical sphere, economic and social spheres have received less attention even though with a humanism trend in social science research. Adapted from Lynch′s framework based on people′s perceptions, this paper proposes a framework based on people′s actual activity consisting five elements, namely, activity path, activity node, CAZ, activity district, and activity edge. In this framework, people and their actual activities instead of their perceptions are our focus. From both the temporal and spatial dimensions in our methodology, the five elements are empirically recognized and analyzed by using Nanjing City as an example. However, there is still room for improvement of this framework in the future studies. For example, this framework concentrates on the actual activity space while ignoring people′s intuitive perception. It will be more comprehensive if emotion information is added to the framework, which will helps to portray the differences among individuals. More importantly, adding the emotion is applicable by revealing through the text in their check-in tweets, which will be our next studying focus.

Through the comparison between urban spatial structure based on people′s actual activity and on population (and land use), the influence of ICT on urban activity space is discussed. First, ICT uses have lead to polarize rather than to smooth the urban spatial structural hierarchy, due to the dual role of distance in the physical and virtual world. Second, activities can be decoupled from physical places but only to a certain degree and the various activities conducted at home and during trips challenge our conventional thinking of the role of home and the utility of travel time. Further research is needed to specify which categories of people might be more sensitive to activities at home or during tips, and thereby to what extent the role of home and the utility of travel time are changed. Third, tele-activities in people′s daily life have weakened the correspondence of activity and activity space node and thus blurred the boundaries between activity districts. Therefore, ICT could play a positive role in enriching districts′ function, which requires more attention in the current urban transformation in China.

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