Computers, Environment and Urban Systems xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Computers, Environment and Urban Systems

journal homepage: www.elsevier.com/locate/ceus

Seoul's Wi-Fi hotspots: Wi-Fi access points as an indicator of urban vitality

Young-Long Kim*

Graduate School of Geography, Clark University, Worcester, MA 01610, USA

ARTICLE INFO

Keywords:
Wireless internet
Urban vitality
Virtual space
Big data
Bivariate spatial association
Path analysis

ABSTRACT

Advances in information and communication technology and the collection of big data at small spatiotemporal scales have opened up new opportunities to reveal spatiotemporal relationships of human dynamics and urban space. As a measure of human dynamics, however, urban vitality has been elusive both in conceptualization and measurements, and previous academic and policy attempts to grasp the concept failed to address the problems. In an effort to operationalize the concept, this paper has two goals: (1) to develop a systematic measurement of urban vitality in social, economic, and virtual dimensions and (2) to empirically investigate the relationship between physical and virtual spaces at small spatial and temporal scales. Three different indicators of urban vitality to represent the three dimensions are (1) pedestrian traffic based on cell phone activities (social vitality), (2) bank card transactions (economic vitality), and (3) the location of Wi-Fi access points (virtual vitality). To verify the correlation between the indicators, both an aspatial measure, Pearson's r coefficient, and a bivariate spatial association between the three dimensions, calculated by Lee's L measure, are used. It is also followed by path analysis to investigate the causal relationship in four path models. The empirical analysis validates the two hypotheses: (1) a spatial correlation exists between the three different urban vitality measures and (2) the spatial distribution of Wi-Fi access points could be an indicator of urban vitality. Further comparative analyses are on the condition-specific differentiation of urban vitality characteristics by time slots, age/gender groups, and regions. The virtual-physical relationship opens up possibilities for urban researchers to adopt virtual dimension as one of the ways to gauge urban vitality.

1. Introduction

The field of urban studies has grappled with understanding spatial and temporal relationships of human dynamics and urban space. Urban vitality has been studied as one of the components that reveal the relationship (Lynch 1981). In recent years, advances in information and communication technology (ICT) and aware technology has provided new data, methods and study subjects for researchers to investigate urban vitality. Although new indicators for systematic measurement of urban vitality have been proposed (Jin et al. 2017; Long & Huang 2017), most studies on urban vitality still have not considered virtual space and how it is intertwined with physical space. Since today's everyday life activities in urban space have both physical and virtual dimensions, it is important for urban scholars to investigate urban vitality in the two spaces and the relationship between them for a better understanding of human dynamics in cities. To fill the gap, the main focus of the paper is to measure the spatiotemporal pattern of human activities in both physical and virtual spaces. As an empirical approach, social, economic, and virtual dimensions of urban vitality are measured by big data collected in Seoul, South Korea. The study compares not only the correlation among the three vitality indicators but also examines the difference in the correlation across different regions, genders, and age groups.

The contribution of the paper is twofold: (1) developing a systematic measurement of urban vitality in virtual space and (2) empirically examining the relationship of urban vitality indicators between physical and virtual spaces at small spatial and temporal scales. To achieve the two goals together, this paper conceptualizes urban vitality as having three dimensions: social, economic, and virtual. In particular, this paper proposes the virtual dimension of urban vitality in addition to the social and economic dimensions that had been relatively well-researched. Wi-Fi (wireless local area network) access points are proposed as a proxy to represent the virtual dimension and to integrate both virtual and physical dimensions. Far from being independent of the physical space of the city, an analysis on the virtual dimension of urban vitality reveals that the virtual space is spatially embedded in the physical space. As a proxy of the virtual dimension of urban vitality, the location of Wi-Fi access points is used in the research.

This paper uses three datasets to derive a specific measure of the social, economic, and virtual dimensions of urban vitality in Seoul,

* Corresponding author.
E-mail address: youkim@clarku.edu.

https://doi.org/10.1016/j.compenvurbsys.2018.06.004
Received 23 October 2017; Received in revised form 1 June 2018; Accepted 11 June 2018

South Korea: big data on pedestrian traffic, bank card transactions, and the density of Wi-Fi access points. The choice of datasets is especially pertinent in the study site of Seoul, whose virtual connectivity is one of the most vibrant in the world (Townsend 2007)[1]. Using the data, this paper firstly investigates the correlation between the temporal dimension of urban vitality and Wi-Fi coverage at a block level, i.e., the smallest spatial unit of analysis of the census system. Secondly, this paper analyzes spatial, temporal, and demographic aspects of urban vitality through Wi-Fi hotspots locations. It is followed by a comparison between three city centers of high urban vitality in Seoul.

In the following sections, this paper reviews previous literature on the urban vitality and the concept's measurement in physical and virtual spaces. Upon reviewing the literature, this paper proposes a third dimension of urban vitality, the virtual dimension, in addition to social and economic dimension to expand the discourse from physical to virtual space. The following section clarifies the big data sources used in the research and describes the socio-cultural characteristics of Seoul and the selected city centers. The Methods section introduces the Lee's *L* (S.-I. Lee 2001), a bivariate spatial association measure, which is applied to verify the relationship among the three vitality measures for each spatial unit. The main findings of the research are presented in the Results section, and the implications and contributions of the paper are further stated in the Discussion section.

2. Measuring urban vitality

Urban vitality can be used as one of the important considerations for a decision making process in cities if it is measured at an appropriate spatial and temporal resolution. The term vitality, in a broad sense, is an environmental condition that “supports the health and biological well-functioning of the individual and the survival of the species” (Lynch 1981, p. 121). The metaphor was adapted to urban researchers' viewpoint that urban vitality refers to “how busy an urban centre is at different times and locations” (Ravenscroft 2000, p. 2534). Urban vitality also reflects the complex and diverse arrangement of activities and built environments (Chion 2009; Jacobs 1961) and the interaction between activities and space in cities (Montgomery 1995). Given the important role of urban vitality in residents' quality of life (Lopes & Camanho 2013), a systematic measuring of urban vitality can contribute to policies for better quality of life.. While the definition of vitality may range from subjective feeling to objective measures, this paper focuses on the latter.

Aggregate measures such as gross regional domestic product (GRDP) and regional employment statistics on creative/cultural industries have been used as proxies of urban vitality in academic research (Florida 2012; Landry 2000; Markusen 2013) and public projects (ArtsWA 2013; Creative Cities International L.L.C 2011). Efforts to develop indicators for urban vitality include a diversity of land uses, retail rents, proportions of vacant street-level property, pedestrian flows, accessibility and consumer behavior (Department of the Environment 1996). Despite these efforts, vitality and its similar concepts vibrancy and livability are criticized as examples of “fuzzy concepts” lacking conceptual clarity to identify and operationalize. (Markusen 2003, 2013, pp. 293–6).

Efforts have been made to tackle the fuzziness by scrutinizing different dimensions of urban vitality. Bromley and Thomas (2002) operationalized urban vitality by dissecting it into social and economic vitality, with the former referring to urban buzz measured by pedestrian traffic flow and the latter to economic activeness measured by purchase, transaction, and investment. For social vitality, pedestrian traffic flow has been used in mobility and transportation studies to measure vitality in urban areas (Gehl 1989; Ravenscroft 2000). In this paper, big data from cell phone activity is used to measure the spatial distribution of human behavior (Ahas et al. 2015; Ratti, Frenchman, Pulselli, & Williams 2006; Yuan, Raubal, & Liu 2012). For economic vitality, bank card transaction data is increasingly regarded as big data on consumption behavior in given period space and time (Dalton & Thatcher 2015; Torrens 2010). The data had been mainly used by banks and credit card companies to improve their customer relationship management (Bhattacharyya, Jha, Tharakunnel, & Westland 2011; Huang, Chen, & Wang 2007; Yeh & Lien 2009). More recently, some research groups began to use proprietary datasets in cooperation with card companies to measure consumer's shopping behaviors (Krumme, Llorente, Cebrian, Pentland, & Moro 2013; Sobolevsky, Massaro, Bojic, Arias, & Ratti 2015).

However, access to such big data is not always available to everyone. Although big data have been increasingly available for research, many data sources are still bounded to proprietary purposes (M. Graham & Shelton 2013; Kitchin 2014). To be useful in social science, big data is necessary to be understood and analyzed within an appropriate theoretical framework for inductive reasoning (Shearmur 2015). In that sense, the major contribution of the paper is the conceptualization and spatial measurement of urban vitality in virtual space and understanding its spatial correlation with the two extant urban vitality measures. To better understand the spatiality of the virtual dimension, the author examines how particular physical space is reconfigured and mediated through virtual space. With the development of information and communication technologies (ICTs), the concept of space has expanded from physical space to virtual space. The transition requires us not only to find ways to research collective human behavior that stretch beyond physical space but also to study the relationship between physical and virtual spaces (Aoyama & Sheppard 2003; Kitchin 1998). One way to do this is to empirically investigate how a phenomenon or a measure plays out in the two spaces. Urban vitality is one of such measures that traverse the two spaces, thus helping us unravel the relationship between the two spaces. This paper addresses this gap and proposes an indicator of urban vitality that incorporates virtual space. In this paper, the empirical investigation demonstrates the virtual dimension of urban vitality is associated with social and economic dimensions by joining them at the common spatial unit of analysis.

3. Urban vitality in physical and virtual spaces

The virtual dimension of urban vitality reflects the growing importance of virtual space in everyday life. Although seemingly free from spatial restrictions, virtual space is argued to be dependent on pre-existing physical space (Malecki 2002; Tranos 2013; Zook 2006). Empirical evidence in the previous studies includes geocoded internet data from Google Maps, Wikipedia, and Twitter (Crampton et al. 2013; Graham, Straumann, & Hogan 2015; Han, Tsou, & Clarke 2017; Zook & Graham 2007). However, rather than examining the virtual dimension in physical space, the studies were limited to representing the geographic footprints in virtual space. Dourish and Bell (2007) argue that we need to investigate “the physicality of the virtual” to understand the social and cultural underpinnings derived from the spatiality of the virtual. In this sense, the previous empirical studies have not been sufficient in studying a more in-depth relationship between the two spaces, such as how the physical space can be challenged or reproduced by virtual space and vice versa (Aoyama & Sheppard 2003). Also, any indicators that represent the two spaces are needed for empirical studies to examine physical-virtual hybridity in an actual urban space in the twenty-first century (Antoniadis & Apostol 2014; Forlano 2013; Kluitenberg 2006).

As the wireless internet technology becomes the primary medium of information flows, the geography of information flows is spatially shaped and regulated by wireless internet infrastructure. The mapping

[1] Seoul's high penetration rate of the Internet (94%) and smartphones (88%) among the citizen (Poushter 2016) and the large share of bank card transactions (71%) in the country (The Bank of Korea 2016) support the representativeness of the data.