Analysing the space-time dynamics of urban structure change using employment density and distribution data

Alireza Salahi Moghadam[a], Ali Soltani[b,*], Bruno Parolin[a,c], Mehdi Aliabadi[d]

[a] Faculty of Built Environment, University of New South Wales, Sydney, Australia
[b] School of Art, Architecture and Design, University of south Australia, Adelaide, Australia
[c] Tran-Stat Research International, 16 Vidal Street, Wetherill Park, New South Wales, 2164 Sydney, Australia
[d] University of Tarbiat Modares, Tehran, Iran

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ABSTRACT

The main objective of this paper was to examine patterns of growth and change in Sydney over the time period from 1981 to 2006. To achieve this aim, the paper took employment density as a structural dimension, and modelled the linear and interactive effects of this dimension in order to better understand the dynamics of urban spatial structure change in the Sydney metropolitan area. The estimation of the traditional negative exponential models of mono-centricity and poly-centricity indicated a polycentric pattern at the beginning and end of the study period. Employment density distributions, suggest a system of polycentric nodes of varying importance between 1981 and 2006. The legacy of this paper for the planning community is the importance of developing an evidence base, and application of concepts and advanced spatial techniques for urban spatial structure analysis.

1. Introduction

The spatial structure of cities encountered dramatic transformations in the late decades of the 20th century (Anas, Arnott, & Small, 1998; Lee, 2007). Its evolution, process, causes and effects were variously studied in the field of urban economics and other disciplines (Button, 2000; Fujita & Ogawa, 1982; Hartwick & Hartwick, 1974; Odland, 1976; Richardson, 1988; White, 1976a, 1976b). Although this field has grown in the tradition of structuralism, the theoretical assumptions were borrowed from functionalism. Structuralism is based on the dynamism of structures, the latter goes further and considers the direct causality of the structures on the form of urban spaces (McCord, 1980). Nonetheless, in urban and regional planning, this approach is disputed in a structural-functional approach (Giffinger & Suitner, 2015) of population and employment distribution (Alidadi & Dadashpoor, 2018; Coffey & Shearmur, 2002; Dadashpoor & Alidadi, 2017; Garcia-Lopez, 2010; Huang, Liu, Zhao, & Zhao, 2017), built-up areas evolution (Taubenböck, Stand, Wurm, Krehl, & Siedentop, 2017), and people, goods, capital, and information flow (De Goei, Burger, Van Oort, & Kitson, 2010; Hall & Pain, 2006; Parr, 2014), etc. Land use-transport models are highly influenced by three structural elements, employment centres, residential zones and commuting costs between two earlier ones. The economy of scale and agglomeration profits naturally contribute to the concentration of jobs in high-density locations, while transportation costs determine the level of residential dispersion of urban domains (Odland, 1976).

Despite the rich literature, there is no consensus on the definition, approach, methodology, and indicators of urban spatial structure (Anas et al., 1998); the subject is highly dependent on the context (Giffinger & Suitner, 2015). However, the spatial structure of cities is more or less the reflection of their function (Vasanen, 2012). Nonetheless, spatial structure is not only reflective of the process of changes (Garcia-Lopez, 2010; Giffinger & Suitner, 2015; Grunfelder, Nielsen, & Groth, 2015; Lambregts, 2009; Meijers, 2008) but also is considered as a normative policy in higher scales (Davoudi, 2003). The spatial structure of cities as an analytical tool (Giffinger & Suitner, 2015) explains the distribution of population and employment through space and time. Where this phenomenon concentrates in a centre it is called mono-centric (Kraus, 2006; Riguelle, Thomas, Verhetsel, & Pasteur, 2007) whereas beyond this it seems to be polycentric, dispersed (Lee, 2007) or scattered (Garcia-Lopez & Muniz, 2010) and yielding new potential patterns. The evolution of spatial structure of cities is an undeniable fact in both population and employment (Anas et al., 1998; Anas & Kim, 1996). However, in the tradition of economic geography, population is mostly considered as dependent on employment variation (Muniz, Garcia-Lopez, & Galindo, 2008). In other words, where employment

distribution is based on different levels of congestion, scales, contiguity, urbanization and other economies and diseconomies (Parr, 2014), then a population minimizes their costs based on the trade-off between access to job location and other life costs (Mills, 1972; Richardson, 1988). However, in the late of 20th century, due to technological advances and other qualitative changes (Anas et al., 1998; Lee, 2007), a priori assumption of employment centralization in the main core of the city made scholars skeptical (Alperovich, 1983; Fujita & Ogawa, 1982; McDonald, 1987; McMillen & McDonald, 1998). Thus, the alternative theoretical and empirical frameworks were developed by planners, geographers and economists (Hartwick & Hartwick, 1974; Ogawa & Fujita, 1980; Richardson, 1988; White, 1976a, 1976b). Accordingly, investigating the subcentering of employment (Fujita & Ogawa, 1982; Giuliano & Small, 1991; Small & Song, 1994) and decentralization of population (Coffey & Shearmur, 2001; Dadashpoor & Alidadi, 2017; Lopez & Angel, 2010; McMillen & Smith, 2003) gained currency from the 1980s. In this respect, it was believed that the concentration of employment in the central business district (CBD) is not an exploratory factor anymore (Papageorgiou & Casetti, 1971). Thus, the polycentricity of spatial structures was analytically replaced by the neoclassical model of monocentricity of Alonso (1964). This concept, despite the former conceptualisations, was not a state, even due its fuzziness (Vasanen, 2012) and its nature encompassed from a completely monocentric structure to a highly polycentric spatial structure (Alidadi & Dadashpoor, 2018). In other words, all regions have some level of polycentricity, and intensity depends on the contextual and external variables of every region.

The study of spatial structure of cities is a processal reality of its socio-economic and political evolution through space and time (Giffinger & Suitner, 2015). Thus, Sydney as a case study is chosen to analyse its evolution from 1981 to 2006. To do this, the spatial structure is modelled by monocentric and polycentric functions and the efficiency of the models are analysed through time. The key objective of this paper is to understand the quantitative relations among the metrics that define the multidimensional characteristics of urban spatial structure in Sydney through development of models that capture the longitudinal nature and space-time dynamics of the data.

This paper is organized as follows. Section 2 reviews the current literature on the spatial structure of metropolitan areas and compares those approaches taken by former studies. Section 3 introduces the case study area, and the data and methodology used throughout this paper. Section 4 then details the statistical and modelling analysis taken for this study and presents the findings in tabular and visual forms. Finally, Section 5 concludes and discusses the policy implications and the directions for further research.

2. Literature review

The study of spatial structure of cities has evolved in different academic fields through time and space. However, three main group of studies are traceable: primary studies before 1960s; the dominance of monocentric model from 1960s to 1980s; and the last three decades. The first endeavour to formulate and analyse spatial structure of regions were presented by Von Thünen (1826) based on market process (Parr, 2014). The trade-off between land rent and distance to the main consumption market (CBD) determines land use types from the centre to the hinterland of the city (Fujita & Krugman, 1995). Moreover, Von Thünen developed a supplementary model to explain the distribution of centres around the isolated state and described these as provincial centres (Parr, 2013). In the beginning of the 20th century Hurd (1903) investigated a large number of cities around the world to identify land price specifiers based on microeconomic variables of urban spatial structure. In this respect, the main driver of changes in land price were the origin of the city as a business centre where there is a high competition for limited space in a highly accessible location. Christaller's Central Place Theory simulated the spatial structure of cities at a regional scale. This model was based on the concept that central goods were supplied by centres according to their demands from hierarchies of settlements in a region; the hierarchical structure of urban systems was based on the goods that they supply (Parr, 2004).

Lösch's supplementary work revised previous models by considering the different hierarchy of centres and the interrelation between cores regardless of their hierarchy (Parr, 2014). However, the spatial structure of cities was not investigated statistically and mathematically until the mid-60s. Alonso (1964) modelled Von Thünen's initial land use theory in a modern city context (Fujita & Ogawa, 1982). The main assumption was that the allocation of values and resources are controlled by two main variables, accessibility and proximity (Kraus, 2006). Jobs are almost always located within a CBD area, therefore, properties located in this zone have the highest price. Jobs are concentrated in a centre and all households rationally create an equilibrium between goods consumption, land price and commuting costs on the one hand and family income on the other (Papageorgiou & Casetti, 1971). Adding to this work, Mills (1972) constructed a monocentric model of resource allocation in an urban area, which was developed into a multiplicity of centres or nuclei by Hartwick and Hartwick (1974). For two decades, the new urban economics was the dominant paradigm in urban modelling (Ogawa & Fujita, 1980) and the monocentric structure was the dominant model in research (Richardson, 1988). However, the inefficiency of the monocentric model was justified by different studies (Fujita & Ogawa, 1982; Odland, 1976; Ogawa & Fujita, 1980; Papageorgiou & Casetti, 1971; Richardson, 1988; White, 1976a, 1976b). The main problem was that the centrality of monocentric model should be evaluated by a model not defined a priori (Odland, 1976). Furthermore, travel patterns (Gordon, Richardson, & Wong, 1986), decentralization of population and employment (Cladera, Duarte, & Moix, 2009; Riguelle et al., 2007) were inadequately explained by a monocentric model (Fujita & Ogawa, 1982). As Papageorgiou and Casetti (1971) discussed, a classical monocentric model ignores the possibility of various forms of equilibrium functions, so, multi-centric (Odland, 1976; Papageorgiou & Casetti, 1971; White, 1976a, 1976b) or non-moncentric (Fujita & Krugman, 1995) models of urban spatial structure were unavoidable (Anas et al., 1998). In the former, subcentres are predetermined and it is assumed to be an endogenous process, while in the latter, a non-monocentric model would be used to explain travel difficulties between nodes in the city (Richardson, 1988).

However, there are some undeniable facts; despite the normativity of poly-centricity (Davoudi, 2003) at an (inter)national scale, it is processal concept at urban regions (Garcia-Lopez & Muniz, 2010) that needs to be temporally considered. This process consists a wide range of patterns and forms (Hajrasouliha & Hamidi, 2017) from strictly monocentric to highly polycentric or dispersed (Garcia-Lopez & Muniz, 2010; Lee, 2007) that depend on available data from the details of changes. Most of polycentric methods (mainly exploratory) focus on subcentre identification (Baumont, Ertur, & Gallo, 2004; Coffey & Shearmur, 2002; Giuliano & Small, 1991; McMillen & Smith, 2003; Riguelle et al., 2007) while confirmatory methodologies are applicable too. In this way, population and employment are not affected solely by the dynamics of the CBD, but the importance of subcentres also becomes significant. Thus, in modelling urban population and employment distribution throughout metropolitan regions, influential cores rather than a metropolitan CBD exert influence by proximity or distance-based factors (Baumont et al., 2004).

Polycentric spatial structure of cities has been a topical issue from 1980s, to explain the suburbanization of the population (Alperovich, 1983; Feng, Wang, & Zhou, 2009; Lopez & Angel, 2010; Muniz et al., 2008) and the decentralization of employment (Burger & Meijers, 2012; Giuliano & Small, 1991; McDonald, 1987; McDonald & Prather, 1994; McMillen & McDonald, 1998; Small & Song, 1994), specifically in metropolitan regions (Gordon et al., 1986). As a monocentric model was less efficient (Small & Song, 1994) in describing the dynamism of