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The topology of urban road networks and its role to urban mobility

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Abstract

This article studies how the topology of Urban Road Networks (URNs) is linked with socioeconomic aspects of their urban systems, aiming in revealing patterns that are related to urban mobility. The rationale of the study is based on the consideration that both the structure of urban networks and the conduct of urban mobility are controlled by complex mechanisms, where a primary driving factor affecting, either directly or indirectly, their planning, evolution and development is the existence of spatial constraints. The analysis examines how some fundamental network measures of global URNs studied in literature are related to socioeconomic indices and focuses on the case study of four URNs of the region of Thessaly, in Greece, where their socioeconomic framework is familiar. Overall, the analysis provides interesting insights about the effects of spatial constraints on the network topology, the magnitude of the examined URNs comparatively to global cases, the growth patterns between connectivity and distance and about how the network topology is related to urban mobility, population and market information.

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1. Introduction

The evolution of cities through time has caused an increase in their structural and functional complexity, setting the acts of manipulating and planning of such systems into a real challenge, both for the everyday policy making and for the academic research (Strano et al., 2012; Polyzos, 2015). Within the structured framework of the evolving cities, urban mobility becomes more and more a complex procedure. The purpose of the everyday movements, the choice of the transport mode, the time of executing the transportation and its cost are some aspects illustrating this complexity (Chowell et al., 2003; Van Ommeren and Fosgerau, 2009; Barthélemy, 2011; Polyzos et al., 2013, 2014). However, the common factor that affects, directly or indirectly, all the aspects of urban mobility and that it sets the rules for the development of urban systems and for the consequent conduct of urban communication is the cost of overcoming the spatial constraints governing each movement between geographical places (Barthélemy, 2011). Recent research on the structure and the topology of urban road networks using complex network analysis (Albert and Barabasi, 2002; Newman, 2010) has shown the existence of quantitative similarities (at least at a macroscopic level) between road networks of cities with different geographical, architectural and socioeconomic characteristics (Cardillo et al., 2006; Scellato et al., 2006; Buhl et al., 2006; Chan et al., 2011; Barthélemy, 2011). Such outcomes appearing in the newly established research field of complex network analysis compose a new perspective in the study of urban transportation

systems and provide evidence for considering the network topology as a determinative factor for the urban mobility and development. Within this framework, this article studies the topology of the urban road networks among the capital cities of the prefectures in the region of Thessaly, in Greece, aiming to reveal links among the structural, the functional (mobility) and the socioeconomic aspects of their urban systems.

The remainder of this article is organized as follows: Section 2 presents the methodology followed in the study, the network modeling, along with the measures and empirical tools used in the analysis. Section 3 presents and evaluates the results of the analysis and, finally, in section 4 conclusions are given.

2. Methodology and Data

Each urban road network (URN) of the Thessaly's capital cities, *Karditsa* (KURN), *Larissa* (LURN), *Trikala* (TURN) and *Volos* (VURN) is constructed in the L -space representation (Barthelemy, 2011; Tsiotas and Polyzos, 2014, 2015a), into an undirected and connective graph $G(V,E)$ with spatial weights, where nodes (V) represent road intersections and edges (E) represent road segments intermediating between successive nodes (without a change in their route). Such representation complies with the common practice for modeling urban road networks (Buhl et al., 2006; Cardillo et al., 2006). The network models for the of Thessaly were self-edited using data from openstreetmap.org[®], while data for the 62 worldwide urban networks considered in this paper were drafted from relevant studies available in the literature (Buhl et al., 2006; Cardillo et al., 2006; Scellato et al., 2006; Chan et al., 2011). The available socioeconomic information for the analysis of the URNs of Thessaly was drafted from the Greek National Census, (ELSTAT), the Greek General Secretariat of Information Systems (GSIS), the official web sites of the Urban Buses Enterprises for each capital city and Polyzos (2015). Apart from the classic network measures, the city organization index proposed by Courtat et al. (2010) is computed, measuring city organization accordingly to the proportion of incomplete crossovers and dead ends. When $r_n \approx 0$, the urban system has a well-organized pattern, while when $r_n \approx 1$ the urban system is deficient of organization and planning (Barthelemy, 2011).

Afterwards empirical analysis is applied, consisting of various statistical and empirical techniques, such as descriptive statistics and correlation analysis (Norusis, 2004) between vector variables. Finally, patterns of magnitude consisting of scores of the URNs of Thessaly per measure are compared in pairs, between cases of network and socioeconomic measures. This approach aims in detecting potential relations between network and socioeconomic measures and in highlighting addresses of further research.

3. Results and Discussion

3.1 Network Analysis

At first, the network measures along with some socioeconomic indicators are calculated and their results are shown in table 1, where all URNs show a leading performance in some aspects of their topology, while for the socioeconomic indicators the LURN excels in the majority of cases. In particular, KURN seems to describe an accessible network (highest $\langle C^C \rangle$ value), but with the longest edge distances (highest $\langle s \rangle$ and $\langle d_{ij} \rangle$), which has also the smoothest decay in its degree distribution as it is shown in figure 1, describing a pattern of homogenous connectivity, which is also reflected on its city's organization index (r_n). Also, VURN has the best city's organization network pattern (r_n), while KURN possess the second optimum place followed by the LURN and TURN. This status seems to reflect the city plans of these networks, where in the two leading cases there are obvious hippodamian characteristics (Polyzos, 2015), while the last cases describe more pericentral city plans (figure 2).

Table 1. Network and socioeconomic measures of the capital cities of Thessaly.

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