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Estimating distance decay of intra-urban trips using mobile phone data: The case of Bratislava, Slovakia

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ABSTRACT

The distance decay function has been attracting attention in diverse disciplines including transportation studies, spatial planning and urban geography. In particular, much discussion has concentrated on the measurement of distance decay on the regional scale, since the emphasis of the model utilisation has been on explaining inter-regional mobility (mainly commuting). The intra-urban context makes the estimation more complicated and the fundamental questions, such as how far people travel within the city to reach a variety of urban destinations, and whether there are potentially significant differences between these types of destinations, are still not answered in a satisfactory way. In response to this challenge, the paper attempts to reveal the spatial variations of the distance decay effect on movements in urban space through the utilisation of mobile phone data. The signalling data from all major mobile network operators in Slovakia represent new opportunities with high accuracy of measurement and complexity of representation. The methodological procedure for deriving data about human daily movements from the mobile network at the level of 1 × 1 km statistical grid cells is presented. The objective is to estimate the appropriate distance decay functions for urban grids and demonstrate the variation of decay curves within the Bratislava city. The findings relativise the decay law of human mobility. For the approximation of daily mobility within the urban area, the polynomial-exponential function – the decreasing function with a small increase of interaction intensity at a greater distance – describes the impedance of travel distance more preferably. However, a significant proportion of urban grids have recorded weak or even no decay. A question worth investigating is whether the resulting friction of distance is a result of a specific functional structure of the study area, or it could reflect an advanced stage of urban evolution.

1. Introduction

Scientists have long been interested in the question of how far human activities reach when engaging in daily mobility. Based on the concept of gravity model developed in geography (Carey, 1858; Ravenstein, 1885; Stewart, 1948, more significant since 1960th: Wilson, 1967 and others) the literature has established quite clearly that the strength of spatial interactions (the aggregate movements of various types over geographic space) decreases with increasing distance. The distance decay character of spatial interactions reflects the first law of geography, that "everything is related to everything else, but near things are more related than distant things" (Tobler, 1970). Analysing the distance decay has proved important in modelling and predicting many aspects of society, e.g. migration and commuting (Halás et al., 2014; Hipp and Boessen, 2017), retail and shopping (Reilly, 1929; Huff, 1959, 1963; Roy and Thill, 2004), transportation networks and travelling (Young, 1975; Martínez and Viegas, 2013; Hooper, 2015), or commodity and capital flows (Celik and Guldmann, 2007). Although the modern computing technology enabled estimation of the effect of distance on an immense variety of phenomena (Eldridge and Jones, 1991), in an era characterised by a massive development of information and communication technologies, current knowledge of urban mobility is still, paradoxically, very limited (Gonzalez et al., 2008; Song et al., 2010; Gao et al., 2013a, 2013b; Zhao et al., 2016; Zhong et al., 2016; Batty, 2018).

The main objective of the paper is to explore the distance decay variability in an urban environment using a dataset derived from a mobile network and to discuss the underlying factors behind the spatial differentiation of a specific type of spatial interaction – periodic intra-

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