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Original Research Paper

Application for developing countries: Estimating trip attraction in urban zones based on centrality

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HIGHLIGHTS

- A network centrality-based trip attraction estimation method is proposed.
- The accuracy of the model is more than 75%.
- Space syntax and spatial analysis tools are used.
- Land use data is not required to estimate trip attraction in the proposed model.
- Effective tool for developing countries.

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ABSTRACT

This paper introduced a network centrality-based method to estimate the volume of trip attraction in traffic analysis zones. Usually trip attraction volumes are estimated based on land use characteristics. However, executing of land use-based trip attraction models are severely constrained by the lack of updated land use data in developing countries. The proposed method used network centrality-based explanatory variables as “connectivity”, “local integration” and “global integration”. Space syntax tools were used to compute the centrality of road segments. GIS-based kernel density estimation method was used to transform computed road segment-based centrality values into traffic analysis zone. Trip attraction values exhibited significant high correlation with connectivity, global and local integration values. The study developed and validated model to estimate trip attraction by using connectivity, local integration and global integration values as endogenous variables with an accepted level of accuracy ($R^2 > 0.75$). The proposed approach required minimal data, and it was easily executed using a geographic information system. The study recommended the proposed method as a practical tool for transport planners and engineers, especially who work in developing countries and where updated land use data is unavailable.

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1. Introduction

Urban planners and transport engineers have long been developing different methods and models to forecast travel demand in urban areas. That is because travel demand forecasting is the core element for designing transportation facilities and developing urban planning policies and regulations. One of the most common approaches used to model demand is the four-step travel demand modeling process. The very first step of four-step travel demand modeling is forecasting the trip generations (Ortúzar and Willumsen, 2011). Trip generation aims at estimating the total number of trips generates from a zone and attracts to a zones. Accordingly, trip attraction identifies the number of trips attracted by land use activities in a traffic analysis zone (TAZ), and trip production identifies the number of trips produced by household in a TAZ (Escamilla et al., 2016; Sasidhar et al., 2016; Stover and Koepke, 1988). Many studies on travel demand have found that trip attraction has strong co-relation with the land use types and its' activities such as land use distribution (Escamilla et al., 2016), floor area, number of employee and number of shops (Sasidhar et al., 2016), number of employees (Parikh and Varia, 2016), number of school and school enrollment rate (JICA, 2014); number of employees in the commercial node, number of offices in the commercial node (George and Kattor, 2013); number of employment opportunities, land uses distribution (CEPT University, 2013); gross floor area, number of stores in the shopping centers (Uddin et al., 2012); number of schools and volume of retail sale (Al-Taei and Taher, 2006); floor area (Fillone and Tecson, 2003); number of parking lots and number of stores (Innes et al., 1990). The above-mentioned relationships are shown in Fig. 1.

Previous studies recognized the need of area-specific land use data and trip rates for modeling purposes (Akin and Alasalvar, 2016; Alonso et al., 2017; George and Kattor, 2013; James et al., 2009; Sperry et al., 2016). However, many researchers highlighted that executing of land use-based trip attraction models are severely constrained, especially in developing countries due to the lack of updated land use data and trip rates (Berg et al., 2017; Bwambale et al., 2017; Cairns, 2011; Cervero, 2013; Jayasinghe and Munshi, 2014; Sperry et al., 2016). Furthermore, recent national transport policies in developing countries (HPEC, 2011; RDA, 2007; Smith, 2009) have highlighted key difficulties of adopting multi-step modeling in the context of developing countries due to inadequate data and lack of financial resources for data collection.

In this background, there is a need to employ alternative methods to estimate trip attractions which can efficiently work under above-mentioned data constraint situations in developing countries. Accordingly, this study is focused on developing an alternative method to estimate trip attraction based on centrality.

1.1. *Centrality: a method for prediction of trip attractions*

Applications of centrality was initially a popular concept in the fields of information technology and computer engineering and recently applied in the field of urban planning (Batty, 2017; Jayasinghe and Munashinghe, 2013; Marcus et al., 2016). In mid-eighties, a group of scholars in London led by Hillier (Hillier and Hanson, 1984) attempted to map centrality in cities under the notion of space syntax. Space syntax is a theory about space and human behavior, which, together with tools; methods for analyzing human interaction with the building environment (Hillier and Hanson, 1984). In space syntax, centrality was termed as "integration" and "choice" mapped distance as a property of topology and angular distance (Batty, 2017; Hillier and Iida, 2005).

Empirical research studies related to the centrality and building environment have revealed strong correlations between street centrality and characteristics of building environment such as density of commercial land uses (Bandara and Munasinghe, 2007; Izanloo et al., 2016; Lee and Choi, 2017; Min et al., 2006; Mora, 2003; Omer and Goldblatt, 2016; Sohn, 2016; Whitehand, 2001), distribution of land values (Liu et al., 2015; Min et al., 2006; Shen and Karimi, 2017; Shi and Huang, 2012), distribution of employment density (Jang and Kang, 2016; Kim and Sohn, 2004; Xiao, 2017), distribution of building density (Batty, 2017; Caruso et al., 2017; Peponis and Allen, 2006), and distribution of spatial form (Batty, 2017; Hillier and Iida, 2005; Hillier and Vaughan, 2007). This relationship is shown in Fig. 2.

Fig. 1 illustrates a relationship of trip attractions to a set of attributes are commercial land use, building density and employment density, and Fig. 2 illustrates a relationship of these three attributes to street centrality. Therefore, the transiting relationship between Figs. 1 and 2 can be shown in Fig. 3.

Based on the relationship between the Figs. 1 and 2, this study hypothesized that there is a relationship between street

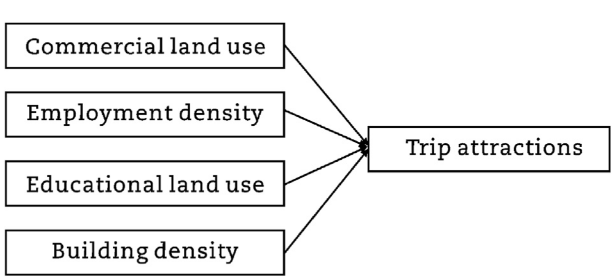

Fig. 1 – Factors contribute to volume of trip attractions.

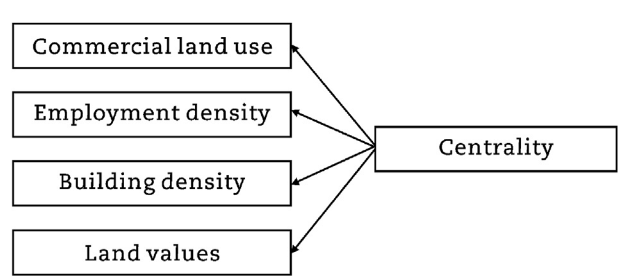

Fig. 2 – Relationship between characteristics of building environment and street centrality.