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# Examining the relationship between different urbanization settings, smartphone use to access the Internet and trip frequencies

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## 1. Introduction

Several scholars have examined the ways in which new technologies influence people's everyday lives, including where they live, work and shop as well as how they travel (Hong and Thakuriah, 2016; Zhou and Wang, 2014; Zhu, 2013). Most of these studies have utilised census or travel survey data and investigated the relationship between information and communication technologies (ICT)—such as the Internet, cellphone, laptop, computer and fax—and various activities. In addition, the potential endogeneity between ICT use and travel behaviour has been examined (Zhou and Wang, 2014). For example, ICT use may encourage people to make more physical trips. However, it is also possible that people who travel more may use ICT more often to find travel or activity information. Ignoring this potential endogeneity problem could result in a mis-estimated relationship between ICT and travel behaviour.

The smartphone is one type of ICT and its usage has grown rapidly (Pew Research Center, 2015). It has also become fully integrated into our daily lives. It allows people to access the Internet through a cellular network or Wi-Fi even on the move, providing more freedom to users. However, its impacts on travel behaviour have not been examined well, partly due to data limitations. In addition, urbanization settings (e.g., urban and rural areas) could influence both smartphone use and travel behaviour. For instance, the quality of ICT infrastructure is different in urban and rural areas, resulting in digital divide issues (Philip et al., 2015; Schleife, 2010). That is, more urban residents may use a smartphone than rural residents. Moreover, people living in urban areas may drive less than those residing in rural areas because of better accessibility to various activities as well as the public transport system. This is important from a policy perspective because land use policy is often considered a fundamental approach to reduce auto dependency but it could also influence smartphone use which, in turn, can affect travel behaviour.

In sum, urbanization settings, smartphone use and travel behaviour are related in complex ways, but empirical studies on this relationship are scarce. The majority of previous research ignored the interconnections between these factors but examined their relationships independently for decades (i.e., relationship between land use and travel behaviour, or relationship between ICT use and travel behaviour). Therefore, the main aim of this paper is to investigate such complex associations empirically while addressing a well-known methodological issue (i.e., endogeneity) between them. In this paper, we employed the integrated Multi-Media City Data (iMCD) survey (Thakuriah et al., 2016) that includes unique instrumental variables for smartphone use (i.e., computer skills) and an endogenous switching model approach to examine the relationships between urbanization settings, smartphone use to access the Internet and trip frequencies. Specifically, we investigated how different urbanization settings (i.e., large urban areas, other urban areas and town or rural areas) are associated with the smartphone use to access the Internet; and how urbanization settings and smartphone use influence trip frequencies.

## 2. Literature review

The relationship between ICT and travel behaviour has been studied for several decades (Choo et al., 2007; Clark and Unwin, 1981; Cohen-Blankshtain and Rotem-Mindali, 2016; Roy et al., 2012; Salomon, 1986). Although the results are inconsistent, a substantial number of studies have found significant associations between ICT, activities and travel behaviour. For example, several empirical studies showed the substitution effects of ICT on travel outcomes. Telecommuting is one technology-enabled example where significant reductions were found on motorized trips and related emissions (Balepur et al., 1998; Choo and Mokhtarian, 2005; Helminen and Ristimäki, 2007; Henderson and Mokhtarian, 1996). On the other hand, Mokhtarian (2009) provided several reasons why ICT actively increases travel. ICT may save time and expense which can then be used to generate other activities, and real-time travel information may stimulate additional trips. This argument is supported by the travel time budget theory. Schafer (1998) showed that people spend about 1 h per day on average for travelling regardless of geographies, cultures and different quality of transport infrastructure. This implies that people will make additional trips if they can save travel time by using ICT. Moreover, Lyons and Urry (2005) suggested that new technologies such as mobile devices enable people to do other productive activities (e.g., work) during their travel, potentially reducing the cost of travel time and increasing longer travel.

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Other ICT impacts such as modification and neutrality have also been discussed in several studies (Cohen-Blankshtain and Rotem-Mindali, 2016; Mokhtarian and Tal, 2013; Salomon, 1985).

The smartphone is one type of ICT and different functions embedded in the smartphone such as computing capabilities, apps and Internet connectivity have great potential to influence patterns of behaviour. For instance, people can easily receive real-time traffic information through apps and choose different routes or transport modes to avoid traffic congestion. Tseng et al. (2013) utilised repeated day-to-day revealed-preference observations and found that the exposure to real-time traffic information through a smartphone is significantly associated with travel behavioural changes. Christin et al. (2014) examined the relationship between smartphone adoption and daily activities/travel behaviour among mobile professionals who work > 20% of their time away from their work environments. Although their sample size is small, they argued that mobile professionals do modify daily activities as well as their travel patterns through their use of smartphones. Schwanen and Kwan (2008) argued that the Internet and mobile phone use influence the space-time constraints to some extent (e.g., temporal flexibility), potentially changing peoples' behaviour. Their results also showed the different influences of new technologies on the space-time constraints between genders, which leads to a digital divide issue.

People also use their smartphones for different purposes such as communication, browsing, entertainment and social networking (Falaki et al., 2010; Park and Lee, 2012), which could influence travel behaviour by generating or substituting activities. People may do on-line shopping with their smartphones and save physical trips to shops. On the other hand, online-shopping may increase physical trips because people still want to see the products in stores (Farag et al., 2007; Zhou and Wang, 2014). In addition, there could be bi-directional associations between smartphone use and travel behaviour; people who travel more may use their smartphones more often to find travel or activity information. However, few empirical studies have examined the complex relationship between smartphone use and travel behaviour with a representative sample.

Recent research from the Pew Research Center (2014) showed that smartphone ownership in the U.S. has grown to 58% in 2014 compared to 35% in 2011 and that education level and age are strongly correlated with smartphone use. They also found that smartphone ownership varies according to residential location. Specifically, about 60% of urbanites and suburbanites own smartphones while only 43% of residents in rural areas own smartphones. The trend is very similar in Scotland. About 63% of adults in Scotland own a smartphone (Ofcom, 2015). People in Scotland spent about 20 h per week online, and a smartphone has become one of the most widely used devices for accessing the Internet. Moreover, a higher proportion of adults in urban areas owned a smartphone than those living in rural areas (72% vs. 63%) in 2016 (Ofcom, 2016a). This is not surprising when considering the socio-demographic characteristics of urban residents and the quality of ICT infrastructures. For example, a body of research suggested that young people (e.g., Millennials) are more likely to live in urban areas and use technologies compared to the previous generation (Mcdonald, 2015; Polzin et al., 2014). Moreover, urban areas have a better quality of data networks as well as more Wi-Fi networks in general. Philip et al. (2015) identified that 4G mobile Internet availability is concentrated in urban areas in Scotland. Data from Ofcom (2016b) further showed significant differences in the average broadband download speeds and mobile coverages between urban and rural areas in Scotland. This evidence implies that residential location, specifically urbanization setting, is one of the influential determinants of smartphone use to access the Internet.

This has an important implication for research on the relationship between land use and travel behaviour. This research question has been examined extensively for many years (Ewing and Cervero, 2010; Handy, 2005; Hong et al., 2014; Sun et al., 2015) and most studies have found significant associations between built environment metrics and travel behaviour. For example, Ewing and Cervero (2010) argued that the combined effects of several built-environment factors could be considerable even though each factor has a limited impact on travel behaviour. That is, people living in neighbourhoods with good access to various activities tend to drive less and use other modes of transport more often than those living in isolated areas. Some researchers used different urbanization settings (i.e., urban and rural areas) instead of specific built-environment factors in their analyses. One of their justifications is that urban areas are more compact and better served by other services than rural areas (Hong, 2016). Cao et al. (2010) found that residential location is a very important determinant of driving distance, even after controlling for the self-selection impact. Specifically, one of their results showed that suburban residents tend to drive on average 7.5 miles per day more than urban residents.

The above review suggests several hypotheses concerning the relationship between urbanization settings, smartphone use to access the Internet and travel behaviour. First, people living in urban areas would be more likely to use their smartphones to access the Internet than those living in rural area, partly due to their socio-demographic characteristics and good quality of ICT infrastructure. Second, people living in urban areas are less likely to be dependent on private cars than those living in rural areas because of better accessibilities to various services and public transport systems. Third, people who use their smartphones to access the Internet will have different travel patterns than those who do not. Based on the dominant effects of ICT on travel behaviour from previous empirical research (Mokhtarian, 2009), smartphone use would increase travel. These three hypotheses, if they are correct, imply that different urbanization settings influence travel behaviour directly and indirectly through smartphone use. Understanding their complex relationship is very important to policy-makers and planners because land-use development is a costly, long-term process, and mobile technologies are developing at a much greater speed with immediate consequences. To test the above hypotheses, this study aims to answer two research questions: Are residents in urban areas more likely to use their smartphones to access the Internet than those living in town or rural areas? and how do different urbanization settings (i.e., large urban areas, other urban areas and town & rural areas) and smartphone use influence the frequency of auto, public transport and active travel?

## 3. Data and empirical model

### 3.1. Data and variables

Our study area is the Glasgow and Clyde Valley Planning area, United Kingdom. Glasgow is the largest city in Scotland with a population of about 615,000 recorded in 2016. The Glasgow and Clyde Valley Planning area covers eight local authorities including the city of Glasgow and a third of the total population of Scotland. It also produces a third of Scotland's economic outputs (Glasgow and the Clyde Valley Strategic Development Planning Authority, 2017). Recently, the city region has experienced population growth as well as aging growth, which requires careful examinations to provide appropriate social services to residents in the future.

The iMCD household survey was administered in 2015 to collect information about education, sustainability, ICT, civic and cultural activities and transport from residents in the Glasgow and Clyde Valley Planning area. It is a representative home-interview survey[1]; moreover, the main survey as well as one-day travel diary data were collected over 8 months from April to November, 2015. A total of 2095 people from

[1] The survey company confirmed its quality by comparing it with the 2014 Scottish Household Survey data (SHS). SHS samples represent the Scottish population broadly (compared with 2011 Census data by the survey company). A technical report is available from: http://ubdc.ac.uk/media/1322/14-061721-01-technical-report-client-use-only.pdf.