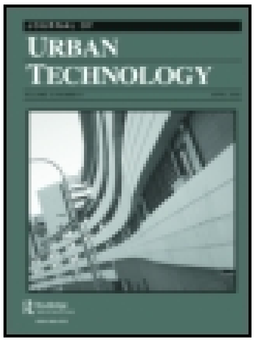

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Smart Cities and Mobility: Does the Smartness of Australian Cities Lead to Sustainable Commuting Patterns?

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ABSTRACT

Smart cities have become a popular concept because they have the potential to create a sustainable and livable urban future. Smart mobility forms an integral part of the smart city agenda. This paper investigates "smart mobility" from the angle of sustainable commuting practices in the context of smart cities. This paper studies a multivariate multiple regression model within a panel data framework and examines whether increasing access to broadband Internet connections leads to the choice of a sustainable commuting mode in Australian local government areas. In this case, access to the Internet is used as a proxy for determining urban smartness, and the use of different modes of transport including working at home is used to investigate sustainability in commuting behavior. The findings show that an increasing access to broadband Internet reduces the level of working from home, public transport use, and active transport use, but increases the use of private vehicles, perhaps to overcome the fragmentation of work activities the Internet creates. How to overcome the need for car-based travel for fragmented work activities while increasing smartness through the provisioning of broadband access should be a key smart city agenda for Australia to make its cities more sustainable.

KEYWORDS

Smart cities; smart mobility; sustainable commuting; sustainable urban development; Australian cities

Introduction

The concept, "smart city," has become almost ubiquitous both in academia and in policy circles due to its potential to address a range of negative effects of rapid urbanization (e.g., congestion, CO_2 emissions), industrialization (e.g., air and soil pollution) and consumerism practices (Mahbub et al., 2011; Wiig, 2015; Taamallah et al., 2017; Trindade et al., 2017). While a number of scholars and smart city sceptics raise their concerns about the ongoing global smart city movement (Yigitcanlar and Lee, 2014; Kunzmann, 2015; Angelidou, 2017), many levels of government—local, regional, state, national, and supra national—across the globe still continue to jump on the smart cities bandwagon (Townsend, 2013; Komninos, 2016). Due to diverse disciplinary and sectoral perspectives, there is no common consensus on the definition of smart cities (Angelidou, 2014; Albino et al., 2015). However, these cities are generally seen as localities that effectively utilize strategic

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planning approaches and innovative solutions to improve the quality of life of their communities, including ecological, cultural, political, institutional, social, and economic components (Neirotti et al., 2014; Yigitcanlar, 2016). Smart cities are also an umbrella concept that contain various sub-elements, ranging from smart economy to smart living, smart governance to smart people, and smart mobility to smart environment (Lee et al., 2014; Lara et al., 2016; Chang et al., 2018).

Because emissions generated from transport causes about a quarter to one-third of greenhouse gas (GHG) emissions, smart mobility forms an integral part of the smart city agenda (Creutzig et al., 2015; Yigitcanlar, 2015; Arbolino et al., 2017). The smart mobility concept, in the fashionable sense, is defined as "integrating the sustainable and smart vehicular technologies, and the cooperative-ITS [intelligent transport systems], accelerated with the cloud-server and big-data based vehicular networks" (Kim et al., 2015, p.59). Similarly, Chun and Lee (2015) see smart mobility as a comprehensive and smarter future traffic service in combination with smart technology. However, in the traditional sense, smart mobility is basically all about reducing congestion, greenhouse gases, and other vehicular emissions, and fostering faster, greener, and cheaper transportation options (Spinney et al., 2009). Moving smartly surely depends on an efficient means of active and public transport systems having a low environmental impact, a network of safe and continuous cycle lanes and walkways, and interchange parking that avoids city congestion (Yigitcanlar and Kamruzzaman, 2014, 2015; Chun and Lee, 2015). In other words, mobility cannot be considered "smart" if it is not also sustainable (Yigitcanlar et al., 2015; Garau et al., 2016).

This study aims to capture the big picture view on the relationship between urban smartness, measured in terms of access to the Internet, and sustainable forms of commuting. In line with this aim, the study focuses on addressing the research question: Do the residents in smarter cities commute more sustainably? In order to address this critical question, the paper concentrates on the following research objectives: (a) Establishing a causal link between urban smartness and new forms of working such as working from home, and (b) Exploring whether changes in urban smartness alter inhabitants' choice of commuting mode.

The methodological approach of this research includes a thorough review of the literature and applying multivariate multiple regression analysis to address the abovementioned research question and execute the research objectives. The case study cities for the empirical investigation are selected from Australia—all local government areas. The selection of Australia as the study context is justified because of (a) the Federal government's recent interest and investment in the smart cities agenda (Australian Government, 2016); (b) Australian cities' success (and failure) experiences in becoming smart cities (Yigitcanlar, 2016); (c) Ever-continuing political and public debates on the appropriate formulation of the delivery of a nationwide fast and reliable broadband network (Glance, 2017).

Literature Review

A decade into the commencement of the contemporary conceptualization and practice of the smart cities notion, the concept is still in its infancy (Alizadeh, 2017; Yigitcanlar, 2017; Praharaj et al., 2018). Today, many scholars are advocating the importance of urban planners and decision-makers being prepared for the onslaught of disruptive urban technologies—whether it is Internet of Things (IoT), social robotics, sharing economy, big data, artificial intelligence, crowdsourcing, drones, or 3D printing (Batty et al., 2012; Batty, 2013; Anthopoulos, 2017). Similarly, smart mobility—although under the ITS brand dating back to the 1980s—is also a relatively new brand, and it has the potential to bring out both the best or worst in our cities by transforming among other things, land use and mobility patterns; for example, as a consequence of the adoption of autonomous vehicles (Firnkorn and Müller, 2015; Truong et al., 2017). Instead of solely focusing on these two fashionable concepts, this literature review concentrates on their more traditional cores—the interplay between information and communication technologies (ICTs) and transport systems, along with their combined impacts on sustainable commuting.

The research on the impacts of ICTs on transport systems has matured over the last four decades (Goldmark, 1969; Messenger and Gschwind, 2016). Given that both transport and ICT are considered communication technologies, the initial expectations were that the old transport technology would be replaced by new ICT technology because of the reduced generalized cost of reaching amenities and services and the improved quality and attractiveness of those amenities and services (Lyons, 2002). Such replacement, as expected, would have three types of impacts: (a) changes in travel demand; (b) changes in transportation systems such as the development of ITS and consequent efficiency gains; (c) changes in urban form caused by the demand for certain types of land uses and the accessibility of such places (Brown et al., 2005; Cohen-Blankshtain and Rotem-Mindali, 2016). This review focuses on the impacts of ICT on travel demand, and more specifically, on travel behavior.

The presumption that ICT potentially changes travel behavior stems from a hypothetical understanding that ICT will replace aspects of the traditional transport system and support sustainable mobility. Numerous studies have been conducted to prove empirically this hypothesis and several review articles have also been published based on these empirical studies (Aguiléra et al., 2012; Cohen-Blankshtain and Rotem-Mindali, 2016). However, most of these studies have focused on investigating the links between telecommunications and travel behavior (Mokhtarian, 1991; Claisse and Rowe, 1993; Fadare and Salami, 2004; Kwan et al., 2007). These studies have shown that telecommunications have four types of effects on travel behavior: (a) substitution (e.g., telecommunications replace travel); (b) enhancement/complementarity (e.g., telecommunications increase travel); (c) modification (e.g., telecommunications change the way people travel); (d) neutrality (e.g., telecommunications have no effect on travel) (Brown et al., 2005; Zhang et al., 2007).

Transport researchers have started examining the impacts of the Internet on the abovementioned four dimensions of travel in the last decade. These studies have broadly been classified into two groups: (a) general use of the Internet and activity-travel patterns; (b) specific use of the Internet (e.g., teleshopping, telecommuting) and their impacts on overall travel (Ren and Kwan, 2009). A range of indicators in relation to the general use of the Internet have been used in the literature such as the frequency and/or amount of Internet use (Viswanathan and Goulias, 2001; Nobis and Lenz, 2004; Srinivasan and Reddy, 2004; Zhang et al., 2007; Kenyon, 2010); and the use of home computers stratified by: (a) private tasks without need of an Internet connection; (b) private tasks with need of an Internet connection; (c) work tasks without need of an Internet connection;

(d) work tasks with need of an Internet connection (Hjorthol, 2002). Typical variables used to assess the impacts of the Internet include vehicle kilometers traveled, total daily trips, daily walking trips, mode of travel, and time spent traveling (Viswanathan and Goulias, 2001; Hjorthol, 2002; Nobis and Lenz, 2004; Zhang et al., 2007).

Mostly, the findings from the studies on the impacts of the Internet on travel behavior correspond to the four types of telecommunication effects as outlined previously (i.e., substitution, complementarity, modification, neutrality). For example, a few studies have reported that ICT use is proportionately related with: (a) trip making (Johansson, 1999; Wang and Law, 2007; Zhang et al., 2007; Lila and Anjaneyulu, 2016); (b) car-dependency (Nobis and Lenz, 2004); (c) travel distance (Hjorthol, 2002; Zhang et al., 2007); and (d) travel time (Wang and Law, 2007). The main reason for the complementarity effect of the Internet on travel behavior is the result of widened travel horizons, an increase in time available for travel, the productive use of travel time, the intrinsic value of travel as an activity in itself and the ability of the Internet to make travel itself more effective (Kenyon, 2010). Other studies found the evidence of the replacement effect of the Internet on travel behavior. For example, Viswanathan and Goulias (2001) revealed that Internet use was correlated negatively with time spent on travel.

The relationship between Internet use and travel behavior is not always straightforward, but possesses many complexities depending on the types of users and usage of the Internet as well as the types of activities investigated. For instance, Hjorthol (2002) indicated that the users of home computers tend to make somewhat fewer work trips but do more chauffeuring and total trips. Similarly, Handy and Yantis (1997) found that in-home entertainment activities generate additional travel whereas online maintenance activities reduced travel. The impacts of Internet activities on travel also vary with gender. For example, Ren and Kwan (2009) revealed that Internet use for maintenance purposes has a greater impact on women's activity-travel in the physical world, while Internet use for leisure purposes affects men's physical activities and travel to a greater extent. Therefore, the results indicate the presence of both substitution and generation effects due to Internet use (Srinivasan and Reddy, 2004).

The Internet can modify travel behavior in a number of ways. One of the ways found in the literature is the fragmentation effect (Couclelis, 2000; Schwanen and Kwan, 2008)—i.e., separation of activities into discrete pieces (e.g., decomposition of work into multiple segments of subtasks, which can be performed at different times and/or locations). Alexander et al. (2010) found that Internet use can lead to three types of fragmentation of work activities: (a) a less temporally and spatially fragmented work pattern; (b) a less spatially but more temporally fragmented work pattern; (c) a more spatially and temporally fragmented work pattern. Fragmentation often leads to an increase in travel as activities are no longer tied to particular places and/or times (Kwan et al., 2007).

Recent studies also reported the neutrality effect of the Internet. For example, Line et al. (2011) found that the effect of the Internet on changes in social practice at the level of the individual is not visibly dramatic among students and part-time working mums. However, they reported that such technologies enable them to better accommodate the uncertainties in activity and travel scheduling—reflecting the modification effect.

Studies focusing on the specific use of the Internet also found mixed results. These studies investigated three types of specific use of the Internet such as teleworking (or telecommuting), teleshopping, and tele-leisure, and empirically tested their effects on travel behavior. Telecommuting occurs when commuting trips are replaced by virtual commuting as individuals are able to work in their homes (Aguiléra et al., 2012). Further refinement of telecommuting is done in the literature into three modes of work: home office, mobile office, and virtual office (Messenger and Gschwind, 2016). A number of authors investigated the effects of teleshopping on travel behavior. They found that teleshopping affects travel behavior in a number of ways, including replacing travel when online shopping is delivered at home (Anderson et al., 2003; Weltevreden, 2007) and reducing unnecessary travel (e.g., visiting multiple shops to explore bargains and offers). Other studies, however, reported no/limited effects of e-commerce when shopping trips are combined with other activities (e.g., work), or trips are made anyway for the purchase of other goods (Mokhtarian, 2004). It is also evident that teleshopping has the complementary effect. For example, increasing advertisement of retailers for bargains may induce additional trips or travel to shops further away that were not previously known to the customers (Rotem-Mindali, 2010).

Scholars have used a range of datasets to investigate the effects of the Internet on travel behavior including (a) nationally representative samples such as the National Household Travel Survey data in the United States (Zhang et al., 2007) and the Norwegian National Personal Travel Survey data (Hjorthol, 2002); (b) travel-diary data from representative samples in Germany (Nobis and Lenz, 2004) and the San Francisco Bay Area (Srinivasan and Reddy, 2004); (c) specifically designed survey data for the purpose of identifying Internet use and travel in Sweden (Johansson, 1999); and (d) qualitative diary and interview data (Line et al., 2011). A common aspect of all these datasets is that they are cross-sectional in nature and the analysis presented provides a snapshot of Internet use and travel behavior in a point in time. These scholars applied a range of analytical techniques to estimate the effect of Internet use on travel behavior such as linear regression models (Hjorthol, 2002; Zhang et al., 2007), the Poisson regression model to investigate the variations in the number of trips made (Zhang et al., 2007), and more complex structural equation models (Wang and Law, 2007; Ren and Kwan, 2009; Lila and Anjaneyulu, 2016). However, given the cross-sectional nature of the data used, their analyses lack the ability to ascertain causal relationships between Internet use and travel behavior (Zhang et al., 2007).

Studies highlighted that a causal relationship is more certain when a change in explanatory factor (Internet use in this case) causes a change in travel behavior (Handy et al., 2005; Kamruzzaman et al., 2016). In this regard, Kenyon (2010) suggested that panel-based research is more likely than cross-sectional research to accurately uncover the strength and form of relationships. Despite this, Kenyon (2010) collected longitudinal panel data, but applied a cross-sectional analysis method. The current evidence base is, therefore, insufficient to answer the research question raised earlier. Clearly, there is a need to expand the empirical investigation base with cause-effect mechanisms to clearly understand the connections between technological changes in cities and their sustainability outcome.

Empirical Investigation

Case Study

There were several reasons for conducting the empirical study in Australia. First, after the Australian Prime Minister's 2015 announcement highlighting cities as a national priority, the Commonwealth's Smart Cities Plan was launched in 2016. The plan aims to deliver jobs closer to homes, more affordable housing, better transport connections, and healthy environments. It includes: (a) establishing of an infrastructure financing unit to work closely with the private sector on innovative financing solutions and (b) committing funding to accelerate planning and development works on major infrastructure projects to develop business cases and investment options (Australian Government, 2016). Although the smart cities agenda only dates back to 2015, Australia has long been a nation that enjoys much of what technology has to offer. For example, significant clusters of wired communities started to become evident in Sydney as early as 2001 (Baum et al., 2004). Similarly, around the same time, most of the Australian local governments started to use ICTs in their daily urban and transport planning tasks (Yigitcanlar, 2005, 2006).

Second, Australian cities have a high-level of vulnerability to the likely consequences of global climate change as they are located in the world's driest continent (Goonetilleke et al., 2014). Against this challenge, a number of cities in Australia showcase various success (and also some failure) stories in their journey to become smart (and thus sustainable) cities. Sydney, Melbourne, Brisbane, Perth and Adelaide are among the cities with strategies in place and are progressing firmly on their smart city agendas. For instance, Brisbane's "City Smart" strategy includes: (a) creating a legible structure plan, (b) uniting disparate precincts, (c) creating definitive pedestrian spines, (d) linking the city center by mass transit, (e) defining a knowledge corridor, (f) investing in sustainability, (g) developing effective planning processes, and (h) developing a smart city model (Hortz, 2016; Yigitcanlar, 2016).

Finally, Australia is behind most of the other OECD countries in terms of a fast and reliable broadband Internet infrastructure. For example, in 2013, Australia was ranked 29 out of 34 OECD countries in average Internet connection speed (OECD, 2014). One of the reasons for this is that political, industry, and public debates lasted for too long and delayed the commencement of the development and thus the completion of the national broadband network (NBN) project—offering up to 100 Mbps download and 40 Mbps upload speeds (Yigitcanlar, 2016). The geographic coverage of the NBN is limited, as this service is mostly available to small parts of the metropolitan cities, and the rest of the country is generally served with ADSL2+—at best up to 24 Mbps download and 1.4 Mbps upload speeds (Yigitcanlar, 2016). Moreover, there are high numbers of connection delay complaints (Glance, 2017). According to Tucker and Branch (2013), at the current rate of NBN roll-out, the project may take more than two decades to cover the whole country. This would not only jeopardize the smart cities agenda in the country, but also cause a major disadvantage in Australia's competitiveness in the digital economy (Bowles and Wilson, 2012).

A country context with aforementioned challenges and opportunities make Australia an interesting testbed for research that investigates whether the smartness of cities lead to sustainable commuting patterns.

Data

This research used the 2006 and 2011 editions of the census data collected by the Australian Bureau of Statistics (ABS). Data are collected from all people (including visitors) on a specified census day in Australia every five years. This is the only source of data that provides information for the entire country, also stratified by different administrative boundaries. This research used Local Government Area (LGA) boundary as the unit of analysis because Australian Commonwealth (Federal) Government funds, to promote smart city agenda in Australia, are channeled through the LGAs (https://cities.dpmc.gov.au/smart-cities-plan). Note that there were changes in the number of LGAs in Australia between 2006 (n = 676) and 2011 (n = 568). For example, some LGAs were merged together or the names of some of the LGAs have been slightly modified. This research used data only from those LGAs that remained fixed in both periods, which resulted in 513 analytical samples of LGAs.

The main exposure variable of interest is access to the Internet. In both the 2006 and 2011 editions of the survey, questions were asked to respondents whether their dwelling is connected with the Internet, and if yes, the type of connection (e.g., broadband, dial-up, others). The datasets also provided information about the respondents who did not answer this question and information about those for whom this question was not applicable (e.g., not living in a private dwelling). Note that the 2016 edition of the survey contained a modified version of the question and asked whether private dwellings have any people who access the Internet from the dwelling, without details of the type of connection. Given that the main objective of this research is to test the causal relationships between access to the Internet and commuting behavior, and that this required a panel nature of longitudinal data, the 2016 edition of the survey data was not included because the questions were not consistent with those of the prior surveys. With the interest of modelling the impact of changes, this research required calculating the percentage of dwellings with Internet connections (and types) in both periods because LGAs experienced population/dwelling growth over the period. As a result, relative changes were derived (percentage of changes in dwellings with Internet connections) rather than absolute changes (changes in the number of dwellings).

The commuting mode of transport was used as the outcome variable of this research. In both surveys, respondents aged 15+ were asked to indicate their "method of travel to work." They were given 14 options to choose from: train, bus, ferry, tram (including light rail), taxi, car-as driver, car-as passenger, truck, motorbike or motor scooter, bicycle, walked only, worked at home, other, and did not go to work. Respondents were also given the option of choosing multiple modes of transport. This research reclassified the modes of transport into the following categories: public transport (merging train, bus, ferry, and tram), private transport (merging taxi, car-as driver, car-as passenger, truck, motorbike or motor scooter), active transport (merging bicycle, walked only), other, worked at home, did not go to work, and not stated (respondents who did not answer to this question). In cases where respondents selected multiple modes, these were assigned to the above categories according to the following priorities: public transport (if public transport was a selected mode among the multiple modes), private transport (if private transport was a selected mode among the multiple modes but not public transport), and active transport (if active transport was a selected mode among the multiple modes but not public transport/private transport). Like the access-to-the-Internet variable, relative changes between the periods in these modal categories were derived. Table 1 outlines descriptive statistics for both exposure and outcome variables.

As shown in Table 1, this research also derived a range of other variables, including household income, vehicle ownership, employment status, and gender. These variables

Table 1. Variable description

Variables	Mean	Std. Dev.	Min	Max
Outcome variables (changes in employed person aged 15+ between 2006 and 2011)				
% of changes in persons worked at home	−1.10	2.02	−14.45	10.56
% of changes in persons commuting by public transport	0.83	2.14	−8.35	17.22
% of changes in persons commuting by private transport	2.02	4.41	−28.38	28.70
% of changes in persons commuting by active transport	−1.23	3.96	−22.35	39.82
% of changes in persons commuting by other mode of transport	0.12	2.23	−42.15	12.26
% of changes in persons did not go to work	−0.32	2.23	−9.33	32.77
% of changes in persons not stating commuting mode	−0.31	1.37	−8.93	16.67
Explanatory variables				
Change factors between 2006 and 2011				
Internet connection: % of changes in dwellings with				
Broadband connection	35.89	9.27	0.00	62.14
Dial-up connection	−16.21	6.34	−42.07	0.12
Other types of Internet connection	3.75	3.41	0.00	65.89
No Internet connection	−8.95	6.48	−66.34	26.08
Internet connection not applicable	−15.14	9.28	−61.23	0.00
Internet connection not stated	0.64	2.89	−20.82	13.46
Income: % of changes in families with income (per week)				
Negative or zero income	0.41	1.17	−7.92	5.93
$1–$999	10.94	8.51	−76.47	37.33
$1k–$1,999	−4.60	8.48	−31.34	76.47
$2k–$2,999	−6.94	4.10	−30.00	8.33
$3k–$3,999	−0.84	1.98	−10.97	12.79
$4k or more	1.02	1.78	−7.09	19.94
Vehicle ownership: % of changes in dwellings with				
Zero vehicle	−0.73	1.79	−20.70	13.40
One vehicle	−0.37	2.63	−22.66	12.71
Two vehicles	−0.22	2.27	−10.94	8.60
Three vehicles	0.53	1.57	−15.79	8.62
Four or more vehicles	0.73	1.22	−4.29	9.21
Vehicles not stated	−0.86	2.66	−15.79	9.67
Vehicles not applicable	0.92	3.67	−17.86	38.89
Gender: % of changes in persons described as				
Female	−0.15	2.39	−16.09	28.54
Employment status: % of changes in employed persons described as				
Full-time employment	−0.02	5.88	−19.66	45.41
Part-time employment	0.02	5.88	−45.41	19.66
Base factors in 2006				
Commuting: % of employed person				
Worked at home	9.57	7.26	0.00	37.54
Commuted by public transport	4.42	6.70	0.00	34.82
Commuted by private transport	60.99	13.65	4.00	80.92
Commuted by active transport	11.00	12.15	1.06	91.72
Commuted by other mode	1.61	3.82	0.00	63.16
Did not go to work	10.34	2.76	0.00	17.43
Not Stated commuting mode	2.08	1.15	0.00	12.12
Internet connection: % of dwellings with				
Broadband connection	22.84	12.02	0.00	62.15
Dial-up connection	19.39	7.05	0.00	48.33
Other types of Internet connection	0.51	0.32	0.00	2.15
No Internet connection	34.23	10.01	0.00	80.00
Internet connection not applicable	16.60	11.68	0.00	101.43
Internet connection not stated	6.42	3.90	0.00	41.51
Income: % of families with income				
Negative or zero income	1.31	1.32	0.00	9.52
$1–$999	43.80	13.50	5.67	100.00
$1k–$1,999	37.77	7.14	0.00	68.42
$2k–$2,999	12.04	6.88	0.00	41.96
$3k–$3,999	3.47	4.10	0.00	20.42

(Continued)

Table 1. Continued.

Variables	Mean	Std. Dev.	Min	Max
$4k or more	1.61	2.42	0.00	24.51
Vehicle ownership: % of dwellings with				
Zero vehicle	7.83	7.48	0.00	55.20
One vehicle	27.73	6.51	0.00	47.54
Two vehicles	27.35	7.31	0.00	43.52
Three vehicles	8.92	3.29	0.00	20.31
Four or more vehicles	4.86	2.85	0.00	19.58
Vehicles not stated	6.67	3.72	0.00	28.57
Vehicles not applicable	16.64	11.70	0.00	100.00
Gender: % of persons described as				
Female	49.14	3.90	7.67	56.87
Employment status: % of employed persons described as				
Full-time employment	68.22	7.88	22.73	96.25
Part-time employment	31.78	7.88	3.75	77.27
N = 513 (local government areas)				

have commonly been identified to have significant effect on the choice of commuting mode (Asensio, 2002; Beckman and Goulias, 2008; Antipova et al., 2011; Kamruzzaman et al., 2014; Cao, 2015; Clark et al., 2016). As a result, changes in these variables between the periods were used as controlling factors to investigate the causal link between access to the Internet and commuting travel behavior. Other time invariant factors such as the remoteness index of the LGAs were not considered because of the panel nature of the data analysis technique applied in this research which differenced out such factors.

Approach: Multivariate Multiple Regression Analysis

The way variables were coded (as described above) in this research can be regarded as panel data with two-time periods for the 513 LGAs. When variables are observed at only two periods, an ordinary least square (OLS) regression model can reliably generate unbiased estimates of coefficients on the difference scores between the time periods (Allison, 2009). However, an OLS model is suitable to estimate a coefficient only when there is a single outcome variable. This research requires modeling five outcome variables (two outcome variables—did not go to work, and commuting mode not stated—were not included in the analysis due to their lack of relevance) with moderate levels of correlations among some of the outcome variables (See Table 2). The observed correlations are expected in this research because the differences in mode choice behavior are calculated in percent, and as a result, if the use of one mode increases, naturally the use of other

Table 2. Correlations among the outcome variables

Outcome variables	% of changes in				
	Worked at home	Public transport use	Private transport use	Active transport use	Other mode use
Worked at home	1				
Public transport use	−0.1684	1			
Private transport use	−0.3127	−0.2975	1		
Active transport use	0.0594	−0.098	−0.7018	1	
Other mode use	−0.1517	0.11	−0.2167	0.0158	1

modes decreases. Research highlighted that when there are multiple outcome variables and at least a moderate level of correlation exists among the outcome variables, multivariate regression is a better suited model over the OLS model (Washington et al., 2010; Kamruzzaman and Hine, 2013).

In a multivariate model, the outcome variables are simultaneously regressed against the explanatory variables. When there is a single explanatory factor in a multivariate regression, it is called multivariate (simple) regression whereas a multivariate regression model is referred to as multivariable multiple regression when there is more than one explanatory factor in a model. More specifically, a multivariate multiple regression is "multiple" because there is more than one independent variable. It is "multivariate" because there is more than one dependent/outcome variable. Interested readers are referred to Dattalo (2013) for a detailed discussion on multivariate multiple regression models. In summary, given the need to model multiple outcome variables with moderate correlations which need to be regressed by more than one predictor variable, as a result, multivariate multiple regression models were estimated as the main analytical method in this research in order to examine whether changes in access to the Internet affected commuting patterns over the period of 2006–2011. The outputs of a multivariate regression model are interpreted in the same way as outputs from an OLS regression model.

This research models the changes in outcome variables (model of commuting choice) in an effort to investigate the impacts of changes in access to the Internet. Research has shown that individuals' changed behavior is a function of not only changed circumstances (e.g., changes in access to the Internet) but also related to their "base" values (status of access to the Internet in 2006) including choice of commuting mode in the base year of 2006 (Krizek, 2003; Kamruzzaman et al., 2016). As a result, base values associated with the choice of commuting mode, socio-demographic status of the LGAs, and status of the Internet connection in 2006 were used as explanatory factors in addition to the changed factors (e.g., changes in access to the Internet and socio-demographic status). This procedure is considered as the best way to define changes by correcting for the phenomenon of regression to the mean (Twisk, 2003).

The number of explanatory factors, however, became very large with the inclusion of both base and changed factors. (See Table 3.) This may result in an over-specification of the multivariate model given the 513 data points used in this research (Wilson et al., 2006). Model over-specification typically results in producing numerically unstable estimates and is characterized by unrealistically large estimated coefficients and/or estimated standard errors (Bursac et al., 2008). In addition, modelling exercises often seek to build a parsimonious model by minimizing the number of variables but without compromising the true outcome experience of the data. Hosmer et al. (2013: 90) stated that "the rationale for minimizing the number of variables in the model is that the resultant model is more likely to be numerically stable and is more easily adopted for use." Several methods exist in the literature to overcome the over-specification problem in a model (see Wilson et al., 2006; Bursac et al., 2008).

This research applied four different strategies to overcoming this problem. First, variables that are undefined (e.g., not stated or not applicable) were not included. Second, the research tested the correlations among the explanatory factors and highly correlated factors were excluded from further analysis in order to avoid multicollinearity problem. Table 3 lists a subset of the explanatory factors with high correlation coefficients. Third,

Table 3. Correlations among a few explanatory factors[a]

Explanatory factors	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1. Changes in no Internet connection	1.00																						
2. Changes in dial-up connection	0.15	1.00																					
3. Changes in broadband connection	0.00	−0.79	1.00																				
4. Changes in not applicable (not residential) Internet connection	−0.69	−0.05	−0.41	1.00																			
5. % of no connection 2006	−0.11	0.18	−0.32	0.21	1.00																		
6. % of broadband connection 2006	−0.39	0.22	−0.36	0.56	−0.53	1.00																	
7. % of dialup connection 2006	−0.14	−0.99	0.83	0.00	−0.19	−0.24	1.00																
8. % of not applicable (not residential) Internet connection 2006	0.70	0.10	0.34	−0.98	−0.19	−0.58	−0.06	1.00															
9. % of not stated connection 2006	−0.02	0.36	−0.38	0.20	−0.11	0.13	−0.37	−0.15	1.00														
10. Changes in $1k–$1,999 income	0.03	0.33	−0.47	0.26	−0.01	0.34	−0.37	−0.26	0.26	1.00													
11. Changes in $1–$999 income	−0.12	−0.31	0.41	−0.12	−0.28	0.05	0.34	0.08	−0.23	−0.80	1.00												
12. % of private transport used 2006	−0.44	−0.28	0.26	0.29	−0.18	0.35	0.30	−0.38	−0.19	−0.20	0.28	1.00											
13. % of active transport used 2006	0.44	0.41	−0.47	−0.17	0.52	−0.44	−0.44	0.25	0.18	0.30	−0.49	−0.81	1.00										
14. Changes in $2k–$2,999 income	0.17	−0.06	0.14	−0.28	0.55	−0.65	0.09	0.29	−0.24	−0.32	−0.23	−0.17	0.30	1.00									
15. Changes in $3k–$3,999 income	0.16	−0.08	0.15	−0.26	0.36	−0.59	0.09	0.32	−0.02	−0.36	−0.17	−0.16	0.27	0.61	1.00								
16. Changes in $4k or more income	−0.10	0.15	−0.22	0.20	−0.24	0.29	−0.17	−0.12	0.32	0.24	−0.34	0.08	−0.02	−0.26	0.14	1.00							
17. % of negative/zero income 2006	0.16	−0.11	0.20	−0.20	−0.16	−0.12	0.11	0.24	−0.08	−0.13	0.14	−0.34	0.08	0.08	0.17	−0.03	1.00						
18. % of $1–$999 income 2006	0.28	0.05	0.02	−0.30	0.70	−0.75	−0.03	0.30	−0.18	−0.10	−0.33	−0.23	0.45	0.81	0.54	−0.32	−0.02	1.00					

(*Continued*)

Table 3. Continued.

Explanatory factors	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
19. % of $2k–$2,999 income 2006	−0.22	0.12	−0.23	0.35	−0.60	0.77	−0.15	−0.35	0.28	0.46	0.02	0.17	−0.29	−0.92	−0.62	0.44	−0.13	−0.87	1.00				
20. % of $3k–$3,999 income 2006	−0.14	0.19	−0.27	0.30	−0.56	0.75	−0.21	−0.31	0.24	0.52	−0.06	0.04	−0.21	−0.73	−0.77	0.32	−0.05	−0.76	0.86	1.00			
21. % zero vehicles 2006	0.05	0.48	−0.66	0.23	0.59	−0.08	−0.53	−0.19	0.16	0.51	−0.56	−0.47	0.71	0.15	−0.04	0.01	−0.11	0.33	−0.09	0.03	1.00		
22. % two vehicles 2006	−0.48	−0.53	0.35	0.42	−0.31	0.46	0.54	−0.48	−0.34	−0.23	0.39	0.74	−0.77	−0.25	−0.20	0.03	−0.12	−0.42	0.25	0.15	−0.61	1.00	
23. % three vehicles 2006	−0.21	−0.67	0.52	0.15	−0.21	0.06	0.68	−0.20	−0.37	−0.27	0.25	0.43	−0.51	0.01	0.11	−0.04	0.07	−0.19	−0.02	−0.12	−0.64	0.75	1.00
24. % 4+ vehicles 2006	−0.01	−0.63	0.55	−0.08	−0.18	−0.17	0.64	0.06	−0.30	−0.39	0.34	0.00	−0.24	0.08	0.21	−0.16	0.30	−0.10	−0.15	−0.23	−0.54	0.39	0.73
25. % not stated vehicles 2006	−0.02	0.37	−0.39	0.21	−0.12	0.16	−0.39	−0.16	0.97	0.28	−0.21	−0.19	0.18	−0.30	−0.07	0.31	−0.11	−0.21	0.33	0.27	0.15	−0.34	−0.37
26. % not applicable (not residential) vehicles 2006	0.70	0.10	0.34	−0.98	−0.19	−0.58	−0.06	1.00	−0.15	−0.26	0.08	−0.38	0.26	0.29	0.32	−0.12	0.24	0.30	−0.35	−0.31	−0.19	−0.48	−0.20
27. % active transport use 2006	0.44	0.41	−0.47	−0.17	0.52	−0.44	−0.44	0.25	0.18	0.30	−0.49	−0.81	1.00	0.30	0.27	−0.02	0.08	0.45	−0.29	−0.21	0.71	−0.77	−0.51

[a] Please note that not all independent factors, as presented in Table 1, are included in the table due to space restriction. It shows some factors with potentially high levels of correlations.

the research applied the purposeful selection method as laid out by Hosmer et al. (2013). Briefly, a multivariable (simple) regression model was estimated separately for each of the independent variables on the outcomes to identify factors that have a significant association with the outcomes. Only factors that were found to be significant at the $p < 0.1$ level were entered (forced entry) into the final multivariate multiple regression model (Bursac et al., 2008). Fourth, the multicollinearity among the selected explanatory factors was tested using ordinary least squares (OLS) regression model. A similar technique has been applied in previous research (Piya et al., 2013). The variance inflation factor (VIF) test showed that several of the significant factors (percentage of households with broadband connection in 2006, percentage of households with zero vehicles in 2006) suffer from multicollinearity problems with greater than 10 VIF. These variables were gradually removed and the OLS model was rerun until the problem was resolved.

The refined sets of explanatory factors were then used to estimate a multivariate multiple regression model. The significance level of these variables in the multivariate multiple regression model was checked again and the final model contained only those covariates that were statistically significant at least at the 0.1 level in the multivariable multiple regression model. All models were estimated in Stata (Version 13.0).

Results and Discussion

Descriptive Analysis

Table 4 shows that about 34 percent of the dwellings had no Internet connection in 2006 and that was reduced by 9 percent to 25 percent of the dwellings without an Internet connection in 2011. It also outlines that about one-fifth of the dwellings had access to dial-up Internet connection and that was also reduced to only 3 percent in 2011. In contrast, broadband Internet connection increased substantially from 23 percent in 2006 to 59 percent in 2011—an overall increase of 35 percent. Dwellings with other types of Internet connections, such as the Naked DSL, also increased by about 4 percent in that time. These changes suggest that there was an overall improvement with Internet connection in Australian dwellings from 2006 to 2011. A strong negative correlation (–0.79) between changes in broadband connection and changes in dial-up connection in Table 3 suggests that the LGAs that gave up dial-up connections gained accesses to broadband connections. Note that dwellings enjoy a better speed when connected by broadband and Naked DSL over the dial-up system.

Table 4. Patterns of change in Internet connection (2006–2011)

Type of Internet connection	2006 (% of dwellings)	2011 (% of dwellings)	Changes (%) between 2006 and 2011
Broadband connection	22.84	58.73	35.89
Dial-up connection	19.39	3.17	−16.22
Other types of Internet connection	0.51	4.26	3.75
No Internet connection	34.24	25.33	−8.91
Not applicable	16.60	1.46	−15.14
Not stated	6.42	7.05	0.63
Total (N = 513)	100	100	0.00

Table 5. Top 10 high-performing LGAs in terms of broadband Internet connection in Australia[a]

Top 10 LGAs in 2006		Top 10 LGAs in 2011		Top 10 LGAs with increasing connection	
LGA	% of dwellings	LGA	% of dwellings	LGA	% increase
Ku-ring-gai (A), NSW	62	Ku-ring-gai (A), NSW	84	Mallala (DC), SA	62
Willoughby (C), NSW	55	Nillumbik (S), VIC	82	Chittering (S), WA	62
Peppermint Grove (S), WA	55	Nedlands (C), WA	81	Woodanilling (S), WA	61
Hornsby (A), NSW	54	Hornsby (A), NSW	81	Wandering (S), WA	59
Lane Cove (A), NSW	52	Lane Cove (A), NSW	80	Wickepin (S), WA	57
Nillumbik (S), VIC	52	Willoughby (C), NSW	80	Dumbleyung (S), WA	57
Nedlands (C), WA	52	Pittwater (A), NSW	79	Kent (S), WA	56
Mosman (A), NSW	51	Joondalup (C), WA	79	Gingin (S), WA	56
Boroondara (C), VIC	50	Cambridge (T), WA	78	Lower Eyre Peninsula (DC), SA	56
Manningham (C), VIC	49	Boroondara (C), VIC	78	Narrogin (S), WA	56

[a]A = area, C = city, DC = district council, S = shire, T = town, NSW = New South Wales, SA = South Australia, VIC = Victoria, WA = Western Australia

Table 5 shows the top 10 LGAs in terms of broadband Internet connection both in 2006 and in 2011. Noticeable is that out of the 10 LGAs, seven remained in the top 10 list in both periods and also experienced a growth in broadband connection during that time. However, as expected, the maximum growth occurred in LGAs that were not in the top 10 list in 2006. The level of growth in these LGAs was found to be similar to the base level Internet connection of the top 10 LGAs. For example, Mallala (DC) in SA experienced a 62 percent increase in broadband connection between 2006 and 2011, whereas Ku-ring-gai LGA in NSW had 62 percent dwellings with broadband connection in 2006 (this was the highest level in 2006). Clearly this shows a distinction among the LGAs: (one having a legacy of high-level of broadband connection and the others that gained high-level connections between 2006 and 2011. This finding also justifies the inclusion of a "base" level variable in the multivariate multiple regression models (as discussed below) to investigate the effects of a legacy of Internet access on mode choice behavior.

Figure 1 shows the spatial distribution of LGAs in Australia with differential levels of change in broadband connection between 2006 and 2011. Clearly, the maximum level of changes occurred in LGAs located close to the capital cities—but not the capital city areas—perhaps because the capital city LGAs had already experienced a higher level of connection in 2006, and as a result, their level of change was minimal in that time. Further hot-spot analysis in ArcGIS, however, does not provide any spatial pattern of changes in broadband access in Australia.

Unlike changes in the exposure variable (access to the Internet), changes in outcome variables were found to be marginal. Table 6 shows that dependency on private transport increased by 2 percent between 2006 and 20ll; 61 percent of the employed people in Australia were dependent on a private vehicle for their travel to work in 2006 which was increased to 63 percent in 2011. In contrast, the rate of teleworking was reduced by 1.1 percent, from 9.6 percent in 2006 to 8.5 percent in 2011. Similarly, active transport use was reduced by 1.2 percent in that time. Eleven percent of the employed persons used

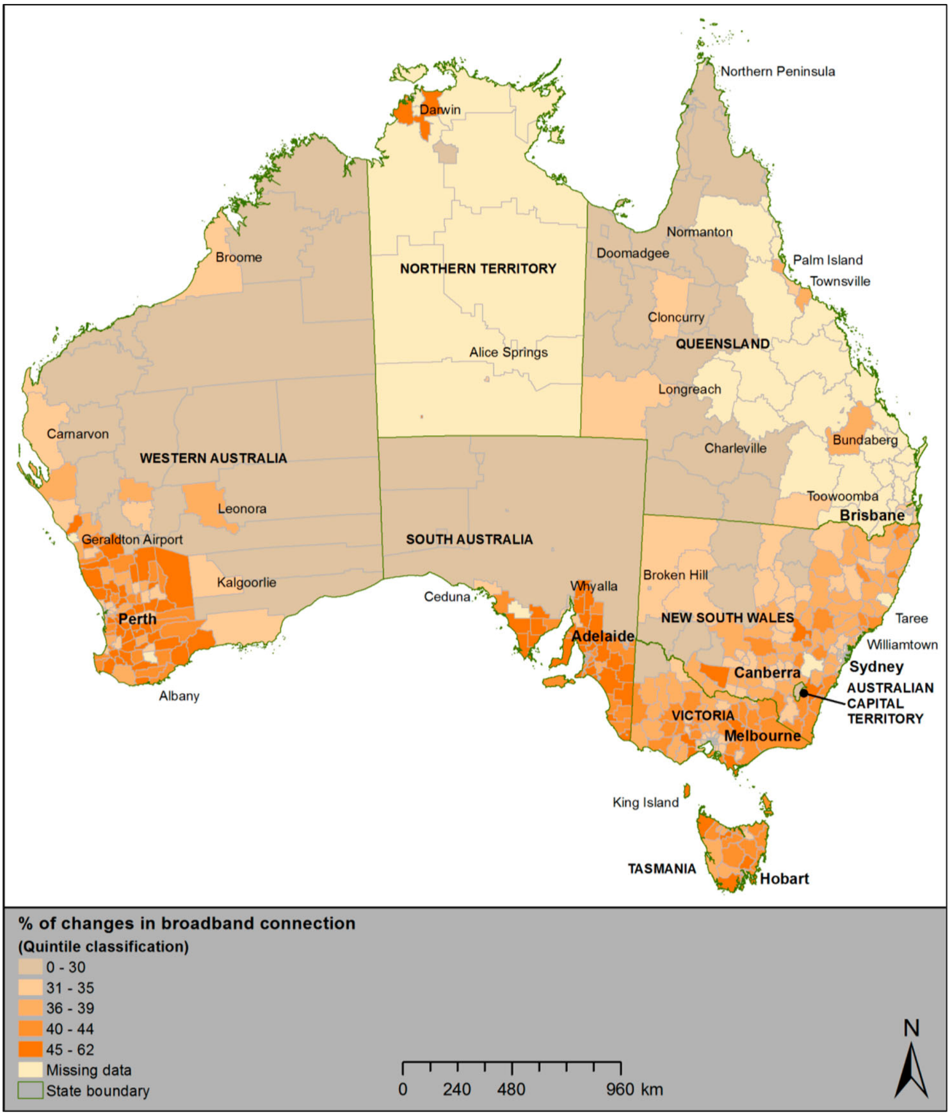

Figure 1. Changes of broadband Internet connection among the LGAs (2006–2011)

Table 6. Patterns of changes in commuting behavior (2006–2011)

	2006 (% of employed persons)	2011 (% of employed persons)	Changes (%) between 2006 and 2011
Worked at home	9.57	8.48	−1.10
Commuted by public transport	4.42	5.24	0.83
Commuted by private transport	60.99	63.01	2.02
Commuted by active transport	11.00	9.76	−1.23
Commuted by other mode	1.61	1.73	0.12
Did not go to work	10.34	10.02	−0.32
Not Stated	2.08	1.76	−0.31
Total	100	100	0.00

an active transport to work in 2006, which was reduced to 9.8 percent in 2011. All these findings point to a trend toward unsustainable commuting in Australia. The only sustainable growth pattern was evident in the use of public transport. The use of public transport for commuting increased by 0.83 percent from 4.42 percent in the base level to 5.24 percent in 2011. Figures 2 and 3 show the spatial distribution of changes in public and private transport uses, respectively.

A visual comparison between Figures 1 and 2 does not indicate a good link between the increase of broadband connection and the increase in the use of public transport. However, a visual comparison between Figures 1 and 3 points to the possibility of there being some link between the increase of broadband connection and the increase of

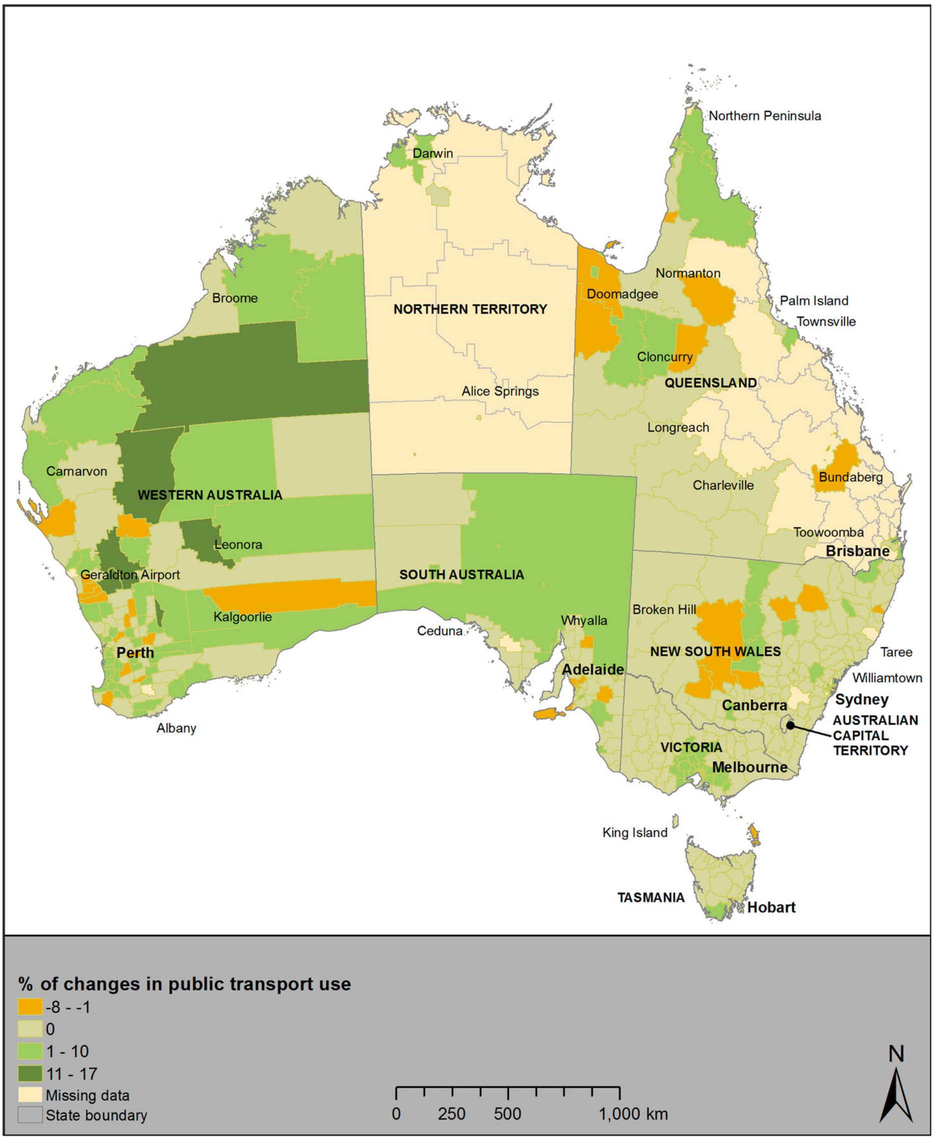

Figure 2. Changes in the use of public transport among the LGAs (2006–2011)

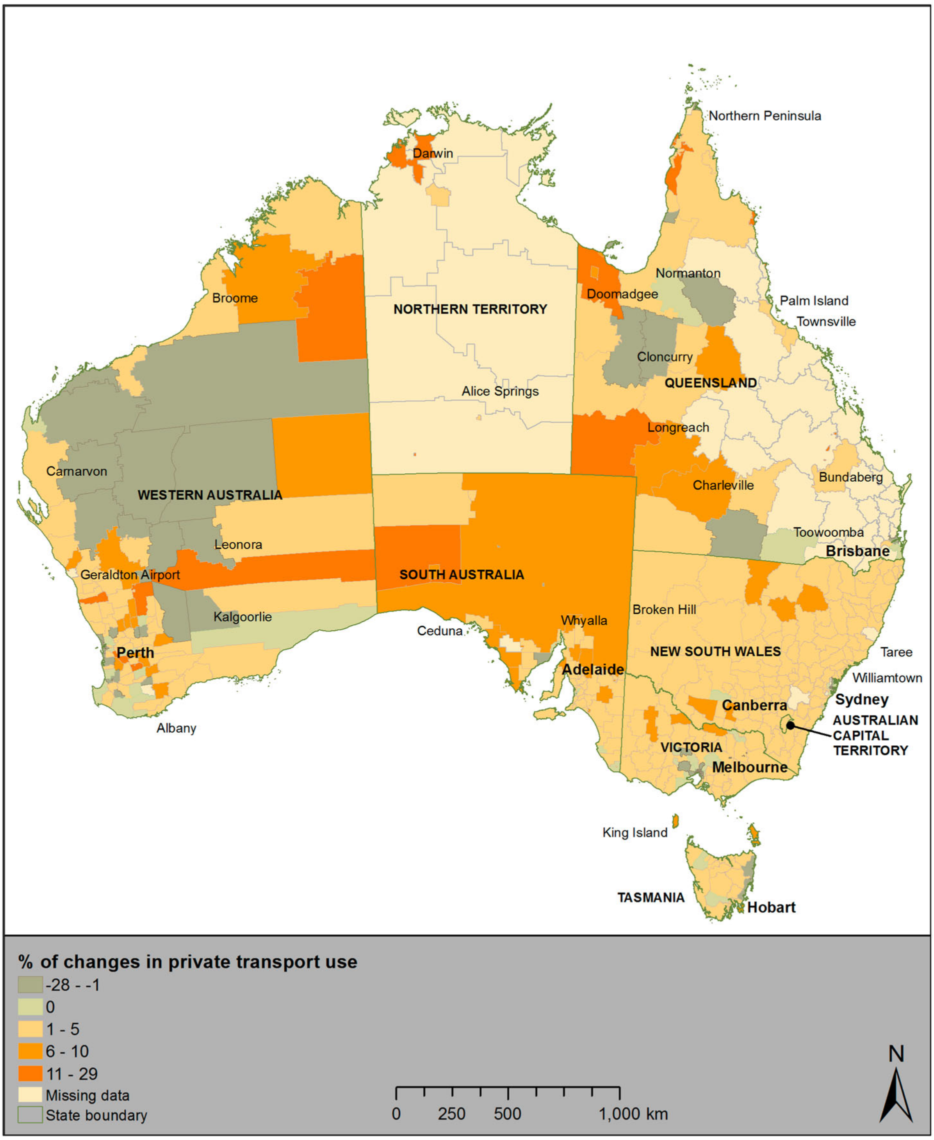

Figure 3. Changes in the use of private transport among the LGAs (2006–2011)

car-dependency. Attempts were made to ascertain these indicative relationships through multivariable multiple regression analysis as will be discussed next.

Multivariate Multiple Regression Analysis

This section reports the regression analysis results showing the factors that significantly affected the choice of commuter mode in Australia. This research conducted four different F tests (Wilks' lambda, Lawley-Hotelling trace, Pillai's trace, and Roy's largest root) to assess the statistical significance of the overall model. The test results for the overall model indicate that the multivariate models are statistically significant, regardless of the type of multivariate criteria used (e.g., Wilks' lambda). In addition, each of the five univariate models (e.g., the percentage of changes in worked at home, the percentage of changes in public transport use, and so on) was also found to be statistically significant (See Table 7). Moreover, the explanatory power (row labelled as R^2) of each of the univariate models was found to be quite favorable in comparison with previous research on this topic (Zhang et al., 2007). Note this value is a standard R-squared, not an adjusted R-squared.

Table 7 shows that broadband Internet connection has a significant effect on the choice of commuting mode in Australia. It reveals that a 1 percent increase in

Table 7. Multivariate multiple regression results (coefficients)

Explanatory factors	Outcome variables:[a] % of changes between 2006 and 2011 i				
	Worked at home	Public transport use	Private transport use	Active transport use	Other mode use
Change factors between 2006 and 2011					
% of changes i					
Dwellings with broadband connection	−0.02*	−0.03**	0.16**	−0.12**	−0.01*
Dwellings with other types of Internet connection	0.04	−0.21**	0.38**	−0.08	0.01
Dwellings with no Internet connection	0.04*	−0.07**	0.19**	−0.16**	0.01
Families with income of $1–$999	0.04**	−0.04**	0.01	0.04	0.00
Families with income of $2k–$2,999	−0.02	−0.02	0.04	−0.09	0.06**
Families with income of $3k–$3,999	0.04	−0.12**	−0.08	0.33**	0.00
Dwellings with zero vehicles	−0.09**	0.12**	−0.20**	0.38**	−0.11**
Dwellings with one vehicles	−0.04	0.22**	−0.11	0.04	0.04**
Dwellings with two vehicles	−0.10**	−0.03	0.55**	−0.24**	−0.02
Dwellings with three vehicles	0.20**	−0.04	−0.08	0.02	0.03
Dwellings with four or more vehicles	0.20**	0.12**	−0.18	−0.03	0.03
Female	0.29**	−0.66**	0.08	0.48**	−0.28**
Persons with full-time employment	−0.03*	0.04**	0.08*	0.01	0.02
Base factors in 2006					
% o					
Individuals worked at home	−0.23**	0.02	−0.02	0.25**	0.01
Individuals commuted by public transport	−0.02	0.06**	−0.12**	0.16**	0.01
Individuals commuted by private transport	−0.04**	0.03**	−0.15**	0.13**	0.00
Individuals did not go to work	0.04	0.13**	0.02	0.29**	0.03
Dwellings with other types of Internet connection	0.02	0.21**	0.16	−0.23	−0.29**
Dwellings with no Internet connection	−0.01	−0.02	0.15**	−0.06*	−0.03**
Families with negative or zero income	0.22**	0.28**	−0.21	−0.13	−0.03
Dwellings with one vehicles	0.05**	−0.07**	0.07	−0.07	0.04**
Dwellings with two vehicles	0.01	−0.04*	0.22**	−0.12**	0.01
Dwellings with four or more vehicles	0.09**	−0.07*	0.10	−0.16*	0.06**
Female	0.04	0.00	0.05	−0.08	−0.23**
Constant	−0.53	1.19	−9.57*	−0.25	11.52**
R^2	0.52	0.65	0.47	0.39	0.42
F	22.14**	37.30**	17.64**	12.92**	14.35**
N = 513 (local government areas)					

[a] Coefficients marked * are significant at the 0.1 level; Coefficients marked ** are significant at the 0.05 level

broadband connection reduced the number of people working from home by 0.02 percent. In contrast, an increasing number of households with no Internet connection increased the number of people working from home. A similar impact was found in the case of households with other types of Internet connection. The household Internet status in the base period (2006) was not found to be a statistically significant factor in the changes of commuting behavior in Australia. The findings, therefore, verify the replacement hypothesis of the ICT impact on travel behavior—but in an unsustainable way.

Even though the use of public transport increased overall between 2006 and 2011 as outlined earlier, Table 7 highlights that an increase in the level of broadband connection significantly reduced the use of public transport services. This is also true for households that increased their use of other types of Internet connections. Again, these findings relate to the replacement hypothesis of ICT impact on travel behavior—again in an unsustainable way. The complementary hypothesis is proved in the case of private transport use. Table 7 indicates that a 1 percent increase in the level of broadband connection in an LGA led to a 0.16 percent increase in private transport use. A similar impact is evident for other types of Internet connections. Access to the Internet may create fragmentation in work activities that need to be performed at different locations and at different times (Couclelis, 2000; Schwanen and Kwan, 2008), and naturally the most suitable mode to perform these fragmented activities is private transport, given their flexibility (Maat and Maat, 2009). Table 7 also highlights that a 1 percent increase in access to a broadband Internet connection led to a reduction in the use of active transport by 0.12 percent, which reflects the substitution hypothesis of ICT, but again in an unsustainable way.

Conclusion

The challenges our cities and societies have been facing in the age of global crises—environmental, economic, or social—have encouraged urban planners, architects, environmentalists, and policymakers to become passionate about new urban paradigms as potential panacea (Perveen et al., 2017; Yigitcanlar et al., 2017). As stated by Kunzmann (2014: 9),

> urban paradigms are urban dreamscapes, full of wishful thinking about better urban worlds. In the beginning of the twenty-first century, the sustainable city, the eco-city, the compact city, the creative city, the knowledge city, the slow city, the resilient city, and more recently, the smart city concept have received considerable academic interest, and attention among media and local governments, searching for popular visions for urban development in times of globalization.

Consequently, being "smart" is on the urban agenda of many cities across the globe with strong support from global technology and development companies—e.g., IBM, Cisco, Samsung, LG, ARUP, Schneider Electric, Siemens, Microsoft, Hitachi, Huawei, Ericsson, Toshiba, Oracle (Yigitcanlar, 2016; Alizadeh, 2017).

On the one hand, for many scholars, smart cities are seen as the immediate future, where smartness is perceived as a characteristic of city systems responding to opportunities, challenges, and unknown consequences (Albino et al., 2015). In contrast, sceptics argue that the smart cities movement should be considered with great caution as "large corporations are exerting significant influence in the era of smart in pursuit of goals that may not strongly align with those of urban planners concerned with social and environmental sustainability as well as economic prosperity" (Lyons, 2016: 1).

One of the key areas in which smartness is crucial for our cities is the transport sector. This importance has placed smart mobility at the heart of smart cities discourse and practice, where smart mobility is widely seen as connectivity in towns and cities that is affordable, effective, attractive, and sustainable (Garau et al., 2016). However, as argued by Lyons (2016), in mobility practice the paradigms of smart and of sustainable are not strongly aligned; the paradigms, thus, need to be brought together towards a common framework for truly smart and sustainable urban mobility development.

This paper investigated the relationship between urban smartness and sustainable forms of commuting in the context of Australian local government areas; in order to address the question of whether the smartness of cities leads to sustainable commuting patterns. The findings of this investigation generated several insights.

First, the descriptive analysis revealed, not to our surprise, that metropolitan regions of the capital cities have a higher-level of Internet (particularly broadband) accessibility and public and active transport use in Australia. Additionally, the level of working from home (or teleworking) has decreased between 2006 and 2011. Despite metropolitan regions having higher public and active transport shares, they are still too low, and the figures point to a clear unsustainable commuting pattern. The visible correlation between Internet access and commuting is as follows: an increase in broadband access leads to an increase in private motor vehicle use.

Second, the multivariate multiple regression analysis revealed that the Internet (particularly broadband) has a significant effect on commuting. An increase in broadband access in a locality decreased teleworking—even though marginally—and affected travel behavior in an unsustainable way. For instance, an increase in broadband has negative effects both on public transport and active transport uses and increases private motor vehicle use. This finding underlines the negative relationship between Internet access (or smartness in this study) and sustainable commuting patterns. In sum, the overall results highlight that an increasing access to the broadband Internet reduces the level of working from home, public transport use, and active transport use; but at the same time increases the use of private vehicles perhaps to overcome the fragmentation of work activities.

Third, even though sustainable urban development and sustainable transport concepts have been widely investigated (e.g., Kamruzzaman et al., 2015; Yigitcanlar and Dizdaroglu, 2015; Yigitcanlar and Teriman, 2015), smart cities and smart mobility concepts have not been extensively empirically investigated in Australia and overseas. Therefore, further empirical investigations are needed to clearly address the issue of whether the smartness of cities leads to sustainable commuting patterns—in other words, the relationship between "smart" and "sustainable." This issue has recently been investigated by Yigitcanlar and Kamruzzaman (2018) in the context of cities in the United Kingdom. They found no clear evidence that smart city policies lead to sustainable cities. In the light of the aforementioned findings, a key to the smart cities agenda in Australia should be the creation of strategies needed to overcome the need for car-based travel for fragmented work activities, while increasing smartness through the provisioning of broadband access. This is a critical issue in order to make Australian cities more sustainable.

Fourth, the aforementioned findings should be considered carefully as the study has limitations. These limitations include: (a) due to data availability and boundary change issues, the study has not used the latest Census data—i.e., 2016. The study might not be able to capture the recent trends as in the age of digital disruption, technologies—e.g., social media—are rapidly altering the behaviors of individuals and societies; (b) using Internet access as the sole indicator of urban smartness has its limitations. As smart cities, urban smartness is also a fuzzy concept and using composite indicators to determine the smartness might be a better approach (Yigitcanlar et al., 2018); (c) the findings would benefit from ground-truthing by discussing them with experts and a group of officials from the investigated local government areas; (d) the data used in this research is panel in nature, but not a true panel data, and therefore, it was not possible to investigate the impacts at the individual level. Consequently, the estimated coefficients might capture effects that are not properly disentangled in this research. For example, previously "not stated" individuals may become part of the "broadband connection" group although they might have had a broadband connection previously.

Finally, considering one of the findings of this study—as individual levels of broadband access increase, commuting preferences lean towards private motor vehicle use—smart mobility technologies may have something to offer. Investments in autonomous vehicle technology may in the long run provide more sustainable, and at the same time, more convenient and comfortable commuting options (Firnkorn and Müller, 2015; Greenblatt and Saxena, 2015). Although it is unlikely to happen anytime soon, shared or pooled electric autonomous vehicles might decrease car ownership and enhance active transport use—as the freed space from cars could be redesigned for a whole new spectrum of social functions, street trees, walkways, or bike lanes (Wadud et al., 2016; Meyer et al., 2017).

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