Impacts of ICTs on Travel Behaviors: A Literature Review

Abstract

As Informational and Communications Technologies (ICTs) are enabling an increasing amount and better quality of everyday activities to be conducted online, it is a common belief that virtual mobility would challenge existing urban form designed for spatially-separated activities. Meanwhile, scholars are considering the direct impacts ICTs have on transportation. These bring up the questions of to what extent do online services influence travel behaviors and how planning initiatives should address the short- and long-term changes. This literature review finds both indirect and direct influences that ICTs have on travel behaviors in terms of activity-travel and transportation, yet the overall impact remains uncertain. It conducts a framework for further empirical research and provides planning implications regarding the travel behaviors influenced by ICTs.

Background

In Economics terms, transportation is derived from the demand for conducting spatially-separated activities and therefore a disutility to be minimized. For certain activities, online services enabled by ICTs innovation have created a dimension where traveling could be completely avoided. For example, people could save a few shopping trips and employees could minimize certain work trips through the use of the Internet. These possibilities create a presumption that virtual mobility enabled by ICTs would be able to reduce physical travel and lead to a more sustainable travel pattern. On the other hand, additional transportation activities could occur because of online services. For instance, the invention of ride-sharing applications may encourage new motorized trips. As the ICTs for transportation are becoming universally available in the 21st century, they have a significant impact on people's travel behaviors. In order to shape an equitable and sustainable future, planners ought to understand the relationship between ICTs innovation and their impacts on travel behaviors.

Measuring Impacts

People's adoption of Information and Communications Technologies (ICTs) already shows myriad effects on everyday activities. A significant amount of existing literature

studied how certain virtual activities change people's travel behaviors in conducting physical activities. One example is how e-commerce shapes shopping trips. On the other hand, ICTs have direct impacts on travel behaviors regardless of associated activities. These impacts are the most obvious in travel modes changes as ICTs have enabled innovative travel solutions, adding more dimensions to both non-motorized trips and motorized trips. My study recognizes that there could be indirect and direct impacts of ICTs on travel behaviors.

In addition, the impacts are on account of different periods of time. When ICTs innovations are first diffused, there will be short-term changes in people's activity-generated travel and travel mode. These travel behaviors will gradually become common mobility choices of people; they would eventually influence people's lifestyle choices in the long term. My research focuses on the relatively short-term impacts of ICTs.

ICTs and Activity-Travel

- Conceptual Framework

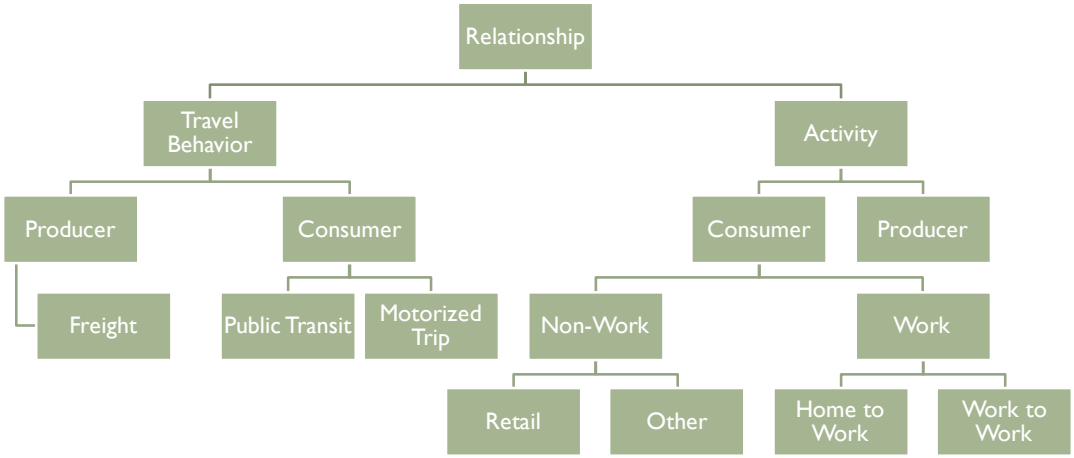

FIGURE 1. A CONCEPTUAL FRAMEWORK FOR ACTIVITY-TRAVEL RELATIONSHIP

Plenty of research including data analysis and literature review was conducted by scholars and they provided important insights on the Internet's impacts on physical activity-travel. The term "activity-travel" is referring to the discourse that the adoption of Information and communications technologies (ICTs) has effects on everyday activities and therefore affects travel behaviors. Noticeably, the impacts have been categorized into six types which are: substitution, complementarity, modification, neutrality, activity fragmentation, and multitasking (Lavieri et al., 2018). Although this classification provides a useful framework, modification, activity fragmentation, and multitasking do not yield meaningful implications

for planning purposes. Therefore, an overarching framework for activity-travel, prioritizing travel than activity, is developed to understand scholars' findings instead. Referring to figure 1, the relationship between activities and travel behaviors is displayed in the form of a tree-map. It shows the hierarchy of both activities and transportation to help understand the scale of different studies concerning the overall impact.

- Non-Work Trips

There is a significant amount of literature on shopping and travel which results fit with either substitution or complementarity effect in terms of shopping trips generation. Substitution effect, meaning that replacement of a location-based activity by a virtual activity eliminates travel, has been an instinctive belief; because it is natural to think that new technology will replace old ways of doing things. Some scholars suggested that shopping or searching for certain goods online could substitute buying these goods physically (Kenyon, 2006; Anderson, Chatterjee, & Lakshmanan, 2003). Specifically, they argued that books, music CDs, computer hardware, and consumer electronics are highly impacted. In addition, Zhen et al. (2018) found that travel time to frequently-visited stores is positively associated with e-shopping for books, but not for clothing, for highly educated people; meaning that the probability of shopping trips for books decreases as the travel distances increase. However, other scholars' findings show no relationship between the overall effect and motorized trips generation (Anderson, Chatterjee, & Lakshmanan, 2003; Kenyon, 2006), and one group of scholars discovered this substitution effect on non-motorized transport use in Australia (Yigitcanlar & Kamruzzaman, 2019). Overall, the substitution effect appears insignificant, as these studies' results demonstrate that virtual accessibility enabled by the technologies (the Internet) can only reduce physical shopping necessity for certain goods, and even increase offline participation for other goods and activities.

On the other hand, a handful of studies concluded that people's internet usage has a positive relationship with motorized trips on different premises (Hong & Thakuriah, 2016; Winslott Hiselius, Smidfelt-Rosqvist, & Adell, 2015; Visser & Lanzendorf, 2004; Yigitcanlar & Kamruzzaman, 2019). Hiselius et al. (2015) compared frequent online shoppers with those who seldom or never shop online in Sweden and found that frequent online shoppers' motorized trip is twice as long per trip. Meanwhile, they found that the trip distances for other errands do not differ much between different intensities of internet users. Also studying

shopping but in Australia, Yigitcanlar and Kamruzzaman (2019) concluded that besides reducing non-motorized transportation use, rising access to the broadband Internet increases the use of private motorized vehicles.

Some scholars looked at the relationship on a broader level than a single activity. Hong and Thakuriah (2016) studied internet use and non-work purpose travel, meaning that they included shopping and other leisure activities as well as motorized and non-motorized trips. Their findings support the complementarity effect, as they obtain a nonlinear relationship between the amount of time spent on the internet for personal purposes and motorized mobility. Nonetheless, the complementarity effect is only significant to moderate-intensity internet users in dense urban areas, while very low- as well as very high- intensity internet users show shorter distances of motorized trips. As Hong and Thakuriah looked at non-work activity-travel, some other scholars studied leisure activities within the non-work activity-travel category. Earlier studies suggested that leisure activities are replaceable by online activities, but later some scholars argued that the effect tends to be complementarity and is dependent on different factors (Mokhtarian & Tal, 2013).

Online shopping could not be made possible without freight and delivery trips. These trips generated by producers are also affected by ICTs and should be considered in the relationship framework. Through studying shipping trips at Tel-Aviv, Rotem-Mindali and Salomon (2007) suggested that shopping electronic appliances online will decrease motorized trips and increase freight delivery. Another group of scholars studied the 2009 National Household Travel Survey data of the United States (Wang and Zhou, 2015), and their study results indicate that freight trips generated by residential units have comparable magnitude as those generated by businesses. Although an increase in producer trips was suggested (Wang and Zhou, 2015; Beyers, 2003), some scholars conceded that the net outcome integrating personal and freight transport remains unclear (Rotem-Mindali & Salomon, 2007; Visser & Lanzendorf, 2004). Concluding from these findings on shopping activity, people's adoption of ICTs tends to increase offline mobility for both freight and personal trips with the exception of certain goods, yet the integrated impacts remain uncertain.

- Work Trips

Different from shopping, work travel is not heavily discussed by scholars, probably because ICT innovations in recent years have not been significant enough to revolutionize

patterns of work commutes for both traveling from home to work and from work to work. Dated further before, ICT such as email and text reduced travel needs. But now, improved ICTs such as video-conference are seen as substitutes for non-travel activities such as emailing and texting (Beyers, 2003). Businesses still value face-to-face interactions in producer industries. With increasing globalization, there has been a rising trend for business travel. Additionally, although the level of working from home increased, the amount is negligible and could be for commute-less works anyways (Mokhtarian & Tal, 2013). According to the U.S. Census, the mean travel time to work has grown from 25.2 minutes in 2009 to 26.4 minutes in 2016 (Bureau, n.d.). Although it is a trivial increase, it preliminarily implies that traveling time did not decrease with the rapid spread of technologies. From limited evidence, it is implied that ICTs would not decrease offline mobility in the near future.

- Discussion

Although these studies proved or expressed meaningful arguments, their findings are not empirical enough to ascertain a causal relationship between ICTs' impacts and travel behaviors. There are mainly two reasons. First, different studies used different key variables and dissimilar methods to quantify ICTs adoption and travel behaviors, contributing to distinct findings in a similar realm of research. Secondly, the uncertainty was because findings presented by different studies were connected to different socioeconomic factors.

The literature reviewed considered different variables along with various quantification methods for internet use and travel behaviors, as illustrated in Appendix A. Nevertheless, there exists a consensus that the complementary effect exists at urban locations. Zhen et al. (2018) suggested that people living and working in suburban Nanjing, China shop at traditional stores more than those staying in the city. They attributed this to the diffusion of innovation theory, claiming that those in the suburban areas receive lower education and fewer internet services compared with urban residents. Their study denotes that study for different geographical scales- city-level centers, city-level sub-centers, and commercial blocks- could provide a richer explanation for the relationship.

There is an alternative perspective that attempts to depict a more accurate relationship. Previously discussed research articles delineate the relationship between ICTs and travel behavior based on the hypothesis that virtual activities influence physical activities, which impacts thereafter affect travel behaviors. Although socioeconomic factors were discussed in

either research premises or separate findings, they isolated ICTs' impacts on travel behaviors from physical factors. Lavieri et al. (2018) argued that this kind of approach is misleading because both physical and virtual activities influence travel behavior. They proposed that activity-travel choices are consequences of individual, household, and work characteristics that are mediated by virtual and physical accessibilities. Their findings suggest that virtual accessibility and physical accessibility jointly influence virtual activity and physical activity engagement, and ICTs' impact on offline mobility is small and one of neutrality. Their study implies that physical accessibility could be more influential than virtual accessibility, as the absolute values of coefficients for the motorized vehicles availability and the natural log of average trip distance are larger. Their result also explains other scholars' finding that frequent online shoppers tend to generate more shopping trips while more shopping trips tend to reduce online shopping (Wang & Zhou, 2015).

These studies' approaches, although different, offer an important emphasis for future research that travel behaviors are influenced by both virtual and physical features simultaneously. Therefore, internet use features including frequency, length, and accessibility should not be the sole indicator for travel behaviors. Different socioeconomic factors could contribute to different levels of accessibility. Hypothetically, income, vehicle-ownership, and residence location could impact physical accessibility; education, age, race, and ethnicity could shape people's virtual acceptance, and with gender, occupation, and residence location, they can influence people's virtual accessibility. Different accessibility index may imply certain travel behavior patterns.

At this point, the research depicts a relatively comprehensive understanding of activity-travel with the increasing development of ICTs. The activity-travel framework assumes travel as a derived demand that is influenced by activities. For example, the possibility of online shopping makes physical shopping trips for certain goods unnecessary. Nonetheless, ICT has obvious influences on transportation itself, despite the types of activities associated. An example is that - bike-sharing applications on mobile devices could make bicycles available for those who previously do not bike, thus could increase offline mobility. One of the studies based on the activity-travel framework had attributed the effect of ICTs have on transportation itself to a single activity. For example, using the Internet for a long time could be for not only shopping on amazon.com but also using transportation-related

applications. As a result, ICTs could influence travel behaviors from its applications in transportation itself.

ICTs and Transportation

- Conceptual Framework

Because of the complex nature of this topic, studies could benefit from a clearer model to illustrate how ICTs influence travel behaviors. Referring to figure 2, there are three modes of transportation linking individuals to activities: virtual mobility, physical mobility, and both. People used to complete activities only by traveling to a physical space. With ICTs, they could complete those activities online without traveling to a certain physical space or become more motivated to travel to places. Moreover, people can travel to physical spaces with the help of ICTs. In other words, virtual mobility could alternate travel behaviors by changing activity-travel, as discussed; it could also influence offline mobility directly. Importantly, it could influence transportation behaviors directly by enhancing the possibility and experience of traveling. Scholars started to observe patterns of ICT uses for travel destination, mode, and route choice decisions (Mokhtarian & Tal, 2013).

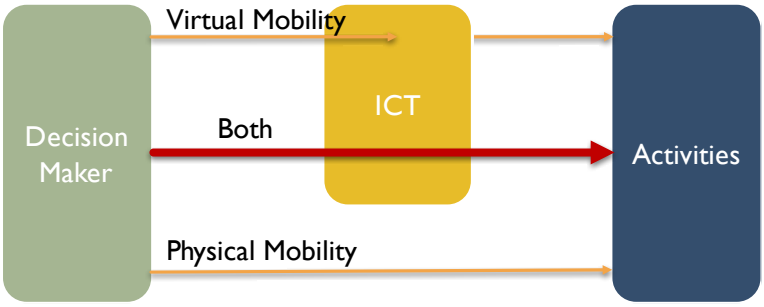

FIGURE 2. CONCEPTUAL MODEL FOR TRAVEL DECISION MAKING

- Direct Impact

As for ICTs' direct impact on transportation, Mokhtarian and Tal (2013) produced a detailed list documenting ICTs' roles as inspiration, information provider, explanatory variable, one of the alternatives, changes the chosen alternative, and modify the trip experience. Summing up the list, ICTs could either increase or decrease trips by providing available information and alternative accessibility for the travel. For instance, online advertisements could encourage customers to generate additional trips that were not previously planned (Rotem-Mindali, 2010). In terms of travel mode, while certain ICTs make driving more attractive, some other ICTs make public transit more user-friendly and even create alternative transportation methods. One study in the United Kingdom found that people

who recently started using the internet daily tend to use non-motorized trips including bus, train, and car-sharing frequently (Wu, Hong, & Thakuriah, 2019). Meanwhile, another study in Australia concluded that the extent of public and active transport use was decreasing with access to broadband internet (Yigitcanlar & Kamruzzaman, 2019). In summary, the roles of ICTs attempt to decrease useless travel and increase useful travel, but the combined impact is yet to be empirically substantiated.

- Mid-term Impact

In their literature review, Visser and Lanzendorf (2003) suggested three terms of effects e-commerce would have on mobility. First was the short-term effects that they anticipated increases in both individual and freight transportation. They also brought up mid-term effects, saying that location logistics of businesses and houses may change with ICT advancement and may influence travel demand. People may change household type, car ownership, or the mode of travel, which in the long-term would shape people's lifestyle choices. So far, scholars studied possible changes in car ownership or mode of travel as a direct result of ICT advancement rather than changes in location logistics of businesses and houses.

As for vehicle ownership, while traditional media still influence vehicle purchase decisions, ICTs provide another medium for dissemination of information and even platforms for buying and selling new and used vehicles (Mokhtarian & Tal, 2013). For example, vehicles could be purchased through not only dealerships but also Carmax and eBay, especially for used-vehicles. Besides, ICT-based features also make automobile vehicles more attractive, possibly making car ownership more attractive to some groups of individuals. On the other hand, ICTs could also make car ownership optional. The possibility of ride-sharing modes and the AI-enabled driverless cars could revolutionize people's mobility choices. However, to what extent driving would be substituted by the alternative modes is controversial and could be a focus of further study.

- Lifestyle Choices

The ICTs platforms also have potential impacts on people's attitudes towards travel patterns especially for young adults, which was argued by Wu et al. (2019). Using longitudinal datasets, the 2004 British Household Panel Survey (BHPS) and the Understanding Society Survey (Wave 4, 2012/14), they investigated young adults' internet use over time, their travel

modes and attitudes towards the environment. They found the formation of pro-environmental attitudes to be closely related to consistently high levels of internet use between adolescence and young adulthood, which significantly encouraged their sustainable travel behaviors.

Another article published by McDonald also stresses the importance of the younger generation in America for sustainable travel behaviors (McDonald, 2015). Also using a longitudinal study, he compared the travel behavior of millennials with other generations through data from 1995, 2001, and 2009 National Household Travel Surveys. He used descriptive statistics to analyze if millennials' travel behaviors can explain the decreasing trend in driving. He clarified that although millennials' environmental attitudes and their use of virtual mobility account for 35% to 50% of fewer motorized trips generation, and their lifestyle-related demographic shifts explain 10%-25%, the decrease in driving is not substituted by using other travel modes or traveling shorter distances. His study illustrates that there exists a general decrease in travel demand across all age groups and the younger generations do drive less than other generations.

Rosqvist and Hiselius' calculations are also in favor of one of Wu and McDonald's findings that the increasing adoption of ICTs could create more sustainable travel patterns. Their study indicates that the predicted increase in online shopping behavior together with the predicted increase of the Swedish population would decrease CO_2 emissions by 22% (Rosqvist and Hiselius, 2016).

Conclusions and Planning Implications

ICTs have both direct and indirect influences on people's everyday travel behaviors in short- and long- terms. While they affect people's activity-travel generation, they also initiate direct changes to transportation itself. Focusing on short-term activity-travel changes produced by ICTs, this review found mixed results from different studies about non-work trips, work trips, and transportation itself. Although the overall effect seems to be controversial and the causal relationship appears to be unclear due to different variables and different study methods used, they imply that ICTs effects on transportation would not naturally decrease physical travel. This gives implications to further empirical research and transportation planning policies. Changes in travel behaviors are largely unpredictable, but

planners should plan for social impacts as this is a good opportunity to address concerns before any negative effects become empirical.

In terms of planning for sustainable urban forms, the study suggests that growth in virtual mobility may be connected to the spatial distribution of economic activities. As substitution effects exist for certain goods, the corresponding retailers may relocate to the cheaper regions and earn profits through online platforms. For the rest, as the studies tend to favor the complementarity effect and few pieces of evidence suggested otherwise, planners should not need to worry about urban deterioration due to virtual activities. For transportation demand management, it would be more accurate and useful if planners examine the virtual accessibility of residents in different types of regions and inform local planning agencies.

Noticeably, most studies would agree that physical activity-travel is jointly influenced by physical and virtual accessibility. One implication considering equitable transportation planning is that virtual mobility could compensate for limited physical access to activities. Some socioeconomic factors including age and wealth were proven or suggested to be associated with the adoption of ICTs. Planners should closely examine innovative ICTs and take advantage of them to ensure inclusive transportation for the population. Besides social equity, ICTs adoption is an approach to promote sustainability, since a study proved that virtual mobility could reduce CO_2 emissions from customer travel. While this study did not consider freight trips, the function of ICTs in reducing useless travel might contribute to efficient transportation patterns and sustainable travel modes.

There are limitations to this literature review. As ICTs are rapidly advancing and changing travel behaviors and the studies reviewed were from different years, this could lead to inaccurate interpretation. Secondly, not many studies have covered this topic comprehensively for the recent years as they tend to focus on a smaller aspect in the transportation system, possibly shaping a biased approach. For activity-travel, most studies were about e-commerce and telecommuting; and for transportation, scholars have been studying autonomous vehicles. However, my study identifies gaps from a limited amount of literature and calls for empirical studies on ICTs' values on equitable transportation planning. Technology advances are changing people's behaviors as well as the field of urban planning. Planners should be proactive in influencing the use of ICTs to improve the communities.

References

Anderson, W. P., Chatterjee, L., & Lakshmanan, T. R. (2003). E-commerce, Transportation, and Economic Geography. *Growth & Change*, *34*(4), 415–432. https://doi.org/10.1046/j.0017-4815.2003.00228.x

Beyers, W. B. (2003). Impacts of IT Advances and E-commerce on Transportation in Producer Services. *Growth & Change*, *34*(4), 433–455. https://doi.org/10.1046/j.0017-4815.2003.00229.x

Bureau, U. S. C. (n.d.). American FactFinder—Results. Retrieved December 17, 2019, from https://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=ACS_17_5YR_GCT0801.US01PR&prodType=table

Cao, J., Xu, Z., & Douma, F. (2011). The interactions between e-shopping and traditional in-store shopping: An application of structural equations model. *Transportation*, *39*. https://doi.org/10.1007/s11116-011-9376-3

Chen, X., & Deng, H. (2019). A correlation analysis of information use, social networks and cooperation consciousness in travel behaviors. *Transportation Research: Part F*, *62*, 819–832. https://doi.org/10.1016/j.trf.2019.03.015

Fang Ren, & Mei-Po Kwan. (2009). The impact of geographic context on e-shopping behavior. *Environment & Planning B: Planning & Design*, *36*(2), 262–278. https://doi.org/10.1068/b34014t

Goldfarb, A. (2014). The Internet Killed Distance. Mobile Phones Brought It Back. *MIT Technology Review*, *117*(1), 62–63.

Hong, J., & Thakuriah, P. (Vonu). (2016). Relationship between motorized travel and time spent online for nonwork purposes: An examination of location impact. *International Journal of Sustainable Transportation*, *10*(7), 617–626. https://doi.org/10.1080/15568318.2015.1079752

Hsiao, M.-H. (2009). Shopping mode choice: Physical store shopping versus e-shopping. *Transportation Research: Part E*, *45*(1), 86–95. https://doi.org/10.1016/j.tre.2008.06.002

Kenyon, S. (2006). The 'accessibility diary': Discussing a new methodological approach to understand the impact of Internet use upon personal travel and activity participation.

Journal of Transport Geography, *14*(2), 123–134. https://doi.org/10.1016/j.jtrangeo.2005.10.005

Kenyon, S. (2010). The impacts of Internet use upon activity participation and travel: Results from a longitudinal diary-based panel study. *Transportation Research: Part C*, *18*(1), 21–35. https://doi.org/10.1016/j.trc.2009.04.014

Kristoffersson, I., Daly, A., & Algers, S. (2018). Modelling the attraction of travel to shopping destinations in large-scale modelling. *Transport Policy*, *68*, 52–62. https://doi.org/10.1016/j.tranpol.2018.04.013

Lavieri, P. S., Dai, Q., & Bhat, C. R. (2018). Using virtual accessibility and physical accessibility as joint predictors of activity-travel behavior. *Transportation Research Part A: Policy & Practice*, *118*, 527–544. https://doi.org/10.1016/j.tra.2018.08.042

Lingqian Hu, & He, S. Y. (2016). Association between Telecommuting and Household Travel in the Chicago Metropolitan Area. *Journal of Urban Planning & Development*, *142*(3), 1–8. https://doi.org/10.1061/(ASCE)UP.1943-5444.0000326

McDonald, N. C. (2015). Are Millennials Really the "Go-Nowhere" Generation? *Journal of the American Planning Association*, *81*(2), 90–103. https://doi.org/10.1080/01944363.2015.1057196

Mokhtarian, P. L., & Tal, G. (2013). Impacts of Ict on Travel Behavior: A Tapestry of Relationships. In *The SAGE Handbook of Transport Studies* (pp. 241–260). https://doi.org/10.4135/9781446247655

Ortiz, L., & Arnold, H. (2018). From mall to mixed use. *Economic Development Journal*, *17*(4), 16–20.

Rotem-Mindali, O. (2010). E-tail versus retail: The effects on shopping related travel empirical evidence from Israel. *Transport Policy*, *17*(5), 312–322. https://doi.org/10.1016/j.tranpol.2010.02.005

Rotem-Mindali, O., & Salomon, I. (2007). The impacts of E-retail on the choice of shopping trips and delivery: Some preliminary findings. *Transportation Research Part A: Policy & Practice*, *41*(2), 176–189. https://doi.org/10.1016/j.tra.2006.02.007

Smidfelt Rosqvist, L., & Winslott Hiselius, L. (2016). Online shopping habits and the potential for reductions in carbon dioxide emissions from passenger transport. *Journal of Cleaner Production*, *131*, 163–169. https://doi.org/10.1016/j.jclepro.2016.05.054

Suel, E., & Polak, J. W. (2018). Incorporating online shopping into travel demand modelling: Challenges, progress, and opportunities. *Transport Reviews*, *38*(5), 576–601. https://doi.org/10.1080/01441647.2017.1381864

Venzke, S., Jones, M.-S., & Dommel, P. (2018). Traditional Case Management Is a Commodity: Mobility, Analytics, and Interoperability drive better Outcomes. *Policy & Practice (19426828)*, *76*(2), 16–32.

Visser, E.-J., & Lanzendorf, M. (2004). Mobility and Accessibility Effects of B2c E-Commerce: A Literature Review. *Tijdschrift Voor Economische En Sociale Geografie (Journal of Economic & Social Geography)*, *95*(2), 189–205. https://doi.org/10.1111/j.0040-747X.2004.00300.x

Wang, X. (Cara), & Zhou, Y. (2015). Deliveries to residential units: A rising form of freight transportation in the U.S. *Transportation Research: Part C*, *58*, 46–55. https://doi.org/10.1016/j.trc.2015.07.004

Winslott Hiselius, L., Smidfelt-Rosqvist, L., & Adell, E. (2015). Travel behaviour of online shoppers in Sweden. *Transport & Telecommunication*, *16*(1), 21–30. http://dx.doi.org/10.1515/ttj-2015-0003

Wu, G., Hong, J., & Thakuriah, P. (2019). Assessing the relationships between young adults' travel and use of the internet over time. *Transportation Research Part A: Policy & Practice*, *125*, 8–19. https://doi.org/10.1016/j.tra.2019.05.002

Yigitcanlar, T., & Kamruzzaman, Md. (2019). Smart Cities and Mobility: Does the Smartness of Australian Cities Lead to Sustainable Commuting Patterns? *Journal of Urban Technology*, *26*(2), 21–46. https://doi.org/10.1080/10630732.2018.1476794

Zhen, F., Du, X., Cao, J., & Mokhtarian, P. L. (2018). The association between spatial attributes and e-shopping in the shopping process for search goods and experience goods: Evidence from Nanjing. *Journal of Transport Geography*, *66*, 291–299. https://doi.org/10.1016/j.jtrangeo.2017.11.007

Zhou, Y., & Wang, X. (Cara). (2014). Explore the relationship between online shopping and shopping trips: An analysis with the 2009 NHTS data. *Transportation Research Part A: Policy & Practice*, *70*, 1–9. https://doi.org/10.1016/j.tra.2014.09.014

Appendix A. Examples of Studies for Literature Review

Studies	Key variables and impacts	Activity	Data and region	Conclusion
Wang and Zhou (2015)	Household income: +*** Education: +*** Urban location: +** Full-time worker: +*** Shopping attitude: -*	Online shopping	NHTS data at both national and state levels	Asymmetric impacts: online shopping -> shopping trips (+) shopping trips -> online shopping (-)
Cao et al. (2012)	Household income: +*** Education: +* Urban location: +** Full-time worker: +** Shopping attitude: -	Online shopping	539 adults survey in Minneapolis-St. Paul seven county metropolitan area	Complementary effect: online shopping -> shopping trips (+)
Ren and Kwan (2009)	Full-time worker: -** Shopping attitude: +** Internet connection: +** White population: +*	Online shopping	A study of the Columbus Metropolitan Area, OH	E-shopping may not substitute for in-store shopping
Hong and Thakuriah (2015)	Urban: +*	Non-work travel	2005-2006 Scottish Household Survey (SHS) with 30,013 households; and 28,261 selected adults within those households for interviews	Complementary relationship: a nonlinear relationship between amount of time spent on personal purposes online and offline mobility

*=p<0.05

**=p<0.01

***=p<0.001