# Chapter 6
# ICT-Dependent Life and Its Impacts on Mobility

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**Abstract** The rapid development of information and communication technology (ICT) is revolutionizing people's lives in many ways. Among their numerous impacts, ICT solutions allow for more flexibility in individuals' schedules, and provide new alternatives for the organization of work, social and recreational activities. Several types of relationships are possible between the adoption of ICT and travel behavior, leading to the eventual *complementarity with*, *substitution of*, *modification of*, or *neutrality with* travel. Modern technologies play an important role in affecting individuals' long- and medium-term decisions as well as numerous daily choices. The application of information and communication technologies is also behind the introduction of new shared mobility services that were barely imaginable only a few years ago. These services expand the set of travel options available to individuals. The effects of the availability and adoption of these technologies on individual behaviors are still largely unclear. They will likely cause long-lasting impacts on travel patterns, vehicle ownership, and life organization.

**Keywords** Information and communication technology · Lifestyles · Mobility · Travel behavior · Shared mobility services · Complementarity · Substitution · Modification · Neutrality · Urban form · Connected and autonomous vehicles

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## 6.1 ICT and Modern Lifestyles

Information and communications technology (ICT) applications are quickly changing the way we live, work, socialize and travel, to a degree that would have been barely imaginable only a few years ago. The readers simply need to look around themselves to see tangible examples of how modern technologies affect their lives and contribute to modifying their habits. ICT applications are nowadays an intrinsic part of daily activities and of most tools of common use, to the point that it is often difficult to identify and separate their presence from the activities and tools themselves. Over the course of the last few decades, technology has allowed for a number of revolutionary transformations spanning several different areas. Not only it has led to a complete transformation of many traditional activities, e.g. through the automation of the most tiring, boring or unpleasant tasks in one's life (such as washing the dishes, or doing laundry). It has improved individuals' quality of life through providing the ability to precisely organize production processes and maintenance tasks, e.g. finely controlling heating or air conditioning in most people' houses, or remotely controlling most household or office appliances. Probably even more revolutionary, technology has improved communications, in the work environment as well as for personal and social purposes, and it has given access to a variety of sources of information and entertainment, e.g. through the continuous improvement in the quality and availability of appliances and services, and the access to a broad selection of contents, which are increasingly available through online streaming. The most recent frontier in the application of modern communication and information technologies allows the integration of various technologies that were initially developed in different fields as independent, standalone applications. All these changes have considerably simplified one's life through a combination of effects.[1] For example, one can nowadays perform a number of activities remotely, from investing in the stock market to controlling the temperature of their home and optimizing its energy consumption based on their real-time schedule (and any fine adjustments to it), through a smartphone app, independently from where they are. They can perform these activities while they ride in a taxi or a car provided by some *ride-sourcing* services such as Uber or Lyft, on the way to dinner (which they have also booked through a dedicated app on their mobile device). They contemporaneously maintain real-time communications with the friends they are supposed to meet for dinner through some instant messaging services, and micromanage the details of their appointment (place to meet and time of arrival), minimizing the waiting time, and accommodating any eventual disruptions (e.g. due to travel delays, etc.). Such types of behavior are becoming increasingly common at least for the majority of

[1]Technology can also make someone's life more complicated, due to the need to learn how to use new technologies and services, the increased number of available activities and services, and the related burden on one's time.

"tech-savvy" users, for whom it is even difficult to imagine a time in which technology did not permeate society as it currently does.

The increased computational power and miniaturization of modern computer processors, the development and application of increasingly cheap and reliable sensors, the adoption of global positioning system (GPS) geolocation technologies, and the access to powerful and reliable communication networks have forever transformed society. They have enabled us to live in a way that would have been barely imaginable to previous generations. The continuous developments in the field of *domotics* are further modifying individuals' life: the path towards a *smart home* paves the way to a future in which common household appliances make large use of automation and electronic technologies, and are increasingly connected through fast and reliable communication technologies. Similarly, technological development is deeply changing the *work* environment. It is also rapidly transforming the features of most vehicles, in a continuous race to improve travel safety, security, comfort and ability to carry out many activities in a variety of conditions. The ubiquitous presence of information and communications technologies has revolutionized individuals' behavior through the ability (and related expectations) to be continuously connected to others.[2]

ICT applications considerably reshape the relationships with time and space. As they simplify the execution of many tasks, they make it easy to engage in additional activities in the same unit of time. Similarly, they often reduce the friction of distance, making travel easier, and letting information and news circulate over long distances in shorter (or almost no) time. The increased presence of ICT devices and services also expands the set of known and available choices in most decision processes, and it increases the amount of related accessible information. Thus, technology enables individuals to access options that would have otherwise been unavailable, or too difficult (and expensive) to access, or of which they would have ignored the existence, if modern information and communication technologies did not exist.

The adoption of ICT solutions is modifying individual lifestyles through several subtle modifications to the organization of work and leisure activities, and the social habits of individuals. Larger effects are associated with specific segments of the population, such as younger and better-educated individuals, and those that live in central regions and cities, who have access to more options, i.e. they are exposed to a larger number of technological innovations.

The effects of the adoption of ICT on individual choices and mobility patterns are not fully understood, and still largely unclear. Numerous studies have investigated the impact of ICT on lifestyles and mobility. Early studies shared an optimistic view that most ICT applications would have contributed to enriching one's life, while at the same time they would have reduced total travel, thus bringing

[2]In this chapter, I generically refer to "others" as either other people (e.g. family members, friends, co-workers) or things (e.g. cell phones, TVs and other home appliances, personal vehicles, office and work networks).

some environmental benefits through the substitution of physical travel with technological alternatives. The reality is, however, more complex: ICT certainly contributes to increasing the amount of options available to users when they perform many activities, and has significantly changed the quality and nature of many of these options, allowing the physical replacement of travel with technological alternatives. It also enables a considerable amount of additional activities, and opportunities to engage in them, which did not exist in the past.[3] This also includes the increased need to travel.

## 6.2 Impact of ICT on Society

The adoption of modern information and communication technologies is generating sizable impacts on many components of modern life. It contributes to changing the organization of the work environment, including office and retail space, and affects the organization of cities and regions and the logistics of good distribution. In addition, communication technologies are reshaping many aspects of individuals' lives, including the way they interact in real time, and access information through new media.

During the last few years, in particular, *online social networks* have acquired an important role in society. The quick growth in the popularity of services such as Facebook, Twitter, and LinkedIn, which have become a popular presence with a user base that includes millions of individuals in every world region, has contributed to restructuring time use and interpersonal relationships, and has affected countless daily choices that people make. The ability to be constantly "connected" (and the related expectation to do so) is revolutionizing many familiar aspects of social and economic life, with impacts on the mobility of people and goods that are still often unclear. ICTs, and social networks in particular, are also reshaping many aspects of political and social life, often modifying the language of the political debate, and increasing the opportunities, and interest, for civic engagement of some groups, e.g. younger adults, who are heavier users of these technologies. Telecommunications increase the coverage and the speed with which news reaches voters and the general public audience. They have changed the political agenda of parties and leaders, and the way they communicate. Online social media, in particular, with their continuous stream of news, the easy sharing of comments and videos, and the amplification of public excitement, disappointment, disapproval and blame, have already established an important role in political processes. Understanding the specific role of these technologies and services, and their outcomes, is not easy, as it comprises a complex pattern of direct and indirect effects. Among the more direct, and visible, effects, is the rise of grassroots movements

[3]This fact, per se, could be interpreted as a positive contribution to the quality of life of most individuals that have access to these modern solutions.

and the emergence of candidates and leaders who share a stronger engagement with the masses of active social media users, and directly use these technologies to spread their message and increase their consensus. Telecommunications and social media also have a more subtle effect, modifying the political agenda of many parties and candidates, as an effect of the feedback obtained from online platforms, organized groups and the general public.[4]

Finally, ICTs affect the political process and public decision-making in a more indirect way, for example, through their effects on the outcomes of general and local elections, with the prevailing of certain candidates and parties who are more able to adjust to social media and are more at ease in communicating their message through these communication channels. This in turn affects the political agenda of governments, for example, in terms of foreign policies, immigration, and infrastructure investments. In the transportation sector, it has important consequences in terms of the delicate (and/or more polarizing) decisions related e.g. to the funding of public transportation, and the delivery of important infrastructure such as high-speed rail systems, or mass transportation in metropolitan areas, vs. the prioritization of road infrastructure investments.

Similar changes are happening in the economy, with ICT playing an important role in assisting and promoting economic development. In almost every field of the economy, those businesses that have easily adjusted to a modern internet-based reality, and were more able to harvest the many opportunities enabled by modern ICTs, have reinforced their presence in the market, while other players have gone out of business or are slowly disappearing. Further, the equilibrium among the various sectors of the economy has changed as a result of the development of modern information and communication technologies, and the production and distribution of related products and services. More traditional economic fields have been shrinking: they have heavily modified the nature of their production, or have increasingly relocated to other regions or countries, where the lower labor costs still make their activity economically sustainable.[5] This has led to the rise of entirely new sectors in the economy, e.g. companies specialized in IT hardware and software, smartphone apps, and the production of internet and other media content. It has also contributed to reshaping the physical patterns of development,

[4]An important role in any political campaign is nowadays played by experts in public relations, as well as polling and online media consultants, who explore the trends in the electoral basis, and analyze the popularity of the political message. They recommend ways in which a candidate should address specific topics, or should communicate (keeping in high consideration the messages received from the political base and general audience) through popular online social networks such as Facebook and Twitter.

[5]Also in the case of delocalization to remote regions or foreign countries, as discussed in more details in the following sections, ICTs play a central role in allowing firms to maintain communications among the members of a geographically distributed partnership, and between the central offices located in major cities and the remote production centers housed in the other regions (or countries) where labor (and other production) costs are lower.

with the impressive growth of some cities and regions and the decline of more traditional industrial centers.[6]

As one of the effects of the adoption of technological solutions, including computers, smartphones, other technological devices and internet-based services, modern lifestyles in the first part of the 21st century considerably rely on the provision of efficient and reliable high-speed transmission and digital networks (Audirac 2005; Tranos et al. 2013). These often provide a way to circumvent the lack of physical accessibility in those locations that are not easy to reach by traditional transportation modes, or because of physical limitations of an individual. The massive adoption of modern technologies, smartphones and online services generates a new type of *virtual accessibility*. The few places that are left outside of this network and communication grid (e.g. because of topography, or the high investments to connect them) become less desirable, and disadvantaged, in a world that is dominated by fast and reliable communications. This factor also opens additional business opportunities, aimed at overcoming these limitations, through providing increased access to WiFi and cellular networks in areas that are not reached by other technological networks (landline phones, cable connections), or when traveling (e.g. on planes, trains or buses).

## 6.3 Impact of ICT on Long-Term Decisions

At the time this book was printed, the access to online social media and communication technology played an important role in shaping the response to emergencies and humanitarian crisis in areas that are torn by civil war, political turmoil and instability. The recent flow of refugees escaping from the war zone in the Middle East and trying to reach Europe (and, to a less visible scale, any migration flows in other parts of the world) has been considerably shaped by the rise of social media, and the access to online information and wireless communications, as an important characteristic of this massive international migration. Probably for the first time in history, wireless communications and real-time information provided by other friends and members of an online network of contacts have been guiding thousands of refugees through their journey, crossing entire regions on foot, or by other informal transportation options. Modern migrants rely on cell phones, instant-messaging apps, and online mapping services to navigate themselves through a complex pattern of topographic, natural and political difficulties. Similarly, the response from many governments, informing the refugees and migrants about the policies that are available to them (or that sometimes are

[6]An emblematic sign of the changes in economic activity associated with the rise of modern technologies is signaled by the rise of San Francisco and the Silicon Valley as one of the main cores of innovation and production of advanced hi-tech services and products, with the contemporaneous decline of Detroit, the former capital of the U.S. auto industry.

designed to keep them away), has been largely organized, and communicated to the public, through online social media, further affecting the migration flows and the movements of masses of refugees in search for freedom and a shelter from persecution and war.

Even in times of peace, and during more conventional migration processes, ICT plays an important role in affecting relocation patterns and decisions on where to live. Migration decisions are usually well-informed rational choices among economic opportunities at various locations (Yankow 2003), which are affected by interpersonal networks, environmental considerations and the available information about the destination options. In the era of massive access to the internet and widespread adoption of ICT devices, modern technologies play an important role in all major phases of the migration process (Villhelmson and Thulin 2013; Dekker et al. 2015). They act as an enabler or *catalyst*, reinforcing the propensity to migrate of an individual, or stimulating the desire in making such long-term and life changing decisions in other individuals, through the increased access to information (*augmented awareness*) and increased knowledge, as well as through affecting personal tastes and decisions with multiple composite impacts (Stevenson 2009; Villhelmson and Thulin 2013).

The widespread adoption of mobile phones, email messages, instant messaging, live chat, and online social networks enables a socially and spatially extended network of friends, family, acquaintances, and colleagues, which reinforces organizational and interpersonal ties, connects local labor markets, and channels immigrants to particular destinations and into particular occupations. These tools help nourish old ties between immigrants and their places of origin, and develop new ties in their new places. They also support temporary migration decisions (e.g., for education or temporary employment), in particular among the most dynamic segments of the population, and increase the level of satisfaction among such *connected migrants* (Komito 2011).

ICTs also affect other important individuals' long-term decisions, as in the case of residential location, through affecting both the decision *process*, i.e. the way in which an individual accesses information and makes a decision, and the *outcome*, i.e. the actual location or housing unit where an individual (or household) decides to relocate. ICT also increases the flexibility in the choice of the place where to relocate, e.g. through the increased adoption of telecommuting and other remote connectivity-based options (e.g. e-shopping), which can reduce the friction of distance, and eventually allow some individuals to relocate further away from the places where they need to commute or travel for other purposes. This process increases the ability to accommodate household members' needs, while fulfilling their preferences, for example, for larger, cheaper, or simply different lots or housing units, or their desire to be located near vibrant parts of a city/region or other amenities (Mokhtarian et al. 2004; Nijkamp and Salomon 1989).

## 6.4 ICT and Urban Form

The adoption of modern information and communication technologies is leading to the gradual modification of a number of relationships behind the current spatial form of cities. It affects the organization of productive activities, and modifies the distance constraints that limit the mobility of people and goods. Historically, technology has contributed to the process of *time-space convergence*, allowing for the contraction of the average travel times to reach a destination (Janelle and Gillespie 2004). It has also expanded the number of destinations that can be reached in a certain unit of time. More recently, ICT has contributed to further relaxing the space-time constraints, through the ability of telecommunications to (at least partially) compensate for physical distance. Physical proximity is thus a less binding constraint for the location of residences and activities at a time "when dominant forces such as globalization and telecommunications seem to signal that place and the details of the local no longer matter" (Sassen 2000, p. 144). The impact of ICT on urban geography has led some to even hypothesize the "end of geography" (O'Brien 1992), and the "death of distance" (Craincross 2001).

Quantifying the effects of ICT on urban geography is not easy: modern telecommunication services can help firms and residences move to places where land is cheaper or where amenities are more attractive, and this may lead to a decrease in urban density, although the effects could vary significantly by region, and with the *scale* of the local economies and local conditions (Nijkamp and Salomon 1989). This would cause negative environmental effects of travel behavior, as lower-density development is usually associated with greater distances traveled, and a reduction in urban density leads to higher reliance on private vehicles (Ewing and Cervero 2010).

One effect of ICT on work organization is associated with the ability for firms to change their structure, in particular moving production activities and back offices farther away from the central business district to locations where land (and/or labor) is cheaper. Only higher-paying and white-collar jobs, management activities and the front offices that need closer interactions with customers remain in central locations. The adoption of modern and reliable telecommunication services allows firms to maintain regular communications and coordination of activities among the central offices and the production sites (and back offices) that relocate to more distant locations. Further, by loosening the effects of distance, ICT can support the rise of spatially distributed work teams and enable larger spatial separation between the manufacturing sites and the end use of goods.

The advent of information and communication technologies is also deeply revolutionizing the relationship of individuals with shopping and, to a wider extent, the entire organization of retail activities. Online shopping already accounts for a sizable percentage of total sales, and its importance continues to increase steadily every year. In the US, the total volume of e-shopping sales has increased from $138 billion in 2007 to $305 billion in 2014. The recent introduction of smartphone apps and additional user-friendly solutions for e-shopping that provide

users with increased opportunities to access online retailers and obtain the purchased items in a fast and convenient way is contributing to further boosting sales and the total volume of business for this economic sector.

The rise of internet shopping has also brought important changes in the organization of traditional retail. On one hand, hybrid forms of "bricks and clicks" stores have emerged, in order to integrate internet sales in the business of more traditional retailers.[7] Further, the advent of internet shopping has deeply modified the nature, and organization, of retail itself. The adoption of technological solutions has modified the nature of many products, as in the case of the dematerialization of books, CDs, and DVDs, which have been gradually replaced by their digital alternative, and by the introduction of online streaming. For other products and services, the large adoption of internet services has deeply changed the channel through which these goods and services are purchased, as in the case of airline tickets, or banking and insurance services, for which the internet has largely replaced purchases made over the phone, or in person at traditional stores and offices. The introduction of modern information and communication technologies has also contributed to reshaping the structure of many physical stores, which have increasingly evolved into entertainment centers that include restaurants, cafes, space for cultural attractions and social gathering, etc., and thus provide additional services that are less amenable to substitution, and thus less subject to the competition of internet shopping.

Through all the changes discussed above, ICTs contribute to changing the urban form, through a process that according to many authors may contribute to further increasing the decentralization of cities, due to the reduction in the importance of physical proximity, and the increase in the importance of technological substitutes. In addition, the application of ICT is transforming the organization of many activities in cities through a number of additional effects, which modify the number of alternatives available to individuals, as well as the characteristics of transportation options, and the way to organize personal schedules. The following sections discuss in more details the changes that ICT brings to daily choices and many individual decisions related to transportation.

## 6.5 ICT and Mobility

Understanding the impact of information and communication technologies on transportation is not easy. ICTs include numerous and diverse applications: in this chapter, I primarily refer to goods and services involved in the production, collection, storage, analysis and/or transmission of information in electronic form,

[7]To date, all large retailers, and many smaller companies, have an internet presence, which compete with giant online retailers, such as Amazon.com, and e-shopping portals, such as E-bay.com, among others.

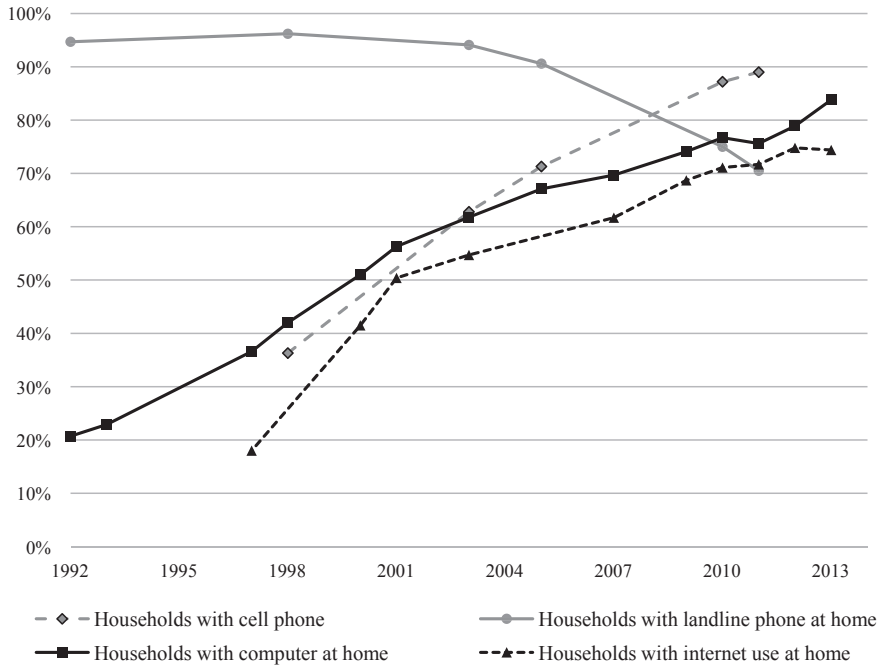


**Fig. 6.1** Percentage of U.S. households using various types of technologies at home: 1990 to 2013 (*Source* Modified from Circella and Mokhtarian, forthcoming. Data from the U.S. Census Bureau)

whether ranging from end-user applications such as smartphones, tablets and computers to network-services that are used to exchange communication and information among users (and/or things, or businesses). The adoption of modern forms of information and communication technologies has experienced a rapid increase during the last few years. In general, more advanced technologies have quickly conquered a large number of users, sometimes substituting for the use of older-generation technologies (as in the case of the use of landline vs. mobile cell phones among US households, shown in Fig. 6.1).

To date, smartphones and internet connections have become a common presence in the life of most American households. The same happens in other developed and (increasingly so) developing countries. The latter, in particular, have experienced a rapid growth in the adoption of some types of technology, e.g. mobile phones and more recently smartphones, which have helped them fill a gap in the availability of communication technologies. In all geographical contexts, the adoption of communication technologies has contributed to reshaping daily habits, the participation in activities and individual lifestyles, in particular through the increased access to multiple services and the easy share of information with others. Overall, technology has increased the flexibility with which many activities can be carried out.

The adoption of modern information and communication technologies can lead to a complex pattern of eventually counteracting effects on transportation. The replacement of travel with ICT alternatives has long been seen as a promising solution to many societal problems, including traffic congestion, air pollution, greenhouse gas emissions, the reduced economic opportunities for the mobility-limited, and the need to improve individuals' work-life balance (Salomon 1998; Mokhtarian et al. 2005). ICTs certainly replace a lot of travel, but they can also generate additional travel as well. ICTs modify an individual's time-space constraints, and affect the participation in activities and travel behavior in a number

**Table 6.1** Impacts of ICT on travel

| Neutrality | Complementarity | Substitution |
|---|---|---|
| Not all ICT-based activities reduce travel:<br>1. Not all activities have an ICT counterpart<br>2. Even when an ICT alternative exists, it might not be practically feasible<br>3. Even when feasible, ICT might be not a desirable substitute<br>4. Travel carries a positive utility per se, not just as a means to access places<br>5. Not all uses of ICT constitute a replacement for travel | ICT actively increases travel:<br>6. ICT saves time and/or money for other activities, some of which involve travel<br>7. ICT permits travel to be sold more cheaply<br>8. ICT increases the efficiency of transportation (and its attractiveness)<br>9. Personal ICT increases the productivity and enjoyment of travel (thus it decreases its disutility)<br>10. ICT directly stimulates travel, through its ability to stimulate communications and transactions<br>11. ICT enables new travel options (e.g. shared mobility services, or connected and autonomous vehicles) which might induce additional travel demand<br>12. ICT is an engine driving the globalization of commerce<br>13. ICT facilitates shifts to more decentralized and lower-density land use patterns | ICT activities may reduce travel:<br>14. ICT may directly substitute for making a trip<br>15. ICT activities consume time and/or money that could be spent on travel<br>16. When travel becomes costly, difficult or dangerous, ICT substitution increases<br>17. ICT can make shared means of transportation more attractive<br>18. ICT can reduce unnecessary travel (e.g. browsing items online, and reducing trips to stores) |

*Source* Created by the author, based on Mokhtarian (2009)
*Note* In addition to the effects listed above, ICT might modify the characteristics of existing travel (*modification*), e.g. affecting the choice of a trip destination, or mode choice, or causing the replacement of a trip made for one purpose (e.g. fewer commute trips due to the adoption of telecommuting) with trips made for other purposes (e.g. trips to meet a new client that was acquired through the use of ICT)

of ways (Schwanen and Kwan 2008; Circella and Mokhtarian, forthcoming): they relax some constraints, while imposing some new ones.

Mokhtarian (2009) discusses several ways in which ICTs affect mobility. Depending on the situation, ICTs can have no relevant effect on travel (*neutrality*), generate new travel (*complementarity*), modify the characteristics of travel that would have happened anyway (*modification*), or reduce travel (*substitution*). Table 6.1 summarizes numerous ways in which ICT affects travel.

The overall impacts of ICT on travel depend on a number of local conditions, and can involve a complex combination of several of the (often counteracting) effects listed in Table 6.1. At the disaggregate level, various forms of ICTs are responsible for different effects on individual choices. The following section discusses some of the likely impacts of ICTs on the everyday choices related to the participation in activities and travel.

## 6.6 ICT and Individual Travel Behavior

Information and communication technologies have brought a number of modifications to individual behaviors, through their revolutionary impacts on the way individuals work, socialize and travel. The previous sections have already discussed how ICTs have an important impact on work organization and the office environment, the shopping experience and retail organization, and more in general how they contribute to reshaping the relationships with space and time, increasing the opportunities for extended forms of team work and social networking opportunities also over long distances. ICTs reduce (though do not eliminate) the physical constraints of distance, reducing the importance of proximity to the work place, and central parts of cities, or to the other members of one's social network. Further, they increase the ability to remain in contact with a geographically-dispersed network of contacts, and increase the ability to access (and exchange) information at distance, thus affecting migration and relocation processes. Further, they increase the flexibility in the choice of residential location of individuals and households. As discussed in the next section of this chapter, modern information and communication technologies have given rise to a number of new mobility services and solutions that reduce the reliance on private vehicle ownership, and might affect medium-term choices such as a household's decision on the number of vehicles to own. In addition, ICTs affect a number of additional choices that individuals make on a daily basis, and affect individual' lifestyles and participation in activities. In particular, the adoption of ICT can have a number of effects on various components of travel-related decision processes.

Specifically for *business travel*, ICT has long been attributed a role in replacing some portion of business-related travel, due to the adoption of virtual alternatives (e.g. teleconferencing). Certainly, ICT does substitute for some portion of business and work-related trips, while at the same time it generates additional opportunities and needs for travel (for the reasons reported in Table 6.1). In particular, travel

substitution with ICT alternatives becomes particularly attractive (and allows individuals and businesses to maintain contact with clients and other peers) also at times in which travel becomes particularly dangerous, difficult or impossible. Business travel has continued to grow in recently years, and will likely continue to grow during a time in which the world becomes increasingly globalized, and the adoption of technology and the movement of goods and people become easier and cheaper: business people travel ever farther and more frequently to develop new clients and serve existing ones (Mokhtarian 2009). The increased adoption of technology is causing several modifications in the nature and characteristics of business travel, though. A number of scholars have commented, for example, on how teleconferencing, and ICT in general, substitutes for some types of face-to-face interaction, e.g. replacing intra-company business trips. However, it does not substantially reduce and often stimulates a growth in other types of trips, e.g. meetings with new clients located in more remote locations that have been acquired through the use of ICT (Denstadli et al. 2012; Circella and Mokhtarian, forthcoming).

With regards to *commuting*, ICT solutions (predominantly, the ability to telecommute) have the potential to significantly affect individuals' commuting patterns. Several studies have investigated the impact of telecommuting on travel: telecommuting offers increased flexibility in the organization of individuals' activities, as well as increased flexibility in the choice of residential location, with larger opportunities to accommodate the needs of the partner, children and other household members. The literature has long debated on the dominant impact of telecommuting on the amount of travel, depending on the different types of telecommuters, e.g. *substituters* (who replace an entire commute trip with working remotely from home or another location), *complementers* (who work at home in addition to the regular hours worked in the office or other work location), *remote back-office workers*, etc. Accordingly, telecommuting can generate a complex mix of multifaceted effects on travel. It provides the ability to replace a work trip with working remotely, but also increases the flexibility in the choice of home locations farther away from work and central locations of a city, which might generate longer (even if less frequent) commuting trips. It also enables telecommuters to engage in additional home-based travel for other purposes during a day (Mokhtarian and Tal 2013; Circella and Mokhtarian, forthcoming). To date, the evidence indicates that telecommuting tends to reduce total travel, even if by a small degree (Choo and Mokhtarian 2005; Helminen and Ristimäki 2007), while it generates additional effects in terms of changes in travel mode, route, and departure time of trips (Downs 2005).

ICT certainly affects the generation and characteristics of *leisure trips*, and the participation in many social activities. Early research in this field suggested that ICT might substitute for some leisure trips, through consuming time and resources that would have been otherwise devoted to the participation in social activities and physical travel. However, the majority of recent research supports the opposite conclusion: the adoption of modern communication technologies and online social networks tends to increase the number of choice options for leisure activities available to an individual, the motivation to participate in them, and the opportunities

for travel. Overall, a greater adoption of internet-based activities is usually associated with more time spent with friends and acquaintances, thus complementing the amount of total travel and not reducing it (Robinson and Martin 2010). Online social networks and improved mobile telecommunications also affect how leisure activities, and trips, are organized. They allow micro-coordination of time and location for social gatherings and last-minute schedule adjustments. Thus, they make it easier to engage in trips that otherwise would have not been made (Circella and Mokhtarian, forthcoming), and influence trip objectives and purposes, mode choice, origins and destinations, and the specific route that is chosen for a trip (Kellerman 2009).

As Mokhtarian and Tal (2013, p. 250) point out, "the same types of roles of ICT generally apply across destination, mode, and route choices": ICT can serve as inspiration, information provider, explanatory variable, and/or as one of the alternatives. ICT also influences decisions related to the time and duration of activities, through the related mechanisms of fragmentation and multitasking (Circella and Mokhtarian, forthcoming):

- *Destination choice*: ICT provides an important channel for acquiring information about potential destinations of a trip. It affects individuals' choices through the increased awareness about the available destinations, it makes it possible to compare the information on a variety of candidate destinations for a given activity (e.g., eating out) and it provides information about how to reach these destinations, contact the vendor/service provider, and make instant reservations. Further, ICT provides access to travel information to reach a destination, making it possible to make adjustments before and during a trip, also as an effect of the reaction to temporary conditions (e.g. traffic congestion, temporary street closures) and coordination with other members of one's social network. ICT also provides a number of opportunities to affect travelers' choices through the availability of internet-based and location-based marketing, online reviews of commercial facilities and companies, instant-sharing of videos and photos, and GPS-enabled location and navigation services.
- *Mode choice*: ICT can make the choice of specific modes more convenient and appealing to travelers, e.g. through the access to information on traffic conditions, and travel time and costs for each specific mode through smartphone apps and advanced traveler information systems. For example, the availability of real-time accurate information on waiting time and expected in-vehicle time at public transportation stops or before the beginning of a trip can make traveling by transit more appealing (Watkins et al. 2011). ICT also affects the subjective evaluation and rating of different travel modes, making some transportation modes (e.g. cycling) more popular among the members of some specific groups of users, or in certain segments of the population that are more exposed to peers' influence or targeted campaigns. It can also provide specific benefits associated with the adoption of specific travel solutions, as in the case of the ability to work productively using ICT devices while riding transit. The possibility to increase the *utility* (or reduce the *disutility*) of travel time might

significantly enhance travelers' experience and become a factor in the choice of the travel mode to use for a trip. Thus, travelers might be willing to travel by public transportation even at the expense of longer total travel time, if they can make positive use of their time while traveling or while waiting at a terminal (Malokin et al. 2015; Dong et al. 2015). Finally, ICT offers increased opportunity for the adoption of new technology-based transportation solutions and travel modes, as in the case of new shared-mobility and ride-matching services, contributing to shifting modal distribution in particular among those individuals, such as younger adults, who are more familiar with these technologies (Circella et al. 2016).

- *Route Choice*: ICTs, and advanced traveler information systems, have a strong role in affecting route choice before and during a trip, and in prompting a route change, for example, in case of heavy traffic congestion or temporary road closures. They might also serve an inspirational role, affecting the selection of the travel route, for example in the case of scenic routes, or historical or cultural interests. Finally, ICT can affect the trip experience of passengers, for example through entertainment systems that deflect attention from the unpleasantness of an unappealing route.
- *Fragmentation of activities*: ICT promotes the blurring of space-time boundaries between and among activities associated with home, work, shopping, and entertainment, and an increased fragmentation of activities in time and space (Couclelis 2004; Hubers et al. 2008). Increased fragmentation usually implies a shorter duration of the fragments of time dedicated to the activities, but a higher number of activities (e.g. increased opportunities to communicate with a larger network of peers through instant messaging), which may generate a larger number of trips, for those activities that cannot be carried out "virtually". Further, a number of additional technological solutions, from the "nanny-cam" and medical-alert systems to daily blogs and frequent tweets, help reassure a traveler that all is well at home and conversely (White and White 2007). At the margin, this process supports travel that might otherwise have been suppressed in favor of staying home (Mascheroni 2007, Circella and Mokhtarian, forthcoming), and modifies the characteristics of those trips that would have been made even if ICTs were not available.

## 6.7 Shared Mobility Services

Technological innovations have also allowed the growth of new mobility services that are quickly reshaping the transportation sector. The massive adoption of ICT combined with the continuously increasing number of smartphone applications provides a great opportunity for users to access transportation services long imagined but never deployed on a large scale. These services, which combine the benefits of modern communication technologies with the principles of the sharing economy, provide access to a number of mobility options without bearing the

costs of owning a vehicle. They can affect key factors affecting travel decisions including travel cost, convenience and security (Taylor et al. 2015). Over longer horizons, the adoption of these services can affect the level of auto ownership of a household, and impact daily schedules, lifestyles, and even residential location. Modern shared mobility services range from *car-sharing* services, including fleet-based round-trip or one-way services (such as Zipcar or Car2Go, in the U.S. market) and peer-to-peer services (such as Turo), to *ridesharing* services, including dynamic *carpooling* (such as Carma, among others) and on-demand ride services (also known as *ridesourcing* or *transportation network companies*, or TNCs, such as Uber and Lyft), and *bike-sharing* services.

The range and availability of shared-mobility services is continuous evolving, and new services and related smartphone apps are introduced almost on a daily basis. Hallock and Inglis (2015) found that 19 of 70 U.S. major cities already have access to nearly all new mobility options included in their review. In addition, 35 other cities have access to most emerging transportation options (but not all), leaving only 16 cities where few technology-enabled transportation options are available. Although the share of total trips made with new shared-mobility services is still rather small, the foreseeable increase in the popularity of these services is expected to cause large effects on future passenger travel. According to the Special Report 319 from the U.S. Transportation Research Board (Taylor et al. 2015), numerous social and environmental effects may derive from the adoption of these services, depending on the regulations and policies that are enacted.

There is no doubt about the potential revolutionary effect that these new mobility services can have on travel behavior. The new services expand the set of choices available to travelers, and can affect key travel-related decisions and the way individuals evaluate factors such as travel cost, convenience and security (Taylor et al. 2015). The effects of emerging transportation and shared mobility services may significantly vary based on the characteristics of each type of service, the local context in which the service is provided, the characteristics of the different groups of users, and the eventual behaviors observed among different subsets of the population. New shared-mobility services may expand the set of choices available to users. They provide a valid alternative to the use of private cars, and may contribute to reducing car ownership and VMT, or stimulate additional demand for trips that would have not been made if these services were not available. Under some circumstances, they can boost transit ridership by better serving the first and last mile, improving the experience of riding transit services (Hallock and Inglis 2015; Shaheen et al. 2015; Taylor et al. 2015), or providing the availability of a ride home outside the hours of operation of public transit or at a time in which traveling by transit and/or walking to/from the transit stops may be considered unsafe (Circella et al. 2016).

The adoption of new shared-mobility services may vary significantly among members of different segments of the population. Not surprisingly, young adults (also known as *millennials*) are reported to be the most frequent users of these emerging transportation options. According to a 2013 study commissioned by Zipcar, millennials are more willing than older peers to use technology-enabled

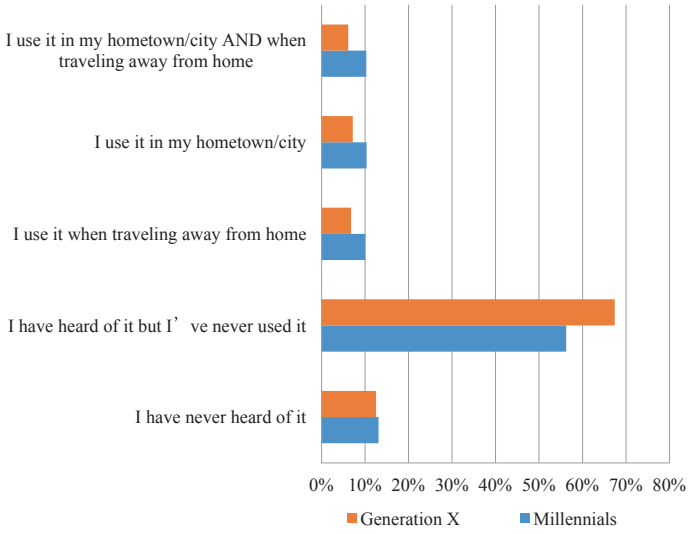


**Fig. 6.2** Familiarity and usage of on-demand ride services (e.g. Uber, Lyft) among young adults ("millennials", age 18–34) and middle-age adults (members of the Generation X, age 35–50) in California (*Source* Circella et al. 2016)

transportation options. In a recent statewide study in California, Circella et al. (2016) found that millennials were consistently more likely to report higher awareness, adoption and frequency of use of all shared mobility services controlled in the study, including fleet-based car-sharing, peer-to-peer car-sharing, bike-sharing, dynamic ridesharing, and on-demand ride services (see Fig. 6.2), if compared to the members of the older Generation X that live in the same regions. Similarly, in a survey of bikesharing users in Washington D.C., Buck et al. (2013) showed that more than half of the annual members of the bikesharing program are in the age group between 25 and 34. In another study, Rayle et al. (2014) showed that the majority of the users of on-demand ride services are young and highly educated people.

Millennials are found to be heavy users of these services, possibly due to the familiarity with technological solutions in general, or because of their residential location, and the availability of new mobility options: millennials seem to be more interested in living in central, urban areas and more open to adopting alternative means of transportation. The two factors combined would mean that not only do millennials have higher accessibility to new mobility options, but when exposed to them they are also more inclined to adopt them. Overall, though, the user base of new shared-mobility services seems to be continuously growing among all age groups.

*Carsharing* encompasses some of the most well-known technology-enabled transportation services, which can be provided through a variety of business and operational models. While fleet-based carsharing services have achieved rather

large popularity in the denser areas of major US and international cities, peer-to-peer carsharing is emerging as an important alternative because of its capability to expand the benefits of carsharing to the suburbs and to rural areas. In these areas, the lack of critical mass associated with the lower urban densities, the high proportion of home-based trips, and the higher auto-ownership rates, makes fleet-based carsharing unprofitable. Carsharing can potentially affect vehicle ownership and mode use, and influence travel behavior in a number of ways. It allows individuals to access a vehicle when needed without bearing the associated fixed costs (e.g. cost of insurance, maintenance, and long-term parking). While this effect can contribute to increasing car use among those individuals that do not feel the need to (or cannot afford to) own a car (or travel far away from the place where their personal vehicle is located), it also contributes to reducing the importance of car ownership among other users, i.e. those that already own one or more vehicles. Thus, carsharing can contribute to reducing vehicle ownership, allowing at least a portion of their users to get rid of one (or all) of their vehicles. Cervero and Tsai (2004) found that 30 % of the members of car-sharing programs were willing to sell one or more of their vehicles, while other members postponed the purchase of an additional vehicle after using carsharing services for about two years. More recently, Mishra et al. (2015) found that vehicle holding among the members of urban carsharing programs is lower by about 10–14 %, while the proportion of transit, biking and walking trips are all higher. However, the behavior of early adopters of these services may not be typical of later entrants to the car-sharing market. In another study, Martin and Shaheen (2011) surveyed members of car-sharing programs in the United States and Canada, and concluded that adding another vehicle to the fleet of shared cars would replace 9–13 privately-owned vehicles among members of car-sharing services, which might contribute to a 27–43 % reduction in vehicle miles traveled (VMT). Chatterjee et al. (2013) suggested that carsharing could enhance the access to the other modes and as a result enrich multimodality.

*Bikesharing* programs are becoming an increasingly popular presence in many American cities. Bikesharing provides users with on-demand access to bicycles for short-distance trips that seem too long for walking. Like carsharing, bikesharing is offered in various operational and business models, including dock-based bikesharing programs (by far the most common model of bikesharing services in large urban areas), dockless or GPS-based systems, and peer-to-peer bikesharing services. Bikesharing programs have been found to reduce driving and taxi use in almost every city in which they are available. In addition, while in small cities bikesharing tends to increase transit use through better serving the first and last mile, in large cities bikesharing may reduce transit ridership through providing a faster and cheaper travel option for many trips (Shaheen et al. 2014). Similarly, bikesharing programs may increase transit use for those living in the urban periphery, where access to public transportation by walk is limited, and decrease transit use for individuals in the urban core (Martin and Shaheen 2014).

Unlike other emerging transportation services, *ridesharing/carpooling* has always been a travel option available to travelers. Thus, the introduction of modern

smartphone-based ridesharing apps has not introduced a new service or travel mode, but rather it has modified the qualities of an existing option. It changed the way travelers can match their travel needs, by helping them find other peers with whom to share a ride. Technological advances have revolutionized traditional ridesharing/carpooling by easily matching riders with drivers in real-time, or on a very short notice. Compared to traditional ridesharing, dynamic ridesharing has higher flexibility, which can improve accountability and reliability of the ridesharing services and can expand its potential markets, even for occasional non-work trips.

One of the most controversial and rapidly growing forms of shared mobility services include *on-demand ride services*, also known as *ridesourcing* or *transportation network companies* (*TNCs*), such as Uber and Lyft in the U.S. market. On-demand ride services primarily resemble taxi services, in that they connect travelers requesting a ride with the pool of drivers through a smartphone application. On-demand ride services are different from dynamic ridesharing because drivers who participate in dynamic ridesharing programs only offer rides to other travelers on the route, including small deviations from it, on which the drivers intended to travel for their own needs. The growth of TNCs has been very rapid, but the information on the effect that these services have on the use of other modes is limited. Not surprisingly, respondents who live in central urban areas (where distances are shorter, parking is more scarce, and these services are more easily available) are found to use on-demand ride services more frequently than users in more suburban or rural areas. As it is common with many technological innovations, several researchers have reported that early adopters and frequent users of these services mainly include higher-educated young adults (Rayle et al. 2014). As these services become increasingly common, future adoption rates and overall impacts on the use of other modes will depend on a number of factors, including the perceived convenience of using these services, for various categories of travelers, and whether current users will continue to use these services with the same frequency as they transition in their stages of life and move to other residential locations. It is currently difficult to ascertain how riders change their behaviors with regard to the use of other transportation modes as a result of the adoption of TNCs (Taylor et al. 2015). For example, in a recent study about millennials' mobility in California, Circella et al. (2016) found that a larger proportion of millennials (compared to the members of Generation X) reported that the overall effect of their last trip with an on-demand ride service company such as Uber or Lyft was to substitute for a trip for which they would have otherwise walked or biked. Instead, a relatively larger proportion of members of the previous Generation X reported that their Uber/Lyft trip replaced a trip that they would have made by car (Fig. 6.3).

It is reasonable to expect that shared-mobility services influence travel demand and mode choice, with their effects varying with the local context, the characteristics of the users, the land use features and the transportation alternatives that are available in each area. Newer services that allow multiple users to share a ride in the same vehicle are also being introduced in many regions: if this type of service became dominant in the field of on-demand ride services, a reduction in

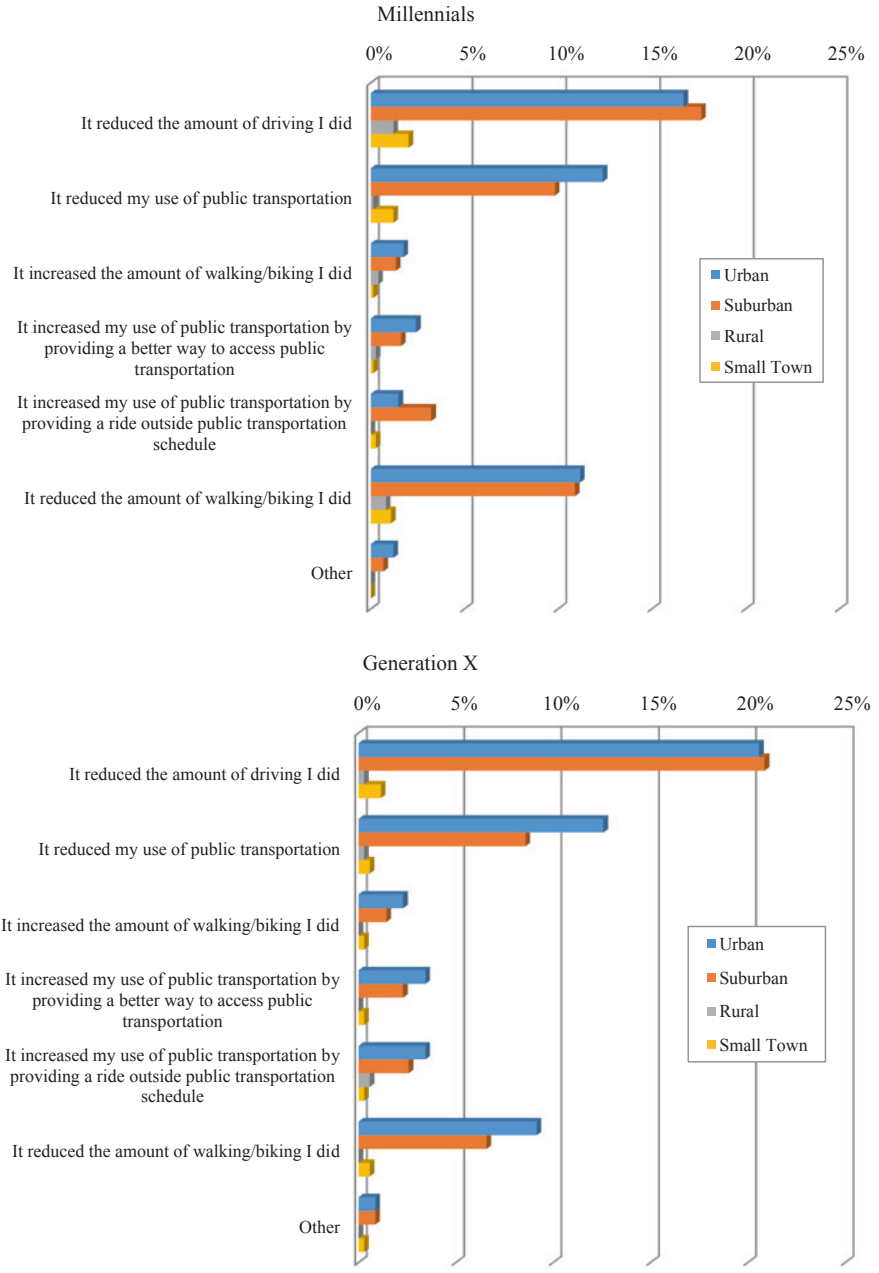


**Fig. 6.3** Impact of the last trip made with Uber or Lyft on the use of other means of transportation, among young adults ("millennials", 18–34) and middle-age adults (members of the Generation X, 35–50) in California (*Source* Circella et al. 2016)

total travel could result (Taylor et al. 2015). Certainly, these emerging transportation services have the potential to change the relationships of individuals with auto ownership, and they may eventually reduce the importance of owning a private vehicle, in favor of having access to transportation options when and where needed. ICT can play an important role in making this cultural transition become reality.

## 6.8 ICT and the Future of Cities

Modern technologies are quickly revolutionizing the way we work, live, socialize and travel. This has forever changed the lifestyles of most individuals, and their organization of activities. The adoption of modern information and communication technologies is also contributing to reshaping cities through the reduction in the importance of physical proximity, and the increased flexibility in location choices and adoption of virtual alternatives. Modern technologies have also given rise to new technology-based services, and have helped apply the principles of the sharing economy revolutionizing several economic fields (e.g. hospitality industry) and bringing innovation to transportation through the introduction of new shared-mobility services. All these changes contribute to changing individual behaviors, preferences and habits, through a complex combination of often counteracting effects associated with the adoption of technology.

Understanding the impact that ICT will continue to have on cities is not easy: ICT is already contributing to reshaping the form of cities, eventually increasing the level of decentralization through the increased reliance on modern telecommunications. This effect, to some extent, seems to be counterbalanced by other trends happening in society. For example, at the same time in which ICTs become ubiquitously common, the process of urban decentralization is slowing down, thanks to the resurgence of downtown and other central areas of cities, and the increased demand for housing units that are located close to the most vibrant and accessible parts of cities in the United States and other developed countries (Wachs 2013). Additional changes in the form of cities will continue to happen in future years, as new technologies hit the market, and contribute to reshaping the life of millions of individuals, e.g. through the organization of *smart cities*, and the increased availability of technology-based services to a larger pool of individuals. In this continuously-changing scenario, planners and policy-makers are called to provide answers to new emerging issues associated with the *digital divide* and *social equity*, the access to new technology-based services, and the eventual gap suffered by those users who, due to personal disabilities, lack of education or economic resources, might not have sufficient access to the ICT devices and services that are quickly becoming part of the new standards of living.

In the field of transportation, additional changes will be associated with the introduction of additional transportation services. Shared-mobility services, including car-sharing, bike-sharing, and on-demand ride services such as Uber

and Lyft, have already revolutionized transportation. They contribute to reducing the dependence on auto ownership in denser urban areas, potentially shifting the importance from ownership to access to transportation options.

In the future, even larger changes will be associated with the introduction of new revolutionary technologies, and in particular with the advent of connected and autonomous vehicles (AVs). The automobile industry has already made significant strides in automating driving: many current car models include features like cruise control, parking assist and other assistive technologies which are all components of what will be needed in the future for full automation of cars. Still, the mass deployment of full self-driving automation (Level 4, according to the classification of the U.S. Department of Transportation's National Highway Traffic Safety Administration) on public roads will require several more years, due to a combination of engineering, economic, and regulatory factors.

Assuming that these technologies will prove to be fully successful and become available to the mass market, subject to regulatory approval and/or any restrictions from federal, state and local agencies, AVs have the potential to dramatically change future travel patterns and individual behaviors. Among other effects, they may lead to safer roads, reduced congestion, increased network capacity, improved travel comfort, and reduced parking requirements. Connected and autonomous vehicles may provide mobility for those too young to drive, the elderly and the disabled. AVs will likely reduce the fatigue associated with driving, and increase the ability to perform activities while traveling. They will further change the way individuals organize their schedule and activity participation, and the concept of travel as a transition between different activities conducted at the origin and destination of a trip. They are expected to increase the utility of using a car, as travelers can combine the scheduling flexibility of being a driver with the comfort of riding as a passenger. Thus, AVs are likely to lower the value of travel time for car users, and affect mode choice by favoring the adoption of private vehicles for a larger number of trips at the expenses of other travel modes (Malokin et al. 2015). The adoption of AVs will likely result in higher per-capita VMT due to latent demand, and the increased utility of using a car: the increased mobility among the elderly and others, as well as lower travel efforts and congestion delays, will almost certainly lead to large increases in car travel, unless demand-management strategies are thoughtfully implemented (Fagnant and Kockelman 2015).

However, the overall effects of AVs on passenger travel will largely depend on the policies and regulations that are implemented, including, but not limited to, eventual restrictions in some portions of the road network (e.g. city centers and local roads), regulations for specific categories of users (e.g. unaccompanied minors), ownership models (e.g. personal autonomous vehicles vs. shared autonomous vehicles), traffic regulations and parking requirements (e.g. whether empty vehicles will be allowed to travel back home or will need to be parked at the final destination of a trip). Further, the use of AVs might be integrated in other transportation services: TNCs such as Uber and Lyft are already evaluating the future integration of fully autonomous vehicles into their fleets, thus revolutionizing on-demand ride services through the use of driverless shared vehicles. To date, it is

still unclear when fully autonomous vehicles will become commercially available, and how quickly consumers will adopt them. Some studies predict that AVs will be an accepted technology by 2030 (or even earlier) and dominate personal transportation by 2050 (Greenblatt and Shaheen 2015). Overall, more research is needed in order to better understand the impacts of AVs on future travel, and the way the introduction of this revolutionary technology will modify the future of cities, and our life.

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