Doctoral Thesis of Urban and Regional Planning

Complementary and Substitutive Effects of Telecommunication on the Frequency of Visiting the City Center

August 2018

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Submitting a Doctoral Dissertation of Urban and Regional Planning
July 2018

Dept. of Environment Planning
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July 2018

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A Dissertation Presented
by
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In Partial Fulfillment of the Requirements
for the Degree of
Ph. D in Urban Planning

Department of Environment Planning
Graduate School of Environmental Studies
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August 2018

Abstract

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Due to the development of information and communication technology, various changes are expected in the non-technical aspects such as society, culture, economy, employment and labor. The use of telecommunication with smartphone and mobile internet has popularized rapidly, and activities in the business and non-business sectors in the city have been replaced online activities such as telecommuting and online-shopping. This study henceforth examines the complementary and substitution effects that development of telecommunication technology affects the frequency of visiting city centers, and figures how the both effects above are co-working.

This study classified the influence of telecommunication technology on the frequency toward city centers into two categories. The substitution effect

of telecommunication technology was conceptualized as a decreasing tendency in the frequency of individuals visiting the city center for work, shopping, and leisure as they utilize telecommuting and tele-working in business sector, or online shopping and online leisure in non-business sector. Complementary effects of telecommunication technology are classified as a increasing tendency in the frequency of visiting city centers for business, shopping, and leisure purposes, despite the introduction of online business, online shopping and leisure. After reviewing the related literatures, it was found that the complementary and substitution effect appear to be interdependent concepts rather than confrontational or unilateral concepts. Therefore, a theoretical model is constructed explaining that the substitution effect of telecommunication technology is inter-connected with complementary effect. In other words, through a simple mathematical model, it could be seen that the total amount of work and shopping leisure time can be increased while enjoying online business, online-shopping, and online-leisure. Proved was the process of complementary effect that the greater the effect of substitution by telecommunication technology, the more the amount of increase in total amount. Also, the data of Life Time Survey of year 2004 and 2014 were examined to identify whether the 'increasing total amount' effect actually occurred. The result found that the non-telecommuting time substitutively decreased as the telecommuting time increased. In addition, the complementary effect of 'the increasing total amount' was confirmed by the total working time increased as the telecommuting time increased, and the offline shopping time increased as the online shopping time increased. These were more evident in 2014, when smartphones and mobile Internet became more popularized

than in 2004.

A mobile survey on smartphone and mobile internet users were conducted in order to determine whether the total amount actually influenced the frequency of individual visits to the city centers. The analysis of the survey results had been conducted using two-stage least square and path model to identify the effect of the total amount increase by the substitution effect on the frequency of downtown visits and their influence of the frequency of visits to the city centers. The results of the analysis were as follows. First, as shown in the mathematical model and the Life Time Survey data, it was confirmed that the total amount effect increased as the substitution effect increased; and the frequency of visits to the downtown is increased accordingly. In addition, it was confirmed that the second stage effect (from the total amount effect to the change of the frequency toward city center) appeared to behave more elastically than the first stage effect (from the substitution effect to the total effect). Third, the substitution effects in business and non-business were expected to be stronger, depending on the technical shrewdness of the individual. Fourth, mutual cross-effects between objectives of visiting citi centers increased the total amount effect. Fifth, the inter-relationships was confirmed between the frequency of visits toward city centers for business purposes and for non-business purposes and vice versa. However, the negative concurrency was also found that the frequency of visits to the city centers between different purposes did not increase simultaneously. Finally, the chain effect was confirmed that the impact from the substitution effect to the frequency toward city centers through the total amount change was increased stepwise.

In conclusion, with the development of information and communication technology, the phenomenon of replacing the existing behavior at the primary level in business and non-business aspects has been found. However, this substitution effect did not directly affect the frequency of visits to the city center, but rather it affected the frequency of visits in a way of the interdependency of the purpose of visiting the city center and the manifestation of potential traffic demand. In addition to increasing the efficiency of work and timeliness of shopping leisure with the application of telecommunication technology, the total amount effect is an important role of mediation in increasing the frequency of visits to urban areas.

Keywords : Telecommunication Technology, Frequency of Visiting City Centers, Complementarity, Substitution, 2SLS, Path Model

ID Number : 2010-31242

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I. Introduction

A. Research Background and Objectives

The influence of the development of communication technology on the urban spatial structure has long been placed in the center of controversy. The development of information technology that can replace the main attraction factor of the city, communication, is to reduce the traffic demand to access toward a city, consequently alleviating density of the city. There have been predictions of futurist that it will bring about 'dismantling' of city. However, though the development of personal computers, the internet communication technology, mobile phones and smart devices have advanced, the disintegration of city has not actually been found, while the density of cities have been increasing.

Telecommunication based on digital information communication technology (ICT) is expected to reduce the meaning of the city as a venue for distribution of information by replacing face-to-face contact. For instance, mobile phones have made the users free from spatial constraints, and internet-based services including remote education, telemedicine, and e-commerce have emerged that extend beyond distance. In addition, telecommuting using diversified information and communication devices is gradually becoming a practical alternative to traditional workplaces, which is consistent with the predictions of futurists.

Telecommunication and electronic contact may further activate the

exchange of information, which may increase the need for face-to-face contact more than in the past. With the development of information and communication, information is becoming one of the most important factors of production. Electronic contact and face-to-face contact are complementary each other in the sense that electronic contact is more contingent than face-to-face contact, although the conversation through electronic contact is largely purposeful (Duranton, 1999). In some cases, face-to-face contact is more effective than electronic contact in some conversation subjects. If the information exchange based on electronic contact increases traditional face-to-face contact, that is, if electronic contact and face-to-face contact are complementary, the city will still play a role as a means of distribution of information and it will continue to grow.

Since the 2000's, in a regional context, the internet communication environment in Korea has evolved to deliver more data to more people at a faster rate. In addition, since 2007, the use of smart-phones has increased dramatically over the past decade, and mobile Internet has reached a level comparable to the landline internet communication market. The ICT Development Index (IDI) of Korea ranked world first in 2016 and second in 2017, which is mainly boosted by high values for fixed-telephone subscriptions and for tertiary enrolment (ITU, 2017: 36-37). Though her values for the percentage of households with a computer and for international Internet bandwidth per Internet user are notably lower than those in Iceland and Switzerland, she still shows strong potential for future ICT development.

The use of mobile Internet in Korea is also increasing. In 2017, 99.5%

of Internet users aged 3 years or older answered that they are using the Internet while they are ‘on the move’. This is higher than the answer that they use the Internet ‘at home’ (98.4%). However, it is hard to say that mobile internet use overwhelm the fixed line, suggesting that the boundaries between mobile and fixed are getting vague due to the increase of usability.

Communication technology has developed remarkably compared with the past, and remote communication methods that can be utilized for business and non-business based on the developed communication technology have been actively spread. However, in spite of this period of transition, there is still no evidence to suggest that the density of cities is lowered or the scope of influence from cities is reduced comparatively and seemingly paradoxically, urban congestion has worsened as the technology continues to advance and spread (Mokhtarian, 2009).

The first purpose of the study hence is to examine why the telecommunication usage which was expected as the main cause of the deconstruction of urban density, such as telecommuting and tele-working, was not higher than expected. Also, it is to witness whether application of telecommunication not only for business purpose but also for non - business such as shopping, leisure, etc. does not contribute to reducing the frequency of downtown visits or contributes to increase the chance toward city. And, the second goal is aimed at clarifying the mechanism by which a substitute or complementary effect of communication on urban spatial structures operates.

The second purpose of this study is to reveal the process by which the disintegration or deepening of the spatial concentration of the city presented

in the first question. If the existing urban functions in business are replaced by tele-working and telecommuting with the online technology introduced, thereby a substitution effect of the communication occurs, an individual will reinvest the increased surplus resources in a way reducing the demand for travel. The entire latent travel demand throughout the city will decrease as aggregated individuals tend to abandon his or her travel demand (Kim, 1997; Kim, 2000). If individuals tend to reinvest the surplus resources created by substitution and decide to make additional travel, the latent travel demand across the city will increase. This tendency may be exacerbated, when a city is assumed to have a mono-centric structure (Lund and Mokhtarian, 1994).

B. Lexicons in use

Definitions of ‘online’ and ‘telecommunication’ are the concept of integrating the broadband (landline) internet communication and mobile internet communication. The reason why mobile communication is not distinguished from broadband is that an individual’s connecting behavior would not connect consciously and separately.

Online activity is broadly defined as the behavior of commuting or enjoying shopping or leisure by using telecommunication media such as telephone and text from wired or wireless Internet. The reasons for not separating the wired Internet from the wireless Internet are that the wired and wireless Internet have become blurred in terms of speed and availability due to the spread of smartphones and the popularization of wireless Internet. Therefore, definition

of online activity for business purpose is an activity that can be processed by wired and wireless Internet such as messenger, email. The online activity for business purpose is often understood with terms of tele-working, working at home (WAH), telecommuting, and New Ways of working (Gerards et al., 2018); tele-working is defined as the broadest concept, and WAH and Telecommuting are defined as the seperated and concrete term (Nilles, 1988).

Online activity for shopping refers to searching or purchasing goods through home shopping, internet shopping, and mobile shopping. Online activities for leisure purposes include listening to music, movies or performances using wired and wireless Internet or spending time for other leisure purposes. The online activity for shopping is defined with different terms of online-shopping, home-shopping, e-commerce, internet shopping, and tele-shopping.

The concept of the 'total amount effect' in this study is to explain the mediating route to the influence of the substitution effect of online activity on the visit to the city center. In other words, replacing existing offline activities with online activities has the effect of shortening workload or shopping time. The concept of total effect is the total amount of online and offline activity brought about by the substitution of online activities, assuming that the resources (eg., time, labor) This will be explained in detail in the third chapter using mathematical models.

The definition of 'city center' or 'downtown' used in this study does not mean a specific area, since it is assumed that the urban spatial structures of Korea, including the metropolitan areas, have multi-centric structures rather than mono-centric. Also, there are not only personal cognitive differences

presumably in the concept, scale, and location of the central region of one's residence, but also environmental differences between the locations of city centers and the downtown.

In this sense, the concept of 'substitution' can be explained with a two-step process. Generally speaking, the substitution effect of telecommunication due to the technological development generally means less need to work with a direct visit to the business district, or reduced need to make purchases in stores. As a result of the substitution effect of communication, the necessity to move directly into business and commercial districts in the city deceases, which makes traffic demand for business-oriented or commerce-centered traffic decreased, thereby reducing the overall density of the city. Moreover, since there is no need to visit the city frequently, the occupancy of the outskirts of the city can further be expanded, resulting that the commuting distance of the city is further increased.

The concept of 'complementarity' can also be explained in two steps. A better communication with convenience due to the development of communication technology can increase the efficiency of a worker, thereby increasing the need for the worker to work in the downtown business district. In the similar ways, the adoption of online shopping can increase the need for consumers to buy commodities by helping them acquire more information of the products than before. The paradoxically increased need for city visits can be linked to travel demand to downtown, and consequently the density of the urban centers concentrated in the business district and the commercial district can be predicted to increase. Salomon (1986) subdivided

complementarity into “enhancement” which was the generation of additional travel due to the availability of additional telecommunications, and ““increasing efficiency” suggesting that the efficiency of travel increased by the application of telecommunications and possibly leading to moderate substitution effects. Complementarity in Salomon’s understanding was the ‘‘increase in demand for transport resulting from the enhanced use of telecommunications”.

However, the emergence of substitution or complementary effects on density of cities cannot be visually found. It is because the effect that the non-physical attributes such as the business behavior of companies located in the business districts, the environmental conditions of the settlements such as transportation demand, urban highway abundance, and the availability of public transportation.

C. Organization of Study and Research Methods

Researches on the influence of newly introduced communication due to the development of technology on urban spaces are not in the new topics; the relationships have been studied in a number of researches. In chapter 2, the researches on how the activities related to work, shopping, and leisure brought about changes due to the introduction of telecommunication will be examined. The trend of increasing and decreasing offline activities due to the introduction of communication shows other aspects depending on the place and time when the research was conducted. Different trends can be classifeid into complementarity and substitution; literatures that already introduced these categories will be also refered in the chapter.

In addition to the complementarity and substitution introduced in Chapter two, it is necessary to examine the processes by which the tendencies arise. The first half of the third chapter introduces a series of mathematical process, by which the complementary effects might be able to occur even though online activity via telecommunication have replaced the existed classic offline activities. The second half will examine the relationships between online activity and offline activity, measured with time for business and shopping, using the national Life Time-Use Survey data provided by Korean Statistical Information Service. For the decade from 2004 to 2014, how the substitution effects of the internet and mobile communication penetration occurred in the business and non-business sectors will be examined. In addition, the relationship between online and offline business hours, the relationship between online business hours and total business hours, and the relationship between

online and offline shopping time will be examined.

In Chapter 4, the effect of substitution due to the increase of smartphone and internet usage on individual change of CBD access will be analyzed based on data collected through mobile survey. Since the purpose of this study is to investigate whether there is a change in total amount of work or total shopping time due to the substitution effect of increased online activity. The process of change of total amount brought by substitution effect and change of visiting city centers in terms of frequency will be verified through two different analysis methods of Two-Stage Least Square and path model. Two-Stage Least Square (2SLS) analysis confirms that the total amount effect increased as the substitution effect increased, and the frequency of visits to the downtown is increased accordingly. Path model did not only verify the mechanisms of the complentarity in that a 'total amount effect' emerged by the substitution of telecommunications, also confirmed the interrelationships between the different purpose of visiting city centers in terms of cross-effects and concurrency.

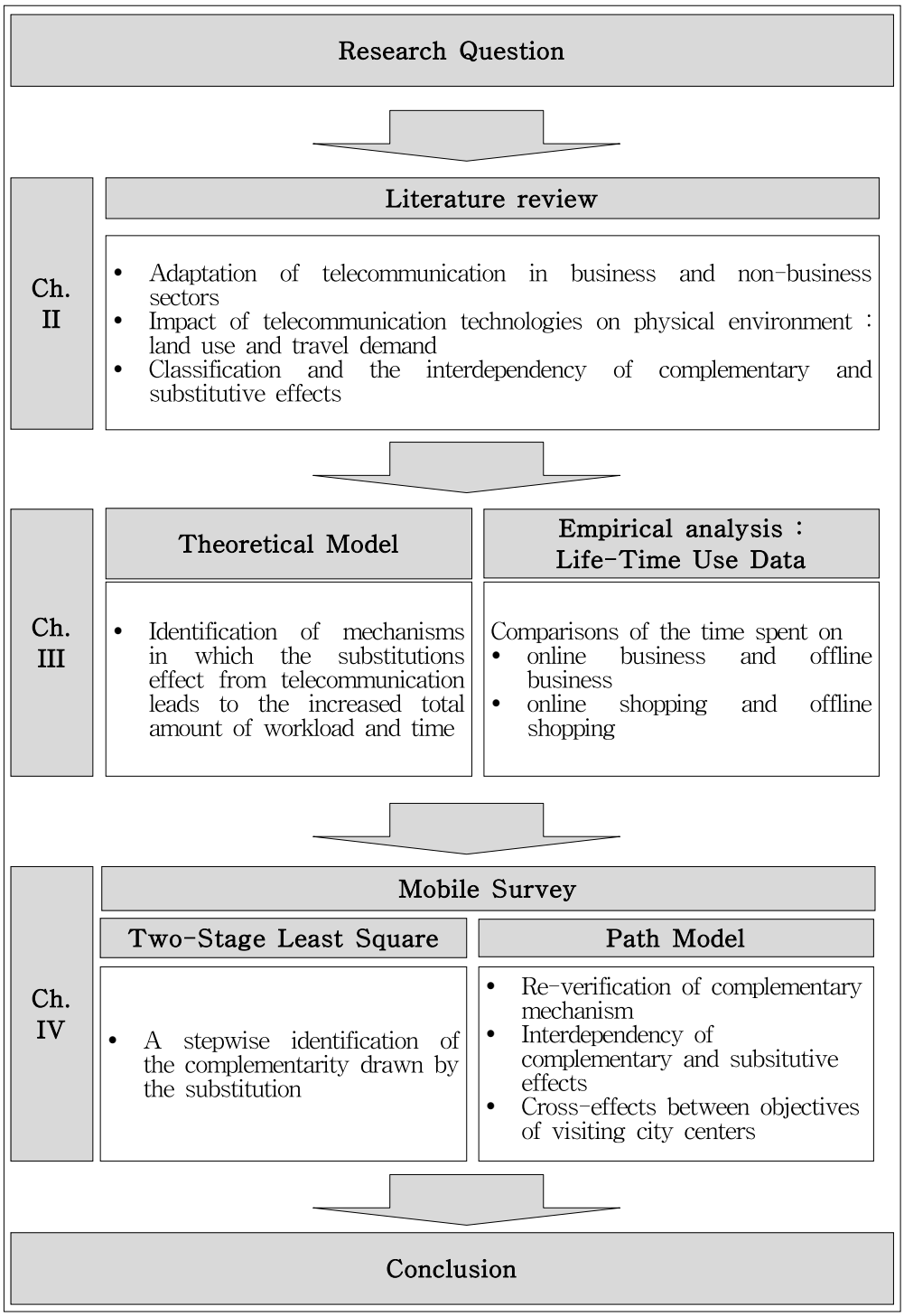

Figure 1. Organization of the study

II. Literature Review

A. Changes in Lifestyles the Telecommunication Technology have drawn in Business and Non-business Sector

Regarding the reason why people move out of their workplace and telecommute, Glenn (2012) pointed out the difference of production that originated from the characteristics of the work; creative task versus dull task. To raise a worker's productivity, dull task with repetitive and supervised work should be done within the location of workplace, whereas creative task doesn't have to be done in the workplace. Rhee (2009) assumed that more telecommuting occured when telecommuters' labor cost share increased and/or workers adopted a more favorable attitude toward working at home. A survey conducted by O'Keefe et al. (2016) suggested that approximately 44% of the population of the Greater Dublin Area telecommuted at least once a month, while Zhu, P. (2012) found no significant reduction in overall travel demand for telecommuters.

Regarding why the consumer goes online rather than buying product from offline stores, Kacen (2013) identified the difference of product categories sold in online and offline shopping, and found the in-store shopping was still dominant in terms of sales amount, especially when purchasing products that required trial operation or that need to be tried, such as shoes and clothing. Product categories that online purchases dominant in sales amount were with the regular specifications or with no problems of specification, such as books

and other industrial products, therefore did not have a high degree of quality doubt. The study of Lee et al. (2017) confirmed the behavior of these consumers; when comparing the cost of shipping, the time of delivery, the reliability of the product shipped and the traveling cost for shopping, online shopping was more prevalent when purchasing predominant product types, whereas daily necessities, groceries, gasoline, etc. are dominated by offline purchases. Levin, et al. (2005) found non-physical items such as airline e-tickets or software downloads strongly favor the online shopping environment. Ren and Kwan (2009) also found that the most frequently purchased online are non-dairy items such as books, CDs and electronics.

Ferrell (2005) discovered that an individual with time-constraints tended to reduce the time spent on the entire time of travel by reducing shopping related travel. Mokhtarian et al. (2006) pointed out that there are temporal and spatial constraints of leisure, and that ICT helps the participant to overcome those constraints, both temporally and spatially. In other words, when the leisure activities with fixed schedule or with promise with other leisure participants is classified as time-constrained leisure, and when the leisure activities that can be enjoyed only in specific space or location is classified as space-constrained leisure, such leisure activities as watching movies at theater, family trips, enjoying live concerts, and shopping in offline shops are both space-dependent and time-dependent leisure. Watching a live sport on TV or on individual's own device, rather than a stadium, is a leisure activity that is outside the bounds of spatial constraint but not temporally independent. Watching movies with own electronic device instead of going movie theater is a behavior that moves away from spatial dependency and

time dependency spontaneously. The impact of ICT on leisure activities therefore can be classified into four categories: replacing time and space dependency of traditional leisure behavior, creating new type of leisure activities independent from temporal and spatial constraints, ICT-based allocation of time and space costs from leisure to non-leisure activities, concentration and promotion of participation in overall leisure behavior. The potential impacts of online shopping include changes in shopping mode share, changes in the volume of goods purchased, changes in per capita consumption spending, and demographic changes. (Mokhtarian, 2004)

Obviously, there are also a number of rationales why some people avoid shopping via the internet. Forsythe and Shi (2003) defined consumers' reluctance to purchase online categorized by four types of perceived risk of financial, product performance, psychological, and time/convenience loss. Hsiao (2009) characterized in-store shopping superior to e-shopping in terms of information quality in that the products purchased offline showed more credentiality and less uncertainty.

Cao et al. (2012) studied relationship between online searching frequency, online buying frequency and in-store shopping frequency using data of 539 adults from a shopping survey in Minneapolis-St Paul metropolitan area and found that online shopping tended to have a complementary effect on in-store shopping. A survey of internet users in the Twin Cities, Minnesota region (Cao, 2012) further supported complementarity, revealing that 14% of respondents researched a product online before purchasing it in a store, while 5% of online purchasers went to a store first to gather information.

Couclelis (2004) discovered the behavior of free-rider who views and tests a product in the store but then purchases it online, or when the main item is bought in a store but accessories are purchased online, which might eventually devote 'decline of stores' by decreasing offline-stores' revenue. Farag et al. (2006) studied shopping behavior of 2190 individuals in the Netherlands. Results suggested that ''people are more likely to adopt e-shopping when their accessibility to shops is relatively low''. Sim and Koi (2002) found that 12% of of online buyers reduced their trips to stores based on a survey on 1500 local consumers in Singapore.

Analyzing 2000 San Francisco Bay Area Travel Survey data, Ferrell (2004) reported a positive association between online shopping and shopping trip frequency at the household level. Despite the higher number of shopping trips for frequent online shoppers, total shopping trip distance was not significantly different, indicating that online shoppers made shorter trips to stores or more efficiently chaining their shopping activities. Upon re-examining using SEM at the individual level with the same survey data, Ferrell (2005) also found that frequent online shoppers tended to make fewer in-store shopping trips. These results were contradictory to the initial study, possibly due to the differing scales of analysis. It is possible to estimate that the individual-level analysis discounted the effects of shared decision-making at the household level. The study also indicated that individuals with greater time constraints might be more likely to take advantage of online shopping's time saving benefits to substitute for shopping trips and reduce their overall travel burden. Using a sample of 740 adults from Seattle, Kansas City and Pittsburgh to explore such inconsistency by examining the spatial variation of the shopping

behavior, Krizek et al. (2005), found that people living in suburbs or away from central business district (CBD) were more likely to make online shopping, though the effects are insignificant. Cao et al. (2010) reported that 29% of online purchasers indicated they would not have made their last online purchase from a store, and nearly half had made a trip to a store solely because of something they saw online.

Weltevreden and Rietbergen (2007) found that desire of shopping might be stimulated, leading to more shopping trips when people were able to freely browse and choose among numerous products. Farag et al. (2007) discovered positive relationships between online and in-store shopping in the Netherlands. The analysis indicated that the frequency of in-store shopping trips had a positive effect on online shopping frequency but not vice versa.

Online shopping would also encourages additional shopping-related travel, given if online purchasers exploited online shopping time or money savings to make additional shopping trips, or if items discovered via online led to a trip toward the store in downtown to examine, to test, and to purchase, or if items bought online would not have been purchased otherwise (Rapp et al., 2015; Lee et al., 2017). Kacen (2013) found in-store shopping would still dominate overall sales despite various methods of online shopping would have been developed.

B. Changes in Travel Demand and Land Use

Alonso's Model (1964) suggested the Bid-Rent function of relationships between rent (housing cost) and commuting cost. As the residential location moves toward urban center, travel cost decreases by the product of distance moved and unit travel cost, while housing cost increases by the product of residential land area and marginal unit of rent. Therefore, under a budget constraint, the residential location is decided at the point that maximizes utility of housing cost and travel cost. (Ellen and Hempstead, 2002; O'Sullivan, 2004))

Under the condition of utility maximization and budget constraints, reducing travel cost with telecommuting can be converted into consumption for other commodities and services. In the long term, the conversion of consumption by the reduced travel cost can be directed to improvement of housing quality, which enables movement to newer and roomy housings out of city. (Moos and Skaburskis, 2007). That is, reduced traveling cost indirectly increases income resulting in expansion of urban boundary.

If the demand for housing is fixed and telecommuting reduces the commuting cost per unit distance, the graph of linear housing price function will be flattened. Assuming that all employees will work full time, the function becomes completely indifferent. (Jen and Hemstead, 2002). In other words, the spread of telecommuting is likely to lead to a decline in the housing price in the long term and to widen the boundaries of the city. It is also possible to explain the causal relationship of telecommuting choice due to

residential location movements. An employer may try to exchange the increase of the housing cost and the commuting cost by moving his company out of city. (Ory and Mokhtarian, 2006; Moos and Skaburskis, 2010). The access-space trade-off theory alone cannot fully account for the causal relationship between telecommuting and residential location movement, but can be a basis of hypothesis for the positive correlation between telecommuting and suburban preference.

The expansion of residential location spread out of city can be further explained in the following aspects. The continuous development of information and communication technology can further promote the sub-urbanization of housings as well as the popularization of telecommuting. The development of information and communication devices can reduce the need for spatial concentration of employment in the city centers and promote decentralization of traditional employment centers. (Janelle, 1995; Tayyaran et al., 2003). Mitche11(2001) addressed that dispersion and re-centralizing of industries occurred simultaneously, according to so-called 'tele-service paradox'. In the case of industries that emphasize the necessity of face-to-face contact such as front office business, they will continue to prefer the central location, while in the case of the industries where the need for face-to-face contact is relatively low, the sub-urbanization is accelerated. Contextually, telecommuting will be more likely to be adopted by suburban backers which require face-to-face contact and less access to the city center. The development of information and communication technology, the sub-urbanization of a specific employment sector and the popularization of telecommuting will mutually be influenced and accelerated, and which may cause telecommuters

to select suburban residence.

On the other hand, the development of ICT can reduce the need for telecommuting households to be located in urban area as the development of information and communication technologies may minimize the spatial imbalance of the information gap. The preference for central location caused by the information gap between urban and suburban areas will hence be gradually decreased. The development of the technology can also be a major factor in increasing the probability of telecommuting (Vilhemson and Thulin, 2001; Helminen and Ristimaki, 2007). As described with residential location theory, the frequent telecommuting maximizes the motivation for the sub-urbanization by further reducing commuting costs and the need for centralized access (Ellen and Hempstead, 2012; Tang et al., 2008). Janelle (2004) also argued that existence of extra-vehicles thanks to the telecommuting improves the mobility of other household members, which causes new housing expansion in suburban areas.

While empirical evidence for the substitution effect are mainly found in shopping related research, there also are a few studies that have found a decrease in travel demand due to the telecommuting. Kim et al. (2015), using the Household Travel Survey in 2006, suggested that the use of households' only automobile might be used for non-commuting purpose given that the household head's commuting behavior was replaced with telecommuting. It is hence notable that the decrease of commuting traffic sufficiently offset the total traffic volume of the city as the non-commuting traffic increases. Lila P. C. and MVLR Anjaeyulu (2013), who studied the

effects of telecommuting on travel time for Indian ICT workers, found that telecommuting policy affected decreased total trip distance for commuting, travel time reduction, and reduction of fuel consumption.

It is possible to explain the reduced travel demand due to the telecommunication's application to individual life with the theory of travel time budget. Though there are divergence according to individual attributes, income and traveling time, (Metz, 2004 ; Prendergast and Williams, 1981;) it is generally known that routine commuting time is around one hour or so (Schafer and Victor, 2000; Ironmonger and Norman, 2007). The reduced travel demand due to the development of communication begins with the condition that the decreasing unit travel cost will converge into infinitely small value due to the development of telecommunication. If the existing transportation cost is infinitely reduced due to the telecommunication development under same communication demand, the range of influence from the pulling factor of the city can be extended infinitely. Ultimately, the development of telecommunication reduces the spatial demand for face-to-face communication, and the 'concentrated density' of the old city may be abated and dispersed due to the substitution effect.

The first order impact from telecommuting (Nilles, 1988) can be defined as the reduction of work-related travel demand, especially in rush hours, thereby helping reduce daytime population of city. If a number of employers adopt remote-office system with regional center, the aggregated trip length for work will be shortened and individual automobile demand will be substituted with by-foot, bicycle and public transit.

In terms of shopping behavior, the substitutive relationship between online shopping and offline shopping can be intuitively expected. Given that purchasing and product research do not necessarily require a trip to the store, online shopping can reduce the travel burden on consumers (Lee et al., 2017). A net substitution effect would imply that some portion of in-store shopping trips was replaced by online purchases, reducing overall travel. Eventually, E-commerce offers the potential substitution of telecommunications for travel, resulting in a trade-off between virtual and physical travel (Rotem-Mindali, O., 2010). A web survey among residents in Tennessee showed about 40% of residents reported less driving with the use of internet (Tonn and Hemrick, 2004) Weltevreden and Rietbergen (2007) studied the impact of e-shopping on in-store shopping based on data of 3074 internet users in the Netherlands. Results indicated that more than 20% online buyers made fewer trips to city center stores.

The fact that ICT might enable multitasking while traveling is expected by many to have an impact on travelers' valuation of travel time (savings): More specifically, it seems intuitive that by enabling multitasking, ICT will decrease the value of travel time savings (VoTTS). Indeed, empirical research (Ettema and Verschuren, 2007) suggested that individuals who dislike multitasking have relatively high VoTTS. The authors, however, cautioned that much more research is needed in this area before more definitive conclusions can be drawn, for example, that self-selection processes could play a role.

Telecommuting may affect the travel demand for commuting from a given

residential district to the city center, and also may cause the existing residential center to move to the outskirts of the city center or even closer to the city center. Using data from the 2006 Seoul Metropolitan Area Household Travel Survey, Kim (2012) investigated the relationships between telecommuting and residential location, considering job location and discovered that the households with telecommuter tend to reside in outlying areas.

The positive relationship between the development of communication and the physical travel is also evidenced in the study of Nobis & Lenz (2009), which tested the interaction effect between communication and traffic at the individual level using mobile panel data from 2004 to 2007. Although the number of mobile phone users in Germany has increased, the number of population heading to cities has not decreased, and the number of users who use mobile phones more frequently has been less than that of other groups. The analysis of time series data of the United States (Choo & Mokhtarian, 2004; Choo et al., 2005) reiterated the complementarity of communication and travel. Choo et al. (2008) analyzed relations between transportation and communications based on the U.S. Consumer Expenditure 1984–2002, whose result indicated that both substitute and complementary effects existed, but the impact of communications on transportation was dominantly complementary.

The complementary effects of communication on urban spatial structure are found in empirical studies on the relationship between communication and travel. These empirical studies provide more abundant observations for complementary relationships as relatively recent studies. Schwanen & Kwan

(2008) and Srinivasan & Raghavender (2006) stated that the relationship between traffic and communication may differ according to the communication means (Nobis & Lenz, 2006; Nobis et al., 2005). In addition, Sung and Kim (2002) estimated the local call demand model between providences and metropolitan areas, showing that as the price of face-to-face contact is higher, the demand for the local call is decreased. It is shown that the electronic contact using the long-distance call forms a complementary relationship, not substitutive to face-to-face contact.

There could be a question why people create trips toward cities even when they are able to telecommute and teleshop. O'Keepe et al. (2016) suggested needing contact with colleagues was the most influential constraint to telecommuting, while greater flexibility and avoiding travelling in peak periods are the most important drivers in the propensity to telecommute. In this context, travel is desired for its own sake (Mokhtarian and Salomon, 2001). People had desire for movement; sometimes they simply want to get out and go somewhere. As Mokhtarian (2004) noted, ''it is likely that a number of shopping trips are 'invented' in order to 'justify' (often subconsciously) an urge simply to get out and go somewhere".

C. The Interrelationships of Complementarity and Substitution effects

Regarding how the changed lifestyle with development of telecommunication, especially due to telecommuting and teleshopping

influeced the spatial structure of cities, Salomon (1986) had proposed a categorized scheme of the potential effects into two basic types, namely ‘‘substitution” and ‘‘complementarity”. Researches on the relationship of telecommunications and travel to city has been driven by the objective to understand the direction in which the use of telecommunication means alters mobility behavior. Based on the work of Salomon and others (e.g. Salomon, 1985, 1986; Mokhtarian, 1990; Market and Goulias, 1999; Hjortol, 2002) Senbil and Kitamura (2003) developed the typology suggesting four potential relationships between telecommunications and travel: *Substitution* (telecommunications leading to a decrease in travel demand through a reduction in total number of trips or in trip duration), *Complementarity* (generation of new trips due to the use of telecommunications), *Modification* (change of spatial and temporal characteristics of existing travel patterns by the use of telecommunications) and *Neutrality* (no impact of one medium on the other). While they added ‘‘Modification” and “Neutrality“ that telecommunications do not necessarily alter travel demand or travel behavior, those two types are supposed to be just branches from the existing definitions as effects that generate trips by the use of telecommunications. Therefore only two major stems in controversiality are introduced in the remaining literature review of this study.

Alvin Toffler (1980) predicted that due to information and communication technology, the city would be de-constructed and people would reside in suburban Electronic Cottage. Negroponte (1995) predicted that the Transmission of Place itself, which transmits a place itself as a virtual reality, could reduce the importance of the city's place. Marshall McLuhan (1964)

also suggested that the dismantling of cities was inevitable. The most important issue of these futurists' predictions is based on the idea that the development of information and communication technologies will replace existing face to face communication and eventually decline. The substitution effect from communication development is based on the basic assumption that the magnitude of travel demand to a city changes in proportion to the size of the pulling factor of the city. Assuming that two different cities with the same size of pulling factors, the traveling distance to the cities varies according to unit traffic cost.

According to Duranton (1999), on the other hand, information communication or electronic contact may further activate the exchange of information, which may increase the need for face-to-face contact more than in the past. With the development of information and communication, information is becoming one of the most important factors of production. Electronic contact and face-to-face contact are complementary in that the face-to-face contact is usually made with purpose, while face-to-face contact is more contingent. This complementarity occurs because face-to-face contact is more effective than electronic contact. If the activation of information exchange through electronic contact is complementary to increasing face-to-face contact, the city will continue to play its role as a means of distribution of information and will continue to grow, despite the substitution effect of information and communication.

On the complementary effect, Glazer (2011) mentioned the theoretical association with ‘Jevon's Paradox’, which would occur when technological

progress increases the efficiency with which a resource is used (reducing the amount necessary for any one use), but the rate of consumption of that resource rises because of increasing demand (Blake, 2015).

The complementary relationship between the use of personal communication and the travel demand toward downtown – for either business purpose or non-business purpose - is caused by the following flow. In general, telecommuting behavior can be utilized as a preliminary work for business that requires physical traffic. Gaspar and Glaeser (1998) set up a theoretical model of face-to-face and electronic contact and provide some empirical evidence on the impact of ICT on face-to-face contact or the role of the city. More specifically, they addressed the role of city will continue as a means of distribution of face-to-face contact, by analyzing the relationships of the amount of local call and distance, the number of long-distance flight for business considering the rate-cut effect, the types of collaborative research and the difference in the frequency of call per household between rural and urban areas. Similarly, Fisher (1992) argued that telephony is primarily used to maintain and strengthen existing face-to-face relationships rather than to form new human relationships. In other words, people use phones to consolidate existing relationships rather than to expand socialization. Sridhar and Sridhar (2003) also found that telecommuting contribute to centralization of cities and that communication technology could be a complement, not a substitute for face-to-face interaction.

One of the attracting factors of the city is the need for communication through face-to-face contact, and the development of communication, like

the substitutionists' argument, leads to a decrease in unit communication costs, but some factors of face-to-face demand cannot be replaced by telecommunication. Electronic communication electronic can only convey explicit knowledge or codified knowledge while tacit knowledge, which cannot be documented and formatted, can be conveyed only through face-to-face contact. Therefore, in the communication between individuals, judgment of reliability through attitude, attitude, expression and etc. is the important factor and at the same time, personal feeling and bond are also considered. Storper & Venables (2004) found that there were differences by occupations, according to the use of form and tacit knowledge and the work liquidity.

Substitution effects and complementary effects varies according to the personal attributes per se as well as the activities' properties that the individual participates. Andreev et al. (2010) reviewed more than a hundred literature to discover that substitution effect is prevalent in mandatory activities such as telecommuting and tele-working whereas complementarity being prevalent for teleshopping and tele-leisure. This was supposed to be originated from the intrinsic characteristics of shopping and leisure, shopping activities provides the consumers information and social motivation (Salomon and Koppelman, 1988) as well as recreational and psychological gratification (Tauber, 1972; Bellenger and Korgaonkar, 1980; Marmorstein et al., 1992; Cao et al., 2010). However, when shopping and leisure are participated separately, offline shopping as a pure information gathering purpose is not justified (Cao, 2012). It is also worth noting that work and shopping are not clearly distinguished in the individual's traveling pathway. Shopping trips are mostly chained with other out-of-home activities. Specifically, shopping is often not the only purpose

for consumers to egress, as Bhat (1996) found that about 18% of sample participated shopping activities on the way home from work. Jou and Mahmassani (1997) also found that about a third of commuters made at least one stop on the way home from work, and that nearly one-fifth of those stops were for shopping.

As seen in the several empirical studies, there still are considerable divergent opinions and controversies over the causes and processes in which substitutive and complementary effects are expressed, no theoretical and empirical consensus has been reached on its potential for substituting or generating additional travel (Kim et al., 2015). Moreover, most of these empirical studies were based on comprehensive data using secondary data. It is hence important to discover with individual's level how ICT technology has changed trip demand toward city for business and shopping purposes.

In sum, the relationship between the substitution and the complementarity discussed above is not a separated effect, having rather an interdependent relation than a unilateral direction (Weltevreden and Rietbergen, 2009). In other words, substitution effects and complementary effects are rarely found in unilateral direction, and rather found in various complex form according to their physical characteristics of geographical environment, socioeconomic conditions and the physical background of urban spatial structure prior to communication development (Lee et al., 2017; Rotem-Mindali and Weltevreden, 2013; Zhu, P et al., 2018).

D. Summary

The transition of online activity thanks to the development of information technology has resulted in substitutions in some classical business and non-business activities. Acceptance of such substitution in business may have a stronger impact on employer's decision than personal preference, because it is important to consider changes in organizational system and corporational productivity rather than a individual employee's decision in the introduction and application of tele-working and telecommuting. Since the productivity gained from tele-working and telecommuting are found in many empirical studies, it can be easily predicted that the occurrence of surplus labor resources due to the productivity improvements can create new opportunity costs.

On the other hand, personal preferences and tendencies are reflected variously in application of online substitution in non-business sector, especially shopping and leisure. In general, online shopping is preferred because of information acquisition, convenience, and speed, which notwithstanding necessarily requires the decline of offline shopping. Rather the occurrence of travel opportunity costs for offline shopping purposes, so is for leisure purposes.

Many studies have investigated the substitution and complementary effects witnessed by the terms of travel budget due to the introduction of ICT. However, as well as in relation with travel budget in time and expenses, the occurrence of surplus resources (for example, the occurrence of remaining time) due to the improvement of work productivity and the efficiency of shopping & leisure time is expected to be reinvested. In the next section, the effect of online substitution on total workload and shopping leisure time in this process will be explained via a simple mathematical model and an exemplary data.

III. Explanations for the substitution and complementary effect

A. A Mathematical Framework about Complementarity

1. Basic Assumption

Reviewing the related literatures found that the complementary and substitution effect appear to be interdependent concepts rather than confrontational or unilateral concepts. Therefore, a theoretical model was constructed explaining that the substitution effect of telecommunication technology is inter-connected with complementary effect. Given that the frequency of visiting city centers is related with the total amount of pulling factors in city (total demand for labor, shopping and etc), it is necessary to clarify how the total amount of the pulling factor would be increased even though the introduction of telecommunication substituted and decreased the necessity to visit city centers.

Let's assume a worker i who is needed to handle the workload of W_t and the length f working hours t_o to complete the amount of W_t. Then we can say that the worker's labor efficiency $\frac{W_t}{t_0}$ is maintained constant.

Assume a worker i who needs to complete the total workload of W_t and the time of t_o to process the total workload offline. In addition, the time

remaining t_r due to the substituted work when such an online activity as tele-working could replace a part of the workload. The rest of the workload except for the online workload W_n will be processed offline, and the remaining workload is defined as W_f, Therefore

$$W_0 = W_n + W_f \qquad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \quad (1)$$

On the other hand, there can be two ideal conditions necessary for the nature of telecommuting. The first condition is that the time spent on online business (messenger, e-mail, etc.) is infinitely small and converges to zero. That is,

$$t_n \rightarrow 0$$

The second condition is that a part of existing offline workload can be substituted as a result of introducing ‘online work’ (i.e., telecommuting).

Also, it is possible to define the work efficiency or working rate R of a worker, which is defined as the amount of workload completed per hour; for a given work W by t hours, R is

$$R = \frac{W}{t},$$

$$t_0 = t_f + t_r \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \quad (2)$$

Where t_r is regarded as time remaining or leisure due to online substitution effect. Worker i may use the t_r again for offline work (in this case, the worker exhausts a whole business hours, so $t_1 = t_0$) or for other leisure activities (in this case, the worker works only for hours which is not substituted, that is, offline work hours, so $t_1 = t_f$) depending on his or her volition and work conditions. Secondly, t_r is a concept reflecting business hours before online substitution. As online substitution effect increases thanks to the information technology development, the amount of t_r increases but is limited to existing business hours. Therefore, it can be defined as a value proportional to t_0. In other words,

$$t_r = \alpha t_0 \text{ , where } 0 \leqq \alpha \leqq 1 \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \quad (3)$$

Where α is a substitution constant; if substitution effect does not exist at all ($\alpha = 0$), t_r is zero. And t_r is equivalent to t_0 if online activity replaces offline activity completely($\alpha = 1$). In addition, the reduced working hours (t_f) due to the substitution effect is expressed as $t_f = t_0(1-\alpha)$. In other words, $t_f = 0$ when 'online activity' completely replaces offline($\alpha = 1$), and time for working offline is the same as existing business hours ($t_f = t_0$) if there is no online substitution effect($\alpha = 0$). Thus, the relationship between offline time t_f and remaining time t_r decreased by substitution effect is as follows,

$$\frac{t_r}{t_f} = \frac{\alpha t_0}{t_0(1-\alpha)} = \frac{\alpha}{1-\alpha} \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \quad (4)$$

On the other hand, the worker i completes the entire work W_0 with the reduced time of t_f (which was done before with the time of t_0) due to the introduction of the telecommuting technology. Also, the changed work efficiency can be defined to be R_1 and the work efficiency before the telecommuting introduction is referred to as R_0. The changed work efficiency R_1 can be defined as the change of the work load ($W_0 \rightarrow W_1$) during the same business hours (t_0) , then

$$R_0 = \frac{W_0}{t_0} \quad \rightarrow \quad R_1 = \frac{W_1}{t_0} \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \quad (5)$$

Where, R_1 is same as that of the existing work amount (W_0) processed for the reduced time ($t_0 \rightarrow t_1$).

$$R_0 = \frac{W_0}{t_0} \quad \rightarrow \quad R_1 = \frac{W_0}{t_1} \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \quad (5\text{-}1)$$

if the worker call it a day without re-using the time remaining (t_r), t_1 will be same as the working hours of 'offline' (t_f) , therefore :

$$R_1 = \frac{W_0}{t_1} = \frac{W_0}{t_f} = \frac{W_0}{t_0(1-\alpha)} \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \quad (5\text{-}2)$$

Since the substitution alpha has a value between zero and one ($0 \leqq \alpha \leqq 1$), the efficiency of work (R_1) increases by the rate of $\frac{1}{1-\alpha}$ as the substitution effects increases. Again, the increased workload for the same length of time (t_0) according to the change in working efficiency ($R_0 \rightarrow R_1$) can be calculated as :

$$W_1 = R_1 \times t_0 = \frac{W_0}{t_0(1-\alpha)} \times t_0 = \frac{W_0}{1-\alpha},$$

$$\therefore W_\Delta = W_1 - W_0 = \frac{W_0}{(1-\alpha)} - W_0 = W_0\left(\frac{\alpha}{1-\alpha}\right) \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \quad (6)$$

That is, if the worker come back to work and use the reduced time – the time earned by the substitution effect ($t_r = \alpha t_0$) - for work, he can process more workload with a proportion of $\frac{\alpha}{1-\alpha}$ compared to the workload before substitution. Since α is a value between zero and one ($0 \leqq \alpha \leqq 1$), $\frac{\alpha}{1-\alpha}$ will have a value between one and infinity($1 \leqq \frac{\alpha}{1-\alpha} \leqq \infty$), accordingly. As technology develops and telecommuting or tele-working increases resulting substitution increased, the total volume of workload increases at a faster pace than the substitution take places. Ideally, if one's 'online activity' completely

replaces ‘offline activity’ (substitution effect = 1), the increased total amount due to substitution can be reached infinity.

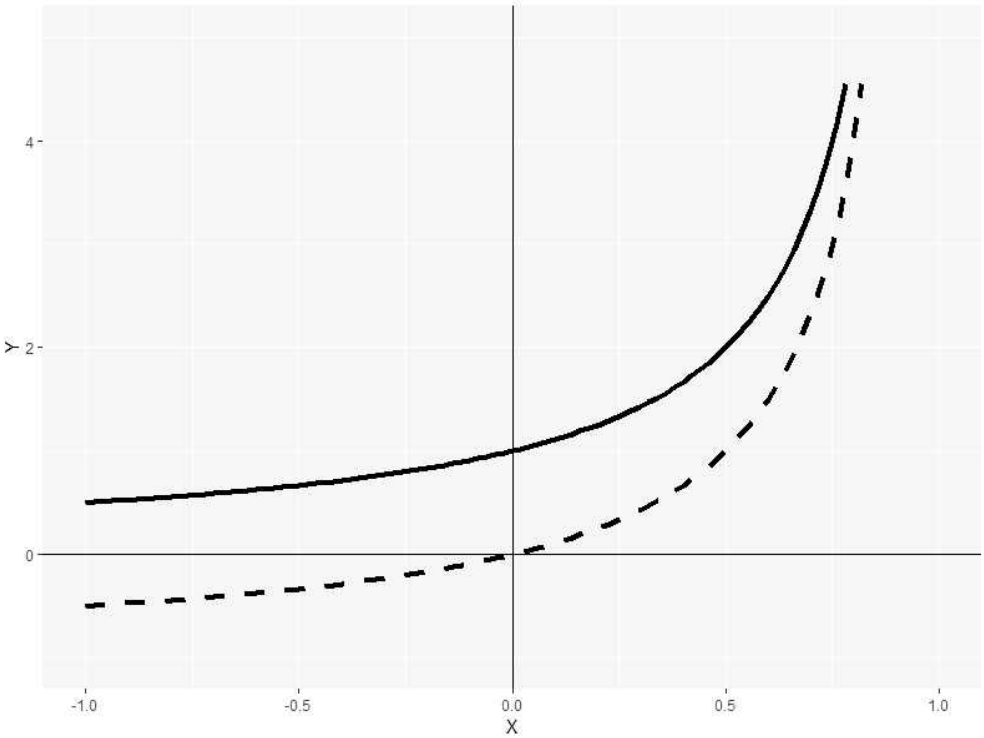

Figure 2. The projected curves of the total time after substitution effect ($W_1 = \frac{1}{1-\alpha} W_0$) and the incremental time changed (dashed, $W_\Delta = \frac{\alpha}{1-\alpha} W_0$)

2. Example Scenarios According to the Different Value of Substitution Effects

Now with the example scenario, it will be calculated how much the amplitude of substitution effect can increase the total amount of workload. Firstly, assuming that a part, say 20 percent, of workload can be completed via online, i.e., alpha is 20%, the necessary time t_0 to complete total amount of workload W_t has been decreased to $t_f = \frac{8}{10}t_0$. Consequently, this 20% of substitution effect and?

The existing working efficiency of the worker is the amount of workload per hour, and he completed the workload of W_t for t_0 hours; the efficiency is $\frac{W_0}{t_0}$. After substitution effect, he presumably should have better working efficiency of R_1 than R_0, with which he can complete more amount of workload W_1 with same length of time t_0: this is the same efficiency that he complete the existing amount of workload with the reduced time ($t_0 \rightarrow t_f$) according to the substitution effect.

$$\frac{W_1}{t_0} = \frac{W_0}{t_f} = \frac{W_0}{\frac{8}{10}t_0} = 1.25\frac{W_0}{t_0}$$

The increasing proportion of workload according to the substitution will be $\frac{1}{1-\alpha} = \frac{1}{1-0.2} = \frac{1}{0.8} = 1.25$, which means that the working efficiency increases by 25% and that the substitution effect helps the worker works

25% more with the same length of time. If substitution effect gets further increased thanks to technological development, so does the reduced working time; the workload after substitution will increase even more despite the time to work off-line is maintained.

Now, lets assume a worker who spends only a half of the time earned (i.e. substituted) into offline work and the other half on shopping or leisure. For instance, he earned two hours from substitution and spent only an hour to work offline again. The efficiency of offline work is the same as that of first example ($t_f = \frac{8}{10} t_0$). If the worker worked 10 hours a day before, then the 'offline' working efficiency is the same as he works for 8 hours to complete the workload of W_0. Therefore,

$$\frac{W_j}{t_0} = \frac{9}{10} \times \frac{W_0}{t_f} = \frac{9}{10} \times \frac{W_0}{\frac{8}{10} t_0} = 1.125 \frac{W_0}{t_0}$$

3. Summary

The proposed mathematical model explained only with the example of a worker. However, any shopper is also supposed to behave with such a mechanism as online-shopping's substitution leads to the increase of total shopping time. Still, there is a shortcoming that the model only able to work under the ideal conditions. It needs to be explained with an empirical study to examine process of substitution's leading the total amount's change. In the next chapter, using Time-Use Survey data published by KOSIS, how the substitution effect works leads to the change of total amount will be examined.

So far, the theoretical background and mechanism has been introduced about how a complementary effect is able to be led by the substitution effects according to the development of internet communication technology. In addition, it is necessary to examine how the telecommunication environment developed in Korea over the past decades has affected individual behavior in business and non - business.

B. Empirical Evidences From the Existing Survey Data

1. Overview of the Data in use

The process of the increased total amount effect described in the previous section was based only on mathematical assumptions. The mathematical explanation is only theoretical, thus different results may be shown considering the attributes of the occupation, sex, and age of actual individual. Therefore, in this section, whether the mathematical process shown in the previous section actually occurred is examined with dataset of the time spent in business and shopping.

Time-Use Survey is a designated statistics, published by the Korean Statistical Information Service for the purpose of understanding people's lifestyle and quality of life. It is a nationwide survey that randomly extracts 8,000 to 17,000 households according to the survey year and records the time-diary for two days (48 hours) of household members over 10 years of age living in these households. The diverse behaviors listed in the time log are classified into three stages: major, intermediate and minor. For example, the major category of "personal retention" includes four intermediate categories such as "Sleep," "Meals and snacks," "Personal care," and "Health care (medical)." At the same time, the subclass of "sleep" consists of two minor subclasses of "sleep" and "nap and drowsiness". In addition to the variables related to time use, the survey data also includes informations about people who were involved in each action, information of sampled households, information of the household members, and the location where each action

had been held.

The data of year 2004 and 2014 were used to analyze the relationship between telecommuting and non-telecommuting,[1] the relationship between online and offline shopping, and the use of Internet and leisure time. The time-diary data in use were extracted from the Time-Use Survey data for each 10-minute period from 0:00 to 23:50. The corresponding time log variables were collected and converted to continuous variables. Therefore, the time that an individual recorded a specific activity during a day had a value of at least 0 minutes and a maximum of 1440 minutes. However, if an activity had been done for zero minute, meaning that the activity was not done at all, which made it treated as a missing value for statistical purposes.

There were some limitations to use the Time Use Survey Data. First, there were data on shopping related activities that consumes time for online shopping through home shopping (via internet, tv, and teleshopping) or mobile shopping, but there was not any activity item that could measure online-business in business activity. Therefore, work related behaviors of 'work at home' were defined as ‘telecommuting’ using data of ‘home’ and ‘out of house’ from ‘place classification’ Activity as non-telecommuting. Likewise, since it was not easy to distinguish between online and offline leisure from the time-diary dataset, only shopping related time-diary data was used for non-business purpose category.

The reason for limiting the survey data to 2004 and 2014 is as follows.

1) the term of non-telecommuting is a defined term limited for this study and not an authorized term.

The year of 2004 was the time for the internet communication to be adopted diversely, not only in the professional field but also in the public domain after the introduction of high-speed broadband in Korea. Therefore it was the suitable time to estimate the online and offline relationship before the mobile Internet became popular. In addition, the year of 2014 is not only a year that a long enough time passed after the introduction of so-called ‘smartphone’, but also a moment immediately after the introduction of 4G mobile communication in Korea.[2)]

Table 1. Variable Setting, Time Worked

	2004	2014
Working Hours Outside Home	[M] Main Job / Side job *	[M] Hired Job / Self-Employed Job
	[C] Main Job / Side job **	[C] Hired Job / Self-Employed Job
Working Hours at Home	[M] Main Job / Side job	[M] Hired Job / Self-Employed Job
	[C] Main Job / Side job	[C] Hired Job / Self-Employed Job
Total Working Hours	Total hours worked last week (Main Job + Sidejob) → Total minutes per day	Total hours worked last week (Main Job + Sidejob) → Total minutes per day

[M] stands for Main Activtivity caterogy from time-diary data

[C] stands for Concurrent activity

Table 1 shows the categories of activity of the Time Use Survey data, classified by the year and the place performed at. The business-related activity of Time-Use Survey data were classified into two categories of main and concurrent activity. For the data of 2004, main and concurrent activities were collected in the name of ‘main job’ and ‘side job’ while the data of 2014

2) Long Term Evolution (LTE), which is called 4G mobile communication, was introduced in Korea in September 2013.

collected the activity of ‘employed’ and ‘self - employed’. Also, since in the data time-based actions and its locations were recorded, work activities could be classified into 'home work' and 'house work' according to the place and locations they performed, which could be the proxy variable for online and offline work.

The time-diary data was recorded from 0:00 to 23:50 with 10-minute’s time gap, in where only business-related data was filtered. The total time of the main and the concurrent activity was created as the work-related variables, and the travel time related to the task was not included. Besides, the variable that respondents recorded total hours worked in the past week were converted into average daily work hours and used as a variable of total workload.[3] In addition, as described in the previous section, if the total time is 0 minutes, it was regarded as not doing the act and treated as a missing value according to the statistical purpose.

Table 2. Variable Setting, Time for Shopping

	2004	2014
Offline Shopping	[Main] Shopping [Sub] Shopping	[Main] In-store Shopping [Sub] In-store Shopping [Main] Shopping-related activity [Sub] Shopping-related activity
Online Shopping	[Main] Teleshopping (Internet, TV) [Sub] Teleshopping (Internet, TV)	[Main] Online Shopping [Sub] Online Shopping

2004 and 2014 Time-Use Survey data asked online and offline shopping time-diary, which could be combined into separated shopping time. As a

3) For example, a worker who worked 40 hours a week worked on average 342.86 minutes a day (about 5.7 hours).

result, the sum of the main action and the concurrent action time were calculated for offline and online shopping behaviors as variables. Also, travel time related to shopping among time-diary data was not included.

In the case of 2014 data, there was a category of ‘other shopping related behavior’ which was not included in 2004 data. This category included behavioral categories such as a product’s trial operation, exchange, return, refund and gift collection. These behaviors were also related to shopping, so they are included in the ‘offline shopping’ category. Finally, if the summed time is 0 minutes, it was considered that the behavior is not performed, therefore treated as a missing value for the statistical purpose.

2. Descriptive Statistics

The descriptive statistics of the work-related time data for the years of 2004 and 2014 are shown in the Table 3. For the decade, the average time spent for ‘work at home’ had increased by two times (105.1 minutes → 210.1 minutes), and the number of people who ‘worked at home’ had increased by more than 2.5 times (4,203 → 10,699). Moreover the maximum value of the variable ‘work at home’ had increased by 230 minutes. However, non-telecommuting hours ‘worked outside home’ increased by only less than 1 minute (388.3 minutes → 389 minutes). It is notable that the time worked in total ‘Total hours worked’ decreased by 32 minutes (418 minutes → 386 minutes), though both the average time ‘worked at home’ and the average time ‘worked outside home’ increased. Histograms for both year are illustrated in Appendix I.

Table 3. Descriptive Statistics for Business-related variables

	Time Worked	N	Mean	ST. Dev	Min	Max
2004	Outside Home	25,000	388.3	175.0	10.0	1,020.0
	at Home	4,203	105.1	119.7	10.0	890.0
	in Total	35,026	418.0	149.5	8.6	1,285.7
2014	Outside Home	18,451	389.0	161.5	10.0	1,090.0
	at Home	10,699	210.1	176.9	10.0	1,120.0
	in Total	30,192	386.0	141.1	10.0	1,088.6

Unlike work-related variables, there was no data available in the Time Use Survey that could measure total hours for shopping. Therefore, it was possible to estimate changes over 10 years only with online shopping time and offline shopping time, as previously mentioned. In 2014, the number of online shoppers increased about three times compared to 2004, and average online shopping time also increased slightly. In the case of offline shopping, the number of people who participated in shopping increased more than five times, but the hours in average of offline shopping was slightly reduced. The descriptive statistics of the shopping time variables for 2004 and 2014 are shown in Table 4.

Table 4. Descriptive Statistics, Time for Shopping

	Variables	N	Mean	ST. Dev	Min	Max
2004	Offline Shopping	2313	52.23	40.53	10	430
	Online Shopping	360	46.11	32.79	10	230
2014	Offline Shopping	12472	49.27	37.85	10	390
	Online Shopping	1350	50.83	29.86	10	250

3. On-Offline Concurrency in time spent for work and shopping

The correlation analysis results for the time, income, and age are shown in Tables 5. In 2004, non-telecommuting time and income were positively correlated with total working time, while telecommuting time had a very low positive (+) correlation with it. In addition, there is a negative (-) correlation between telecommuting time (time worked at home) and non-telecommuting time (time worked outside home), which was a kind of concurrency problem. It is worth noting that the non-telecommuting time were positively correlated, while the telecommuting time and income were negatively correlated. In the case of 2014, the positive correlation between total working hours and in-home working hours was stronger than data in 2004. In addition, negative correlation between telecommuting time and non-telecommuting time also indicated strong concurrency.

Time for Online shopping and offline shopping time were positively related in both years, but the positive correlation of them was weak in the dataset of 2014 compared with 2004. There was a negative correlation between age and shopping; and the younger they were the more shopping they did. However, in 2004, younger people had more online shopping, and in 2014, they were more likely to shop offline than online shopping.

Correlation between income and the time for offline shopping varied according to the year. In 2004, income and the time for online shopping had only a weak positive correlation. On the other hand, they showed a weak negative correlation, while income and the time for offline shopping had

a weak positive correlation.

Unlike business behavior, shopping behaviors are generally seen to show differences between males and females. Therefore, a couple of T test was conducted in order to test the hypothesis that there will be differences in shopping time between men and women,

Table 5. Correlation Coefficients, between time worked, income and age

	Correlation Coeffecients (P-Value)	Time Worked			Monthly Income	Age
		In Total	Outside Home	at Home		
2004	Time Worked In Total	1				
	Time Worked Outside Home	0.278***	1			
	Time Worked at Home	-0.003	-0.306***	1		
	Monthly Income	0.180***	0.099***	-0.193***	1	
	Age	-0.063***	-0.152***	0.010	-0.075***	1
2014	Time Worked In Total	1				
	Time Worked Outside Home	0.317 ***	1			
	Time Worked at Home	0.187 ***	-0.586 ***	1		
	Monthly Income	0.273 ***	0.093 ***	-0.018 ***	1	
	Age	-0.050 ***	-0.080 ***	0.055 ***	0.101 ***	1

* p<0.1; ** p<0.05; *** p<0.01

Table 6. Correlation Coefficients, between shopping time, income and age

	Correlation Coeffecients (P-Value)	Time Spent for		Monthly Income	Age
		Offline Shopping	Online Shopping		
2004	Time Spent for Offline Shopping	1			
	Time Spent for Online Shopping	0.147***	1		
	Monthly Income	0.043***	0.043	1	
	Age	-0.026***	-0.057	-0.075***	1
2014	Time Spent for Offline Shopping	1			
	Time Spent for Online Shopping	0.116***	1		
	Monthly Income	0.002	-0.136***	1	
	Age	-0.096***	-0.111***	-0.101***	1

* p<0.1; ** p<0.05; *** p<0.01

As for the offline shopping time, women spent more in offline shopping time than men, significantly at both time of year. In 2004, women were using 4.3 minutes more than men and 4.14 minutes more in 2014. These results were all significant at 1% significance level, showing the general belief that women were investing more time in shopping. However, these gender differences were not significant for online shopping in 2004 and 2014. While males spent more time online shopping than females (a difference of 1,2 minutes in 2004 and 2.1 minutes in 2014), the differences were not significant

at the 10% significance level (t = 0.264, 1.03). In conclusion, gender effect was evident in offline shopping time, but there was no gender difference discovered in online shopping.

Table 7. Gender difference time spent for shopping, 2004 and 2014.

Test	Offiline Shopping 2004	Offiline Shopping 2014
Male	49.09	46.3
Female	53.37	50.43
Diff	4.27	4.13
T	2.25	5.47
P	0.012	0
Test	Online Shopping 2004	Online Shopping 2014
Male	47.05	52.55
Female	45.89	50.42
Diff	1.17	2.12
T	0.264	1.03
P	0.39	0.15

4. Result and Summaries

To summarize the results, in work-related variables, it was confirmed that the concurrency or substitution effect between telecommuting and non-telecommuting; as telecommuting hours (time worked at home) increased, non-telecommuting hours (time worked outside home) decreased. However, it also confirmed that a speculatively complementary relationship in which the total working hours increased as the telecommuting time increased. In the shopping-related variables, only the relationship between online shopping and offline shopping was examined because unfortunately the variable indicating total time for shopping was not available; as the online shopping time increases, the offline shopping time also increases. These tendencies were more evident in 2014, when mobile Internet and smart devices became more popular than in 2004.

However, there calls a limitation to compare the complementarity and substitution of online and offline activities using the Time-Use Survey data. First, though it was possible to distinguish between online and offline shopping time activity data in the Time-Use Survey, there was no data available on online activity for leisure. In addition, it was impossible to measure the amount of online activity only by the amount of time spent. Since the data used was sectional, it was also impossible to measure the time changed for the same individual. Moreover, as for the business purpose, since there was no suitable variable for the time spent on telecommuting, the case of ‘Worked at home’ was used as the proxy variable for telecommuting, although working on-line and telecommuting should be strictly separated matter.

IV. Substitution led to increase the Total Frequency of Visiting City Centers

A. Overview

The life time survey presented in the previous chapter confirmed that the total business hours and total shopping-leisure time had positive relationships with online business and online shopping time. In addition, the positive relationships became stronger in 2014 compared to 2004, when the mobile Internet environment became popular. However, even if the total amount effect is increased due to technological development and its popularization, it is not known whether there is an effect of complementary effect or substitution effect affecting travel demand toward downtown. In other words, there was no data that could confirm whether the relationship of the increase in time actually affected the actors' entry into the central region of city. Therefore, it was necessary to confirm whether the actual actor was utilizing the total amount or the total time to be spent in the city center. This chapter presents the result of the mobile survey conducted to analyze more specifically the relationship between the substitution effect and/or the complementary effect and the process how both effects emerged.

For a purpose of supplementing the results from Time-Use Survey data, an additional analysis was conducted on the effect of the communication's substitution on the frequency of visiting city centers for business and non-business purpose. As shown in literature review, traffic data in regional

level have been used so far to understand the effect of online introduction on urban spatial structure and traffic demand. However, in this study, a mobile questionnaire on individual respondent was conducted to understand how the path of substitutive and complementary effects at the individual level influenced the individual's travel demand toward city.

The data in use had been collected via a mobile survey which had been conducted for 5 days from September 4th to 8th, 2017. The questionnaire was distributed through Socal Network Services such as Facebook and Twitter, as well as the internet communities of Daum and Naver Café. Not only the completed questionnaire but also their descriptive statistics are shown in Appendix 1.

1. Questionnaire and Data Collection

An bias of respondents might have occurred inadvertently due to the methodological characteristic of the mobile and internet questionnaires, since majority of the respondents would be the users who are skillful to smart devices and computers. In other words, there was a possibility that the responses of groups[4] such as elderly people or disabled people who are not technologically savvy would be relatively less reflected. However, as described in the research question, the target group of the study was the technology-friendly (Tech-Savvy) class familiar with smartphone and internet use enough to

4) Hwang et al. (2012) suggested that individual socioeconomic factors could be a determinant of the communication competence, while Min (2010) regards the demographic factor of the individual as the first stage of digital divide.

demonstrate the effect of communication substitution. These respondents' bias therefore was not considered to be a problem.

Another issue of the mobile Internet survey was that it often shows low credentiality compared to the face-to-face survey, which might create another bias issue. In particular, survey data collected from anonymous identities on online may not show high reliability even if the size of the sample is sufficient. In general, there are two ways to improve this reliability issue: pairwise deletion of suspicious answers and listwise deletion of missing respondents. In this study, The answers of the doubtly irresponsible respondents were deleted listwisely, regarding the possibility of the respondents' error. As a result, 1,144 respondents, after excluding 200 out of a total of 1,300 respondents, are used in the analysis.

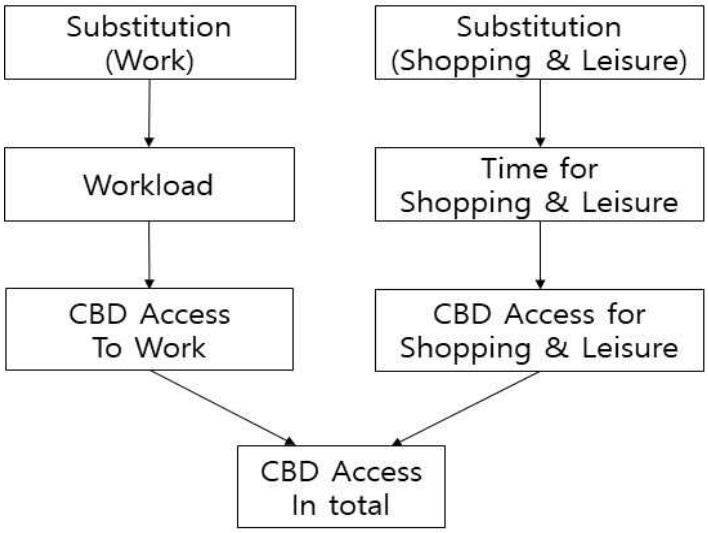

Figure 3. Assumed Relationships among the Dependent and Independent variables ('CBD Aeess' referes to the changes in frequency of visiting city centers)

2. Dependent and Independent Variables

Figure 3 illustrates the relationships of the dependent and independent variables. The most important keyword in the research question of this study is the dependent variable on the change of frequency of visiting city centers. There are three variables related to the change of downtown visits: change of frequency of visiting city centers for business purpose, change of frequency of visiting city centers for shopping and leisure purpose, and the variables of total change in frequency of visiting city centers, indicating aggregated change for both purposes.

The concept of downtown or city centers used in this analysis includes the concept of both central business district and commercial center simultaneously. Technically speaking, however, the concepts of city centers, downtown and central district are different. In addition, it was the right way to make separated questions about business-oriented areas for the business-related trips, and about commercial-center for non-business-related purposes. Nevertheless, the concrete and academic terms could be considered to be somewhat difficult for the general public to answer, and it might hence make them reluctant to participate the mobile questionnaires which required quick answers in a short time. Therefore, the concept of city center or downtown that can be intuitively perceived by the general public was questioned.

The emergence of complementarity, if existed, through the substitution of telecommunication was expected to have two different effects on the latent demand of a individual's travel. Assuming the extra time budget saved from

the communication was reintroduced into travel demand, the individual would have the opportunity to visit the city center more often or to head to the city from a further distance. However, to explain that the latent demand drew him to travel further, it was necessary to assume the region's monocentric structure and all pulling factors must occur only from the city center. Plus, there must have been a sufficient residential zone outskirt with reduced rent in proportion to the time budget, so that it had to be easy and free to get the opportunity of residential movement. Therefore, the latent traffic demand was assumed to impact on a change in the frequency of traffic and which was presumed to be perceived by the individual.

The variables of the total amount – of workload and of time spent for shopping and leisure- was measured by 7 point Likert scales, questioning how much the total amount of the workload or time changed after use of smart devices and internet communication for business and shopping leisure purposes; from 'decreased a lot' through 'no change' to 'increased a lot'. The variables of the frequency of visiting city centers also was measured by 7 Likert scales, asking how much the chance to travel toward city or downtown changed.[5)]

Another group of independent variable is the substitution effect of internet communication, which was measured by question how much the internet communication substituted the respondent's work, shopping and leisure activity. The substitution effect was composed of 5 point Likert scale, from

5) Since the Likert scale is a ordinal scale, there exitsts a risk of violating the basic assumptions of classic linearity (Knapp, 1990) The Likert scale used in this analysis is assumed to be linear, assuming that the distances between the intervals are equally distributed.

0% to 100%.

3. Control Variables

The control variables used in the analysis were added for the following purposes. Age, gender, income, and occupational data were put on the assumption that socio-economic attributes of an individual would affect tech savviness. Demographic factors of age and income are the primary factors influencing online shopping activity (McDonald, 1994; Lee et al., 2015) since online shoppers tend to be younger and have higher incomes (Soopramanien and Robertson, 2007; To et al., 2007; Burkolter and Kluge, 2011; Cao and Douma, 2012; Hashim et al., 2009; Lee et al., 2015). Regarding gender effect of technological savviness, there still are controversies. some (Hasan, 2010; Passyn et al., 2011) addressed that male rather than female customers tend to have more positive attitude towards online shopping, while other (Ren & Kwan, 2009; Sener and Reeder, 2012) found women are more frequent online shoppers than men. Even though no significant gender effect (Lian and Yen, 2014; Lee et al., 2015) were found for online shopping; men tend to have slightly more favorable opinions of online shopping than women, but were no more likely to shop online.

The frequency of visits to the city center by individuals was set as a separate variable, questioning how frequently the respondent travel to urban center or downtown. This was based on the assumption that there would be different frequency of downtown visits by individuals due to occupational

factors (Glenn, 2012) and behavior patterns. (One thing to note is that the dependent variables are not the frequency of downtown visits- how often does a respondent visit CBD, but the vicissitudes of the frequencies; how much the respondent's visit increased or decreased.)

With regard to using variables that are not continuous as control variables, there had been issues of conversion of the scale. In general, it was difficult to ask respondents and receive accurate answers from them how often they visited urban center. This was due to the high possibility that they might not accurately recognize movement of themselves; using an multiple choice question could get a rough estimate of the frequency of their visits to the city center. The question choice was listed as a 7-point Likert scale, from low frequency to high frequency. Though the answer from the multiple choice question could not be used as a continuous variable in the regression analysis, it could be assumed to be scaled with equal interval. [6] The similar issue arised when using individual income variable as a control variable. Generally, asking the income of a person was likely enough to get a false answer or no response because of privacy issue. Therefore, the income variable as a control variable was used by replacing the median value of each income category with the interval scale after obtaining as many answers as possible using a multiple choice question.

Along with the demographical characteristics of respondents, the location data of the respondents work and reside had been collected, under the

6) A Generalized Ordered Scale Method (GSM) must be adapted in the case that the ordered-scale variable is used for the dependent variable. However, GSM was not assumed for the analysis since the variables were input as control variables.

assumption that the location where the individual resides as well as her job-housing distance might have relationships with her physical and non-physical trips to work and shop. The location of respondent was therefore to test whether urban residents tend to have a higher online shopping likelihood. (Pérez-Hernández and Sánchez-Mangas, 2011; Sener and Reeder, 2012)

In addition to the personal attributes, subscription of the unlimited data plan was input as another control variable; the variables for individual tech savviness was collected, under the assumption that a person with more savviness might adopt new technology in his business, shopping, and leisure activity; more savviness assumed higher substitution effect. Monthly bill for mobile phone and the average monthly data usage of an individual were measured as proxy variables for measuring the degree of internet usage of the individual. On the other hand, Korean mobile internet service providers sell unlimited data plan to customers who use large amount of data per month. So, a user uses more than 10Gb data per month, whose bill presumably will not exceed 100,000 won.

Finally, history of the smartphone how many years the respondent had been used smart devices was collected. This was according to an assumption that a person who is the more familiar with the recent technologies, i.e. who is tech-savvy, would have been using his smart device for the longer period. Table 8 shows all variable collected and in use.

Table 8. Type and configurations of the variables in Use.

Variable	Type of Variable
Change in Workload	7 Point Likert
Substitution in Business	5 Point Likert
Changes in Frequency of Visiting City Centers for Business Purpose	7 Point Likert
Substitution in Non-business	5 Point Likert
Change in Time for Shopping & Leisure	7 Point Likert
Changes in Frequency of Visiting City Centers for Shopping and Leisure Purpose	7 Point Likert
Existing Frequency of Visiting City Centers	Ordered
Total Frequency of Visiting City Centers	7 Point Likert
Job-Housing Distance	Continuous
Age	Continuous
Monthly Mobile Bill	Continuous
Monthyl Mobile Data	Continuous
Gender	Categorical
Unlimited Data Plan	Categorical
Smartphone History	Ordered
Monthly Income	Continuous (transformed from Categorical)
Occupation	Categoreical

4. Filtering Respondents' Irresponsibility

The selection and filtering of irresponsible respondents were conducted according to the following criteria. First, respondents who did not enter their residence and work address were excluded. In addition, respondents who answered inappropriately to the questions (monthly mobile bill, monthly mobile data usage, and age) were also excluded for the problem of reliability. Finally, the respondent reliability was judged based on the question response related to the visit to city centers, which was a 7-point Likert scale item. The respondents who bluntly marked all questions for the downtown visit for business purpose and the shopping for leisure purpose as 'Highly Increased' were excluded, so were the 'Highly Decreased' cases.

B. Descriptive Statistics

The variables used in the analysis and the order of the question items are shown in the table 8, and the descriptive statistics for the main variables such as the changes in frequency of visiting city centers, changes in total amount of workload, and time for shopping & leisure are shown in Table 9 & 10. The basic descriptive statistics for other control variables are presented in the Appendix II - Mobile Survey.

A majority of respondents reported that less than 50% of the substitution effect occurred in business, while more than half of the respondents reported that the substitution effect in shopping & leisure was more than 50%. In addition, respondents who replied that they had a lot of job substitution effects had a greater effect of substituting shopping leisure, which suggested that individual smart device utilization was affecting both work and shopping leisure.

The variables of total amount, workload and time, and the variables for changes in the frequency of visiting city centers locate their mean value between ‘no change’ and ‘slightly increased’. hen ‘decreased a lot’ is coded as −3, ‘no change’ as zero, and ‘increased a lot’ as +3, the mean value five variables of total amount and the frequency of visiting city centers is larger than zero and less than one. Consequentively, the popularized internet communication and smart devices had people to adopt themselves in business and non-business sectors, resultedly increased increased frequency of visiting city centers as well as the total amount of workload and the time for shopping & leisure.

Table 9. Descriptive Statistics, frequency in visiting city centers and total amount variables

		Deacreased a lot	Decreased	Slightly Decreased	Not Changed	Slightly Increased	Increased	Increased a lot	Total
Change in Workload	Freq.	7	44	158	356	266	207	106	1,144
	%	0.61	3.85	13.81	31.12	23.25	18.09	9.27	100
Change in Time for Shopping & Leisure	Freq.	35	101	179	149	259	277	144	1,144
	%	3.06	8.83	15.65	13.02	22.64	24.21	12.59	100
Changes in Freq. of Visiting City Centers for Business Purpose	Freq.	25	64	112	587	162	120	74	1,144
	%	2.19	5.59	9.79	51.31	14.16	10.49	6.47	100
Changes in Freq. of Visiting City Centers for Shopping & Leisure	Freq.	85	128	151	251	203	184	142	1,144
	%	7.43	11.19	13.2	21.94	17.74	16.08	12.41	100
Total Changes in Freq. of Visiting City Centers	Freq.	28	65	120	511	160	145	115	1,144
	%	2.45	5.68	10.49	44.67	13.99	12.67	10.05	100

Table 10 . Descriptive Statistics, frequency in visiting city centers and total amount variables

Variable	Obs	Mean	Std. Dev.	Min	Max
Total Changes in Freq. of Visiting City Centers	1,144	.403	1.394	-3	3
Changes in Freq. of Visiting City Centers for Business Purpose	1,144	.270	1.261	-3	3
Changes in Workload	1,144	.639	1.315	-3	3
Changes in Freq. of Visiting City Centers for Shopping & Leisure	1,144	.293	1.762	-3	3
Changes in Time for Shopping & Leisure	1,144	.663	1.635	-3	3

In addition to the descriptive statistics, correlations between the selected variables had to be done to examine linear relationships between the major variables. (Positive correlations were found in all pairs, with the highest correlated pairs of ‘total changes in frequency of visiting city centers’ and ‘changes in frequency of visiting city centers for shopping & leisure’ (0.77), followed by the pair of ‘total frequency of visiting city centers’ and ‘frequency of visiting city centers for work’ (0.72). The correlation of travel frequency variable between business and non-business purpose was also high (0.63), confirming the simultaneous relationship between each objective.

The coefficient between the total amount effect and frequency of visiting city centers by each purpose was not sufficiently high. However, since positive correlations were found in all variables, it was necessary to grasp the relationship between the individual variables under controlled condition using the control variables. Especially, in case of changes in frequency of visiting city centers, although there was a high correlation between visiting changes, it was necessary to control the difference between the people with high frequency of visits and those with low frequency.

However, since the multiple regression analysis assumes a single dependent variable, it was not possible to examine the effect of frequency of visiting city centers for each purpose to total frequency of visiting city centers. In other words, as the substitution effect increases, followed by the increased total amount effect, and thus the process of the travel frequency per purpose should have been examined. In the next chapter, the sequential effect of key variables through two-stage model and path analysis will be investigated.

C. A stepwise confirmation of the substitution led to complementarity

According to the basic assumption of multivariate regression analysis, *Ceteris Paribus,* the impact from substitution effect of internet communications on city visit can be found only when having same workload or shopping time. However, as seen in the theoretical model, the substitution effect of communication strongly leads to a change in the total amount rather than a direct effect on the chance to visit downtown. Therefore, it was necessary to conduct an additional analysis on the chain effect of ‘total amount increased by substitution effect on downtown visit’.

2-Stage Least Square analysis (2SLS) was conducted to confirm the chain effect: when there is suspicion of endogeneity among the explanatory variables in a regression model, 2SLS can be used by conducting regression analysis between explanatory variables step by step to eliminate it. That is, assuming that the following regression equation exists,

$$\widehat{Y_2} = \beta_0 + \beta_1 Y_1 + \beta_2 X$$

and assuming that there be an endogenity found between Y_1 and X, estimates from the first-step regression equation $\widehat{Y_1} = \beta_{10} + \beta_{11} X$ is obtained and the estimates from the second-step regression equation $\widehat{Y_2} = \beta_{20} + \beta_{21} \widehat{Y_1}$ can be obtained to eliminate the endogeneity. In this study, not only the method of performing the multiple regression analysis step-by-step, but also the method

of performing the 2SLS analysis command provided in the statistical package are presented. [7] The reason that both the step-by-step method and the method provided by the statistical package is because, in the case of using the general multiple regression analysis, the standard error reported under the null hypothesis assuming exogeneity among explanatory variables cannot be used, and because the *t*-distribution that generally used for ordinary least square is not appropriate.

IVREGRESS command provided in STATA assumes an asymptotic distribution of given variable and conducts significance test with z-test, in which, with same regression coefficients, more rigorous significance test can be performed than the multiple regression analysis using the t distribution assuming a normal distribution. For the purpose of comparison, the result of 2SLS as well as the result of step-by-step OLS is presented in the result tables. According to the process explained above, the results of analysis will be presented as follows:

Model 1 (OLS): A multivariate regression, with the estimation equation as follows :

$$Y_2 = \beta_0 + \beta_1 Y_1 + \beta_2 X_1 + \beta_n X_n$$

Model 2(1SLS): The first stage of 2SLS - An endogeneity equation between independent variables which is estimated by multivariate regression, with the estimation equation of :

7) STATA 15.1 was in use, along with ivregress command and 2sls option. R 3.5.3 was also in use for the purpose of crosschecking.

$$Y_1 = \beta_{10} + \beta_{11}X_1 + \beta_{1n}X_n$$

Model3(2SLS): The second stage of 2SLS – A multivariate regression between dependent variable and instrumental variable, with the estimation equation of :

$$Y_2 = \beta_{20} + \beta_{21}\widehat{Y_1} + \beta_{2n}X_n$$

Model 4 (IVREGRESS-2SLS): Similar model with the Model 3 above but with asymtotic distribution. The estimation equation is same with the model 3.

Since the two-stage least-squares method assumes the endogeneity between the explanatory variables, it is necessary to test whether the endogeneity actually exists before conducting the analysis. Since there is a suspicion of endogenous generation between explanatory variables of the substitution and the total amount for workload and time for shopping & leisure, pre-estimation tests should have been done with correlation analysis of given variables as well as F-test of the first-stage of least square (i.e. Model 2), to determine the adequacy of endogenous diagnosis. In addition, post-estimation using Hausman test was performed to judge whether the 2SLS analysis results were more appropriate than the OLS results.

1. Pre-Estimation

For the preparation step for the 2SLS analysis, it was necessary to confirm whether an explanatory variable was appropriate for the instrumental variable. The appropriateness of instrumental variable can be tested by checking correlation between the endogeneous variable and explanatory variables, or by finding *t* value higher than 3.3 [8] from the first stage of least square regression. (Min & Choi, 2015) Therefore, as per each purpose of business and shopping & leisure, the variables of substitution effect, total amount effect and frequency of visiting city centers change were tested if they were appropriate for instrumental variables.

As a result of the correlation analysis of the variables that correspond to the business purpose (Table 11), the variable of total amount effect rather than the substitution effect showed higher correlation with the dependent variable - the change in frequency of visiting city centers; that is, suitable for an instrumental variable. In the first stage of 2SLS, the *t*-value of the corresponding variable was 12.14 and the *F*-value of the estimation model was 18.19, rejecting the null hypothesis of the weak instrumental variable and satisfying the condition for an instrumental variable of 2SLS analysis.

8) or *F*-value larger than 10

Table 11. Correlation Coeffecients between Business-Purpose variables (N=1,144)

Correlation Coeffecients (P-Value)	Changes in Freq. of Visiting City Centers	Change in Workload	Substitition (Work)
Changes in Freq. of Visiting City Centers	1		
Change in Workload	0.3088***	1	
Substitition(Work)	0.2829***	0.3436***	1

* p<0.1; ** p<0.05; *** p<0.01

In addition, as a result of the correlation analysis (Table 12) of the variables corresponding to the non-business purpose, the total change in time for shopping and leisure showed higher correlation with the dependent variable of the change in frequency of visiting city centers. In addition, the corresponding variable in the first stage regression showed *t*-value with 7.23, which could be regarded satisfying the pre-condition for use.

Table 12. Correlation Coeffecients between Shopping & Leisure variables, (N=1,144)

Correlation Coeffecients (P-Value)	Changes in Freq. of Visiting City Centers	Change in Time	Substitition (Shopping & Leisure)
Changes in Freq. of Visiting City Centers	1		
Change in Time	0.4287***	1	
Substitition (Shopping & Leisure)	0.2153***	0.2293***	1

* p<0.1; ** p<0.05; *** p<0.01

2. Visiting City centers for Business Purpose

Table 13 shows the results of the two-stage least-squares analysis (2SLS) for the variables of business purpose. Model 1 is a multivariate regression model that did not consider endogeneity. Model 2 is a multivariate regression model with the independent variables of substitution (X) and the dependent variable of change in workload (Y_1), which was the first stage of 2SLS. Model 3 is the second stage of two-stage regression, in which the estimator ($\widehat{Y_1}$) of the workload changes obtained from Model 2 was set for the independent variable and CBD access for the dependent variable. Model 4 is the estimation result of 2SLS model using 2SLS option of IVREGRESS command provided by STATA, which shows the same coefficient but stronger significance test result.

As a result of 2SLS, the increment of substitution with one-unit change (25%) led to a 0.73-unit increase of frequency of visiting city centers with the increase of 0.44 unit of the total workload, and the result was significant at 1% significance level. It should be taken into account that the workload variable and variable of the frequency of visiting city centers were composed of a 7-point Likert scale and should be understood as a relative indicator rather than an absolute unit.

Compared to the result of multivariate regression (Model 1), the magnitude of coefficient showed higher value stage by stage. VIF (between 1.08 to 1.58) value to test multi-collinearity was satisfactory.

Table 13. Estimation result of 2SLS estimation and comparison with multivariate regression, for Business Purpose ('CBD Aeess' referes to the changes in frequency of visiting city centers)

Model	(1) OLS	(2) OLS ($Y_1 \sim X$)	(3) OLS ($Y_2 \sim Y_1$)	(4) 2SLS
Dependent Variable	(Y_2) CBD Access for Business	(Y_1) Change in Workload	(Y_2) CBD Access for Business	(Y_2) CBD Access for Business
Change in Workload (Y_1)	0.221			0.726
	(0.00)***			(0.00)***
Estimated Change in Workload ($\hat{Y}_1$)			0.726	
			(0.00)***	
Substitution (Work)(X)	0.220	0.436		
	(0.00)***	(0.00)***		
Frequecy of CBD Access	0.185	0.030	0.170	0.170
	(0.00)***	(0.30)	(0.00)***	(0.00)***
Gender (Female=0)	-0.065	0.146	-0.138	-0.138
	(0.38)	(0.06)*	(0.07)*	(0.10)*
Age	0.003	-0.009	0.008	0.008
	(0.52)	(0.11)	(0.15)	(0.19)
Monthly Income	0.000	0.000	0.000	0.000
	(0.26)	(0.58)	(0.17)	(0.21)
Job (Whitecollar =1)	0.033	0.206	-0.071	-0.071
	(0.64)	(0.01)***	(0.33)	(0.37)
Job-Housing Distance	0.001	0.000	0.001	0.001
	(0.47)	(0.84)	(0.55)	(0.58)
Monthly bill	0.000	0.000	0.000	0.000
	(0.70)	(0.38)	(0.40)	(0.45)
Monthly Data Use	-0.008	0.010	-0.013	-0.013
	(0.33)	(0.27)	(0.13)	(0.17)
Unlimited Plan (Yes=1)	0.104	0.105	0.050	0.050
	(0.22)	(0.24)	(0.56)	(0.60)
Constant	-1.151	-0.028	-1.136	-1.136
	(0.00)***	(0.92)	(0.00)***	(0.00)***
R2	0.17	0.14	0.12	.
R2_Adj	0.16	0.13	0.12	.
N	1,144	1,144	1,144	1,144

* p<0.1; ** p<0.05; *** p<0.01

Generally, 2SLS analysis needs a series of post-estimation steps, to check if the instrumental variable in use are appropriate; Endogeneity test, weak instrumental variable (IV) test and correlation test between IV and error terms. Endogeneity test is conducted with Durbin test and Hausman test, under the null hypothesis of "the variables are all exogeneous". (Durbin, 1954 ; Wu 1974 ; Hausman 1978) Weak IV test, under the nll hypothesis of "the instrument variable has weak relationship wth the proposed endogeneous variable", checks if the IV has enough correlationship with endogeneous variable on the first stage analysis. (Wooldridge, 1995) Correlation between IV and error terms tests to check if the estimated results are more suitable than the one from ordinary multivariate regression. (Min & Choi, 2015) The Haussmann-test compares the estimated coefficients from both 2SLS and OLS and tests their covariance via χ^2 test with a null hypothesis assuming no endogeneity with which the difference between two coefficients is not systematic. (Hausman 1978)

Regarding the endogeneity test, the Durbin $\chi^2(1)$ was 36.76 ($p<0.000$) and Wu-Hausman F(1, 1,131) was 37.55, both rejecting the null hypothesis. The weak IV test with minimum eigenvalue statistics with F(1, 1132) was 147.40 ($p<0.000$), also rejected the null hypothesis of weak instrumental variable. According to the Haussmann-test, $\chi^2 = 130.64$, $P > \chi^2 = 0.00$, which rejected the null hypothesis of non-endogeneity (Table 14). Consequently, two stage least square rather than multivariate ordinary least square regression was supposed to be appropriate.

Table 14. Test result of Endogeneity, for Business Purpose
('CBD Aeess' referes to the changes in frequency of visiting city centers)

	Coefficients			
	(b) IV	(B) OLS	(b-B) Difference	S.E
Workload	0.726	0.221	0.505	0.830
CBD Access	0.170	0.185	-0.015	0.015
Gender	-0.138	-0.065	-0.073	0.040
Age	0.008	0.003	0.004	0.003
Monthly Income	-0.000	-0.000	-0.000	0.000
White-collar Dummy	-0.071	0.033	-0.104	0.039
JH Distance	0.001	0.001	-0.000	0.000
Monthly Bill	0.000	0.000	0.000	0.000
Monthly Data	-0.013	-0.008	-0.005	0.004
Unlimit. Plan Dummy	0.050	0.104	-0.053	0.045
Constant	-1.136	-1.151	0.014	0.139

H0 : Difference in Coefficients not systematic

$\chi^2(10) = 130.64$
$P>\chi^2 = 0.00$

3. Visiting City centers for Shopping & Leisure Purpose

Table 15 shows the results of a two stage least squares regression analysis, conducted for shopping and leisure purposes. the two-stage least-squares analysis for non-business purpose. Model 1 is a multivariate regression model that does not consider endogeneity. Model 2 is a multivariate regression model with the independent variables of substitution effect (X) and the dependent variable of change in time for shopping & leisure (Y_1) , which is the first stage of 2SLS. Model 3 is the second stage of two-stage regression, in which the estimator ($\widehat{Y_1}$) of the change in time for shopping & leisure obtained from Model 2 was set for the independent variable and frequency of visiting city centers for the dependent variable. Model 4 is the estimation result of 2SLS model using 2SLS option of IVREGRESS command provided by STATA, which shows the same coefficient but stronger significance test result.

The increment of online substitution in shopping and leisure with one -unit(25%) led to a 0.4 unit increase of the time for shopping and leisure as well as a 1.06 unit increase of frequency of visiting city centers. Compared to the dataset fo business purpose, the impact from the total amount change to frequency of visiting city centers was higher than from the substitution effect to the total amount of change. Adjusted R^2 value was lower (0.06) than that of the business purpose data (0.12). Multi-collinearity was not detected, since VIF varied from 1.08 to 1.65. Significant Hetero-scedacities from the Model 2 and Model 3 were discovered, presumably because of the characteristics of Likert scale.

Table 15. Estimation result of 2SLS estimation and comparison with multivariate regression, for Shopping & Leisure Purpose ('CBD Aeess' referes to the changes in frequency of visiting city centers)

Model	(1) OLS	(2) OLS ($Y_1 \sim X$)	(3) OLS ($Y_2 \sim Y_1$)	(4) 2SLS
Dependent Variable	(Y_2) CBD Access	(Y_1) Change in Time	(Y_2) CBD Access	(Y_2) CBD Access
Change in Time (Y_1)	0.424			1.056
	(0.00)***			(0.00)***
Estimated Change in Time ($\widehat{Y_1}$)			1.056	
			(0.00)***	
Substitution Effect (X)	0.249	0.394	1.056	
	(0.00)***	(0.00)***	(0.00)***	
Frequecy of Visiting City Centers	0.170	0.042	0.144	0.144
	(0.00)***	(0.26)	(0.00)***	(0.00)***
Gender (Female=0)	-0.005	-0.147	0.087	0.087
	(0.96)	(0.15)	(0.44)	(0.47)
Age	0.012	0.004	0.010	0.010
	(0.07)*	(0.59)	(0.18)	(0.22)
Monthly Income	0.000	0.000	0.000	0.000
	(0.93)	(0.31)	(0.61)	(0.64)
Occupation (White-collar =1)	0.134	0.170	0.027	0.027
	(0.16)	(0.08)*	(0.80)	(0.82)
Job-Housing Distance	-0.001	-0.001	0.000	0.000
	(0.58)	(0.60)	(0.84)	(0.86)
Monthly Bill	0.000	0.000	0.000	0.000
	(0.77)	(0.66)	(0.60)	(0.63)
Monthly Data Use	0.010	0.017	-0.001	-0.001
	(0.41)	(0.15)	(0.92)	(0.93)
Unlimited Data Plan (Yes=1)	-0.175	0.039	-0.200	-0.200
	(0.12)	(0.73)	(0.11)	(0.14)
Constant	-1.931	-0.547	-1.585	-1.585
	(0.00)***	(0.17)	(0.00)***	(0.00)***
R2	0.22	0.06	0.07	.
R2_Adj	0.21	0.05	0.06	.
N	1,144	1,144	1,144	1,144

* p<0.1; ** p<0.05; *** p<0.01

Table 16. Test result of Endogeneity, for Shopping & Leisure Purpose ('CBD Aeess' referes to the changes in frequency of visiting city centers)

	Coefficients			
	(b) IV	(B) OLS	(b-B) Difference	S.E
Time Change in Shopping Leisure	1.056	0.424	0.632	0.158
Freq. CBD Access	0.144	0.170	-0.026	0.024
Gender	0.087	-0.005	0.929	0.070
Age	0.010	0.012	-0.002	0.004
Monthly Income	0.000	-0.000	0.000	0.000
White-collar Dummy	0.027	0.134	-0.108	0.064
JH Distance	-0.000	-0.001	0.000	0.001
Monthly Bill	0.000	0.000	0.000	0.000
Monthly Data	-0.001	0.010	-0.011	0.008
Unlimit. Data Plan	-0.200	-0.175	-0.025	0.072
Constant				
Test : H0 : Difference in Coefficients not systematic Chi2(10) = 22.27 P>chi2=0.00				

Regarding the endogeneity test, the Durbin's $\chi^2(1)$ was 20.25 (p<0.000) and Wu-Hausman's F(1, 1,131) is 20.38, both rejecting the null hypothesis. The weak IV test with minimum eigenvalue statistics with F(1, 1132) is 52.589 (p<0.000), also rejected the null hypothesis of weak instrumental variable. Haussmann-test (Table 19) showed χ^2 value of 22.27 (p <0.000), which rejects the null hypothesis of non-systematic difference in between coefficients. In conclusion, estimation with 2SLS was more suitable than ordinary multivariate regression model.

D. The Process of Change in Total Frequency of Visiting City Centers

The result of 2SLS analysis confirmed that the greater the substitution effect, the greater the total amount of work and shopping leisure time, and consequently the frequency of visiting city centers also increased. However, there is no evidence of a reduction in trips to city due to the substitution effect; in other words, it can be understood that the trips to downtown occurs with 2 step-basis due to the increase in the total amount as well as due to the total amount driven by increased substitution effect. If it was a natural consequence that increased total amount draws out increased number of trips to downtown, it was necessary to clarify the paradoxical relationship between "increase in the total amount due to the substitution between online and offline".

Therefore, in order to clarify the paradoxical relation, the path model analysis was additionally conducted on the relationships among the substitution effect, the total amount increase effect, and the variables of the frequency of visiting city centers.

1. Model Configuration and Estimation

Path 1 of the model was the subset which assumes 4 directional influences from substitution variables to total amount variables; work substitution to workload, work substitution to time for shopping & leisure, shopping & leisure

substitution to workload, and shopping & leisure substitution to time for shopping & leisure.

Path 2 added an assumption of correlation between the variables of substitution. The correlation assumeed that an individual who used more internet communication experienced more online substitution effect, both in business and in shopping & leisure. According to Lee et al. (2015), online shoppers tended to have a more favorable perception of technology.

Path 3 added an assumption of correlation between the variables of total amount. If one's time worked had decreased for whose substitution effect of tele-working, his time remaining (i.e. t_r) could be reinvested either to work more amount of workload or to enjoy himself for shopping & leisure. Therefore, a substitution effect derived from telework could increase not only the total amount of workload but also the total length of time for shopping & leisure. A substitution effect from online shopping & leisure could be assumed to behave same way, under the similar condition.

Path 4 added correlation hypothesis between the variables of frequency of visiting city centers of each purpose, assuming simultaneity of both variables.

Path 5 added a couple of additional recurring path, assuming an inter-causality between the variables of CBD access. If one's chance to access toward city had been increased due to his increased workload, his increased number of trips toward city centers also was supposed to increase the frequency of visiting city centers for shopping & leisure purpose, and vice versa. The paths consequently create non-recurring path models, necessarily accompanied

by the correlation between both variables of frequency of visiting city centers (as created from Path 4). This was according to the hypothesis that shopping trips were mostly chained with other activities and often not the only purpose for consumers to egress (Bhat, 1996; Jou & Mahmassani, 1997).

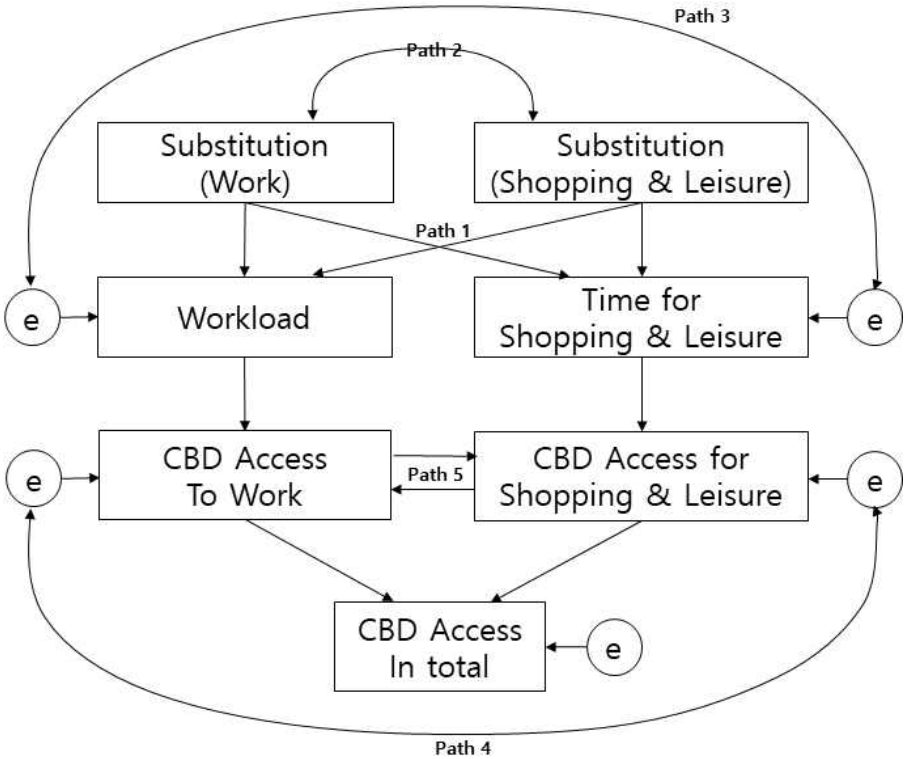

Figure 4. Assumed Settings for each Path Model Fit
('CBD Aeess' referes to the changes in frequency of visiting city centers)

As a result of the path analysis, significant positive coefficients were found in all paths except for a few intercepts. In other words, even though the total amount of change as a parameter was taken into consideration, the effect of substitution effect for business purpose and non-business purpose had significant effect on downtown visit through total amount effect.

Based on the assumption of Path 1, the correlation between the 'substitution' variables according to each purpose, it was confirmed that the online substitution effect was related to the individual's Internet utilization and familiarity to information technologies. In path 2 and 3, a cross-effect was possibly confirmed that putting the remaining time (or resources) from the business hours and re-investing them in the shopping leisure time.

The inter-causality between the variables of visit frequency of path 4 and 5 shows that the changes in trips for business purpose affects the increase of the trips for shopping & leisure purpose and vice versa. However, the negative correlation in Path 4 was interpreted to be due to the negative simultaneity between the downtown visit for business purposes for non-business purposes, with which visiting city centers had to be done within a limited time. The estimated results of the path model (unstandardized) are shown in Table 17. [9)]

9) The analysis was conducted with STATA 15.1 with its built-in SEM command. R 3.5.3 was also in use for the purpose of crosschecking and calculation of fit statistics that STATA doesn't support.

Table 17. Estimated result of the model (unstandardized)

('CBD Aeess' referes to the changes in frequency of visiting city centers)

PATH (←)		Coef.	P-value	Beta
Change in Total Workload	Work_substitution	0.383	(0.00)***	0.298
	Shop & Leisure Substitution	0.178	(0.00)***	0.122
	Constant	-0.314	(0.00)***	-0.239
Change in Total Time for Shop & Leisure	Work_substitution	0.205	(0.00)***	0.128
	Shop & Leisure Substitution	0.328	(0.00)***	0.181
	Constant	-0.389	(0.00)***	-0.238
Change in CBD Access for Business Purpose	Change in Total Workload	0.118	(0.00)***	0.123
	Change in CBD Access for Shop & Leisure	0.454	(0.00)***	0.634
	Constant	0.062	(0.05)*	0.049
Change in CBD Access for Shop & Leisure	Change in Time for Shop & Leisure	0.231	(0.00)***	0.214
	Change in CBD Access for Business Purpose	0.93	(0.00)***	0.666
	Constant	-0.112	(0.01)**	-0.063
Total Change in CBD Access	Change in CBD Access for Business Purpose	0.443	(0.00)***	0.400
	Change in CBD Access for Shop & Leisure	0.408	(0.00)***	0.515
	Constant	0.164	(0.00)***	0.118
/	mean(work_substitution)	1.406	(0.00)***	1.374
	mean(ls_substitution)	2.329	(0.00)***	2.577
	var(e.work_load_)	1.503	(0.00)***	0.869
	var(e.ls_time)	2.494	(0.00)***	0.933
	var(e.work_visitchange)	0.937	(0.00)***	0.589
	var(e.total_visitchange)	0.611	(0.00)***	0.315
	var(e.ls_visitchange)	1.736	(0.00)***	0.560
	var(work_substitution)	1.047	(0.00)***	1.000
	var(ls_substitution)	0.817	(0.00)***	1.000
	cov(e.work_load,e.ls_time)	0.686	(0.00)***	0.355
	cov(e.work_visitchange,e.ls_visitchange)	-0.924	(0.00)***	-0.725
	cov(work_substitution,ls_substitution)	0.345	(0.00)***	0.373
N				1,144

* p<0.1; ** p<0.05; *** p<0.01

2. Post-estimation of the Model

The models was run on the basis of Maximum Likelihood as well as and Asymtotic Distribution Free (ADF) options. To confirm the fit of a model, it is common way to check the Chi Square value. The calculated Chi Square value[10] in this analysis was quite large, both in the default Maximum Likelyhood model and ADF model, which might reject the basic null hypothesis of "the model fully explains the relationship among variables". ($p < 0.001$). Moreover, a modified ChiSquare value also showed only marginal value to test the goodness of model fit. [11] However, since the Chi square value often tends to increase sensitively in proportion to the sample size, the larger the size of the sample, the greater the probability of rejecting the null hypothesis. Therefore, the fitness of the model had to be evaluated by considering other fitness indices. (Browne & Cudeck, 1993)

Unlike Chi-Square value that sensitively fluctuate according to sample size, Root Mean Square Error of Approximation (RMSEA) and Tucker-Lewis index (TLI)[12] are vastly used, for their insensitiveness to sample size, consideration of parsimonity of model, and clear standard of interpretation. The RMSEA avoids issues of sample size by analyzing the discrepancy between the hypothesized model, with optimally chosen parameter estimates, and the population covariance matrix. (Hu & Bentler, 1999) The RMSEA ranges from 0 to 1, with smaller values indicating better model fit. A value of 0.06

10) 71.189 for ML and 64.480 for ADF estimation.
11) the model has a degree of freedom of 14, the modified Chi-Square value would be 5.18 for ML and 4.606 for ADF.
12) TLI is also called Non-Normed Fit Index (NNFI)

or lower is indicative of acceptable model fit: lower than 0.08 for fair fit, lower than 0.10 for not bad, and higher than 0.1 for non-acceptable. For the path model in use, the calculated RMSEA value indicated 0.083 under maximum likelihood assumption and 0.079 under the assumption of asymtotic distribution free, which wer both acceptable value for model fit.

Another index to find the goodness of fit is the Tucker-Lewis index (TLI) of baseline comparison index.[13] TLI ranges from 0 to 1 with a larger value than 0.95 indicating better fit of the model. The calculated TLI value indicated 0.94 under maximum likelihood assumption which marginally failed the standard of acceptance. Another criterion for evaluating the fit of the entire model is the Goodness of Fit Index(GFI). GFI is a measure of fit between the hypothesized model and the observed covariance matrix. The GFI ranges between 0 and 1, with a value of over 0.9 generally indicating acceptable model fit. The calculated GFI for the model was 0.983, satisfying the standard.

To evaluate the fitness of the model, the modified Chi-Square, RMSEA and TLI were marginally located on the scarce threshold of standard, while GFI fully satisfied. Regarding the fitness of the path model, it was necessary to examine various problems that the model possibly have. First, considering the fact that the main variable consists of the Likert scale, the heteroscedasticity could be presumable to be the main cause of the low fitness of the model. The heteroscedasticity problem can generally be solved by estimating the robust model, by adding the 'Robust' option to the maximum likelihood method estimation of the path model. The result from the robust option, however,

13) While the Comparative fit index(CFI) is also used for the baseline comparison, it is excluded from the goodness of fit table due to the problem of parsimonity.

was opted out in that both model fit statistics and coefficients for each path didn't show any differences from those of the base maximum likelihood.

Secondly, the normality issue of the data. Contrast to regression models with single dependent variable, in path model where a variable is able to take in place of both endogeneous variable and exogeneous variable, a variable without normal distribution may harm the fitness of model. The normality issue can be solved by adopting maximum likelihood option after transforming the variable into the one with normal distribution, or by adopting Asymptotic Distribution Free (ADF) option which does not have to assume normal distribution. Asymptotic Distribution Free method is also called Weighted Least Squares (WLS), with which assigns weights to each sampling group and modifies the maximum likelihood according to the weight matrix. The ADF method is often used to estimate parameters with orderd scale or test models without a normal distribution assumption on variables, both in covariance structure analysis and in correlation structure analysis. The result of fit statistics estimated with ADF is presented with ML in Table 19, indicating that ML still performed better.

Generally, it is known that re-sampling method such as Bootstraping and Jackknife is efficient to abate the RMSEA value. However, since the given data had a large enough size of sample with more than a thousand and also had strong heteroscedasticity rather to show counter-effect, the re-sampling method was not suitable for use in this case.

Since the path model includes a non-recursive subset that assumes inter-direction between the changes in downtown visit for both purpose, the

stability index (Fox, 1980; Bentler and Freeman, 1983) had to be calculated. The calculated index was 0.6498 and considered to be stable, since a model with a stability index between −1 and +1 was considered to be stable.

The Squared Multiple Correlation (SMC, Table 18) is the communality[14] estimate for variables in use, which was measured by the percent of variance in a given variable explained by its factor and might be interpreted as the reliability of the indicator. A variable with low theoretic importance and a low communality may be targeted for removal in the model-modification. It is generally known that fitness of structure model can be improved by eliminating variables showing lower SMC value than 0.4. Notwithstanding four variable of work substitution (0.23), shopping & leisure substitution (0.18), change in workload(0.26) and change in time for shopping and leisure(0.28) showed lower SMC value, they were not removed from the model because of the variables' significance and of the fitness of the model that still remained marginal even if the variables were included.

Table 18. Squared Multiple Correlations of variables in use

Variable	SMC	95% CI	
Total Change in Frequency of Visiting City Centers	0.6897	0.6623	0.7111
Change in Frequency of Visiting City Centers for Business Purpose	0.5510	0.514	0.5803
Change in Total Workload	0.2562	0.2117	0.2933
Work_substitution	0.2333	0.1894	0.2701
Change in Frequency of Visiting City Centers for Shop & Leisure	0.6211	0.5886	0.6466
Change in Total Time for Shop & Leisure	0.2806	0.2358	0.3178
Shop & Leisure Substitution	0.1801	0.1385	0.2153

14) The communality is equal to the squared standardized regression weight and sometimes defined as the squared factor loadings

Table 19. Fit statistics for the Path Model

Fit statistic	Default Model	ADF	Description
Likelihood ratio			
chi2_ms(8)	71.189	64.480	model vs. saturated
p > chi2	0.000	0.000	
chi2_bs(20)	2652.108	759.007	baseline vs. saturated
p > chi2	0.000	0.000	
Population error			
RMSEA	0.083	0.079	Root mean squared error of approximation
90% CI, lower bound	0.066	0.061	
upper bound	0.101	0.097	
pclose	0.001	0.004	Probability RMSEA <= 0.05
Information criteria			
AIC	24,182.31		Akaike's information criterion
BIC	24,318.46		Bayesian information criterion
Baseline comparison			
CFI	0.976	0.924	Comparative fit index
TLI (NNFI)	0.94	0.809	Tucker-Lewis index
Size of residuals			
SRMR	0.064	0.069	Standardized root mean squared residual
CD	0.717	0.789	Coefficient of determination
Goodness of Fit Indices			
GFI	0.983	0.982	Goodness of Fit Index
AGFI	0.941	0.936	Adjusted GFI

Table 20 indicates the direct, indirect and total effects of the model, while Figure 5 illustrates the standardized model to show the relative magnitude of paths' coefficients. Overall, it could be confirmed that the biggest change in the change of the visit frequency to city was not the business purpose but the shopping & leisure. For business purposes, it could be found that the coefficient of the path of the substitution effect on the workload was greater than the coefficient of the path of the workload on the frequency of visiting city centers. On the other hand, in shopping leisure, the effect in increase of shopping leisure on frequency of visiting city centers was greater than the effect of substitute effect on total time of shopping & leisure. In other words, the path from the substitution effect to the total amount effect was greater than the work leisure (0.18), but the relative size of the path from the gross effect to the frequency of visiting city centers was reversed. This could be inferred to be due to the fact that the path from the substitute job to the shopping leisure time was relatively more powerful than the return from shopping leisure to work.

When direct, indirect and total effects were taken into consideration, the total effect of business purpose (1.423) showed stronger impact on total change of frequency of visiting city centers than that of shopping & leisure (1.054) does. The total effect from the trips toward city centers for shopping & leisure purpose (0.786) to trips toward city centers for business purpose was stronger than from that of work-substitution effect (0.116) and from total change of work load (0.204). Similarly, the effect of frequency of visiting city centers from shopping & leisure purpose to business purpose (0.165) was larger than the substitution effect of shopping & leisure (0.165) and time increase in

shopping & leisure (0.400). This could be interpreted with two possiblities, according to the assumptions of path model. First, in terms of utilization of time after business hours, an individual visiting a city for business purpose put his time remaining into shopping or other leisure activities and vice versa. Second, in terms of mobility, people who had already been engaged in off-line business activity in urban areas tended to enjoy shopping and leisure in the vicinity of city center he already located.

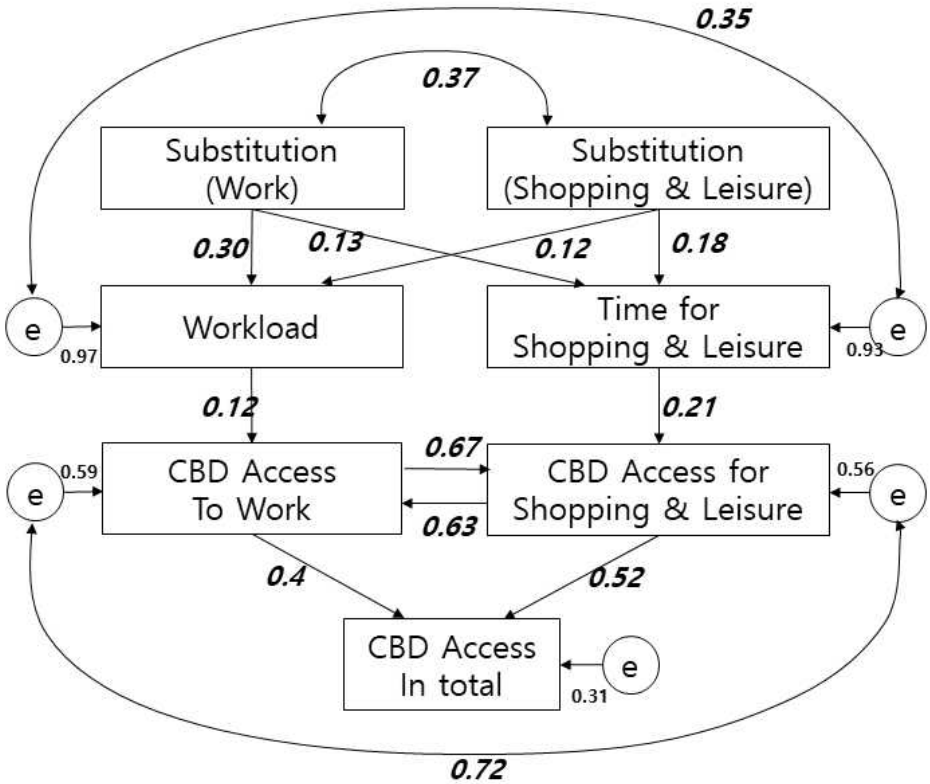

Figure 5. Standardized Model with Beta Coefficients
('CBD Aeess' referes to the changes in frequency of visiting city centers)

Table 20. Direct, indirect and total effect of the variables
('CBD Aeess' referes to the changes in frequency of visiting city centers)

Dependent(←)	Independent	Direct	Indirect	Total
Total Change in CBD Access	Change in CBD Access for Business Purpose	0.443	0.980	1.423
	Change in Total Workload	-	0.168	0.168
	Work_substitution	-	0.114	0.114
	Change in CBD Access for Shop & Leisure	0.408	0.646	1.054
	Time for Shop & Leisure	-	0.243	0.243
	Shop & Leisure Substitution	-	0.110	0.110
Change in CBD Access for Business Purpose	Change in CBD Access for Business Purpose	-	0.731 *	0.731
	Change in Total Workload	0.118	0.086	0.204
	Work_substitution	-	0.116	0.116
	Change in CBD Access for Shop & Leisure	0.454	0.332	0.786
	Time for Shop & Leisure	-	0.182	0.182
	Shop & Leisure Substitution	-	0.096	0.096
Change in Total Workload	Work_substitution	0.383	-	0.383
	Shop & Leisure Substitution	0.178	-	0.178
Change in CBD Access for Shop & Leisure	Change in CBD Access for Business Purpose	0.930	0.680	1.610
	Change in Total Workload	-	0.190	0.190
	Work_substitution	-	0.155	0.155
	Change in CBD Access for Shop & Leisure	-	0.731 *	0.731
	Time for Shop & Leisure	0.231	0.169	0.400
	Shop & Leisure Substitution	-	0.165	0.165
Time for Shop & Leisure	Work_substitution	0.205	-	0.205
	Shop & Leisure Substitution	0.328	-	0.328

* indirect effect generated by the non-recursive paths

3. Results and Findings

The path model so far confirmed the increase in the amount of work and shopping leisure time brought by the increase of online activity and its substitution from individual's business, shopping, and leisure behavior. The result confirmed a chain effect in the process of increasing visits to the downtown area. This chain effect was similar to the one found in the 2SLS analysis of previous section.

In addition to the chain effect, it was confirmed that the total amount of workload, as well as the total length time for shopping and leisure increased due to substitution effect from business, and a cross-effect also occurred in which the total work amount increased due to shopping & leisure. In addition, it could be concluded that the change in trips to city centers for business purposes and the changes in trips to city centers for shopping and leisure purposes had both simultaneous relationship and the inter-complementary relationship. The inter-complementary relationship is that, as the number of chances toward the city for business purpose increases, the frequency of visiting city centers for non-business purpose also increased and the opposite relationship was established. Simultaneous relationship occurred when the number of trips to the city for business purposes increased due to spatio-temporal constraints, resulting the decreased number of trips to the city for non-business purposes and vice versa.

Though the reason for the increase in the overall trips toward city was obviously the business-related behavior, trips to city for non-business purposes

could be considered as another major factors leading to the increase in total visits. Finally, it could be concluded that the density of city visits to the downtown area will cause ‘increase rather than decrease' due to the business and non-business substitution effects caused by internet communication.

V. Conclusion

A. Summary and Findings

This study analyzed the relationship between complementary and substitutive effects on the frequency of visiting city centers for the purpose of business and non-business according to the development of internet and mobile communication. A simple mathematical model explained that the surplus resources created by substitution effect of telecommunication would contribute to the increase of total amount of workload or total length of time for shopping and leisure. The procedure that substitutions due to telecommunications increasing totality was proved by the simultaneous relationship between telecommuting and non-telecommuting time using data of the National Time Use Survey, and also was confirmed that the complementary relationship in which the total working time increased as the telecommuting time increased. In the case of shopping, it was confirmed that the increase of the online shopping time had a complementary effect by increasing the offline shopping time.

The chain effect from the substitution effect to complementary effect was more evident in the results of the analysis conducted with mobile survey data. The result of the 2SLS analysis confirmed that the substitution effect of Internet and mobile communication was in the path which contributed to the increase of the total amount of workload and the total time of shopping and leisure, and which led to the increased frequency of visiting city centers

for both purpose of business and non-business. Also, it was confirmed that the increase of the total amount played a mediating role in increasing frequency of visiting city centers, and the tendency is confirmed to be stronger not only in business trips but also in non-business trips.

B. Discussion and Implications

Former researches mostly focused on substitution effect *per se* of communication and its influence to travel demand, illuminating the opposing relationship between substitution and complementarity, or contributing their focus on the choice probability of telecommuting according to the development of telecommunication technology. This study, however, found whether the substitution effect of telecommunication replaced the existing functions of cities rather than increasing the demand for telecommuting, considering the physical environment of Korea which does not generate urban sprawl seemingly because of the insufficiently long commute distance and the environment where mobile internet and broadband is considerably active. The study is also significant in focusing the procedure itself that frequent use of mobile and Internet at the individual level has a complementary impact on the increasing frequency of visits to the city centers.

By concentrating on the "total effect", which corresponds to the pulling factor of the city, it could be confirmed that the substitution effect and complementary effect do not operate within separated mechanisms, but rather are correlated. In addition, the mediating role of total effect is important,

constituting the core of the complementary effect presented empirically in former researches.

Since the metropolitan area of Seoul has a poly-centric structure, unlike american metropolis, it is necessary to grasp the effect of the substitution effect or the complementary effect on the potential travel demand more closely. The mono-centric structure theoretically assumed is easy to understand the influence of the traffic demand due to the substitution effect. However, not only there exists a sense of deviation between the concept of the city centers that general public perceive and the notion that planners do, but also the prediction of where the travel demand influenced by the substitution and/or complementarity will lead in the polycentric structure may be a comprehend problem beyond the theoretical assumption.

In fact, the controversy over complementarity and substitution is a question of whether tele-working or telecommuting can perform as the complete substitute for offline face-to-face contact. Indeed, most of the activities that affect the vibrancy of a city come from the intimate face-to-face contacts between the acting individuals, and communication methods nowadays that require trust within and outside the workplace are still the face-to-face contact. Although advances in technology may replace some classic modes of communication, complete replacement of the travel with telecommunication is also unlike to expect without the possibility of complete replacement of close contact.

On the other hand, the fact that the substitution effect has been led into a complementary effect may only be the current trend. It still needs to be

seen if the complementary effect will continue to occur and that it will continue to be a force to support travel toward city. As technology develops faster and so-called smart city paradigm popularizes, there still remains a possibility that the predictions of futurists will be realized.

C. Limitation of Study

Undoubtedly, there are limitations in the analysis of Time Use Survey data only with shopping time. If there were additional data available for shopping such as the amount of purchase or frequency of transactions, a more accurate analysis would be possible. Even though the time for online shopping and that of offline shopping have increased together, the purchase amount through offline shopping cannot be supposed to be increased as the purchase amount via online shopping increases, under the limited condition of disposable income.

As mentioned in Chapter 3, there is a limitation in distinguishing between online and offline work only with business hours and work places. In particular, since face-to-face contact is important in offline business, and it would be better if the frequency of face-to-face communication could be measured.

In Chapter 4, it needed more rationale on why individuals' increased online substitution impacted frequency of visiting city centers. In this study, though the path analysis and the two-stage least square analysis were conducted to identify the process of complementarity, there still remains an empirical question as to ‘why people have been able to go to the city even though

their work and shopping could have been substituted'. In addition, it is very unsatisfactory that the individuals' attributes such as income, age, sex, and occupation in the survey data did not significantly perform as control variables. In particular, the research showed a critical limit in that the results of age and gender effects revealed from the literature review were not significant.

Additionally, theoretical limitations of research in consideration were the latent travel demand for complementary effects. From the questionnaire of Chapter 4 of this study, while the empirical results of complementarity were discovered as of the increased frequency of visiting city centers for business and non-business purpose, whether the respondents with more complementarity were getting more distances in the city center was not discovered. As indicated in the questionnaire design in Chapter 4, the increased distance toward the city centers rather than the increase or decrease of the frequency of visiting city centers were not the subject of this study. However, considering the regional condition and individual attributes and the polycentric structure of the Metropolitan Region of Seoul, further researches on the change in travel distance toward city centers are expected to be necessary.

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국문 초록

통신 기술이 도심방문 빈도에 미치는 보완효과 및 대체효과

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도시 및 지역계획 전공

정보통신 기술의 발달은 사회, 문화, 경제, 고용, 노동 등 기술 외적인 측면에 있어서 다양한 변화를 가져올 것으로 예상된다. 최근 스마트폰 및 모바일 인터넷 보급으로 인한 개인의 이동 통신 사용이 급증하였으며, 도심에서 이루어지던 업무 및 비업무 분야에서의 활동은 재택근무나 온라인 쇼핑 등을 이용하여 온라인으로 대체되는 양상을 보이고 있다. 이에, 본 연구는 스마트폰과 인터넷 등 이른바 통신기술의 발달이 개인의 도심 방문에 영향을 미치는 보완효과와 대체효과의 발현과정을 살펴보고 현재 한국적 맥락에서 위 두 효과가 어떻게 작동하고 있는지 파악하는 것을 목적으로 한다.

선행연구를 토대로, 본 연구에서는 통신기술이 도심 방문에 미치는 영향을 대체효과과 보완효과로 분류하였다. 먼저, 통신기술의 대체효과는 업무 분야에서 재택근무 및 원격근무를 활용하거나 온라인 쇼핑 및 온라인 여가를 이용함에 따라 업무, 쇼핑, 여가 목적의 도심 방문빈도가 감소하는 것으로 정의하였다. 반면, 통신기술의 보완효과는 온라인 업무, 온라인 쇼핑 및 여가의 도입 이후에도 업무, 쇼핑 및 여가목적의 도심 방문 빈도가 증가하는 것으로

정의하였다. 여러 선행연구를 살펴본 결과, 통신기술의 도입으로 인하여 도심 방문 빈도에 미치는 보완효과와 대체효과는 대립적이거나 일방적인 개념이 아닌 상호의존적인 개념임을 확인하였다. 이에, 통신기술 도입으로 발생하는 대체효과와 보완효과가 연쇄적으로 연결되어 있음을 설명하는 이론 모형을 구축하였다. 즉, 통신기술의 발전에 따라 온라인으로 업무, 쇼핑, 여가를 즐기는 것이 기존의 방식에 비하여 상대적으로 적은 시간비용이 소요됨에도 불구하고 오히려 업무량 및 쇼핑 여가 시간의 총량은 증가할 수 있음을 수학적 모형을 통하여 설명하였다. 또한, 통신기술에 의한 대체효과가 더욱 커질수록 이로 인한 총량의 증가량은 더욱 증가하는, 일련의 연쇄적 과정의 결과로서 보완효과가 발현됨을 설명하였다. 또한, 2004년과 2014년의 국민 생활시간조사 자료를 통해 이러한 총량 증가 현상이 실제로 발생하고 있는지 확인하였다. 생활시간 조사 자료에서는 재택근무 시간이 증가할수록 비재택 근무시간은 감소하는 대체성을 발견하였으나, 이와 더불어 재택근무시간이 증가할수록 총 근무시간이 증가하고 온라인 쇼핑 시간이 증가할수록 오프라인 쇼핑 시간이 증가하는 총량증가 효과를 확인하였다. 아울러 이러한 현상은 2004년에 비하여 스마트폰 및 모바일 인터넷이 대중화된 2014년에서 더욱 뚜렷함을 확인하였다.

대체효과의 발현에 따라 증가한 총량이 실제로 개인의 도심 방문의 빈도에도 영향을 미치고 있는지 파악하기 위하여 스마트폰 및 모바일 인터넷 이용자를 대상으로 한 설문조사를 실시하였다. 설문 조사 결과의 분석은 업무 목적 및 비업무 목적별로 대체효과에 따른 총량증가효과가 도심방문 빈도에 미치는 영향을 2단계 최소제곱 방법(2SLS)으로 분석하였으며, 서로 다른 목적의 도심 방문이 상호간에 미치는 영향과 전체 도심 방문 빈도의 변화에 미치는 영향을 경로모형을 통해 분석하였다. 분석의 결과는 다음과 같다. 첫째, 전술한 수학모형 및 국민생활시간조사에서 나타난 바와 같이, 업무와 비업무 목적에서 대체효과가 클 수록 총량효과 또한 증가하며 이에 따른 목적별 도심 방문의

빈도가 증가함을 확인하였다. 또한 대체효과에서 총량효과에 이르는 1단계 효과보다 총량효과에서 도심 방문 빈도 변화에 이르는 2단계 효과가 더욱 탄력적으로 반응함을 확인하였다. 셋째, 개인의 기술 친숙도 및 숙련도에 따라 업무 및 비업무상의 대체효과가 강하게 나타나는 상관성을 확인하였다. 넷째, 온라인 업무로 인하여 대체되고 남은 시간을 비업무 목적으로 사용하거나, 온라인 쇼핑 및 여가로 인하여 대체되고 남은 시간을 업무목적으로 사용함에 따라 업무 및 비업무 측면에서의 총량효과가 증가하는 목적간 상호 교차효과가 확인되었다. 다섯째, 이로 인하여 도심을 방문하는 목적이 다르더라도 업무 목적의 도심 방문이 비업무 목적의 도심 방문에 영향을 미치고 그 역도 성립하는 방문목적별 상호연관성을 확인하였다. 단, 서로 다른 목적간의 도심 방문 빈도는 함께 증가하지 않는 음(-)의 동시성 또한 확인하였다. 마지막으로, 대체효과에서 총량 변화를 거쳐 도심 방문 빈도에 이르는 영향이 단계별로 증가하는 연쇄효과를 확인하였다.

결론적으로, 정보통신 기술의 발달에 따른 1차적 단계에서의 대체효과는 존재하나, 이러한 대체효과가 직접적으로 도심 방문 빈도를 감소시키는 데 미치는 영향은 발견하지 못하였다. 오히려 도심 방문 목적의 상호 의존 관계 및 잠재적 통행수요의 발현으로 인하여 도심 방문의 빈도에 영향을 미친다고 볼 수 있다. 결국, 정보통신 기술 도입으로 인하여 발생한 대체효과가 업무 효율 및 쇼핑 여가시간의 활용 효율을 증가시킴으로써, 결과적으로 개인의 업무 및 비업무 목적의 도심 방문 빈도 증가에도 영향을 미치는 연쇄적인 과정을 파악하였다.

주요어 : 통신기술, 도심방문 빈도, 보완효과, 대체효과, 2SLS, 경로모형

학번: 2010-31242

Appendix I.

Figure 1. Histograms of Time Worked, by Locations, 2004

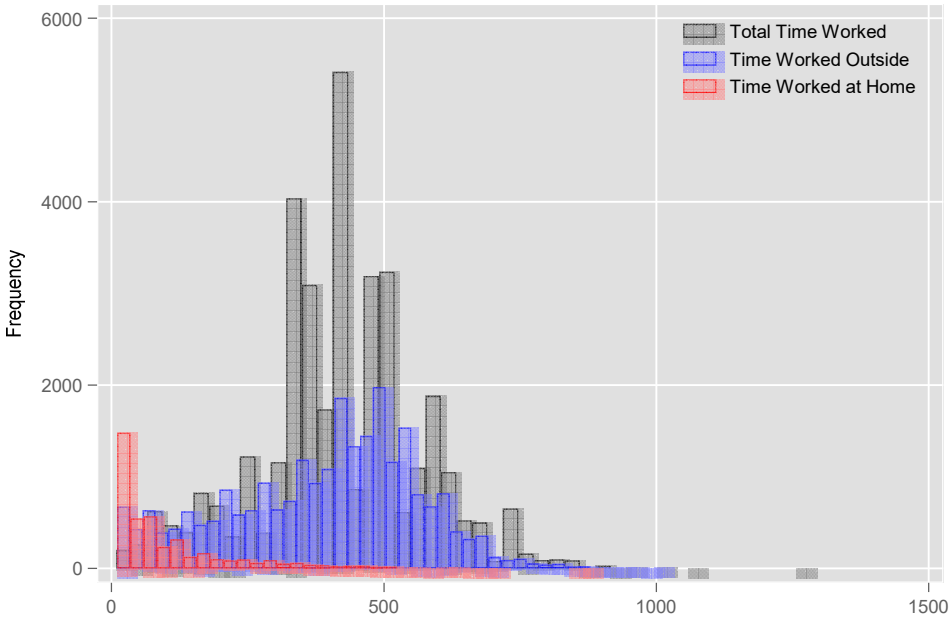


Figure 2. Histograms of Time Worked, by Locations, 2014

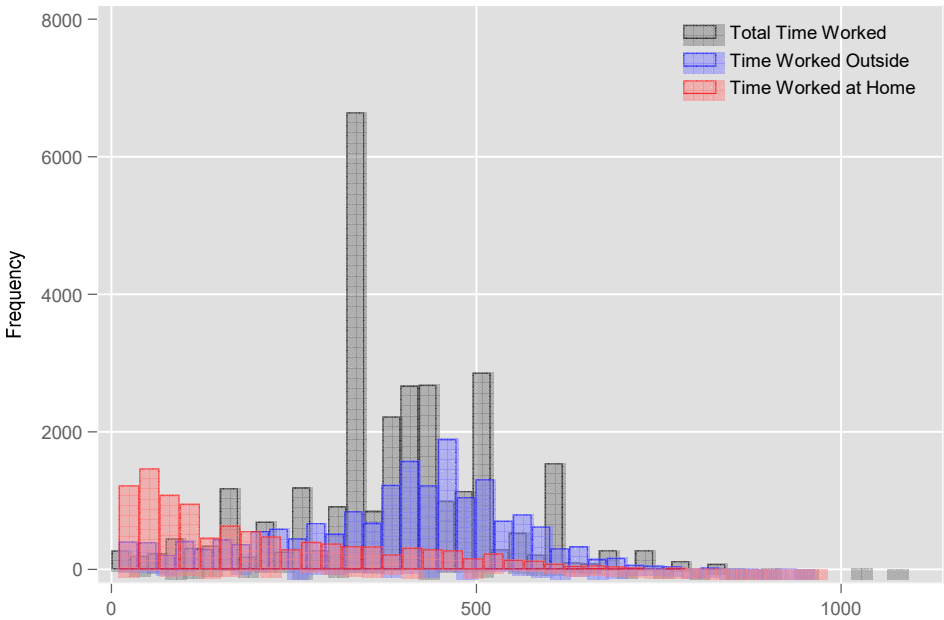


Figure 3. Relationships between the time worked at home versus outside, 2004

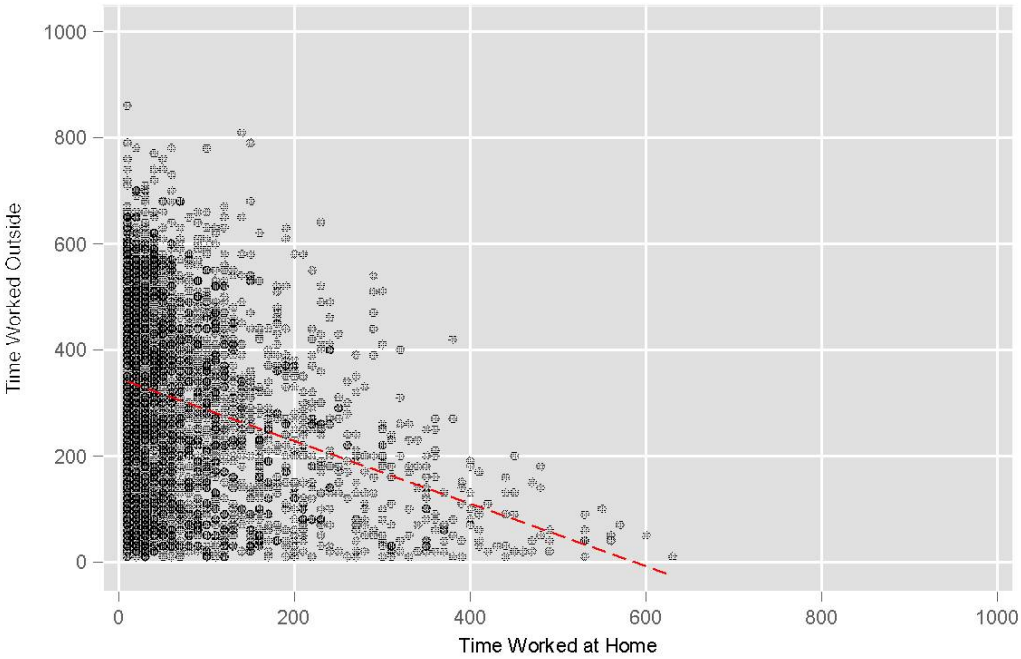


Figure 4. Relationships between the time worked at home versus Total time worked, 2004

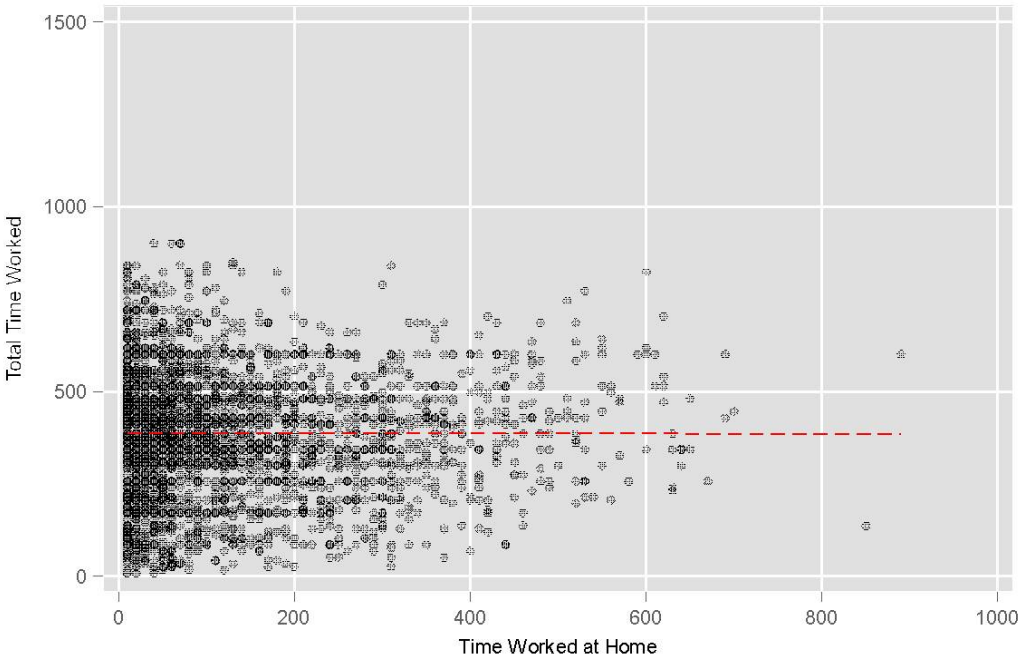


Figure 5. Relationships between the time worked at home versus outside, 2014

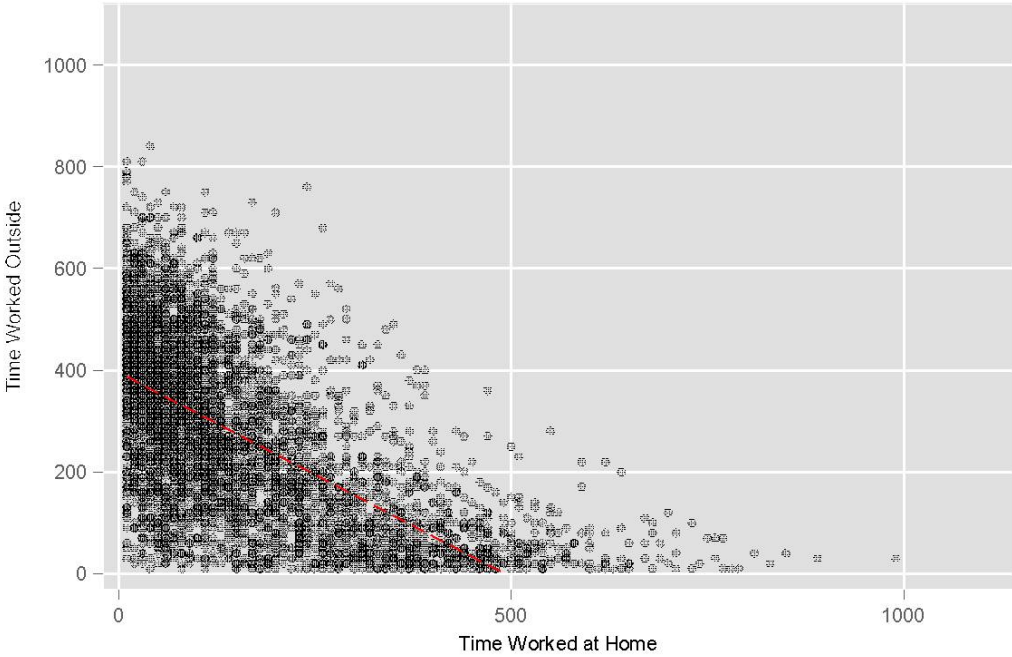


Figure 6. Relationships between the time worked at home versus Total time worked 2014

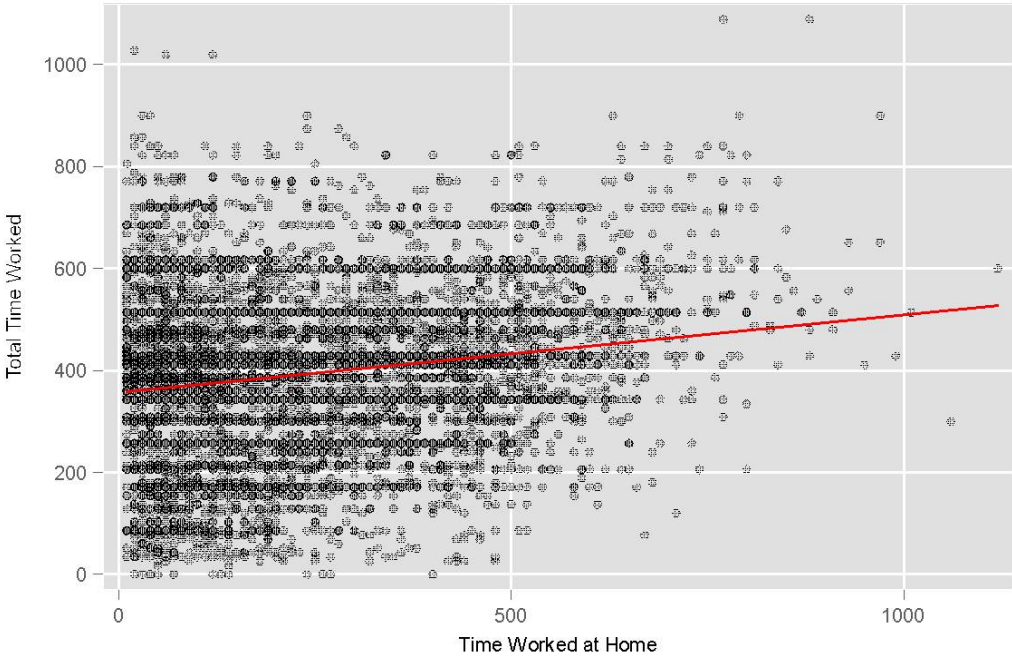


Figure 7. Histograms for Shopping Times, Online and Offline 2004

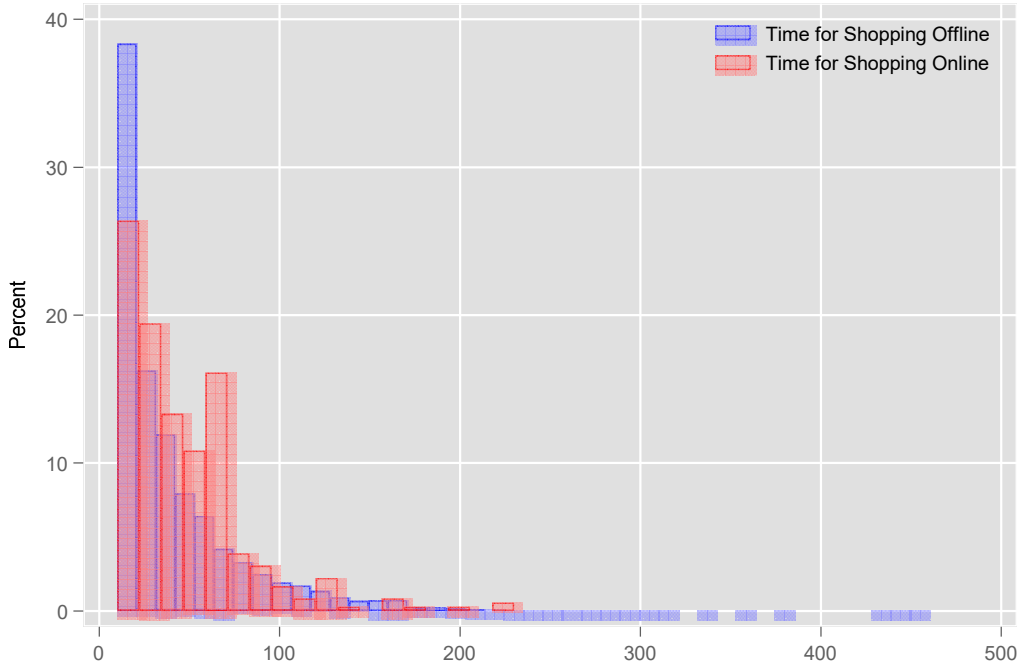


Figure 8. Histograms for Shopping Times, Online and Offline 2014

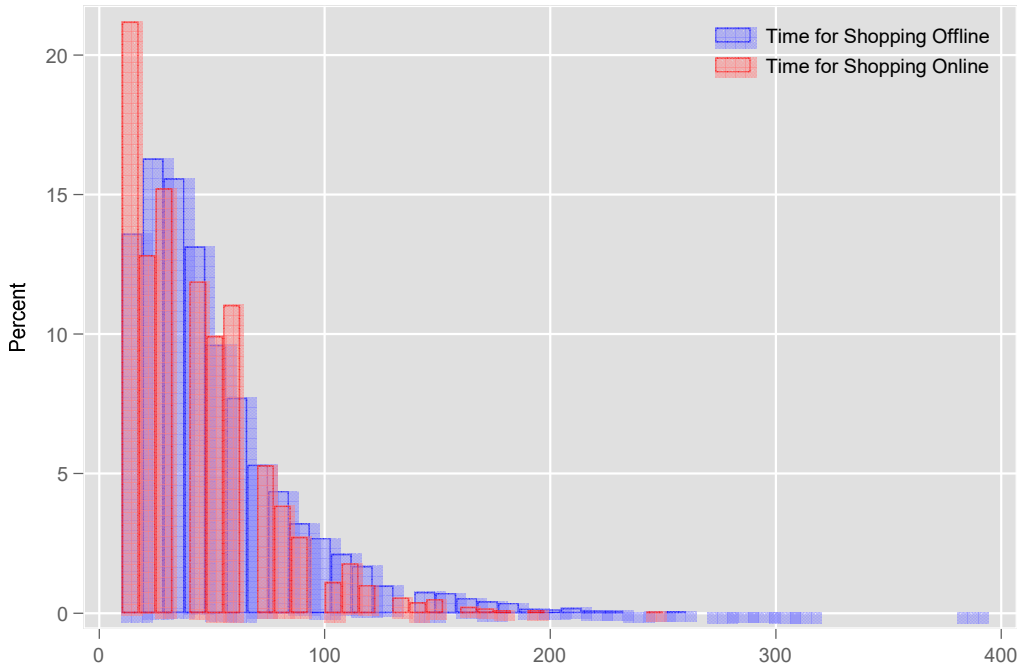


Figure 9. Relationships of the shopping time, between online and offline 2004

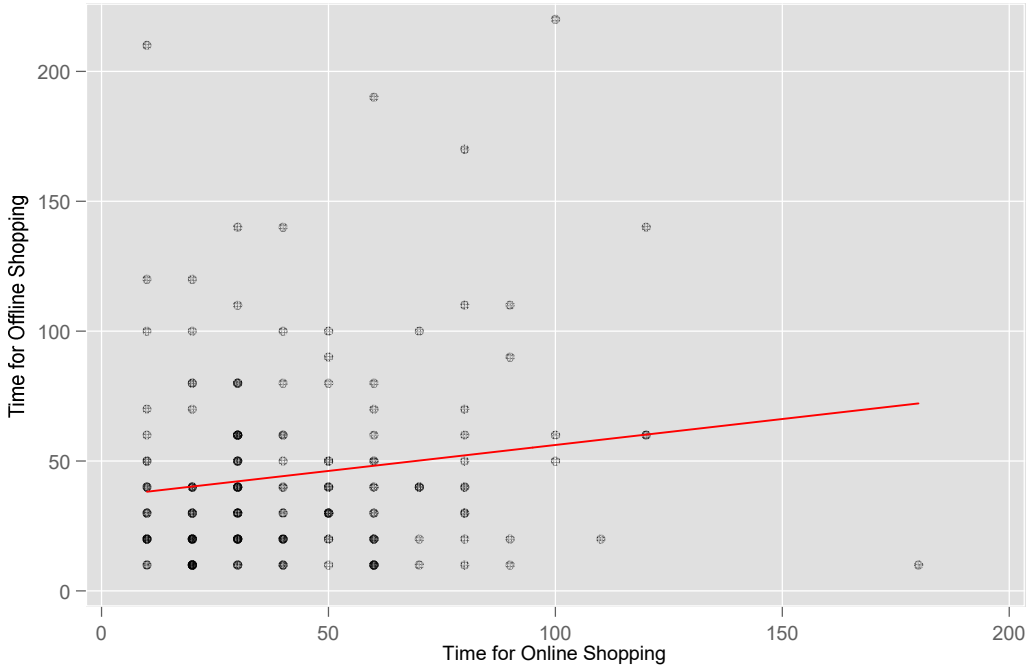
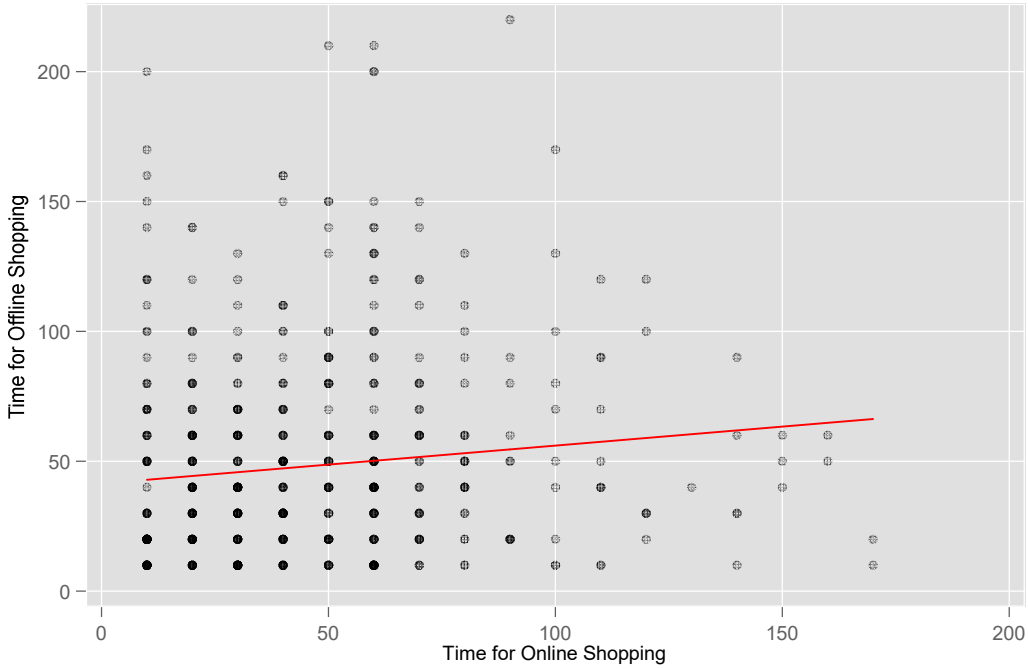


Figure 10. Relationships of the shopping time, between online and offline 2014



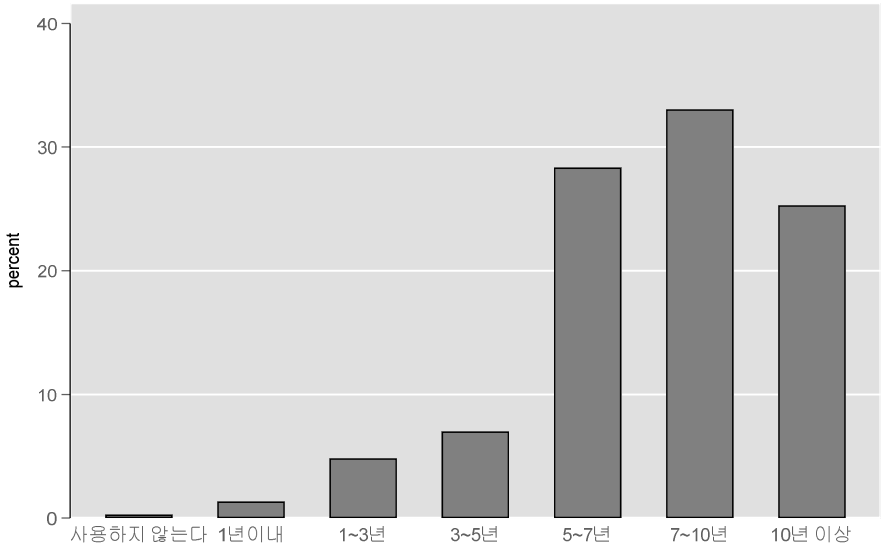
Appendix II – Mobile survey

인터넷/스마트폰으로 이용으로 인한 업무/여가활동 및 도심방문 변화

※ 1~3번 질문은 귀하의 스마트폰의 사용 경력과 도심방문 빈도에 대한 질문입니다

1. 귀하께서는 스마트폰을 얼마나 오랫동안 사용하셨습니까?

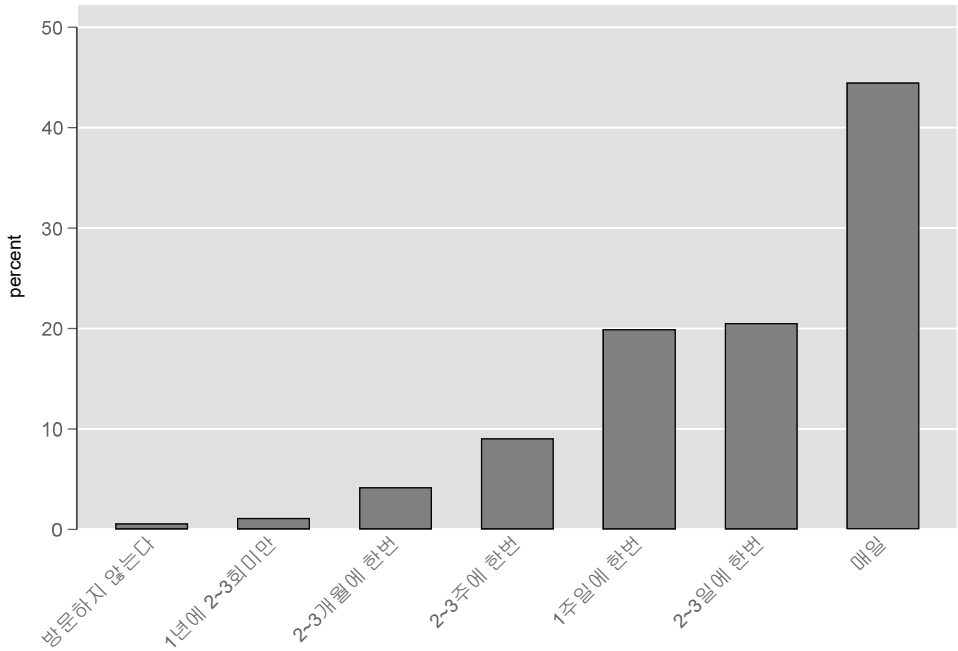
Smartphone History	Freq.	Percent	Cum.
사용하지 않는다	3	0.26	0.26
1년이내	15	1.31	1.57
1~3년	55	4.81	6.38
3~5년	80	6.99	13.37
5~7년	324	28.32	41.70
7~10년	378	33.04	74.74
10년 이상	289	25.26	100.00
Total	1,144	100.00	



2. 귀하께서는 시내(도심)을 얼마나 자주 방문하십니까?

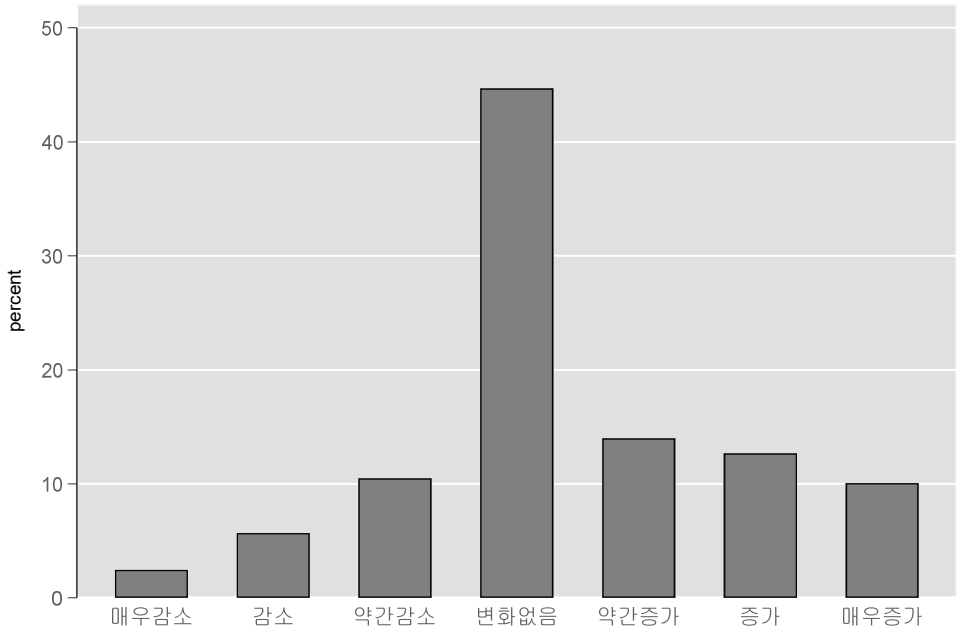
(여기서 도심 또는 시내의 개념은 특정한 지역을 지칭하지 않으며, 일반적인 개념의 상업 중심지나 번화가를 떠올리시면 됩니다.)

Total Frequency of visiting City Centers	Freq.	Percent	Cum.
방문하지 않는다	7	0.61	0.61
1년에 2~3회미만	13	1.14	1.75
2~3개월에 한번	48	4.20	5.94
2~3주에 한번	104	9.09	15.03
1주일에 한번	228	19.93	34.97
2~3일에 한번	235	20.54	55.51
매일	509	44.49	100.00
Total	1,144	100.00	



3. 스마트폰 사용으로 인하여 시내(도심)를 방문할 필요성에 변화가 있습니까?

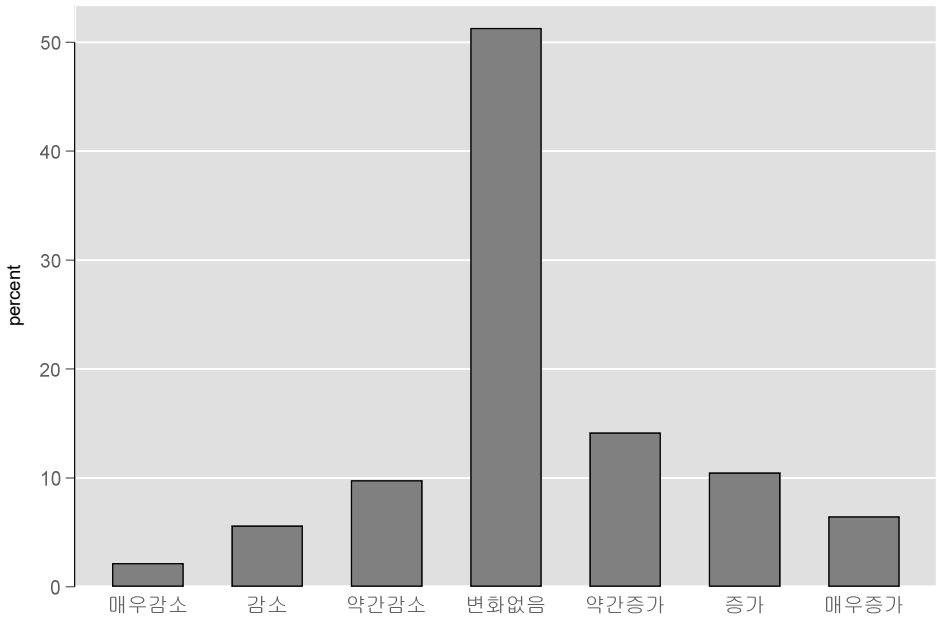
Total Change in Frequency of Visiting City Centers	Freq.	Percent	Cum.
매우감소	28	2.45	2.45
감소	65	5.68	8.13
약간감소	120	10.49	18.62
변화없음	511	44.67	63.29
약간증가	160	13.99	77.27
증가	145	12.67	89.95
매우증가	115	10.05	100.00
Total	1,144	100.00	



※ 4~5번 질문은 귀하의 스마트폰 사용으로 인한 귀하의 생활 도심 방문 변화에 대한 질문입니다.

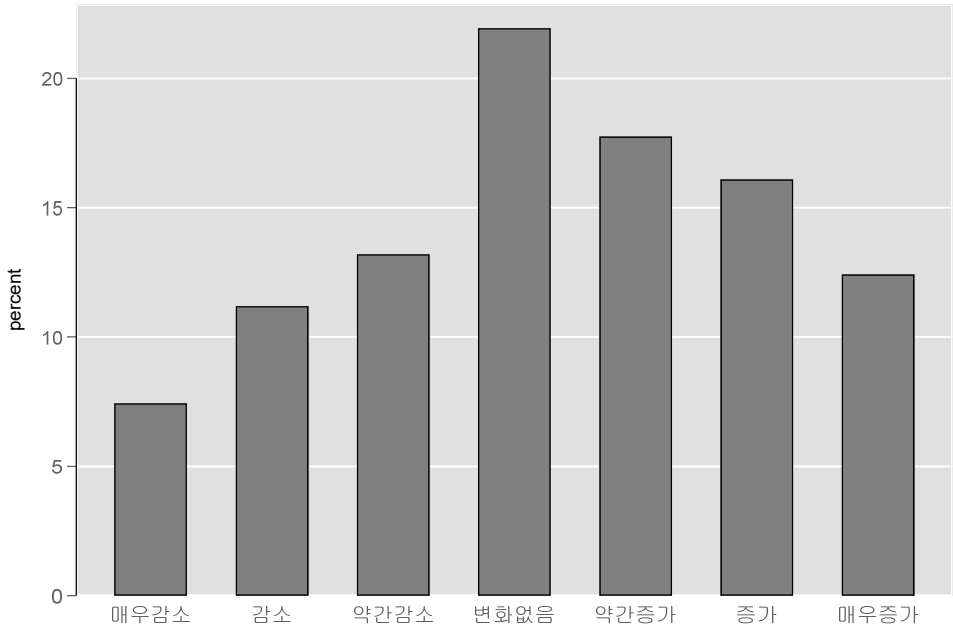
4. 스마트폰/인터넷 사용 후 업무상 목적으로 시내(도심)를 방문할 필요가 증가했습니까? 감소했습니까?

Change in Frequency of Visiting City Centers in Business Purpose	Freq.	Percent	Cum.
매우감소	25	2.19	2.19
감소	64	5.59	7.78
약간감소	112	9.79	17.57
변화없음	587	51.31	68.88
약간증가	162	14.16	83.04
증가	120	10.49	93.53
매우증가	74	6.47	100.00
Total	1,144	100.00	



5. 스마트폰 사용 후 쇼핑 또는 여가 목적으로 시내(도심)를 방문할 필요가 증가했습니까? 감소했습니까?

Change in Frequency of Visiting City Centers in Non-Business Purpose	Freq.	Percent	Cum.
매우감소	85	7.43	7.43
감소	128	11.19	18.62
약간감소	151	13.20	31.82
변화없음	251	21.94	53.76
약간증가	203	17.74	71.50
증가	184	16.08	87.59
매우증가	142	12.41	100.00
Total	1,144	100.00	

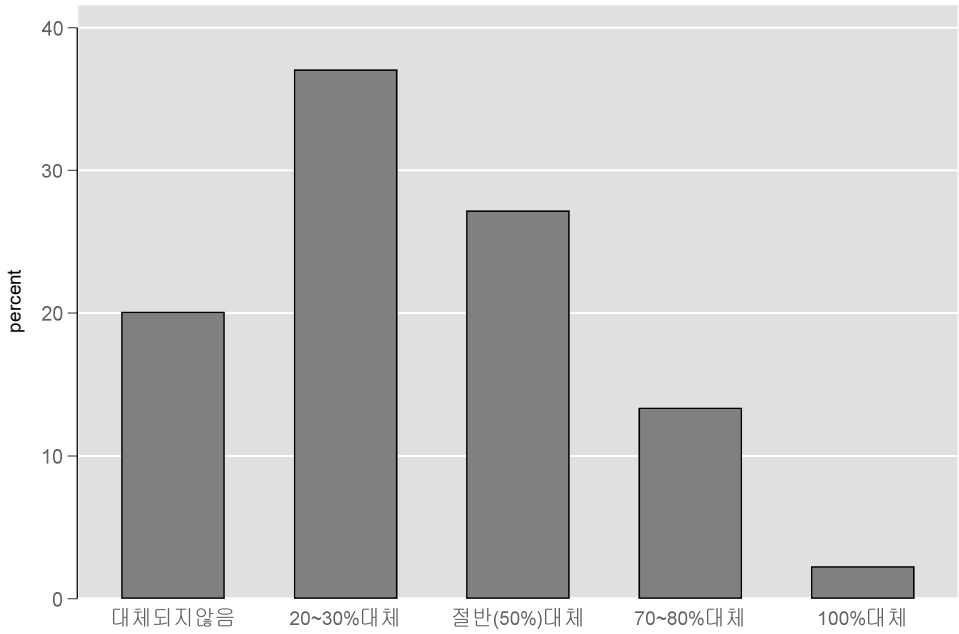


※ 6~7번 질문은 스마트폰의 사용이 업무 및 쇼핑/여가생활에 미친 대체효과에 대한 질문입니다

6. 스마트폰/인터넷을 사용 후 스마트폰/인터넷 등이 회의, 출장 등 대면접촉을 통한 업무를 얼마나 많이 대체되었습니까?

- 대면접촉 업무: 회의, 출장, 외근 등 직접 담당자를 만나서 처리하는 업무
- 스마트폰/인터넷 업무 : 메신저, 이메일 등으로 처리하는 업무

Substitution in Business	Freq.	Percent	Cum.
대체되지않음	230	20.10	20.10
20~30%대체	424	37.06	57.17
절반(50%)대체	311	27.19	84.35
70~80%대체	153	13.37	97.73
100%대체	26	2.27	100.00
Total	1,144	100.00	

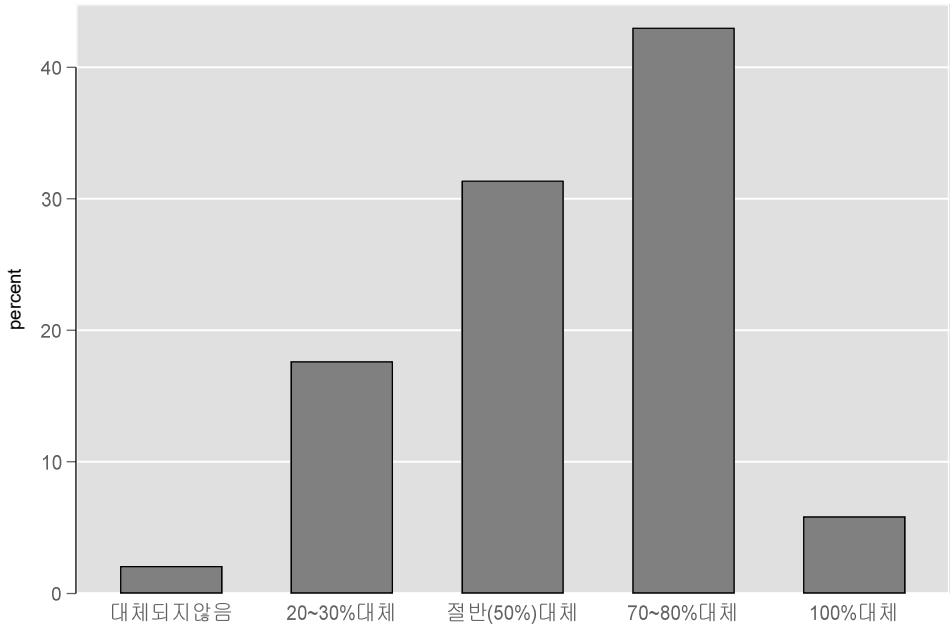


7. 스마트폰 사용 후, 온라인 쇼핑/여가 생활이 오프라인 쇼핑/여가생활을 얼마나 많이 대체하였습니까?

-온라인 : 모바일,인터넷 쇼핑으로 상품을 구매하거나 음악,영화,공연 등 스트리밍/다운로드로 감상

-오프라인 : 상점에서 직접 상품을 구매하거나 공연장, 영화관 등을 직접 방문

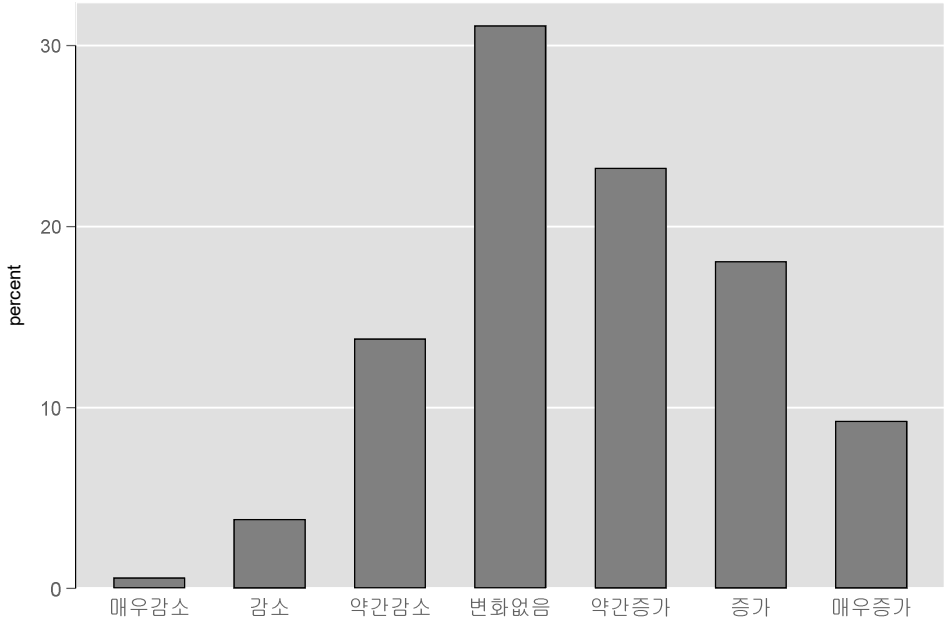
Substitution in Non-Business	Freq.	Percent	Cum.
대체되지않음	24	2.10	2.10
20~30%대체	202	17.66	19.76
절반(50%)대체	359	31.38	51.14
70~80%대체	492	43.01	94.14
100%대체	67	5.86	100.00
Total	1,144	100.00	



※ 8~9번 질문은 업무량 및 쇼핑여가시간의 총량 변화에 대한 질문입니다

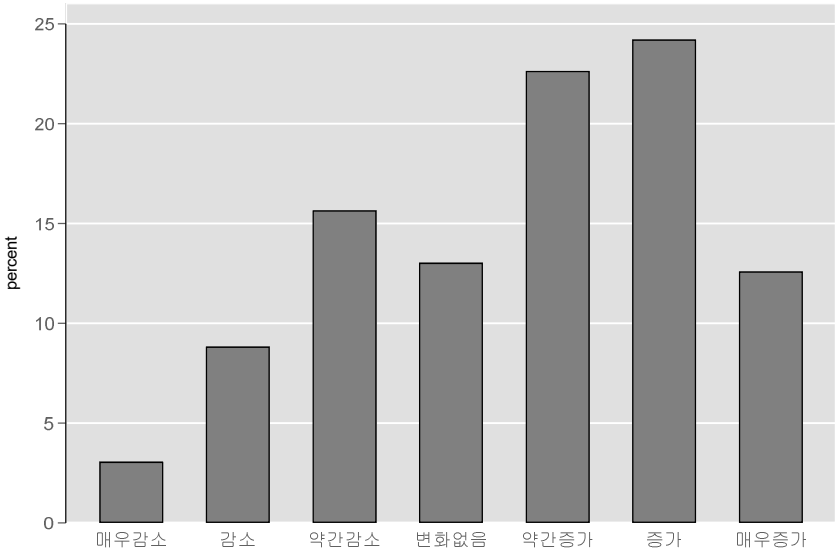
8. 스마트폰 및 인터넷 사용 후 귀하의 업무량 및 업무상으로 직접 만나는 사람의 수는 증가했습니까? 감소했습니까?

Change in Workload	Freq.	Percent	Cum.
매우감소	7	0.61	0.61
감소	44	3.85	4.46
약간감소	158	13.81	18.27
변화없음	356	31.12	49.39
약간증가	266	23.25	72.64
증가	207	18.09	90.73
매우증가	106	9.27	100.00
Total	1,144	100.00	



9. 스마트폰 사용 후 쇼핑, 음악감상, 영화 관람 시간은 증가했습니까? 감소했습니까?

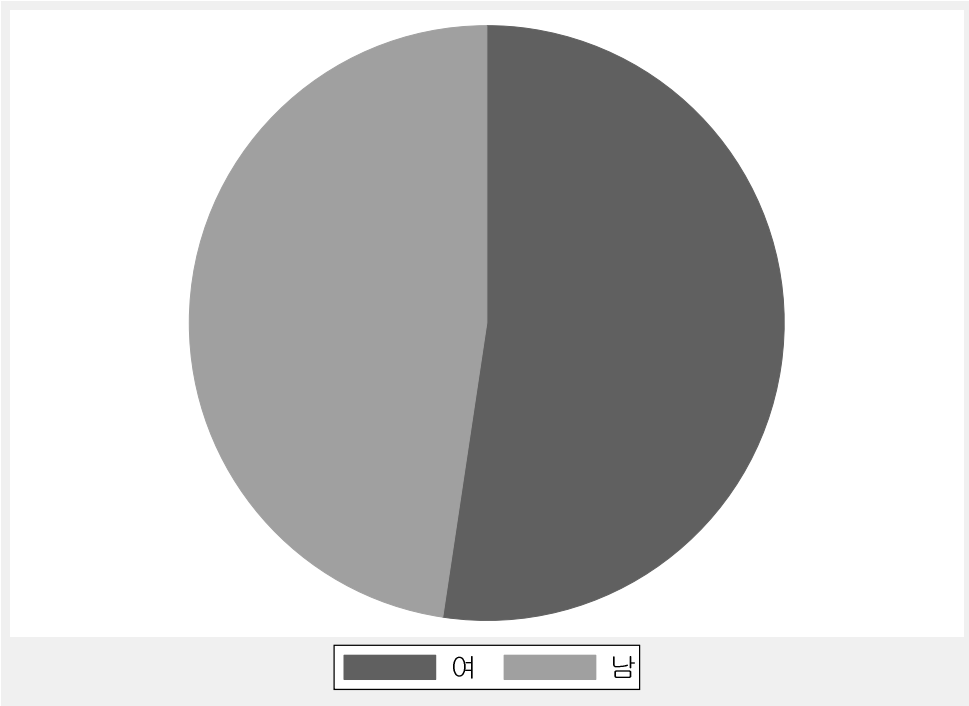
Change in Time for Shopping & Leisure	Freq.	Percent	Cum.
매우감소	35	3.06	3.06
감소	101	8.83	11.89
약간감소	179	15.65	27.53
변화없음	149	13.02	40.56
약간증가	259	22.64	63.20
증가	277	24.21	87.41
매우증가	144	12.59	100.00
Total	1,144	100.00	



※ **10~17번 질문은 귀하의 개인신상 및 스마트폰 이용현황에 대한 질문입니다.**

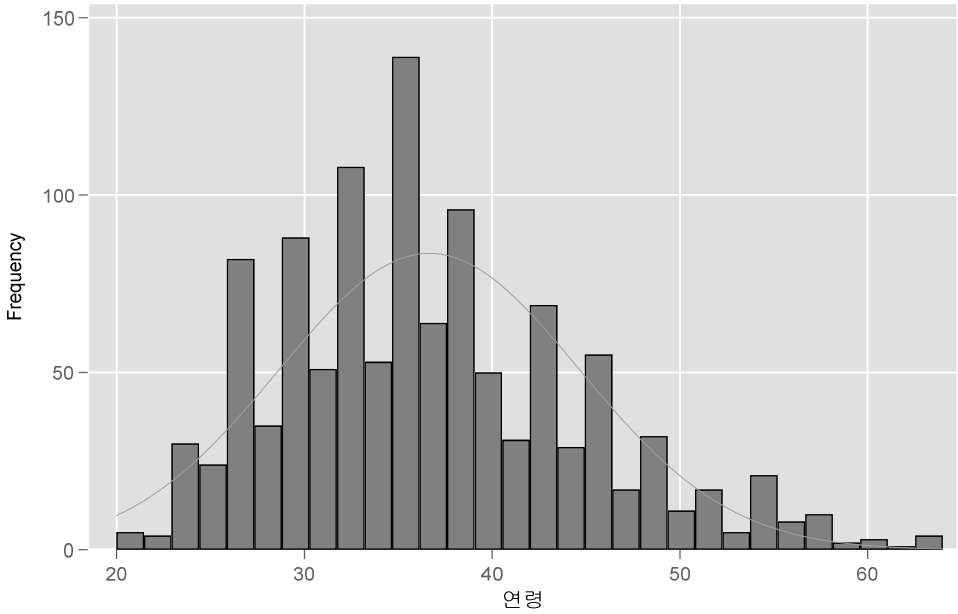
10. 귀하의 성별은**? (**남 **/** 여**)**

Gender	Freq.	Percent	Cum.
여	599	52.36	52.36
남	545	47.64	100.00
Total	1,144	100.00	



11. 귀하의 연령은? (만 ___세)

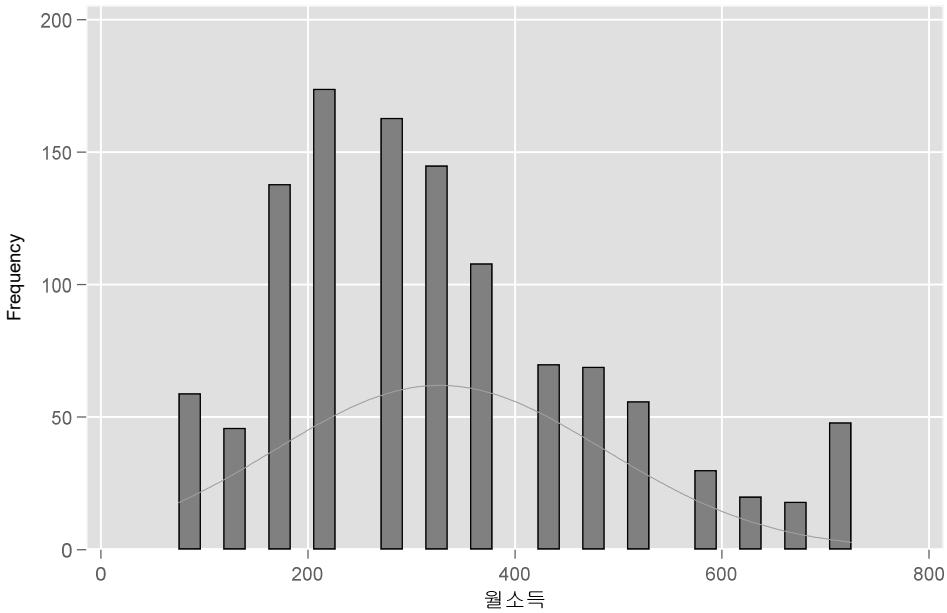
	Obs	Mean	Std. Dev.	Min	Max
Age	1,144	36.65559	8.010399	20	64



12. 귀하의 월 소득은 ?

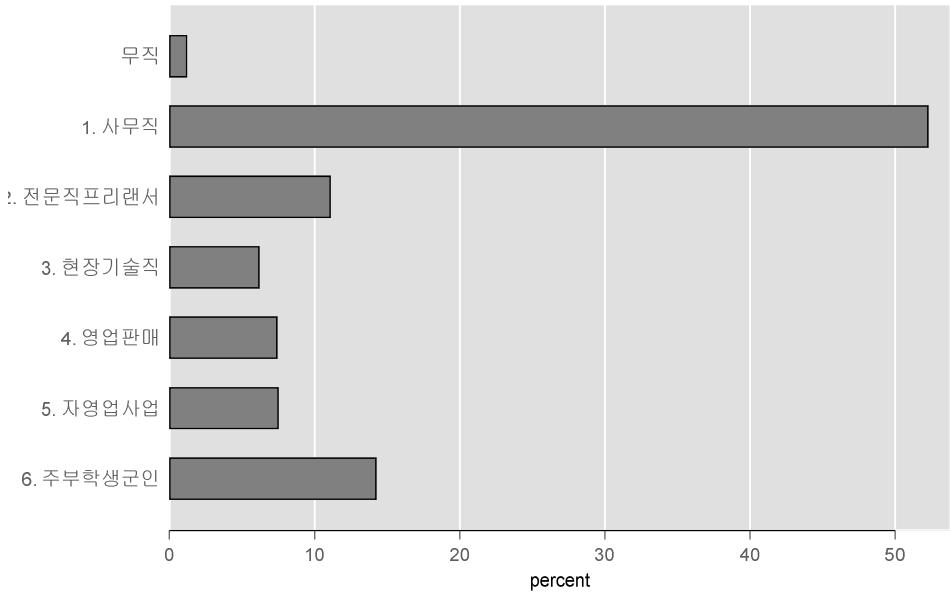
① 100만원 이하
② 100~150만원
③ 150~200만원
④ 200~250만원
⑤ 250~300만원
⑥ 300~350만원
⑦ 350~400만원
⑧ 400~450만원
⑨ 450~500만원
⑩ 500~550만원
⑪ 550~600만원
⑫ 600~650만원
⑬ 650~700만원
⑭ 700만원 이상

	Obs	Mean	Std. Dev.	Min	Max
Monthly Income	1,144	327.4038	159.5485	75	725



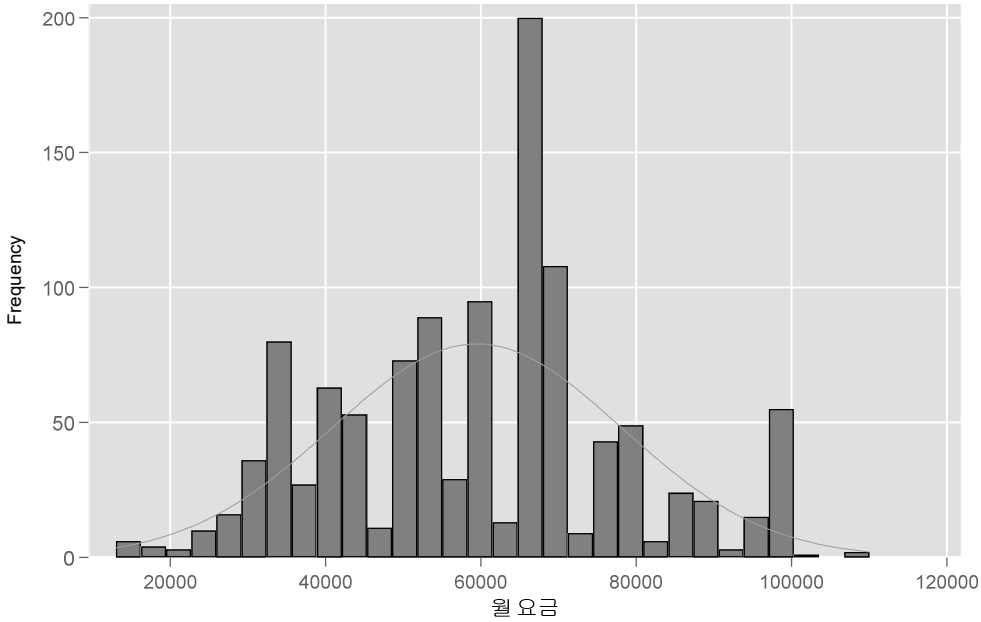
13. 귀하의 직업은 무엇입니까?

Occupation	Freq.	Percent	Cum.
1. 사무직 (일반기업 사무직 및 교직, 공무원, 연구원 등)	598	52.27	53.50
2. 전문직프리랜서 (의사, 변호사, 회계사 등)	127	11.10	64.60
3. 현장기술직 (현장기사, 목공, 토목 및 농수산업 등)	71	6.21	70.80
4. 영업판매 (세일즈, 상점 점원 등)	85	7.43	78.23
5. 자영업 또는 개인 사업	86	7.52	85.75
6. 주부, 학생 군인(직업군인 포함) 및 기타	163	14.25	100.00
0. 무직	14	1.22	1.22
Total	1,144	100.00	



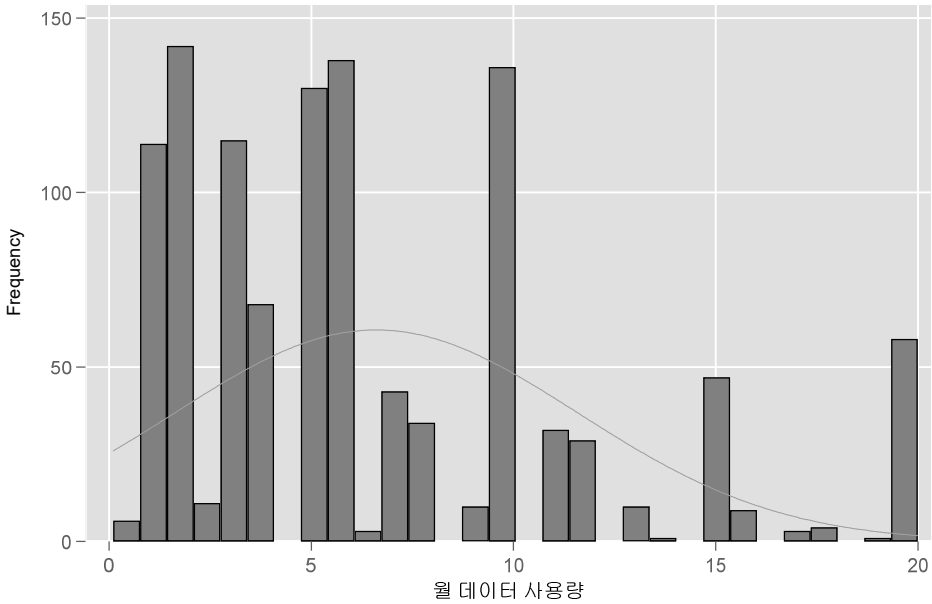
14. 귀하께서 현재 사용하시는 이동전화 요금제의 월 요금은 얼마입니까?
(월 ___ 만원)

	Obs	Mean	Std. Dev.	Min	Max
Monthly Mobile Bill	1,144	59,480.88	18,658.4	13,000	110,000



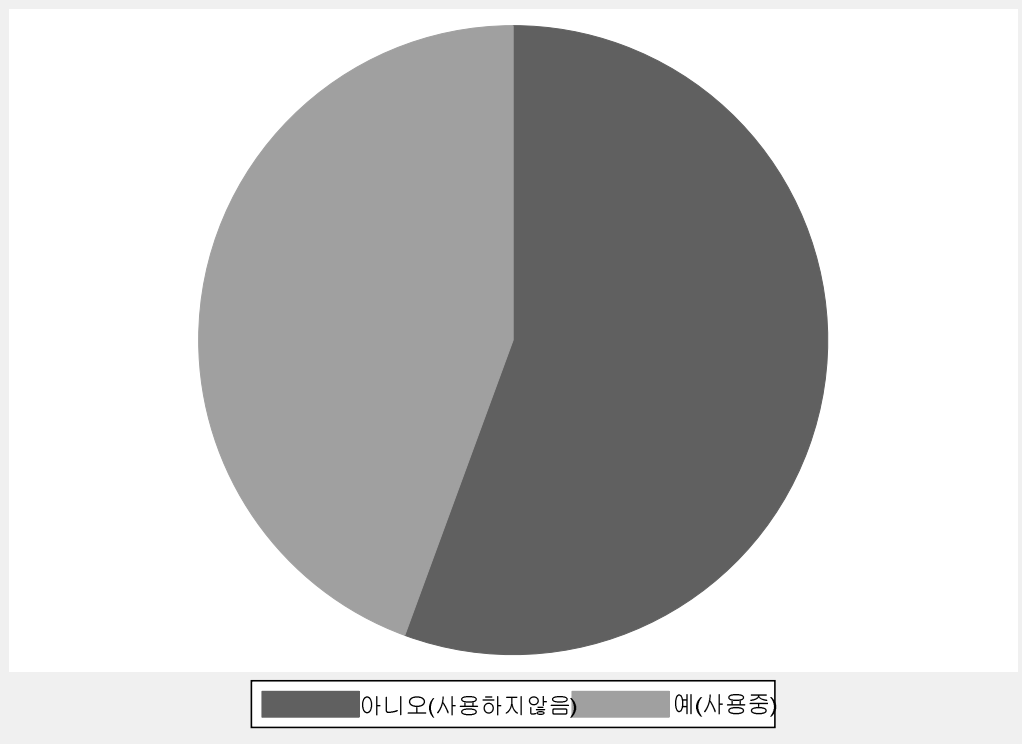
15. 귀하께서는 스마트폰으로 한달 평균 몇GB의 데이터를 이용하십니까? (___GB)

	Obs	Mean	Std. Dev.	Min	Max
Monthyl Mobile Data	1,144	6.608	4.995	0.1	20



16. 귀하께서는 무제한 데이터요금제를 사용중이십니까? (예 / 아니오)

Unlimited Data Plan	Freq.	Percent	Cum.
아니오(사용하지않음)	636	55.59	55.59
예(사용중)	508	44.41	100.00
Total	1,144	100.00	



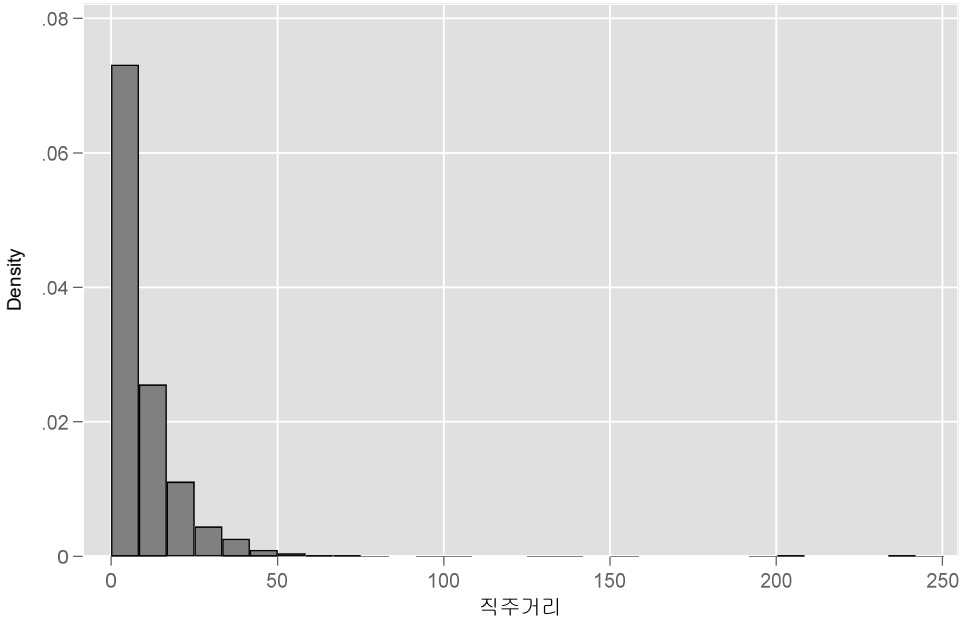
※ 다음 두 질문은 귀하의 근무지와 거주지에 관한 질문입니다. 연구에 필수적인 질문이며 귀하의 개인정보와는 무관한 질문이므로, 성실하게 답변 부탁드립니다.

17. 귀하의 거주지 주소를 동단위까지 입력해 주세요 (예: 경기도 성남시 분당구 판교동)

18. 귀하의 근무지 주소를 동단위까지 입력해 주세요.

	Obs	Mean	Std. Dev.	Min	Max
Job-Housing Distance	1,144	10.12251	20.36317	0	250.29

Note: the distance is variable calculated from the respondents' answers



※ **Correlations of The Selected Variables**

	Total Change in Frequency of Visiting City Centers	Change in Frequency of Visiting City Centers in Business Purpose	Change in Workload	Substitution in Business	Change in Frequency of Visiting City Centers in Non-Business Purpose	Change in Time for Shopping & Leisure	Substitution in Non-Business
Total Change in Frequency of Visiting City Centers	1.0000						
Change in Frequency of Visiting City Centers in Business Purpose	0.7244	1.0000					
Change in Workload	0.2779	0.3088	1.0000				
Substitution in Business	0.2634	0.2829	0.3436	1.0000			
Change in Frequency of Visiting City Centers in Non-Business Purpose	0.7670	0.6288	0.2926	0.2667	1.0000		
Change in Time for Shopping & Leisure	0.3819	0.3220	0.4058	0.1962	0.4287	1.0000	
Substitution in Non-Business	0.2516	0.2091	0.2337	0.3735	0.2153	0.2293	1.0000