International Journal of Engineering & Technology
CENTRE OF PROFESSIONAL RESEARCH PUBLICATIONS
ISSN 2049-3444
International Journal of Engineering and Technology Volume 5 No. 10, October, 2015

A Frequency Model of Home-Based Telecommuting: A Case Study of Washington-Baltimore Metropolitan Area

Taehyeong Kim
Senior Researcher, Korea Institute of Civil Engineering and Building Technology, Korea

ABSTRACT

This study focused on research for a better understanding of home-based telecommuting behavior by analyzing factors affecting the individual frequency to home-based telecommuting in Washington-Baltimore Metropolitan Area. With an extensive review of literature, this study expands the existing body of home-based telecommuting research by using data from the 2009 National Household Travel Survey (NHTS) to consider a larger sample and to include characteristics unavailable in previous analysis. As factors that can affect the individual's frequency of home-based telecommuting, personal characteristics, household characteristics, accessibility to the workplace, and job-related characteristics are considered. Also, the frequency of home-based telecommuting is modeled as an ordered logit model. Regression result suggests that driver, number of drivers in household, number of workers in household, number of vehicles in household, annual household income-more than $75,000, one-way distance from home to work and full-time worker are significant determinants of telecommuting frequency in Washington-Baltimore Metropolitan Area.

Keywords: *Telecommuting, Frequency, Ordered logit model, Washington-Baltimore, NHTS*

1. INTRODUCTION

Telecommuting specifically refers to working from home or telecenter using telephones, computers, or other advanced communications facilities to maintain linkage to the office and to central management and administration. And, telecommuting may be able to reduce physical travel demand, traffic congestion and vehicle emissions. Also, it may increases employees' productivity and flexibility for working parents and other employee.

However, these benefits of home-based telecommuting from a system-wide perspective depend on the adoption of home-based tele-commuting as a substitute for physical travel. Therefore, it is important to examine the choice and frequency of home-based telecommuting and the characteristics of the workers who currently work from home to assess and predict the impacts of home work on policy issues of concern.

The purpose of this study is to analyze and model the relationships between personal and household characteristics, accessibility to the workplace, job-related characteristics, and the frequency to home-based telecommuting in Washington-Baltimore Metropolitan Area, based on the 2009 NHTS.

This study contributes to the field in three aspects. First, this study provides comprehensive information, such as dependent variable, explanatory variable, used statistical method or model, data, number of samples, and location, of literature related to the choice and frequency of telecommuting. Second, this study expands the existing body of home-based telecommuting research by using data from the 2009 National Household Travel Survey (NHTS) to consider a larger sample and to include characteristics unavailable in previous analysis. Lastly, it shows a comparison result between the model based on Washington-Baltimore Metropolitan area in this study and the developed models based on California area and other areas in previous research. Actually, there has been no study related to tele-commuting in Washington-Baltimore metropolitan area, and Jin and Wu [1] commented that in 2009, workers in the Northeast became the leader of telecommuting in the United States. We expect the findings give better understanding of home-based telecommuting behavior and provide some insights on telecommuting policies.

2. RELATED WORKS

Telecommuting is not a new concept since the term was defined as "the partial or total substitution of telecommunications for the daily work trip" [2]. Also, Nilles defined four types of telecommuting: home based, satellite centers, local centers, and neighborhood center [3]. Early visions of telecommuting assumed that telecommuters were information workers who worked almost entirely with computers, who telecommuted full-time, and who worked from home [4]. But, it is now recognized that telecommuters need not be computer-users, and even if they are, they may not use computers at home.

2.1 Telecommuting choice and frequency

Several researches have studied to understand the relationships between personal and occupational characteristics and choice and frequency of home-based telecommuting. And, without doubt, previous empirical and conceptual studies on telecommuting have provided valuable information on individuals' choice and frequency to telecommute. Generally, empirical studies about the choice and frequency of telecommuting may be divided into two groups: studies using stated-preference survey data and studies using revealed-preference survey data. The first group of studies based on stated-preference surveys [5-8] appeared mainly in 90's, which is earlier than the second group of studies.

2.2 Studies using stated-preference survey data

The earliest published research in the first group of studies using stated-preference survey data appears to be one by Bernardino et al. [5]. This study postulated a two-tiered decision tree for the adoption of telecommuting by individual. A pilot study using stated preference data from 100 survey respondents examined the hypothetical choice to adopt or not adopt telecommuting. An ordered probit model estimated from the data indicated that having to pay telecommuting cost made people less inclined to adopt telecommuting, whereas people who have more number of children in the household and commute time savings are more likely to adopt telecommuting.

Sullivan et al. [6] estimated a multinomial logit model to analyze stated telecommuting choice and participation frequency based on the survey data of 694 respondents in Austin, Houston, and Dallas, Texas. In their study, round-trip commute time, being female with children, being female, being married have positive impact on the stated telecommuting frequency preference, whereas length of time with firm, need for face-to-face communication, and age have negative impact.

Mokhtarian and Saloman [7] used survey data that collected from 628 employees of the city of San Diego and showed relationships between individual sociodemographic variables and stated telecommuting preferences using t-test and Chi-squared test. This study shows that longer commute, women and younger people have positive influence on the preference of telecommuting, whereas lack of awareness about telecommuting, job unsuitability, and manager unwillingness have negative influence on the preference of telecommuting. However, it is notable that household size, number of vehicles per driver, presence of children, education, and in-come are not significantly different between preferrers and nonpreferrers in this study.

Yen and Mahmassani [8] developed a mathematical model of the employee's telecom-muting adoption process on the basis of a dynamic generalized ordinal probit model using a stated-preference data of 545 employees in selected organizations in Austin, Houston, and Dallas, Texas. Their estimation results show that salary increase, commute distance, job suitability and family orientation will increase the probability that employees choose a higher frequency of telecommuting. Employees with more children under age 16 or personal computers at home or with higher computer proficiency levels are more likely to adopt telecommuting. However, the longer employees need to communicate face-to-face with workers, the lower probability they will choose a high frequency of telecommuting. The studies based on stated-preference provided useful insights into the factors affecting telecommuting choice and frequency. However, most of the earlier studies using stated-preference data are limited to data from a single employer or, at most, two or three employers.

2.3 Studies using revealed-preference survey data

Also, the studies using revealed-preference survey data are classified into two categories: one for modeling actual choice or frequency of telecommuting and the other for modeling jointly actual choice and frequency of telecommuting. The first category of studies using revealed-preference survey data [9-14] appeared mainly in 90's, which is earlier than the second category of studies [15-18].

Mannering and Mokhtarian [9] investigated the revealed preference of workers, focusing on contextual factor that constrain or facilitate decision to home-based telecommuting. An estimated multinomial logit model revealed that telecommuting was positively associated with larger household sizes, the presence of small children in the household, more vehicles in the household, higher degrees if family devotion, familiarity with other telecommuters, preferences for working alone, and being male. It is notable that variables unexpectedly not significant were distance to work, time to work, a recent departure time change in response to congestion, managerial or professional occupation, and the amount of work time in face-to-face contacts. Also, this study was limited by small sample sizes (90 employees of a government agency for Sacramento, 90 employees of a government agency for San Francisco, and 628 employees of a government agency for San Diego).

Bernardino and Ben-Akiva [10] explained the telecommuting adoption process of employer and employee using multinomial logit model estimation based on a survey data of 80 managers and 176 employees across the United States. The results show that change in lifestyle quality and higher salary to telecommuters have positive impact on adoption of telecommuting, whereas increase in work-related costs and lower salary to telecommuters have negative impact on adoption of telecommuting.

Mokhtarian and Salomon [11] developed a binary logit model of telecommuting adoption using a survey data of 628 employees of the city of San Diego, California. The results shows that overtime and commute stress have positive influence on the adoption of telecom-muting, whereas misunderstanding, lack of manager support, job suitability, technology requirements and office discipline have negative influence on the adoption of telecommuting.

Mokhtarian and Salomon [12] presented the results of measuring the variables for the preference for telecommuting based on the binary logit model using the same data of Mokhtarian and Salomon [11]. The explanatory variables include attitudinal and factual information. In the explanatory variables, disability/parental leave, stress, personal benefits, com-mute stress, commute time, and job suitability have positive impact on telecommuting preference, whereas workplace interaction, household distractions, and commuting benefit have negative impact on telecommuting preference.

Drucker and Khattak [13] expands the existing body of home-based telecommuting re-search by using data from 1995 NPTS focused on metropolitan statistical areas containing populations of at least 1million. They proposed the three estimated models based on ordered logit, ordered probit, and multinomial logit. However, used data in this study did not include any job or occupational characteristics. As a result, educational attainment and the presence of small children in the household encourage frequent working from home, and males and drivers choose to work from home more often than females or non-drivers. It is

notable that distance to work is negatively correlated with working at home.

Wells et al. [14] conducted case studies of a large private high-technology firm and a public agency located in the Minneapolis-St. Paul area to examine the implications of telecom-muting. They used data from a cross-section survey of non-telecommuting employees, a census survey of telecommuters and in-depth interviews with telecommuters, their coworkers, and their supervisors. Unlike other studies, they used t-test and Chi-square test for analysis without any estimated model. Women, married, having children, job suitability, trip time and distance are positively correlated with telecommuting preference, whereas face-to-face interaction with client and/or coworkers are negatively correlated with telecommuting preference.

Unlike the previous studies, Popuri and Bhat [15] estimated a joint model of telecommuting choice and frequency based on the data from 1997-1998 survey of 14,441 household (6532 employees) in the New York metropolitan area. The Results show that female with children, being married, number of vehicles, work in a private company, pay to park at work, household income, fax availability, and multiple phone lines at home have positive impacts on both the choice to telecommute and the frequency of telecommuting unlike transit to work.

Tang et al. [16] examined the effect of residential neighborhood built environment (BE) factors such as perceived regional accessibility, safety and quietness, diversity, and outdoor appeal with travel attitude and sociodemographics on working at home with a combined adoption/frequency multinomial logit model based on a survey data (1246 workers) of eight neighborhoods in Northern California. The results show that number of institutional establishments within 400m has a negative impact on adoption of telecommuting, whereas square of com-mute time, current annual household income, and education level have positive impacts on the adoption of telecommuting. Also, the number of eating out places within 400m, pro-biking attitude, and pro-transit attitude have positive impacts on the frequency of telecommuting, whereas perceived regional accessibility has a negative impact on the frequency of telecom-muting.

Sensor and Bhat [17] jointly examined the propensity and frequency of workers to tele-commute using the data drawn (9624 employees) from the Chicago Regional Household Travel Inventory, collected between 2007 and 2008. The results indicate that telecommuting choice and the frequency of telecommuting are governed by quite different underlying behavioral processes. Female, age less than 30 years have a negative impact on choice of telecommuting, while they are not significant in impact on frequency of telecommuting. Graduate degree, partially flexible, service-based on management of companies or enterprise, art, entertainment, or recreation, and number of household workers have positive impacts on the frequency of tele-commuting, whereas number of household vehicles has a negative impact on the frequency of telecommuting. It is notable that unexpectedly children, income, and commute distance were not significant in both the choice and frequency of telecommuting.

Singh et al. [18] estimated a joint model of three dimensions-option, choice and frequency of telecommuting as a generalized ordered-response (GOR) model using 2009 NHTS data and a built environment data base. In the explanatory variables, graduate degree, flexible work start time, presence of children less than or equal to 5 years, number of vehicles in the house-hold, rural area and length of bicycle lanes/10 have positive impacts on the choice of tele-commuting, whereas number of workers in the household and total population/10000 have negative impacts on the choice of telecommuting. Unexpectedly female and income were not significant in a trivariate model for option, choice, frequency of telecommuting.
This study falls into the first category of studies using revealed-preference survey data for modeling actual frequency of telecommuting in Washington-Baltimore metropolitan area based on the survey data of 2009 NHTS.

3. DATA COLLECTION AND ANALYSIS

3.1 Data collection

The data were obtained from the 2009 NHTS of a national travel survey sponsored by the U.S. Department of Transportation agencies. NHTS served as the nation's inventory of daily travel. Previous NHTS surveys were conducted in 2001. Since NHTS covers a wider range of employees and jobs unlike the data used in previous studies, it can provides not only a variety of information on individual characteristics of the respondent but also revealed preference da-ta of individual's telecommuting information as one of the few large national samples available for study. Thus, NHTS presents a good chance to study and develop a current perspective of frequency of home-based telecommuting. However, since NHTS are not specifically de-signed for studies on telecommuting, there is a need of caution for determining telecommuters and non-telecommuters.
In this study, home-based telecommuting data were obtained from a question that whether respondents had the option for work from home and if so how many days they worked from home in the past 1 month. Hence, the data concerning frequency of home-based telecommuting is aggregated into three categories: frequent (4 or more per month), infrequent (less than 4 per month but at least once per month), and never. In this study, 5562 persons for Washing-ton-Baltimore Metropolitan Area were simply extracted from the 2009 NHTS. After removing missing data and data of persons age 5 to 15 to consider the minimum legal age for full time work, finally 2,160 persons having part-time or full-time job were selected.

3.2 Data analysis

Data analysis is conducted with two steps. The first step is to profile and investigate the various factors affecting the frequency of home-based telecommuting from revealed preference data. The second step is to categorize and distinguish these factors and prepare modeling frequency of home-based telecommuting.

3.2.1. Personal characteristics

Table 1 shows the statistics of personal characteristics.

Table 1: The statistics of personal characteristics

Variable Description	Frequency(*N*=2,160)
Frequency of working from home in past month (WKFMHMXX)	-Never: 1,855 (85.9%) -Infrequent: 173 (8.0%) -Frequent: 132 (6.1%)
Age(R_AGE)	-16-30: 246 (11.4%) -31-40: 396 (18.3%) -41-50: 661 (30.6%) -51-60: 585 (27.1%) -Above 60: 272 (12.6%)
Sex(R_SEX)	-Male: 1,178 (54.5%) -Female: 982 (45.5%)
Race(HH_RACE)	-White: 1,787 (82.7%) -African American: 264 (12.2%) -Asia: 66 (3.1%) -Others: 43 (2.0%)
Drive status(DRIVER)	-Driver: 2,119 (98.1%) -Not driver: 41 (1.9%)
Education level-Highest grade completed (EDUC)	-Less than high school: 55 (2.5%) -High school: 400 (18.5%) -College: 517 (23.9%) -Bachelor: 575 (26.6%) -Graduate or Professional: 613 (28.4%)
Frequency of internet use in past month (WEBUSE)	-Almost every day: 1,728 (80.0%) -Several times a week: 211 (9.8%) -Once a week: 63 (2.9%) -Once a month: 42 (1.9%) -Never: 116 (5.4%)

The data comprised 54.5% males and 45.5% females, most falling into the 31-50 year (48.9%). The responses of most persons (85.9%) were that they never worked from home last two months instead of work location. This result is similar to that of "State of the Commute 2001 Survey Results from the Washington Metropolitan Region" surveyed by Metropolitan Washington Council of Governments. About 15% of survey respondents said they telecom-muted at least occasionally. As 98.1% of total persons were the status of driver, most persons can drive. Most persons were well educated with 23.9% completing college, 26.6% bachelor, and 28.4% graduate or professional degrees. Also it shows high frequency of internet use as 80.0% of total persons used internet almost every day.

3.2.2. Household characteristics

Table 2 shows the statistics of household characteristics.

Table 2: The statistics of household characteristics

Variable Description	Frequency(*N*=2,160)
Annual household income (HHFAMINC)	-Less than 25,000: 85 (3.9%) -25,000-49,999: 241 (11.2%) -50,000-74,999: 288 (13.3%) -Above 75,000: 1,546 (71.6%)
Number of drivers in household (DRVCNT)	-0: 10 (0.5%) -1: 247 (11.4%) -2: 1,306 (60.5%) -3: 434 (20.1%) -More than 4: 163 (7.5%)
Number of persons in household (HHSIZE)	-1: 179 (8.3%) -2: 745 (34.5%) -3: 507 (23.5%) -4: 434 (20.1%) -More than 5: 295 (13.7%)
Number of vehicles in household (HHVEHCNT)	-0: 43 (2.1%) -1: 262 (12.1%) -2: 896 (41.5%) -3: 553 (25.6%) -More than 4: 406 (18.8%)
Number of workers in household (WRKCNT)	-1: 778 (36.0%) -2: 1,067 (49.4%) -3: 268 (12.4%) -More than 4: 47 (2.2%)
Life cycle classification for the household (LIF_CYC_15)	-1+ adults, youngest child 0-15: 813 (37.6%) -Otherwise: 1,347 (62.4%)
Home address in urbanized area (URBAN)	-In an urban area: 1,415 (65.5%) -In an urban cluster: 81 (3.8%) -Not in urban area: 664 (30.7%)
Size of urban area in which home address is located (URBANSIZE)	-50,000-199,999: 432 (20.0%) -1 million or more without subway or rail: 91 (4.2%) -1 million or more with subway or rail: 892 (41.3%) -Not in an urbanized area: 745(34.5%)
Household in urban/rural area (URBRUR)	-Urban: 1,496 (69.3%) -Rural: 664 (30.7%)

Most persons (84.9%) had a yearly household income of above $50,000, and 71.6% of total persons had annual income of above $75,000. This represents that the workers of this area had high salaries. Most households (88.1%) had more than two drivers and 85.8% of households had more than two vehicles. About 91.7% of households had more than two persons and 85.4% of households had one or two workers. 37.6% of households had youngest child under 15 and more than one adult.

3.2.3. Accessibility to the workplace

Table 3 shows the statistics of accessibility to the workplace

Table 3: The statistics of accessibility to the workplace

Variable Description	Frequency(*N*=2,160)
One-way distance to work (DISTTOWK)	-0 miles-20 miles: 230 (55.7%) -20 miles-40 miles: 88 (21.3%) -40 miles-60 miles: 72 (17.4%) -Above 60 miles 23 (5.6%) (Mean: 21.53, Std. Deviation: 20.82)
Minutes to go from home to work last week (TIMETOWK)	-0 minutes-20 minutes: 108 (26.2%) -20 minutes-40 minutes: 120 (29.1%) -40 minutes -60 minutes: 91 (22.0%) -60 minutes -80 minutes: 50 (12.1%) -80 minutes -100 minutes: 27 (6.5%) -Above 100 minutes: 17 (4.1%) (Mean: 37.44, Std. Deviation: 28.5)

77% of workers had below 40 miles of one-way distance to work and average one-way distances and travel time to work was 21.53 miles. 22.7% of workers experienced more than 1 hour of travel time from home to work and average travel time to work was 37.44 minutes.

3.2.4. Job-related characteristics

Table 4 shows the statistics of job-related characteristics.

Table 4: The statistics of job-related characteristics

Variable Description	Frequency(*N*=2,160)
Job category(OCCAT)	-Sales/service: 411(19.0%) -Clerical/admin support: 229(10.6%) -Manufacture, construct, maintenance, or farming: 176 (8.1%) -Professional, managerial, or technical: 1,344 (62.2%)
Self-employed (SELF_EMP)	-Yes: 148 (6.9%) -No: 2,012 (93.1%)
Work full or part-time(WKFTPT)	-Full-time: 1,815 (84.0%) -Part-time: 327 (15.1%) -Multiple jobs: 18 (0.8%)
Has option to work at home (WKRMHM)	-Yes: 468 (21.7%) -No: 1,692 (78.3%)

It is notable that 62.2% of total workers have a professional, managerial or technical job. Only 6.9% of total persons were self-employed. Most persons (84.0%) had full-time jobs, and only 21.7% of total persons had option to work at home.

3.2.5. Chi-square tests

Like Sensor and Bhat (2011) and Singh et al. (2013), in order to reduce the ambiguity in the difference between home-based telecommuting and operation of a home-based business, we removed self-employed workers and workers who do not have an option to work at home from the data, and finally 413 workers were chosen for modeling and further analysis.

To identify the factors influencing frequency of home-based telecommuting, most of the potential explanatory variables such as the personal characteristics, household characteristics, accessibility to the workplace and job-related characteristics were tested for relation with the frequency of home-based telecommuting by chi-square test. The result of chi-square tests was summarized in Table 5. A detailed cell display of frequency for each variable is omitted.

Table 5: Results of Chi-square tests between frequency and each variable

Variable	Pearson χ^2 statistic (Sig.)	Variable	Pearson χ^2 statistic (Sig.)
R_AGE	16.656 (0.034^{+})	WRKCNT	5.746 (0.676)
R_SEX	11.081 (0.004*)	LIF_CYC_15	0.173 (0.917)
HH_RACE	8.857 (0.182)	URBAN	4.371 (0.358)
DRIVER	2.278 (0.320)	URBANSIZE	9.462 (0.149)
EDUC	8.314 (0.216)	**DISTTOWK**	19.689 (0.003*)
HHFAMINC	14,317 (0.026^{+})	**TIMETOWK**	30.010 (0.001*)
DRVRCNT	8.167 (0.417)	OCCAT	8.325 (0.215)
HHVEHCNT	15.896 (0.460)	WKFTPT	6.541 (0.162)

+ : significant at the 0.05 level, but not at the 0.01 level

* : significant at the 0.01 level

As a result, R_AGE (age), R_SEX (sex), HHFAMINC (annual household income), DISTTOWK (distance to work) and TIMETOWK (Minutes to go from home to work) were significant at the 0.05 level. However, HH_RACE (race), DRIVER, EDUC (education lev-el-highest grade completed), DRVRCNT (number of drivers in household), HHVEHCNT (number of vehicles in household), WRKCNT (number of workers in household), LIF_CYC_15 (1+ adult, the youngest child 0-15), URBAN (urban or rural), URBANSIZE, OCCAT (job category) and WKFTPT (full-time or part-time) were not significant at 0.05 level.

Old age or male persons are more likely to work at home. The persons in households that have high annual in-come are more likely to work at home. And, it represents that distance and travel time to work affect frequency of home-based telecommuting.

However, these results are considered advisory because such individual tests are not a conclusive indication of relation between explanatory variables and the frequency of telecommuting. These results of chi-square tests were analyzed with the results of estimated models.

4. MODEL OF HOME-BASED TELECOMMUTING FREQUENCY

A Model based on ordered responses to frequency of home-based telecommuting was considered for use in the analysis of the data.

4.1 Model structure of ordered logit model

One approach to analyzing the data is to consider the individual's choice of home-based telecommuting frequency as an ordered response. Ordered response questions are used frequently in marketing surveys and can be modeled using ordered logit and probit models [9]. The use of an ordered response model in this case has significant limitation. The most

critical disadvantage is that an ordered model assumes monotonically increasing (or decreasing) desirability of the choice alternatives for each explanatory variable. Therefore, this modeling approach cannot accommodate explanatory variables that would favor a mid-range choice alternative over higher and lower frequency choices. In this study, the frequency of home-based telecommuting categories (never, infrequently, and frequently) is ordered. The regression equation is

$$Y^* = \beta' X + \varepsilon \quad (1)$$

where, Y^* = unobservable variable,

β' = estimated parameters,

X = vector of independent variables affecting frequency of home-based telecommuting,

ε = error term.

We can transform Y^* into the observed variable Y according to the following rules:

$$Y=0 \text{ (never)} \qquad if\ Y^* \le 0, \quad (2)$$

$$Y=1 \text{ (infrequent)} \qquad if\ 0 < Y^* \le \mu_1, \quad (3)$$

$$Y=2 \text{ (frequent)} \qquad if\ \mu_1 < Y^*. \quad (4)$$

where, μ_1 is unknown parameter to be estimated with β as category boundary parameter.

If ε 's are assumed to be gumbel distributed, then the probability of an individual choosing never, infrequently, or frequently home-based telecommuting is given by the ordered logit model.

4.2 Estimation of ordered logit model

A correlation matrix for all variables in Table 5 was computed and then the potential variables were tested together in an initial ordered logit model. But, the result represented that coefficients of many variables were not significant. Therefore, the calibration procedure was that the significances of estimated parameters were tested by t-test and the insignificant variables were excluded. After repetition of the procedure, the ordered logit model was constructed as shown in Table 6.

Table 6: The results of estimation of ordered logit model

Variable name	Description	Coefficient	t-statistic
μ_1	Category boundary parameter	1.721	13.86(0.000)
Constant	Constant	-2.623	-2.098(0.036)
DRIVER	Person is a driver	2.970	2.903(0.004)
DRVRCNT	The number of drivers in household	0.477	2.549(0.010)
WRKCOUNT	The number of workers in household	-0.401	-2.379(0.017)
HHVEHCNT	The number of vehicles in household	-0.225	-1.989(0.047)
HHINC_HIGH	Annual household income-more than $75,000	0.926	2.573(0.010)
DISTTOWK	One-way distance to work(mile)	0.024	4.526(0.000)
FULLLTIME	Person is a full time worker	-0.987	-2.728(0.006)
Significance(Chi-squared) : 0.000(43.986)			
Log-likelihood at convergence = -417.8823, Log-likelihood at zero = -439.8755 ρ^2= 0.050, $\bar{\rho}^2$= 0.044			

As shown Table 6, the t statistics of all explanatory variables were more than 1.96. This shows that these variables are quite significant. Likelihood ratio index (ρ^2) and adjusted likelihood ratio index ($\bar{\rho}^2$) representing goodness-of-fit of the model are 0.050, 0.044 respectively. The null hypothesis that all coefficients are zero can be tested through a likelihood ratio test. The statistic is given by

$$-2[L(0) - L(\beta)] \quad (5)$$

where, $L(0)$ = initial log-likelihood

$L(\beta)$ = log-likelihood at convergence

The test statistic χ^2 distributed with k degrees, where k is the number of coefficients estimated. In this model, the χ^2 value was 43.986 with 7 degrees of freedom. This means that the null hypothesis that all coefficients are zero can be rejected with greater than 99.9% confidence.

4.2.1. Variables

Unlike the results of chi-squared tests in the previous chapter, R_AGE (age), R_SEX (sex), and TIMETOWK (travel time to work) variables were removed. Finally, DRIVER (person is a driver), DRVRCNT (number of drivers in household), WRKCOUNT (number of workers in household), HHVEHCNT (number of vehicles in household), HHINC_HIGH (annual household income-more than $75,000), DISTOWK (one-way distance from home to work), FULLTIME (full-time worker) were added to the model.

Among several variables related to personal characteristics, only DRIVER was significant at 95% confidence level. Like Drucker and Khattak [13], driver has positive impact on the frequency of telecommuting, and the coefficient of driver is bigger than others. As household characteristics, DRVRCNT, WRKCOUNT, HHVEHCNT, and HHINC_HIGH were significant at 95% confidence level. Unlike other studies, the number of drivers in

household has positive impact on the frequency of telecommuting. The number of workers and vehicles in household has negative impact on the frequency of telecommuting like Sensor and Bhat [17] and Singh et al. [18]. Also, like Drucker and Khattack [13], Popuri and Bhat [15], and Tang et al. [16], household income was found to be positive for the frequency of telecommuting. This means that home-based telecommuting is expected to be more available to individuals with high income. As job characteristics, full-time worker has negative impact on the frequency of telecommuting. It means that part-time workers are more likely to work at home. Distance to work positively influenced the tendency to work at home like Wells et al. [14]. However, sex, age, presence of children, and job type were not significant unlike other studies.

4.2.2. Constant

Also, the constant coefficients for this model were negative. The negative sign of constant coefficients indicates that for the frequency of home-based telecommuting, the mean of unobserved effects is negative.

5. CONCLUSION

This study focused on research for which the central goal is a better understanding of home-based telecommuting behavior by analyzing factors affecting the individual frequency to home-based telecommuting such as personal characteristics, household characteristics, accessibility to the workplace, and job-related characteristics. In this study, 2,160 workers were selected from the 2009 NHTS for Washington-Baltimore Metropolitan Area, and 413 workers having the option to work at home of 2,160 workers were used to estimate the model. The result of the estimated ordered logit model is as follows: drivers more likely to work from home. Also, home-based telecommuting is expected to be more available to individuals with high income. Part-time worker is more likely to work at home. Distance to work positively influenced the tendency to work at home. However, a person whose household does not have many works and vehicles is more likely to work at home.

With an extensive review of literature, this study is so meaningful because there was not a study focused on propensity to work from home in Washington-Baltimore Metropolitan Area although there were several studies in California. And, these findings support implications for trip-generation forecasting and suggest directions for policies intended to influence commute travel. But, this model does not directly provide an aggregate forecast of telecommuting.

Therefore, development of method for aggregating results is needed. In this NHTS data, the employer information and employees' trip diary were not included. Therefore to exactly estimate the relationship between frequency of home-based telecommuting and other factors, the acquisition of additional data is required.

REFERENCES

[1] X. Jin and J. Wu (2010), Propensity to telecommute: exploring the national household travel survey, *Transportation Research Record: Journal of Transportation Research Board*, 2231, pp. 110-119.

[2] J. M. Nilles, F. R. Carlson, P. Gray, and G. G. Hanneman (1976), *The telecommunications-transportation tradeoff*, John Wiley and Sonc, Inc., New York.

[3] J. M. Nilles (1988), Traffic Reduction by Telecommuting: A Status Review and Selected Bibliography, *Transportation Research Part A*, 22A(4), pp. 301-317.

[4] P. L. Mokhtarian (1991), Defining telecommuting, *Transportation Research Record*, 1305, pp. 273-281.

[5] A. Bernardino, M. Ben-Akiva, and I. Salomon (1993), Stated preference approach to modeling the adoption of telecommuting, *Transportation Research Record*, 1413, pp. 22-30.

[6] M. A. Sullivan, H.S. Mahmassani, and, J.-R. Yen (1993), Choice Model of Employee Participation in Telecommuting under a Cost-Neutral Scenario, *Transportation Research Record*, 1413, pp. 42–48.

[7] P. L. Mokhtarian and I. Salomon (1996a), Modeling the choice of telecommuting 2: a case of the preferred impossible alternative, *Environment and Planning A*, 28, pp. 1859-1876.

[8] J.-R. Yen, and H. S. Mahmassani (1997), Telecommuting adoption conceptual framework and model estimation, *Transportation Research Record*, 1606, pp. 95-102.

[9] J. Mannering and P. L. Mokhtarian (1995), Modeling the Choice of Telecommuting Frequency in California: An Exploratory Analysis, *Technological Forecasting and Social Change*, 49, pp. 49-73.

[10] A. Bernardino and M. Ben-Akiva (1996), Modeling the process of adoption of telecommuting: comprehensive framework, *Transportation Research Record*, 1552, pp. 161–170.

[11] P. L. Mokhtarian and I. Salomon (1996b), Modeling the choice of telecommuting 3: identifying the choice set and estimating binary choice models for technology-based alternatives, *Environment and Planning A*, 28, pp. 1877-1894.

[12] P. L. Mokhtarian and I. Salomon (1997), Modeling the desire to telecommute: the importance of attitudinal factors in behavioral models, *Transportation Research Part A*, 31(1), pp. 35-50.

[13] J. Drucker and A. J. Khattak (2000), Propensity to work from home: modeling results from the 1995 nationwide personal transportation survey, *Transportation Research Record*, 1706, pp. 108-117.

[14] K. Wells, F. Douma, H. Loimer, L. Olson, and C. Pansing (2001), Telecommuting Implications for Travel Behavior: Case Studies from Minnesota, *Transportation Research Record*, 1752, pp. 148–156.

[15] Y. D. Popuri and C. R. Bhat (2003), On modeling choice and frequency of home-based telecommuting, *Transportation Research Record: Journal of the Transportation Research Board*, 1858, pp. 55-60.

[16] W. Tang, P. L. Mokhtarian, S. L. Handy (2008), The role of neighborhood characteristics in the adoption and frequency of working at home: empirical evidence from Northern California, Institute of Transportation Studies, University of California, Davis, Research Report UCD-ITS-RR-08-21.

[17] I. N. Sensor and C. R. Bhat (2011), A copula-based sample selection model of telecommuting choice and frequency, *Environment and Planning A*, 43, pp.126-145.

[18] P. Singh, R. Paleti, S. Jenkins, and C. R. Bhat (2013), On modeling telecommuting behavior: option, choice, and frequency, *Transportation*, 40(2), pp. 373-396.

