ALTERNATIVE WORK ARRANGEMENTS: CURRENT TENDENCIES, MODELING APPROACHES, AND IMPACT ON TRAVEL IN MAJOR METROPOLITAN REGIONS

Peter Vovsha, Parsons Brinckerhoff, New York, NY, USA, 1-212-465-5511, vovsha@PBworld.com

Eric Petersen, Cambridge Systematics, Chicago, IL, USA, 1-312-665-0214, epetersen@camsys.com

ABSTRACT

The paper proposes a conceptual framework and analyses the current tendencies and approaches to modelling work arrangements that affect commuting patterns in major metropolitan regions in US. It is argued that the traditional approach focusing on a "typical" urban commuter — i.e. a full time worker with a fixed workplace to which he or she has to commute every workday according to a fixed schedule — does not reflect the significant changes observed in the dynamic world today. Work arrangements are parameterized across multiple dimensions including full-time vs. part-time status, number of commuting days per week, frequency of telecommuting, schedule flexibility, and others. Previously suggested approaches to modelling more complicated work arrangements are discussed. A general approach for modelling work arrangements in the framework of a regional Activity-Based travel model is suggested. Estimation results are presented based on a rich dataset of more than 14,000 workers obtained from the Household Travel Survey for the Chicago metropolitan region undertaken in 2007. Possible ways to include this model in an activity-based travel model system are discussed.

Keywords: work arrangements, commuting, telecommuting, flexible schedule, activity-based model.

INTRODUCTION

Commuting to work remains the most important travel segment contributing to the growing congestion problem in major metropolitan regions in US, as it tends to be concentrated at peak travel periods. The traditional approach is to focus on "typical" urban commuters, who are full time workers with fixed workplaces and who commute every workday according to a fixed schedule in the peak periods. This paradigm was the cornerstone of the 4-step modelling process and has been largely inherited by the first generation of activity-based models in practice. The paper investigates the evolution of the treatment of alternative work arrangements such as part-time work, self-employment, working from home, telecommuting, and flexible and/or compressed work schedules in travel modelling. These alternative work arrangements have already reached 30%-40% of workers in major metropolitan regions in the US.

On the one hand, alternative work arrangements may help reduce congestion in peak traffic periods (and to a large extent these arrangements already represent travellers' responses to growing congestion). Workers with alternative work arrangements may represent the most elastic travel market that would be responsive to Travel Demand Management policies. However, the impact of this growing share of non-traditional commuters on the total regional Vehicle Mileage has not been yet explored. Conventional travel models do not explicitly distinguish between work arrangement types and do not predict tendencies associated with them. The current paper presents a conceptual approach to introduce a system of models that accounts for this important component in a framework of a regional activity-based model. Some prototype model structures are formulated and estimated based on a large household survey recently completed in the Chicago Metropolitan Region in 2007.

PREVIOSLY REPORTED ANALYSIS

There is a considerable body of literature and interest from both practitioners and researchers with regard to the evolution of work arrangements, leading to some attempts to estimate statistical models that would predict a worker's choice of possible arrangements as a function of person, job, household, and travel characteristics. Most of the research to date has been focused on some particular dimension of work arrangements. For example, introduction of compressed work week where a worker can work less than 5 days a week has received considerable attention since it is viewed as a simple and effective way to reduce commuting traffic [*Hung, 1996; Sundo & Fujii, 2005; Zhou & Winters, 2008*]. Another aspect that has been frequently discussed is telecommuting [*Bagley & Mokhtarian, 1997; Mokhtarian 1997; Krishna et al, 1998; Mokhtarian & Bagley, 2000; Popuri & Bhat, 2003*]. Work from home on a permanent basis has become a frequent phenomenon (7-8% of workers in many metropolitan areas in the U.S.) [*Drucker & Khattak, 2000*]. Work schedule flexibility is considered important for the evaluation of the elasticity of travel demand to congestion pricing and other travel demand management strategies [*Golden, 2001; Yeraguntla & Bhat, 2005*]. The dichotomy of part-time vs. full-time worker status and the

associated impacts on travel patterns is another important dimension for analysis [*Vovsha & Bradley, 2006*; *Yeraguntla & Bhat, 2005*].

The purpose of the current research is to statistically explore the inter-related nature of these different aspects of work arrangements and propose modelling approaches that could be incorporated in the framework of operational activity-based models. With this purpose in mind we further summarize several research works that represent attempts to outline a modelling approach to predict individual work arrangements beyond the full-time/part-time dichotomy.

Yeraguntla & Bhat, 2005 proposed a classification taxonomy for work arrangements. The authors argued that the work activity acts as a peg around which other non-work activity episodes are scheduled. Hence, predicting work-related activities and schedules for each individual should be the first step in the activity-based model chain. However, the actual work activity schedule on any given day is a strong function of the long-term work arrangements of the individual. The authors also explained that while one could argue that work-related decisions are dictated by employers, this misses the point that individuals make career decisions over their lifetime and switch jobs in the medium-to-long term to locate a job with their preferred work arrangement. (The same logic holds true for long-term choices of workplace location relative to home location.)

The analysis in this research is restricted to workers who travel to a distinct out-of-home work location. Thus, the important (and growing) phenomenon of working from home is not covered. The authors define the combination of full-time work, no teleworking, inflexible work schedule and a regular working shift as the "traditional" work arrangement generating the peak temporal concentration of commute trips. Any work arrangement that differs from the traditional one at least by one of the characteristics (i.e. either part-time employment, or some teleworking, or some flexibility in schedule, or alternate shift) is considered as an "alternative" arrangement.

Yeraguntla & Bhat, 2005 estimated separate choice models for three specific dimensions:

1. Binary choice between full-time and part-time status. The most important variables explaining part-time work choice are young age, female gender in households with children, and work for an educational institution.

2. Binary choice between fixed and flexible work schedule. The authors mentioned that according to the May 2001 Current Population Survey in US, almost 30% of full-time workers have flexibility to vary their work start and end times, nearly double the percentage in 1991. Amongst the primary variables explaining a flexible work schedule the authors mention medium-to-senior age, college or higher degree, medium-to-high income, presence of small children in the household, workplace location in CBD or high-density urban area, and later usual start time for work activity (after 9 AM).

3. Binary choice of telecommuting (yes, no) combined with an ordered response choice for the frequency category for those who telecommute. The most important variables explaining higher propensity to telecommute include female presence in households with children, educational attainment of college degree or higher, medium-to-high income group, part-time work status, and working for an educational institution or federal government office.

The authors envision the developed choice models as precursor medium-term choice models to a daily activity-travel pattern model in an activity-based model system. We also share this view and believe that inclusion of an explicit model for work arrangements in an activity-based model system would improve the explanatory power of the subsequent chain of travel-related models. This also would create additional policy levers in the model system useful for testing future scenarios.

Mokhtarian & Bagley, 2000 proposed an approach to model employees' perceptions and proportional preferences of three types of work locations: 1=regular workplace, 2=home, and 3=telecommuting centre. Four generic workplace perception factors were identified (with measures for each of the work locations of interest): personal benefits, work effectiveness, autonomy, and supervisor control. The model suggested by the authors is one of desired (relative) frequency for each workplace location type. Accordingly, discrete choice modelling is still employed here, but using fractional proportions data rather than a 0/1 indicator of single chosen alternative. The authors found an interesting particular effect that is counter-intuitive and contrary to many other studies. Higher educated workers desired to spend a lower percentage of time telecommuting relative to workers with less than a college degree.

Zhou & Winters, 2007 presented an empirical analysis of compressed work week choices based on Washington State Commute Trip Reduction data. They reported that the participation rates in compressed work week arrangements increased steadily from 14.5% in 1993 to 20% in 2005. A multinomial logit model was estimated to analyze the determinants of compressed week choices with the following alternatives:

1. Normal work week (5 days for 40 hours every week).
2. Compressed work week (9 days for 80 hours every two weeks).
3. Compressed work week (4 days for 40 hours every week).
4. Compressed work week (3 days for 36 hours every week).
5. Other Compressed work week schedules.

The authors found that employer's promotion level of the Travel Demand Management program and the number of compressed work week program years (i.e. the longer the program was available to workers) both have a significant positive impact on commuter's decision to participate. They also found that the longer distance from home to work, the higher probability that an individual would chose an alternative work schedule. In addition,

usual commuting mode proved to be correlated with the work week type. In particularly, transit commuters and carpoolers were less interested in compressed work weeks relative to those who drove alone. The causal linkages between commuting mode and work week arrangement remain to be explored, however. It might be that the choice of commuting mode is a consequence of the work arrangement choice rather than a factor determining it.

Employees' decisions to participate in compressed work week programs were also affected by their job titles and their employer's major business types. For all of the business types, employees working in health care had the highest participation rate of working on compressed work week schedules (33.6% in 2005). The only business type that experienced a decrease in compressed work week participation rate for the last 15 years was retail/trade. It was also interesting to see that employees working in the information service / software / technical business, an industry that is expected to have a high proportion of compressed work weeks given the nature of the job and the availability of technology, had the lowest rate (5.5% in 2005). On the other hand, employees working for manufacturing, a business type that is expected to have a low participation rate, had a relatively high participation rate (24.3% in 2005). This suggests that old stereotypes of commuting patterns do not hold anymore in an increasingly dynamic world.

Vovsha & Bradley, 2006 presented an analysis of the proportions between full-time and part-time workers in the labour force in several metropolitan regions in US as well as associated impacts on the regional travel. In general, the share of part-time workers ranges from 10% to 25%. This percent has important implications for the regional travel forecast since an average part-time worker has a much lower commuting rate per workday (56%) compared to full-time workers (86%) and a much shorter commuting distance (9.9 miles) compared to full time workers (13.1 miles). The authors demonstrate that different assumptions regarding percent of part-time workers alone as a factor create a significant leeway (of 10%) in the regional commuting mileage estimate.

The purpose of the current stage of research is to outline a conceptual framework and general approach to modelling work arrangements across all relevant dimensions. These dimensions preferably should be modelled simultaneously in order to account for interdependencies between different dimensions but this may result in a complicated choice structure with hundreds or even thousands of alternatives. A logical hierarchy that puts the associated choices in a manageable sequence is suggested below. The proposed model structure is supported by statistical analysis and first estimation results. The adopted model specification is not final but rather simplified for illustrative purposes.

STATISTICAL EVIDENCE

The recent Chicago Household Travel Survey, conducted in 2007, provides a rich set of 14,315 households of which 8,025 were surveyed for one full travel day and 6,290 were surveyed for two consecutive days. There are 15,960 paid workers in these households (not including volunteers) of which 12,718 are full-time workers (30+ hours a week) and 3,242 part-time workers (less than 30 hours a week). The subsequent analysis is focused on three main dimensions:

- Usual number of workdays per week, ranging from 1 through 7.
- Telecommuting frequency formulated as follows: 1) almost every day, 2) once a week or more, 3) once a month or more, 4) few times a year, 5) once a year, 6) no telecommuting.
- General self-assessment of schedule flexibility that was formulated as follows: 1) no flexibility, 2) some flexibility, 3) free schedule.

After exclusion of workers with item non-response along at least one of these dimensions, we obtained a clean sample of 14,293 workers, of which 11,509 are full-time and 2,784 are part time. Below are three possible 2-way tabulations out of these three dimensions that help substantiate the choice model structure. In these tabulations, green areas correspond to the expected logical tendencies, pink areas correspond to special phenomena, and yellow areas correspond to segments that are "thin" in statistical terms and require aggregation. Tabulation for telecommuting frequency by workday frequency is presented in **Table 1**.

Table 1: Telecommuting Frequency by Workday Frequency

Number of workdays per week	**Telecommuting frequency**						
	1=almost every day	**2=once a week or more**	**3=once a month or more**	**4=Few times a year**	**5=once a year**	**6=no**	**Total**
Full-time workers - number of observations							
1	29	25	9	2	1	84	150
2	14	36	6	0	1	68	125
3	14	91	10	1	0	215	331
4	13	122	18	3	1	433	590
5	119	353	449	190	36	8,124	9,271
6	34	55	22	9	1	719	840
7	24	20	4	5	0	149	202
Total	247	702	518	210	40	9,792	11,509
Full-time workers - % frequency							
1	19.3%	16.7%	6.0%	1.3%	0.7%	56.0%	100.0%
2	11.2%	28.8%	4.8%	0.0%	0.8%	54.4%	100.0%
3	4.2%	27.5%	3.0%	0.3%	0.0%	65.0%	100.0%
4	2.2%	20.7%	3.1%	0.5%	0.2%	73.4%	100.0%
5	1.3%	3.8%	4.8%	2.0%	0.4%	87.6%	100.0%
6	4.0%	6.5%	2.6%	1.1%	0.1%	85.6%	100.0%
7	11.9%	9.9%	2.0%	2.5%	0.0%	73.8%	100.0%
Total	2.1%	6.1%	4.5%	1.8%	0.3%	85.1%	100.0%

Number of workdays per week	Telecommuting frequency						
	1=almost every day	2=once a week or more	3=once a month or more	4=Few times a year	5=once a year	6=no	Total
Part-time workers - number of observations							
1	12	19	6	1	1	144	183
2	14	36	3	5	0	372	430
3	13	47	19	6	1	748	834
4	7	20	4	10	0	468	509
5	10	26	10	6	1	690	743
6	4	2	1	0	0	53	60
7	6	1	0	0	0	18	25
Total	66	151	43	28	3	2,493	2,784
Part-time workers - % frequency							
1	6.6%	10.4%	3.3%	0.5%	0.5%	78.7%	100.0%
2	3.3%	8.4%	0.7%	1.2%	0.0%	86.5%	100.0%
3	1.6%	5.6%	2.3%	0.7%	0.1%	89.7%	100.0%
4	1.4%	3.9%	0.8%	2.0%	0.0%	91.9%	100.0%
5	1.3%	3.5%	1.3%	0.8%	0.1%	92.9%	100.0%
6	6.7%	3.3%	1.7%	0.0%	0.0%	88.3%	100.0%
7	24.0%	4.0%	0.0%	0.0%	0.0%	72.0%	100.0%
Total	2.4%	5.4%	1.5%	1.0%	0.1%	89.5%	100.0%
All workers - number of observations							
1	41	44	15	3	2	228	333
2	28	72	9	5	1	440	555
3	27	138	29	7	1	963	1,165
4	20	142	22	13	1	901	1,099
5	129	379	459	196	37	8,814	10,014
6	38	57	23	9	1	772	900
7	30	21	4	5	0	167	227
Total	313	853	561	238	43	12,285	14,293
All workers - % frequency							
1	12.3%	13.2%	4.5%	0.9%	0.6%	68.5%	100.0%
2	5.0%	13.0%	1.6%	0.9%	0.2%	79.3%	100.0%
3	2.3%	11.8%	2.5%	0.6%	0.1%	82.7%	100.0%
4	1.8%	12.9%	2.0%	1.2%	0.1%	82.0%	100.0%
5	1.3%	3.8%	4.6%	2.0%	0.4%	88.0%	100.0%
6	4.2%	6.3%	2.6%	1.0%	0.1%	85.8%	100.0%
7	13.2%	9.3%	1.8%	2.2%	0.0%	73.6%	100.0%
Total	2.2%	6.0%	3.9%	1.7%	0.3%	86.0%	100.0%

The following conclusions can be made with respect to joint distribution of workers by number of workdays and telecommuting frequency:

- There is a significant logical difference between full-time and part-time workers with respect to number of workdays. While an absolute majority of full time workers work 5 days a week, the distribution by number of workdays for part-time workers is much more uniform.

- There are a small number of workers who reported telecommuting once a year. This category will be combined with the adjacent category of telecommuting few times a year.

- In general, full-time workers telecommute more frequently than part-time workers with the exception for frequent telecommuters (almost every day). This is a special arrangement that is slightly more frequent for part-time workers.

- In general, there is a logical tendency of less frequent telecommuting paired with an increase in the number of workdays for both full-time and part-time workers. However, the tendency is reversed for long work weeks comprised of 6 or 7 workdays. These special arrangements are characterized by more frequent telecommuting.

- There is no significant difference between workday frequency categories 2 and 3. They can be combined to simplify the model structure at this stage.

- Workday frequency categories 6 and 7 represent the same general tendency (longer than usual workweeks). They can also be combined to simplify the choice structure at this stage.

Tabulation for schedule flexibility by workday frequency is presented in **Table 2**.

Table 2: Schedule Flexibility by Workday Frequency

Number of workdays per week	Number of observations by schedule flexibility				% frequency by schedule flexibility			
	1=no flexibility	2=some flexibility	3=free schedule	Total	1=no flexibility	2=some flexibility	3=free schedule	Total
Full-time workers								
1	32	58	60	150	21.3%	38.7%	40.0%	100.0%
2	30	48	47	125	24.0%	38.4%	37.6%	100.0%
3	69	166	96	331	20.8%	50.2%	29.0%	100.0%
4	172	288	130	590	29.2%	48.8%	22.0%	100.0%
5	4,063	4,207	1,001	9,271	43.8%	45.4%	10.8%	100.0%
6	340	342	158	840	40.5%	40.7%	18.8%	100.0%
7	66	76	60	202	32.7%	37.6%	29.7%	100.0%
Total	4,772	5,185	1,552	11,509	41.5%	45.1%	13.5%	100.0%
Part-time workers								
1	42	62	79	183	23.0%	33.9%	43.2%	100.0%
2	114	167	149	430	26.5%	38.8%	34.7%	100.0%
3	212	429	193	834	25.4%	51.4%	23.1%	100.0%
4	140	261	108	509	27.5%	51.3%	21.2%	100.0%
5	287	343	113	743	38.6%	46.2%	15.2%	100.0%
6	17	27	16	60	28.3%	45.0%	26.7%	100.0%
7	6	8	11	25	24.0%	32.0%	44.0%	100.0%
Total	818	1,297	669	2,784	29.4%	46.6%	24.0%	100.0%
All workers								
1	74	120	139	333	22.2%	36.0%	41.7%	100.0%
2	144	215	196	555	25.9%	38.7%	35.3%	100.0%
3	281	595	289	1,165	24.1%	51.1%	24.8%	100.0%
4	312	549	238	1,099	28.4%	50.0%	21.7%	100.0%
5	4,350	4,550	1,114	10,014	43.4%	45.4%	11.1%	100.0%
6	357	369	174	900	39.7%	41.0%	19.3%	100.0%
7	72	84	71	227	31.7%	37.0%	31.3%	100.0%
Total	5,590	6,482	2,221	14,293	39.1%	45.4%	15.5%	100.0%

The following conclusions can be made with respect to joint distribution of workers by number of workdays and schedule flexibility:

- This tabulation, like the previous one, is subject to significant differences between full-time and part-time workers with respect to the number of workdays. While an absolute majority of full time workers work 5 days a week, the distribution by number of workdays for part-time workers is much more uniform.

- In general, full-time workers are characterized by more rigid schedule constraints than part-time workers.

- In general, there is a logical tendency of having a more rigid schedule with growing number of workdays for both full-time and part-time workers. However, the tendency is reversed for long work weeks with 6 or 7 workdays. These special arrangements are characterized by a high percentage of free schedules especially for part-time workers.

Tabulation for schedule flexibility by workday frequency is presented in **Table 3**.

Table 3: Schedule Flexibility by Telecommuting Frequency

Tele-commuting frequency	**Number of observations by schedule flexibility**				**% frequency by schedule flexibility**			
	1=no flexibility	**2=some flexibility**	**3=free schedule**	**Total**	**1=no flexibility**	**2=some flexibility**	**3=free schedule**	**Total**
Full-time workers								
1=almost every day	16	66	165	247	6.5%	26.7%	66.8%	100.0%
2=once a week or more	31	388	283	702	4.4%	55.3%	40.3%	100.0%
3=once a month or more	44	301	173	518	8.5%	58.1%	33.4%	100.0%
4=few times a year	19	134	57	210	9.0%	63.8%	27.1%	100.0%
5=once a year	7	22	11	40	17.5%	55.0%	27.5%	100.0%
6=no	4,655	4,274	863	9,792	47.5%	43.6%	8.8%	100.0%
Total	4,772	5,185	1,552	11,509	41.5%	45.1%	13.5%	100.0%
Part-time workers								
1=almost every day	2	16	48	66	3.0%	24.2%	72.7%	100.0%
2=once a week or more	6	64	81	151	4.0%	42.4%	53.6%	100.0%
3=once a month or more	2	15	26	43	4.7%	34.9%	60.5%	100.0%
4=few times a year	0	13	15	28	0.0%	46.4%	53.6%	100.0%
5=once a year	0	2	1	3	0.0%	66.7%	33.3%	100.0%
6=no	808	1,187	498	2,493	32.4%	47.6%	20.0%	100.0%
Total	818	1,297	669	2,784	29.4%	46.6%	24.0%	100.0%
All workers								
1=almost every day	18	82	213	313	5.8%	26.2%	68.1%	100.0%
2=once a week or more	37	452	364	853	4.3%	53.0%	42.7%	100.0%
3=once a month or more	46	316	199	561	8.2%	56.3%	35.5%	100.0%
4=few times a year	19	147	72	238	8.0%	61.8%	30.3%	100.0%
5=once a year	7	24	12	43	16.3%	55.8%	27.9%	100.0%
6=no	5,463	5,461	1,361	12,285	44.5%	44.5%	11.1%	100.0%
Total	5,590	6,482	2,221	14,293	39.1%	45.4%	15.5%	100.0%

The following conclusions can be made with respect to joint distribution of workers by number of workdays and schedule flexibility:

- Overall, there is a logical tendency for a positive correlation between free schedules and telecommuting frequency for both full-time and part-time workers. The only exception is a special case of very frequent telecommuting (almost every day) that has a relatively high frequency of combination with non-flexible schedules for full-time workers.

- In general, full-time workers are characterized by more rigid schedule constraints than part-time workers for the same telecommuting frequency category.

- There are only a few observed cases for telecommuting part-time workers with no schedule flexibility.

OUTLINE OF CHOICE MODEL DIMENSIONS

The suggested structure of choice models for work arrangements is shown in **Figure 1** below. It includes the following three main components:

- Core characteristics of the modelled population with socio-demographic mix of persons and households including worker occupation. It is currently suggested these characteristics should be generated as part of population synthesis (exogenously to the travel model system). These parameters serve as an important input to the travel modelling procedure. They can only be endogenized in a framework of integrated land-use and transportation model. While general population synthesis procedures have become a routine of travel modelling in US, most of them do not address worker occupation as a controlled variable subject to policy analysis. We assume it is only a matter of time before this becomes more routine. The first successful example of the inclusion of worker occupation in travel models is the San-Diego activity-based model integrated with a PECASS Land-Use model.

- Strategic long-term model for main individual work arrangements. This model should cover such characteristics as full-time vs. part-time worker status, number of jobs (to account for specifics of multiple-job holders), and usual workplace location choice including work from home as a special alternative. Some components of this model that relate to usual workplace location and work from home have been already incorporated in many Activity-Based Models in practice in US. Full-time vs. part-time worker status has not been endogenized yet and is normally treated as uncontrolled variable in population synthesis. Number of jobs has not been explicitly addressed; iin practically all model systems it is assumed by default that every worker can have only one usual workplace.

- Mid-term model that relates to usual commuting frequency and flexibility. Commuting frequency choice incorporates the possibility of a compressed work week. It is logically combined with possible telecommuting frequency. All three dimensions for this choice model are categorized according to the data items available from the Household Travel Survey in the Chicago Metropolitan Region. To date, model development has focus on this component. Estimation results for this model are presented.

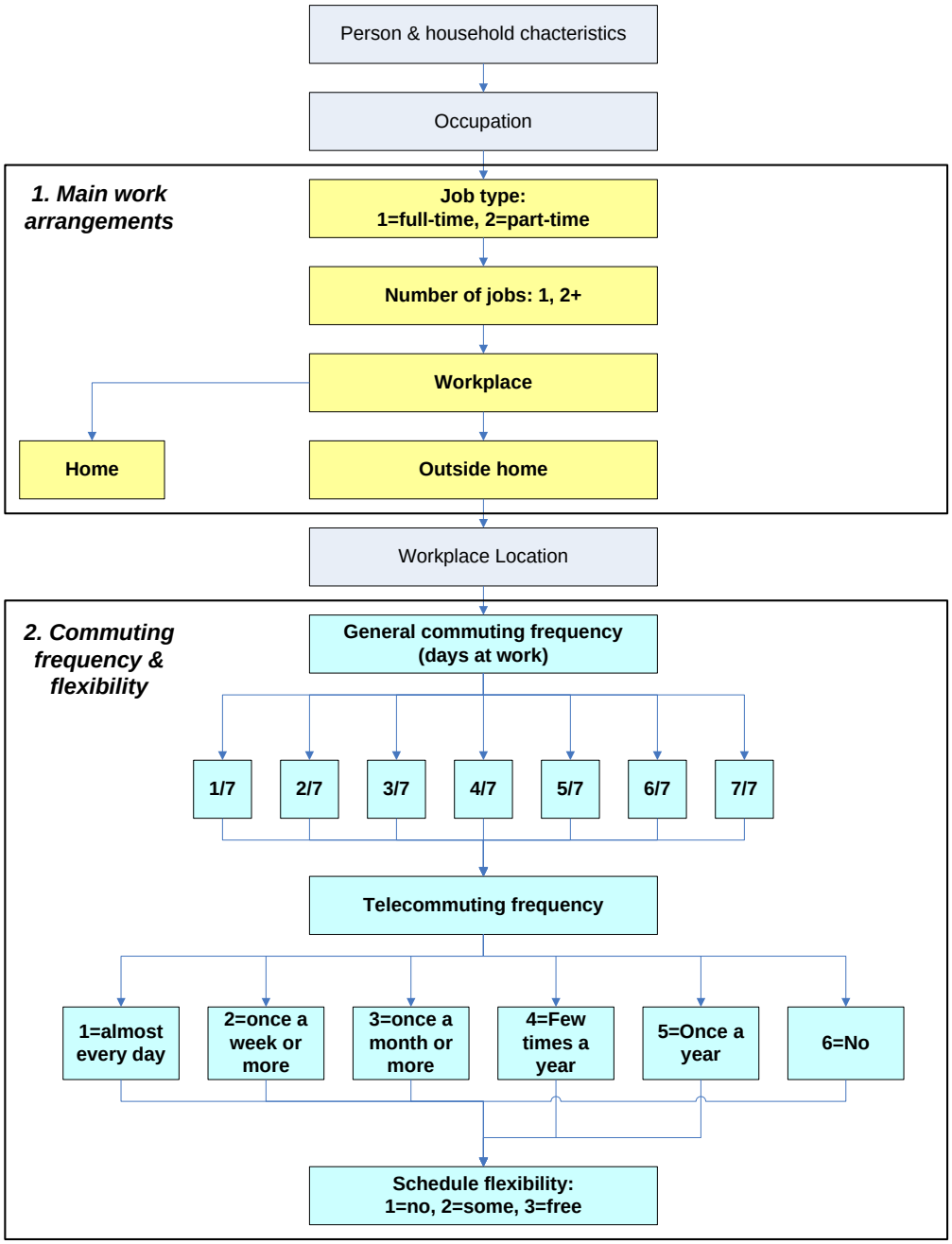

Figure 1: Choice of Work Arrangement Type

After combinations of similar alternatives we obtain a choice structure with 4×5×3=60 alternatives for a full-time worker and 5×5×2=50 alternatives for a part-time worker that is a manageable and convenient vehicle for the current research. The aggregation rules are shown in **Figure 2**.

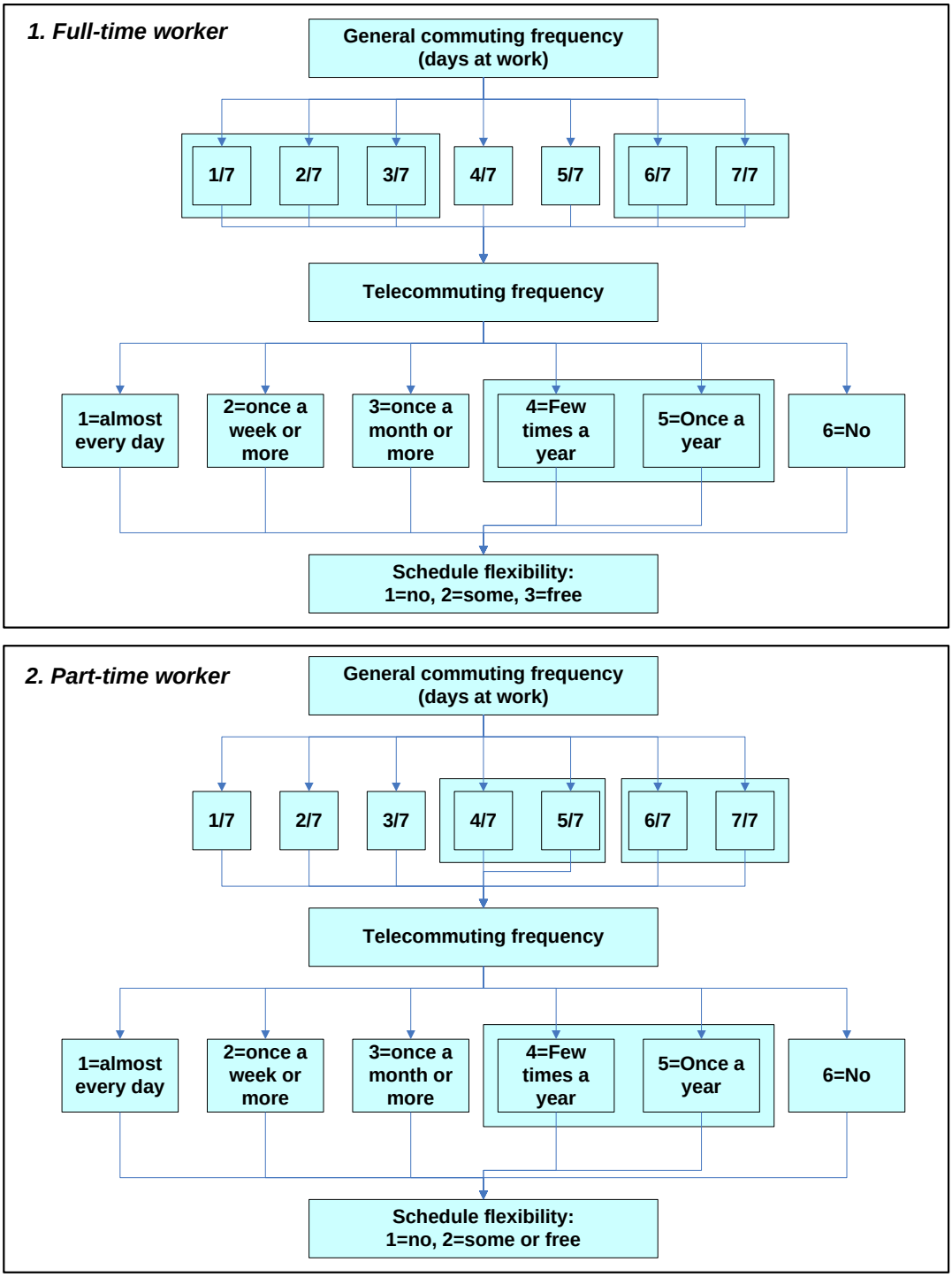

Figure 2: Aggregation of Similar Alternatives

FORMULATION OF CHOICE MODEL AND UTILITY FUNCTIONS

For the current stage of research we adopted a simple multinomial logit (MNL) model for joint choice of commuting frequency, telecommuting frequency, and schedule flexibility applied separately for full-time and part-time workers with the aggregation of alternatives as described in the previous section. We recognize that a simple MNL model may be not the best statistical tool in view of differential similarities across alternatives. However, at this (exploratory) stage of research we preferred to focus on the main effects and variables with a wide range of possible utility functions, and it was most convenient to analyze this with MNL. We plan to apply more elaborate statistical tools to finalize the model structure after the main variables and approximate utility specifications have been identified.

The applied model can be written in the following general way:

$$P_n(c,m,f) = \frac{\exp(V_{ncmf})}{\sum_{d,u,g} \exp(V_{ndug})}, \quad \textbf{(1)}$$

where:

n	=	individual workers,
c,d	=	number of workdays per week category,
m,u	=	telecommuting frequency category,
f,g	=	schedule flexibility category,
V_{ncmf}	=	utility function of joint choice of commuting frequency, telecommuting frequency, and schedule flexibility by the individual,
$P_n(c,m,f)$	=	probability of choosing commuting frequency, telecommuting frequency, and schedule flexibility by the individual.

The utility function is formed in a special component-wise fashion as follows:

$$V_{ncmf} = W_{nc} + T_{nm} + S_{nf} + WT_{cm} + WS_{cf} + TS_{mf}, \quad \textbf{(2)}$$

where:

W_{nc}	=	individual utility with respect to number of workdays,
T_{nm}	=	individual utility with respect to telecommuting,
S_{nf}	=	individual utility with respect to schedule flexibility,
WT_{cm}	=	interaction between number of workdays and telecommuting frequency,
WS_{cf}	=	interaction between number of workdays and schedule flexibility,
TS_{mf}	=	interaction between telecommuting frequency and schedule flexibility,

Three major components designated by single letters correspond to the main choice dimensions (number of workdays, frequency of telecommuting, and schedule flexibility). Most of the person, household, and zonal variables enter one or several of the main utility

components. In addition to the main components, and in order to take into account correlations between the main choice dimensions, interaction terms (designated by double letters) are introduced for each possible pair of dimensions and tested statistically for significance. At this stage, the interaction terms are not parameterized by individual variables. The choice model does not have "flat" three-dimensional alternative-specific constants. All constants are either one-dimensional (as part of main components) or two-dimensional (as interaction terms) that makes the model more behaviourally appealing, although the introduction of three-dimensional constants would improve the statistical fit (at the risk of over-specifying the model).

Without the interaction terms the joint choice model could be decomposed into three independent choice models by dimensions that could be estimated separately. The interaction terms keep the model together and require joint estimation. To avoid redundancy in the model estimation, in each dimension, one of the categories (the first one) is chosen as the reference case with the corresponding utility term set to zero.

The structure of utility functions for each alternative is shown in detail in **Table 4** for a full-time worker and in **Table 5** for a part-time worker.

Table 4: Structure of Utility Function for Full-Time Worker

Alternative				**Main components**			**Interaction terms**		
#	**Work days**	**Tele-com**	**Schedule flex**	**Work days**	**Telecommute frequency**	**Schedule flexibility**	**Work days by telecom**	**Work days by schedule flexibility**	**Telecom by schedule flexibility**
111	1-3	1	1	Ref.	Ref.	Ref.	Reference	Reference	Reference
112	1-3	1	2	Ref.	Ref.	S(2)	Reference	WS(12)	TS(12)
113	1-3	1	3	Ref.	Ref.	S(3)	Reference	WS(13)	TS(13)
121	1-3	2	1	Ref.	T(2)	Ref.	WT(12)	Reference	Reference
122	1-3	2	2	Ref.	T(2)	S(2)	WT(12)	WS(12)	TS(22)
123	1-3	2	3	Ref.	T(2)	S(3)	WT(12)	WS(13)	TS(23)
131	1-3	3	1	Ref.	T(3)	Ref.	WT(13)	Reference	Reference
132	1-3	3	2	Ref.	T(3)	S(2)	WT(13)	WS(12)	TS(32)
133	1-3	3	3	Ref.	T(3)	S(3)	WT(13)	WS(13)	TS(33)
141	1-3	4-5	1	Ref.	T(4)	Ref.	WT(14)	Reference	Reference
142	1-3	4-5	2	Ref.	T(4)	S(2)	WT(14)	WS(12)	TS(42)
143	1-3	4-5	3	Ref.	T(4)	S(3)	WT(14)	WS(13)	TS(43)
161	1-3	6	1	Ref.	T(6)	Ref.	WT(16)	Reference	Reference
162	1-3	6	2	Ref.	T(6)	S(2)	WT(16)	WS(12)	TS(62)
163	1-3	6	3	Ref.	T(6)	S(3)	WT(16)	WS(13)	TS(63)
411	4	1	1	W(4)	Ref.	Ref.	Reference	Reference	Reference
412	4	1	2	W(4)	Ref.	S(2)	Reference	WS(42)	TS(12)
413	4	1	3	W(4)	Ref.	S(3)	Reference	WS(43)	TS(13)
421	4	2	1	W(4)	T(2)	Ref.	WT(42)	Reference	Reference
422	4	2	2	W(4)	T(2)	S(2)	WT(42)	WS(42)	TS(22)
423	4	2	3	W(4)	T(2)	S(3)	WT(42)	WS(43)	TS(23)
431	4	3	1	W(4)	T(3)	Ref.	WT(43)	Reference	Reference
432	4	3	2	W(4)	T(3)	S(2)	WT(43)	WS(42)	TS(32)
433	4	3	3	W(4)	T(3)	S(3)	WT(43)	WS(43)	TS(33)
441	4	4-5	1	W(4)	T(4)	Ref.	WT(44)	Reference	Reference
442	4	4-5	2	W(4)	T(4)	S(2)	WT(44)	WS(42)	TS(42)
443	4	4-5	3	W(4)	T(4)	S(3)	WT(44)	WS(43)	TS(43)
461	4	6	1	W(4)	T(6)	Ref.	WT(46)	Reference	Reference
462	4	6	2	W(4)	T(6)	S(2)	WT(46)	WS(42)	TS(62)
463	4	6	3	W(4)	T(6)	S(3)	WT(46)	WS(43)	TS(63)

Alternative				Main components			Interaction terms		
#	Work days	Tele-com	Schedule flex	Work days	Telecommute frequency	Schedule flexibility	Work days by telecom	Work days by schedule flexibility	Telecom by schedule flexibility
511	5	1	1	W(5)	Ref.	Ref.	Reference	Reference	Reference
512	5	1	2	W(5)	Ref.	S(2)	Reference	WS(52)	TS(12)
513	5	1	3	W(5)	Ref.	S(3)	Reference	WS(53)	TS(13)
521	5	2	1	W(5)	T(2)	Ref.	WT(52)	Reference	Reference
522	5	2	2	W(5)	T(2)	S(2)	WT(52)	WS(52)	TS(22)
523	5	2	3	W(5)	T(2)	S(3)	WT(52)	WS(53)	TS(23)
531	5	3	1	W(5)	T(3)	Ref.	WT(53)	Reference	Reference
532	5	3	2	W(5)	T(3)	S(2)	WT(53)	WS(52)	TS(32)
533	5	3	3	W(5)	T(3)	S(3)	WT(53)	WS(53)	TS(33)
541	5	4-5	1	W(5)	T(4)	Ref.	WT(54)	Reference	Reference
542	5	4-5	2	W(5)	T(4)	S(2)	WT(54)	WS(52)	TS(42)
543	5	4-5	3	W(5)	T(4)	S(3)	WT(54)	WS(53)	TS(43)
561	5	6	1	W(5)	T(6)	Ref.	WT(56)	Reference	Reference
562	5	6	2	W(5)	T(6)	S(2)	WT(56)	WS(52)	TS(62)
563	5	6	3	W(5)	T(6)	S(3)	WT(56)	WS(53)	TS(63)
611	6-7	1	1	W(6)	Ref.	Ref.	Reference	Reference	Reference
612	6-7	1	2	W(6)	Ref.	S(2)	Reference	WS(62)	TS(12)
613	6-7	1	3	W(6)	Ref.	S(3)	Reference	WS(63)	TS(13)
621	6-7	2	1	W(6)	T(2)	Ref.	WT(62)	Reference	Reference
622	6-7	2	2	W(6)	T(2)	S(2)	WT(62)	WS(62)	TS(22)
623	6-7	2	3	W(6)	T(2)	S(3)	WT(62)	WS(63)	TS(23)
631	6-7	3	1	W(6)	T(3)	Ref.	WT(63)	Reference	Reference
632	6-7	3	2	W(6)	T(3)	S(2)	WT(63)	WS(62)	TS(32)
633	6-7	3	3	W(6)	T(3)	S(3)	WT(63)	WS(63)	TS(33)
641	6-7	4-5	1	W(6)	T(4)	Ref.	WT(64)	Reference	Reference
642	6-7	4-5	2	W(6)	T(4)	S(2)	WT(64)	WS(62)	TS(42)
643	6-7	4-5	3	W(6)	T(4)	S(3)	WT(64)	WS(63)	TS(43)
661	6-7	6	1	W(6)	T(6)	Ref.	WT(66)	Reference	Reference
662	6-7	6	2	W(6)	T(6)	S(2)	WT(66)	WS(62)	TS(62)
663	6-7	6	3	W(6)	T(6)	S(3)	WT(66)	WS(63)	TS(63)

Table 5: Structure of Utility Function for Part-Time Worker

Alternative				Main components			Interaction terms		
#	Work days	Tele-com	Schedule flex	Work days	Telecommute frequency	Schedule flexibility	Work days by telecom	Work days by schedule flexibility	Telecom by schedule flexibility
111	1	1	1	Ref.	Ref.	Ref.	Reference	Reference	Reference
112	1	1	2-3	Ref.	Ref.	S(2)	Reference	WS(12)	TS(12)
121	1	2	1	Ref.	T(2)	Ref.	WT(12)	Reference	Reference
122	1	2	2-3	Ref.	T(2)	S(2)	WT(12)	WS(12)	TS(22)
131	1	3	1	Ref.	T(3)	Ref.	WT(13)	Reference	Reference
132	1	3	2-3	Ref.	T(3)	S(2)	WT(13)	WS(12)	TS(32)
141	1	4-5	1	Ref.	T(4)	Ref.	WT(14)	Reference	Reference
142	1	4-5	2-3	Ref.	T(4)	S(2)	WT(14)	WS(12)	TS(42)
161	1	6	1	Ref.	T(6)	Ref.	WT(16)	Reference	Reference
162	1	6	2-3	Ref.	T(6)	S(2)	WT(16)	WS(12)	TS(62)
211	2	1	1	W(2)	Ref.	Ref.	Reference	Reference	Reference
212	2	1	2-3	W(2)	Ref.	S(2)	Reference	WS(22)	TS(12)
221	2	2	1	W(2)	T(2)	Ref.	WT(22)	Reference	Reference
222	2	2	2-3	W(2)	T(2)	S(2)	WT(22)	WS(22)	TS(22)
231	2	3	1	W(2)	T(3)	Ref.	WT(23)	Reference	Reference
232	2	3	2-3	W(2)	T(3)	S(2)	WT(23)	WS(22)	TS(32)
241	2	4-5	1	W(2)	T(4)	Ref.	WT(24)	Reference	Reference
242	2	4-5	2-3	W(2)	T(4)	S(2)	WT(24)	WS(22)	TS(42)

Alternative				Main components			Interaction terms		
#	Work days	Tele-com	Schedule flex	Work days	Telecommute frequency	Schedule flexibility	Work days by telecom	Work days by schedule flexibility	Telecom by schedule flexibility
261	2	6	1	W(2)	T(6)	Ref.	WT(26)	Reference	Reference
262	2	6	2-3	W(2)	T(6)	S(2)	WT(26)	WS(22)	TS(62)
311	3	1	1	W(3)	Ref.	Ref.	Reference	Reference	Reference
312	3	1	2-3	W(3)	Ref.	S(2)	Reference	WS(32)	TS(12)
321	3	2	1	W(3)	T(2)	Ref.	WT(32)	Reference	Reference
322	3	2	2-3	W(3)	T(2)	S(2)	WT(32)	WS(32)	TS(22)
331	3	3	1	W(3)	T(3)	Ref.	WT(33)	Reference	Reference
332	3	3	2-3	W(3)	T(3)	S(2)	WT(33)	WS(32)	TS(32)
341	3	4-5	1	W(3)	T(4)	Ref.	WT(34)	Reference	Reference
342	3	4-5	2-3	W(3)	T(4)	S(2)	WT(34)	WS(32)	TS(42)
361	3	6	1	W(3)	T(6)	Ref.	WT(36)	Reference	Reference
362	3	6	2-3	W(3)	T(6)	S(2)	WT(36)	WS(32)	TS(62)
411	4-5	1	1	W(4)	Ref.	Ref.	Reference	Reference	Reference
412	4-5	1	2-3	W(4)	Ref.	S(2)	Reference	WS(42)	TS(12)
421	4-5	2	1	W(4)	T(2)	Ref.	WT(42)	Reference	Reference
422	4-5	2	2-3	W(4)	T(2)	S(2)	WT(42)	WS(42)	TS(22)
431	4-5	3	1	W(4)	T(3)	Ref.	WT(43)	Reference	Reference
432	4-5	3	2-3	W(4)	T(3)	S(2)	WT(43)	WS(42)	TS(32)
441	4-5	4-5	1	W(4)	T(4)	Ref.	WT(44)	Reference	Reference
442	4-5	4-5	2-3	W(4)	T(4)	S(2)	WT(44)	WS(42)	TS(42)
461	4-5	6	1	W(4)	T(6)	Ref.	WT(46)	Reference	Reference
462	4-5	6	2-3	W(4)	T(6)	S(2)	WT(46)	WS(42)	TS(62)
611	6	1	1	W(6)	Ref.	Ref.	Reference	Reference	Reference
612	6	1	2-3	W(6)	Ref.	S(2)	Reference	WS(62)	TS(12)
621	6	2	1	W(6)	T(2)	Ref.	WT(62)	Reference	Reference
622	6	2	2-3	W(6)	T(2)	S(2)	WT(62)	WS(62)	TS(22)
631	6	3	1	W(6)	T(3)	Ref.	WT(63)	Reference	Reference
632	6	3	2-3	W(6)	T(3)	S(2)	WT(63)	WS(62)	TS(32)
641	6	4-5	1	W(6)	T(4)	Ref.	WT(64)	Reference	Reference
642	6	4-5	2-3	W(6)	T(4)	S(2)	WT(64)	WS(62)	TS(42)
661	6	6	1	W(6)	T(6)	Ref.	WT(66)	Reference	Reference
662	6	6	2-3	W(6)	T(6)	S(2)	WT(66)	WS(62)	TS(62)

ESTIMATION RESULTS

The results of the estimation are reported in Tables 6 (full-time workers) and 7 (part-time workers). The reference categories are suppressed. For the full-time worker model, this represents Workday = 1 (1 workday per week), Telecommuting frequency = 1 (almost every day) and Schedule flexibility = 1 (no flexibility). The reference categories are the same for the part-time worker model, though it is worth noting that the residual schedule flexibility category is a combined category representing “some flexibility” and free schedule. T-ratios are reported beneath the coefficients. The interaction terms between the categories are only reported in the first category in which they appear rather than reporting the results as a full matrix.

Table 6: Results of estimation for full-time workers

	Work days			Telecommuting frequency				Schedule flexibility	
	4	5	6-7	2	3	4-5	6	2	3
Constant term	0.163	1.766	0.459	0.385	-1.000	-2.324	4.499	1.151	2.494
	1.3	13.2	2.7	3.0	-3.6	-5.1	22.2	5.4	12.7
Age 55+	0.120	0.120		-0.393	-0.528				0.373
	1.7	1.7		-2.3	-2.9				5.5
Male			0.757		0.340	0.258		0.125	0.393
			10.1		3.5	1.9		3.0	6.1
Female and preschool children in HH		-0.392	-0.392						
		-3.1	-3.1						
No children in hh	0.132	0.132				0.264	0.264		
	2.2	2.2				4.1	4.1		
0 vehicles in HH	-0.420	-0.420	-0.420	-0.567	-0.567	-0.285	-0.285	0.482	0.750
	-1.7	-1.7	-1.7	-2.2	-2.2	-1.9	-1.9	3.6	3.9
Car insufficiency in hh		0.253	0.395		-0.323	-0.357	-0.384		-0.270
		2.7	3.3		-2.2	-1.8	-4.0		-3.1
College education	-0.352		-0.685				-0.855	0.420	0.291
	-4.0		-9.6				-12.2	9.7	4.2
Employed in government sector	-0.729	-0.593	-0.835	0.901	0.901	0.901	0.901	-0.398	-0.674
	-3.4	-4.5	-4.6	2.6	2.6	2.6	2.6	-5.7	-5.6
Employed in manufacturing sector	0.345	0.345	0.484		0.487	0.532	0.419		-0.375
	2.1	2.1	2.6		2.7	2.4	3.2		-3.8
Employed in health sector	0.342	-0.839	-0.528				0.683	0.221	0.378
	2.4	-7.3	-3.5				6.8	3.3	3.7
High income household	-0.321	-0.321	-0.485	0.463	0.756	0.392	-0.222	0.186	0.283
	-3.7	-3.7	-4.4	3.1	4.7	2.1	-1.6	4.1	4.0
Distance to work (log)	0.099	0.041	-0.049		0.060	0.238	0.047		-0.069
	3.7	2.4	-2.4		1.9	2.4	3.7		-5.9
Interaction with telecommuting cat. 3		1.831	1.154						
		12.5	2.7						
Interaction with telecommuting cat. 4		2.542							
		7.3							
Interaction with telecommuting cat. 6		1.710	0.794						
		19.0	6.5						
Interaction with flexibility cat. 2		-0.376	-0.337	1.191	0.596	0.508	-1.248		
		-4.8	-3.2	7.3	2.3	1.7	-6.2		
Interaction with flexibility cat. 3	-0.492	-1.169	-0.496		-0.614	-0.952	-3.570		
	-3.7	-10.0	-3.4		-2.6	-3.4	-22.1		

Table 7: Results of estimation for part-time workers

	Work days				Telecommuting frequency				Schedule flexibility
	2	3	4-5	6-7	2	3	4-5	6	2-3
Constant term	1.683	2.385	2.266	2.120	0.582	-0.656	-0.366	3.784	0.953
	5.5	7.8	7.1	5.6	3.0	-2.3	-1.1	20.4	11.1
Age 55+	-0.374	-0.374	-0.374	-0.374					0.311
	-2.4	-2.4	-2.4	-2.4					3.4
Male				0.793		-1.215			-0.149
				3.5		-2.5			-1.7
Female and preschool children in HH			-0.298					-0.520	
			-2.1					-2.9	
0 vehicles in HH				1.040					
				3.3					
Car insufficiency in hh					0.532	0.532			
					3.3	3.3			
College education	-0.442	-0.442	-0.700	-1.533			-1.219	-1.219	-0.214
	-2.7	-2.7	-4.2	-5.0			-8.4	-8.4	-2.5
Employed in government sector		0.715	0.715						-0.706
		3.0	3.0						-4.1
Employed in manufacturing sector									1.041
									3.7
Employed in health sector	-0.401	-0.401	-0.864	-0.864		-0.847	-2.015		0.201
	-2.3	-2.3	-4.7	-4.7		-1.8	-2.0		1.8
High income household			-0.379	-0.379				-0.365	
			-4.1	-4.1				-2.8	
Distance to work (log)					0.175	0.106	0.106	0.118	
					3.2	1.7	1.7	2.8	
Interaction with workday cat. 1								0.578	
								2.0	
Interaction with telecommuting cat. 2			-0.891						
			-2.8						
Interaction with telecommuting cat. 6			1.103	-1.436					
			4.0	-5.2					
Interaction with flexibility cat. 2				-1.613	0.972	0.857	1.057	-0.398	
				-6.3	3.7	2.2	2.4	-4.6	

The results appear sensible with a few unusual findings, particularly for the part-time worker model, which was estimated on a smaller sample. Men are more likely to be working 6 or 7 days a week than women, both for full-time and part-time workers. Female workers with preschool aged children present in the household are less likely to work a full schedule. For full-time workers, women with young children were less likely to work 5+ days. This impact was only significant for 5 days (not 6+ days) for part-time workers, though the male coefficient for 6-7 days is larger in the part-time model.

Full-time government workers were less likely to telecommute (the reference being telecommuting every day). The impact of this coefficient was almost twice as large as being in manufacturing. Employment in the health care sector also tended to discourage telecommuting, consistent with others' findings.

Older full-time workers seemed to either telecommute a lot or a little with only the intermediate categories 2 and 3 being reduced for workers 55+. Interestingly, older full-time workers were more likely to report they had a free schedule. High income individuals were relatively unlikely to never telecommute (category 6). College education and beyond had an even stronger negative impact on never telecommuting. College educated full-time workers tended to have some work flexibility, followed by a free schedule as the second most common response. This finding is reversed for part-time workers, which calls for further investigation.

Interaction constants reflect the strong correlation patterns across different pairs of dimensions. These effects also prove to be specific to full-time and part-time workers. With respect to correlation between number of workdays and telecommuting frequency, for full-time workers, there is a clear negative correlation between them. Full-time workers who have to work 5, 6, or 7 days a week do not telecommute frequently. For part-time workers, the effect is obscure with a clear tendency for rare telecommuting for those who work 5 days a week with somewhat reversed trend for those who work 6-7 days. The last group is very small though and may relate to very special occupation types (working only several hours a day but 6-7 days a week) that assume some form of telecommuting (or working from home periodically). With respect to the correlation between number of workdays and schedule flexibility, there is a quite clear and logical negative correlation for both full-time and part-time workers. Those who work 5, 6, or 7 days a week have generally reported lower schedule flexibility. Stated otherwise, workers who have schedule flexibility tend to take advantage of it and not to commute every day. This is quite obvious for part-time workers. For full-time workers, this is a manifestation of a compressed schedule (for example, working 4 days / 10 hours each day instead of working 5 days / 8 hours each day) that becomes more and more common in major metropolitan areas in US. Finally, with respect to correlation between telecommuting frequency and schedule flexibility, there is a strong positive correlation for both groups of workers. In other words, in most cases the ability to telecommute is directly associated with schedule flexibility while those workers who have inflexible schedules normally commute to workplaces rather than telecommute. This effect proved to be especially strong for full time workers who reported full schedule flexibility. Most of them telecommute at least occasionally.

POSSIBLE PLACEMENT IN ACTIVITY-BASED MODEL SYSTEM

We envision the work arrangement models to be included in operational ABM systems. In a general way, an ABM system can be characterized by the following cascade of choices as shown in **Figure 3**.

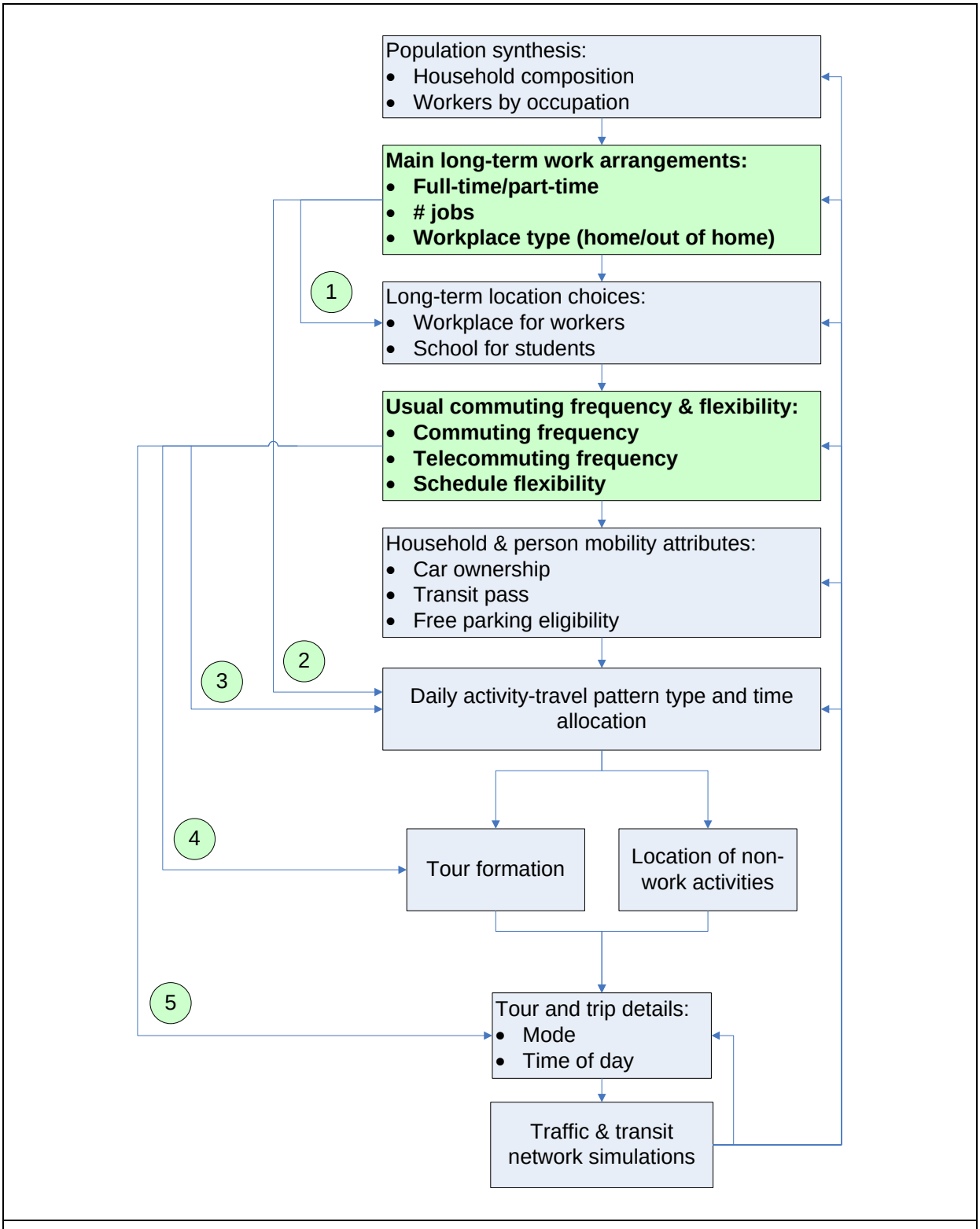

Figure 3: Possible Placement of Work Arrangement Models in ABM System

The proposed models have a natural placement in the ABM structure within the following sequence of models conditional upon each other:

- Population synthesizer that creates a list of households and persons in each zone; in the context of work arrangements it is beneficial to include occupation for each worker as an important attribute that is correlated with work arrangements.

- Main long-term work arrangements (a new model discussed in the current paper) that would give the most general characteristics of each worker like full-time vs. part-time status, number of jobs, and work from home on a permanent basis vs. having a usual workplace out of home.

- Long-term location choices including workplace for each worker and school for each student.

- Usual commuting frequency and flexibility (a new model discussed in the current paper) that would predict commuting frequency, telecommuting frequency, and general schedule flexibility for each worker.

- A model that predicts individual mobility attributes like household car ownership, person transit pass holding, eligibility for free parking at the workplace, etc.

- Choice of general household and person daily activity-travel pattern and associated time allocation.

- Interlinked models that predict tour structure and location of activities (tour primary destination and intermediate stops); different model structures are possible here including a model that generates tours and then locates their primary destination and stops or a model that would locate activities first and then form tours. Activity scheduling process can also come into play at this stage in different forms.

- Choices associated with tour-level and trip-level details such as mode and time of day, i.e. departure and (preferred) arrival time for each tour and trip.

- Traffic and transit simulations of trips in the networks. These simulations also provide transportation level-of-service variables that are fed back to different model components in the model application for equilibration.

Addition of the two models described in the current paper would specifically enhance the following travel choice models (depicted as major impacts 1-5 in **Figure 3**):

1. An explicit accounting for main work arrangements would enhance the workplace location choice. For example, part-time workers and multiple-job holders are characterized by significantly shorter commuting distance compared to conventional full-time workers with a single job. Work from home represents a special case that is largely a long-term life-style decision that has to be singled out from the general workplace location choice framework.

2. Main work arrangements have also a direct impact on individual daily activity-travel patterns and time allocation. For example, part-time workers have a very different

pattern compared to full-time workers in terms of proportion between work and non-work activity episodes and durations (highly biased towards non-work activities for part-timers). Work from home on a permanent basis creates a very specific pattern with a larger share of chained non-work travel (in absence of regular commuting).

3. Usual commuting frequency and flexibility is an important determinant of the daily activity-travel pattern of individual. Traditional workers are characterized by a high commuting frequency (daily), low telecommuting frequency, and low schedule flexibility. For this population segment, a typical workday pattern with a low frequency of additional non-work tours is mostly observed since the commuting tour takes the lion share of time budget on a regular workday. Contrary to that, the growing segment of workers with alternative work arrangements like non-daily commuting, frequent telecommuting, and flexible schedules is characterized by a variety of daily patterns and high propensity to implement additional non-work tours.

4. Usual commuting frequency and flexibility has a specific impact on tour formation. In particular, for traditional daily commuters with inflexible schedules, it is more common to add stops to the inbound (return) commuting leg while activities before work are mostly bound to short stops for dropping-off passengers. Workers with flexible work arrangements are characterized by higher degree of variation with respect to commuting tour structure and wider trade-offs between pre-work and post-work activities on the work tour vs. implemented from home.

5. Usual commuting frequency and flexibility may have specific impacts on mode choice and time of day choice. For example, daily commuters with fixed schedules are the most transit-oriented (and normally take advantage of a monthly transit pass) while non-daily and flex-time commuters are biased towards auto. Fixed-schedule commuters also value travel time reliability more and (all else being equal) are willing to pay more for reliable travel modes like rail transit or dynamically-priced toll roads. Interestingly their value of mean time might be relatively low since they may use commuting time productively (at least rail commuters). Flexible-schedule commuters might exhibit a lower value of reliability in combination with higher value of mean time in view of their busier and more varied travel patterns.

CONCLUSIONS

Commuting to work remains the most important travel segment contributing to the growing congestion problem in major metropolitan regions in US. Understanding and modelling commuting patterns require detailed analysis of the work arrangements that actually generate the observed commuting travel patterns. The conceptual analysis of the existing approaches as well as the concurrent statistical analysis we conducted utilising the recent Household Travel Survey in the Chicago metropolitan region can be summarized along the following logical lines and aspects:

Understanding principal changes in commuting patterns. It is argued that the traditional view of the" typical" urban commuter is of a full time worker with a fixed workplace to which she or he must commute every workday according to a fixed schedule and presumably in the peak hours does not reflect the significant changes observed in the dynamic world today. There is a growing share of full and partial telecommuters, a growing share and variety of compressed work weeks, a significant share of jobs with at least partial schedule flexibility, etc. This makes it important to properly incorporate the wide range of work arrangements in travel demand models including both direct impacts on commuting travel and indirect impact on non-work travel.

Incorporation of work arrangements component in travel demand models. Work arrangements are parameterized across multiple dimensions including full-time vs. part-time status, number of commuting days per week, frequency of telecommuting, schedule flexibility, and others. A general approach for modelling work arrangements in the framework of a regional Activity-Based travel model is suggested by means of additional choice models that are envisioned as a long-term and mid-term components preceding daily activity-travel pattern model. Making work arrangements an explicit choice in the travel model system would substantially improve the subsequent models for travel choices that would benefit from additional explanatory variables representing work arrangements. A spectrum of travel choice models from daily activity travel pattern choice to mode choice would be among immediate beneficiaries since work arrangements may have a strong impact on these choices. This also creates useful policy levers for testing different future scenarios (for example, policies promoting compressed work weeks and telecommuting). Estimation results for a prototype model for work arrangements are presented based on a rich dataset of more than 14,000 workers from the Household Travel Survey for the Chicago metropolitan region undertaken in 2007. These results show that a model of this type is viable.

Impact on regional travel and possible policy implications. A complete travel demand model system with an explicit modelling of work arrangements has yet to be developed. This model system could be used as a vehicle for further research that would address the range of possible travel impacts and policies. In particular, flexible work arrangements may induce additional travel for non-work purposes as well as joint travel due to a better possibility for synchronization of schedules with the other household members. Taking into account the generally smaller transit share for non-work travel compared to work commute tours, the consequences of the growing number of alternative work arrangements for the regional Vehicle Miles Travelled remains unclear. Spatial and temporal distribution of work trips and the entire regional balance of labour force and jobs could be significantly improved by a proper segmentation by work arrangement type. This structural analysis is not yet in the transportation planning and modelling culture. Development of travel modelling tools that would endogenize work arrangements would be a good first step to move this culture towards more elaborate structural analysis of labour force and jobs with the subsequent implications for both work commute and non-work travel. It is difficult to exactly predict tendencies in a dynamic world where new communication technologies provide effective options like telecommuting that may not have been fully practical before. However, inclusion of this model in an explicit way (rather than through reduced work commuting rates in the

daily activity-travel pattern) would allow for testing specific scenarios associated with an expected growth in telecommuting.

REFERENCES

Bagley, N.M., and P.L. Mokhtarian (1997) Analysing the Preference for Non-Exclusive Forms of Telecommuting: Modeling and Policy Implications, Transportation, 24 (3), 203-226.

Drucker, J., and A.J. Khattak (2000) Propensity to Work from Home – Modeling Results from the 1995 Nationwide Personal Transportation Survey, Transportation Research Record 1706, 108-117.

Golden, L. (2001) Flexible Work Schedules: What are We Trading off to Get Them? Monthly Labor Review, Bureau of Labor Statistics, U.S. Department of Labor, Vol.124(3), 50-67.

Hung, R (1996) Use Compress Work Weeks to Reduce Work Commuting, Transportation Research Part A, 30(1), 11-19.

Krishna, V., C.I. Ho, D.M Stanek., and P.L. Mokhtarian. (1998) Duration and Frequency of telecenter Use: Once a Telecommuter, Always a Telecommuter? Transportation Research Part C, 6(1/2), 47-68.

Mokhtarian, P.L. (1997) The Transportation Impacts of Telecommuting: Recent Empirical Findings. In Understanding Travel Behaviour in an Era of Change, eds. P. Stopher and M. Lee-Gosselin. Oxford, UK: Pergamon.

Mokhtarian, P.L. and M.N. Bagley (2000) Modeling Employees' Perceptions and Proportional Preferences of Work Locations: The regular Workplace and Telecommuting Alternatives, Transportation Research Part A, 34, 223-242.

Popuri, Y.D., and C.R Bhat (2003) On Modeling Choice of Frequency of Home-Based Telecommuting, Transportation Research Record 1858, 55-60.

Sundo, M., and S. Fujii (2005) The Effects of a Compressed Working Week on Commuters' Daily Activity Patterns, Transportation Research A, 39 (10), 835-848.

Vovsha, P., and M. Bradley (2006) Advanced Activity-Based Models in Context of Planning Decisions, Transportation Research Record 1981, Washington, D.C., 34-41.

Yeraguntla, A. and C.R. Bhat (2005) A Classification Taxonomy and Empirical Analysis of Work Arrangements, Transportation Research Record 1926, 233-241.

Zhou, L. and P. Winters (2008) An Empirical Analysis of Compressed Work Week Choices Based on Washington State Commute Trip Reduction Data. Presented at the Annual Meeting of the Transportation Research Board (CD-ROM).