# Work Schedule Arrangements in Two-Adult Households with Children 

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# Work Schedule Arrangements in Two-Adult Households with Children 

PROEFSCHRIFT

ter verkrijging van de graad van doctor aan de Technische Universiteit Eindhoven, op gezag van de rector magnificus, prof.dr.ir. F.P.T. Baaijens, voor een commissie aangewezen door het College voor

Promoties in het openbaar te verdedigen op woensdag 30 november 2022 om 11.00 uur
door

## Bilin Han

geboren te Hebei, China

Dit proefschrift is goedgekeurd door de promotoren en de samenstelling van de promotiecommissie is als volgt:

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|  | prof. dr. F. Witlox (Ghent University) |

Het onderzoek of ontwerp dat in dit proefschrift wordt beschreven is uitgevoerd in overeenstemming me de TU/e Gedragscode Wetenschapsbeoefening.

## Work Schedule Arrangements in Two-Adult Households with Children

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## Summary

## Work schedule arrangements in two-adult households with children

It is well known that daily work schedule arrangements considerably influence traffic flows and therefore traffic jams, especially during the morning and evening peak hours. In travel behavior research, work schedule arrangements also play an important role in individual/household daily time use and task allocation. Although several studies addressed the topic of individual/household work schedule arrangements from the perspective of model development, existing modeling approaches still need further development.

The aim of this PhD dissertation, therefore, is to contribute to the understanding of the formation of work arrangements by developing a new approach of modeling weekly work schedule arrangements in the context of activity-based models of transport demand, predicting work start and end times/duration for each weekday in two-adult households with children. In order to build this modelling approach, we first develop a conceptual framework of work schedule arrangements in two-adult households with children, which involves job application, household task allocation and work schedule arrangement.

Job application choice is the first step in negotiating and finalizing work schedule arrangements. The job application decision is estimated using a binary mixed logit model to analyze the effects of job attributes, social influence and sociodemographic characteristics on the decision to apply for a job profile or not. The results suggest that work attributes (e.g. number of working hours) and sociodemographic attributes (e.g. the number of children) play a more significant role than social influence in job application decisions.

In order to better understand the relationship between work schedule arrangements and household task allocation, in this thesis, we take the escorting children to school decision as an example. Based on parents' work schedules and children's agendas, a multinomial logit model is estimated predicting who (father, mother or other) is escorting the children as a function of personal characteristics, work schedules, characteristics of the child, nature of the activity that is conducted,
and gender-match. The results indicate that women tend to be primarily responsible for escorting their children, but this tendency becomes less strong with an increasing number of working hours and higher education. Moreover, gender match is a significant factor, particularly for fathers.

Following the findings of the studies on the job application and household task allocation decisions, a new approach for modeling work schedule arrangements in two-adult households with children is developed which can be used to predict parents' work schedules with start times and number of working hours/end time for each day of the week. First, we investigated the effects of socio-demographic characteristics and children's schedules on parents' work schedule decisions. We suggested a random utility model to represent the work schedule decision-making process assuming that individuals have sufficient flexibility in deciding their start and end times of work and an individual chooses the start time and number of daily working hours/end time of work to maximize his/her utility. We assume that the utility model is composed by systematic utility of work duration (from start time to end time of work) and additional utility stemming from an overlap/mismatch of the work schedules of individual and his/her spouse, and the school/daycare schedules of their children, which generate (dis)utility on the random utility of work schedule. On the basis of the utility function of the work schedule, the changing of one parent's work schedule on a day will lead to a change of utility derived for the other parent's work schedule, and vice versa. Therefore, parents' work schedules in a household interact and should be generated simultaneously instead of separately. We assume that parents tend to arrange their work schedules such that the household utility derived from their work schedules on a weekly basis is maximized. The estimated results reveal that the probability of parents working on a particular time of the day is influenced by the schedule of the children. In particular, parents prefer to choose to work when their child(ren) are at school/daycare, indicating that they would like to have more overlap between their work schedule and children's school/daycare schedule. In contrast, they have a lower preference to start work earlier or finish later than their children's school/daycare schedule which means they not only cannot escort their children, but also loose joint time with their whole family.

In order to validate the model and assess its predictive power, work schedules were predicted by using the formulated model and compared these predictions against observations in terms of number/percentage of correctly predicted working days, start times and number of working hours, for each day of the week under different conditions varying different strengths of constraints: no total number of working hours
constraints, predicted number of household weekly working hours are equal to the observed number of household weekly working hours, each parent's predicted number of weekly working hours are equal to the observed number of weekly working hours of each parent, predicted number of household working hours on each day is equal to the observed number of household working hours on the same day and each parent's predicted number of working hours on each day is equal to the observed number of working hours on the same day of each parent. The results suggest that the model can predict working days, start times and working hours for each day of the week accurately, especially when the strength of constraints increases.

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## 1

## Introduction

### 1.1 Background and motivation

Daily work schedule arrangements substantially influence traffic volumes and therefore congestion, especially during the morning and evening peak hours. An abundant volume of literature in travel behavior research has examined the effects of work schedules on reducing congestion (e.g. D'Este, 1985; Arnott, et al., 1990; Crane, 2000; Saleh \& Farrell, 2005; Komma \& Srinivasan, 2008; Daganzo \& Lehe, 2015; Haustein et al., 2018; Tang et al., 2020). In addition, work schedule arrangements play an important role in individual/household time use task allocation decisions (e.g. Zhang et al., 2002, 2005; Habib, 2012; Han et al., 2020). For many people, work is a mandatory activity, which needs to be conducted at fixed times and a fixed location. Hence, the spatial and temporal constraints induced by the work activity will restrict the possibility to engage in other individual/household activities within that time window. In addition, in households with children, parents' work schedule arrangements are a consequential factor of children's development and well-being (e.g. Strazdins et al., 2006; Hsueh \& Yoshikawa, 2007; Han \& Fox, 2011; Parcel \& Bixby, 2016; Rönkä et al., 2017; Matias \& Recharte, 2021; Oliveira et al., 2022). In order to alleviate traffic jams, improve environmental protection, better understand household time use and task allocation, and be conducive to children's development and well-being, it is necessary to examine how people arrange their work schedules.

When arranging their work schedule, people need to decide which days of the week to work, at what time to start, and how many hours to work on each day of the week, assuming the job allows such flexibility. If individuals/households have the opportunity to choose, deciding on a work schedule arrangement is anything but easy.

On the one hand, individuals have their personal preferences about which day and which time of the day to work, and how long to work on a day/week. On the other hand, work schedule arrangements may be constrained by specific job requirements, such as specific working hours, non-flexible working hours, fixed work place, etc. Moreover, parents' need to synchronize their work schedule arrangements with the timing of household activities. Further, in two-adult households with children, parents need to spend time on child-related activities such as child care, escorting and child development. However, limited by 24 hours per day, parents face the challenge of balancing their own career aspirations and the joy of working, and their responsibility of parenting, possibly constrained by specific job requirements. They need to find the right balance between working more hours to generate enough money to support their aspired way of living and allocating enough time to spend with their children, individually and jointly. Hence, deciding on a work schedule arrangement is not a simple matter of deciding how many hours to work in total and how to allocate these hours across the days of the week from the perspective of optimal work conditions, but is more complicated due to personal/household preferences, space-time constraints, financial considerations, and task allocation and gender roles in the household.

Despite the critical importance of work schedules arrangements in organizing daily activity-travel patterns, studies on this topic are relatively scarce, particularly in transportation and time use research. Only a very limited number of studies addressed the topic of individual/household work schedule arrangements, both analytically and from a modeling perspective. For instance, Vyas et al. (2014) focused on flexible work arrangements by building three interlinked sub-models for this decision process to predict individual's work arrangements of long-term trends as well as possible travel demand management policies. Khan et al. (2012) developed a multivariate binary probit model to estimate individual work arrangement choice, which can be also used to predict individual's choice of work arrangements. Gupta \& Vovsha (2013) formulated a hybrid time-of-day -duration model for work schedules with intrahousehold interactions in multiple-workers households. Their results evidenced significant synchronization to create time overlaps between the work schedules of household members. However, none of these studies took the children's schedules into account.

### 1.2 Research objectives

Considering the critical importance of work schedules in daily life, the aim of this PhD study is to contribute to the understanding of the formation of work arrangements by developing a new approach of modeling weekly work schedule arrangements in the context of activity-based models of transport demand, predicting work start time and end times/duration for each weekday. The focus is on two-adult households, mainly dual-earner households, with children. To this end, the following research questions will be addressed:

1. How can the household work schedule arrangement decision in two-adult households with children be conceptualized?
2. What kind of information do we need to operationalize the conceptual framework and how to collect the information?
3. Which factors influence the decision of parents to apply for a job?
4. Are parents' job application decisions significantly affected by social influence?
5. To what extent do children's schedules affect parents' choice of work schedule? Is this effect gendered?
6. Can we develop a model that predicts parents' weekly work schedule (start time and end times/working hours on each day of the week)?
7. Is the model valid and what is its predictive power?

In order to answer these research questions, several activities are undertaken. First, a conceptual framework of household work schedule arrangements is developed based on a review of the literature. Three types of decisions are considered: job application, work schedules and household task allocation. Second, based on the conceptual framework, a questionnaire is designed and administered using webtechnology. Data consists of the current work schedule of parents, children's agendas, socio-demographic characteristics of each family number, and a stated choice experiment of job application decisions. Third, we develop a new approach for modeling work schedule arrangements in two-adult household with children which can predict parents' work schedules.

### 1.3 Thesis outline

This thesis is organized in eight chapters. As shown in Figure 1.1, following this introduction, Chapter 2 provides a definition of work schedule arrangement in an activity-travel behavior context, and describes the conceptual framework, with a particular focus on the process of the choice of work schedule arrangements in twoadult households with children, emphasizing the relationship between work schedule arrangements and household time use and task allocation.

On the basis of this conceptual framework, Chapter 3 describes the data collection and discusses sample characteristics. The chapter discusses the design and administration of a web-based questionnaire. A random sample of Dutch two-adult households with children was used to collect data about socio-demographic characteristics, parents' current work schedule and the fixed schedule components of each child in the household. Moreover, a stated choice experiment was included to mimic job application decisions. Sample characteristics are described. The analysis in Chapters 4, 5 and 6 will be based on different parts of data and samples which collected in Chapter 3.


Figure 1.1 Thesis outline

As shown in Figure 1.1, the process of work schedule arrangement in two-adult household with children is discussed in Chapter 4 to 7 , which involves the job application decision, household task allocation and work schedule arrangements.

Chapter 4 discusses the construction of a stated choice experiment to better understand the influence of different factors, including the number of working hours, on the decision to apply for a particular job profile. The experiment allows to better understand the trade-off between the number of working hours and factors such as generated income, and kind of job, and how the job application decision is affected by social influence. The chapter discusses the effects of job attributes, social demographic characteristics and social influence on the decision whether a parent will apply for a specific job profile.

In order to better understand the relationship between parents' work schedule arrangement and household task allocation, Chapter 5 investigates how parents allocate household tasks based on their work schedule, taking escorting children to school as an example. In addition, the effect of gender roles and gender match on household task allocation are investigated in this chapter.

Chapters 6 and 7 are the core chapters of this study. In Chapter 6, a new approach of modeling work schedule arrangements in the context of activity-based models of transport demand, which takes children's agendas into account, is developed. By using parents' observed work schedules, children's agendas and selected socio-demographic characteristics, the effects of these variables on the work schedule choice of parents are investigated and the estimation results are discussed. The model predicts parents' weekly work schedules with start times and end times/duration for each weekday in two-adult households with children. Chapter 7 discusses the goodness-of-fit of the model by predicting parents' weekly work schedules and comparing generated work schedules against observations in terms of work vs non-work days, work start times and number of working hours. Under the assumption that the predicted work schedule should satisfy particular marginal constraints, we discuss model performance for five different constraints.

Finally, Chapter 8 concludes this thesis by discussing its main contributions to the state-of-the art, its limitations, relevance, transportation policy implications and possible directions of further research.

## 2

## Conceptual Framework

### 2.1 Introduction

As discussed in the introduction, work schedule arrangements play a prominent role in travel behavior. To address the topic, this chapter presents the theoretical context and conceptual framework for understanding how parents in two-adult households with children arrange their work schedules across a week, taking into account their children's agendas. The conceptual framework differentiates between work schedule decisions, job application decisions and household task allocation decisions.

The chapter is organized as follows. First, before presenting the conceptual framework, a definition of work schedule arrangement is provided and the basic theoretical framework used in this study, random utility theory is discussed. The next section focuses on discussing a conceptual framework of work schedule arrangements in two-adult households with children. Attributes which may affect work schedule arrangements will be also identified. This chapter ends with a discussion and some conclusions.

### 2.2 Theoretical orientation

This section discusses basic concepts and assumptions of work schedule arrangements in two-adult households with children. Deciding on work schedules may be a complicated problem which involves a series of decisions such as start time, number of working hours per day/week, where to work, etc., assuming such flexibility exists. In case these aspect are fixed and non-negotiable, what is left is the decision whether or not to apply for such a job profile. In this study, a work schedule arrangement involves the decisions of how many hours to work per week, and how to allocate these working hours across the days of the week and time of day.

The theoretical framework underlying the choice work schedule arrangements in this study is based on random utility theory which assumes that a decision maker will choose the alternative which generate the highest utility for each choice situation (Koenig, 1980). Alternate approaches could be used in principle, but in this study we follow the dominant approach in travel behavior research. Random utility theory has proven its value as it has been widely used in transportation research for understanding effects of various attributes and socio-demographic characteristics, on transportation mode, time use and task allocation (e.g., Zhang et al., 2002; Zhang et al., 2005; Habib, 2012). It has also been applied in modeling work schedule arrangements (e.g., Khan et al., 2012; Gupta \& Vovsha, 2013; Vyas et al., 2014). However, very limited attention has been paid to investigating the influence of household activities, especially children-related activities on arranging work schedules. A random utility maximizing framework is needed for understanding how parents arrange their work schedule taking children-related activities into account. In twoadult households with children, parents may organize their work schedule in many ways with different start and end times of their work activities. We assume they will choose the work schedule with the highest utility.

### 2.3 Conceptual framework

As defined in Chapter 2.2, work schedule arrangements involve the decisions of how many hours to work per week and how to allocate these working hours across days of the week and times of day (start and end times of the work activity). Figure 2.1 illustrates the conceptual framework used in this study. The conceptual framework of work schedule arrangements in two-adult household with children involves job application, work schedule arrangement and household task allocation.

Job application decisions are the basis of work schedule arrangements and household task allocation. Before arranging a work schedule, people need to decide whether or not to apply for a specific job by considering whether attributes of the job such as income, working hours/week, and flexibility, can satisfy their preference and requirements. One of the core attributes of a parent decision to apply for a job is the number of working hours (part time vs. full time job). On the one hand, the number of working hours is proportional to income: the longer of a person works, the more income is generated for the same job. On the other hand, the number of working hours plays an important role in individual and household task allocation (Zhang et al., 2005). Due to the fact that time on a day is limited to 24 hours, the number of working hours not only reflects the time people spend on the work activity, but also
reflects the remaining time that people can use to organize other individual and household activities. Hence, the household task allocation can affect people's job application decision. In two-adult households with children, parents need to spend time on their personal and household activities such as shopping, meet friends, etc. They also need to spend time on numerous activities related to children, for example, child care, escorting them to school and other activity locations and spend joint time with them. In some cases, especially for households with young children, parents need to trade-off between working longer hours to afford professional child care or work less hours to take care of their children themselves.

Distance from home to the work place is an important attribute which influences job application decisions. The commute distance from home to the work place affects the time a person needs to spend commuting and people's transportation mode choice. For the same start and end time of work schedule, people with a longer commute time need to depart earlier from home and arrival at home later than those who have a shorter commute time.


Figure 2.1 Conceptual framework

In recent years, the flexibility of work has become more important for people's preference of job (e.g., Rothausen, 1994; Origo \& Pagani, 2008; Possenriede \& Plantenga, 2014; Kim et al., 2020; Ray \& Pana-Cryan, 2021). The flexibility of work involves flexible working hours and flexible work place. People with flexibility of work have more options when arranging their work schedule. For example, they may have a chance to avoid traffic jams during morning and evening peak hours. For parents in two-adult household with children, having a flexible work schedule means they have more options to allocate household activities, especially mandatory children-related activities. Besides working hours, distance from home to work place and flexibility, income and interests may also affect people's job application decisions. The detailed job application decision will be discussed in Chapter 4.

After applying for a specific job, a parent's work schedule should be arranged, subject to constraints stemming from the job requirements such as the minimum number of working hours per week, location of the work place, etc. In addition to the job requirements, individuals have their personal and household preferences regarding which day and which time to work, and how long to work on a day/week. For instance, some people prefer to start work earlier to avoid peak hours or because they feel more productive in early morning hours, whilst some people prefer to start work late to have more available time to get organized before going to work. Some people with a part time job prefer to work less days but work longer on the working day, while others prefer to allocate the working hours to more days so that they can work less hours on that day.

Moreover, in two-adult households with children, household task allocation, especially children-related activities play an important role in parents' work schedule arrangement decisions. The existence of children triggers several children-related activities, such as escorting children to school, care giving, joint activities, child development, etc., some of which are mandatory and need to be organized at fixed times and/or fixed places. Escorting children to school is a typical example of mandatory children-related activities. In order to conduct these children-related activities, parents need to adjust their work schedule to their children's agendas, or reallocate particular activities to other household member, or find other solutions. From a certain age onwards, children are obliged go to school, which have a fixed location and tend to adhere to fixed hours, although some offer limited flexibility. The escorting activity thus needs to be conducted within the spatial and temporal constraints set by the location and (institutionalized) opening hours. Several studies evidenced that school start time influence work commute departure time (e.g. Fox et
al., 2014; Mehdizadeh et al., 2016; Deka, 2017; Ehteshamrad et al., 2017a, 2017b; Wohner, 2022). Meanwhile, parents also need to consider the time their children come out-of-school when organizing their work schedule. They may worry when their children are home alone. In addition to school, they need to consider any other escorting needs of their children such as bringing them to sports, ballet or music lessons. These children-related activities may restrict parents' work schedule arrangements in time and space, which implies that parents need to link their work schedule to their children's agendas and cooperate in conducting children-related activities.

Last but not the least, gender roles affect parents' work schedule arrangements. Compared to the traditional gender role that more mothers work less and spend more time on household activities, including children-related activities, in recent decades, with an increasing number of women participating in the workforce, the household decision process has become more complicated in the sense that both parents may be time-pressured and carry with them the burden and anxiety of their jobs and careers. It implies that former more or less habitual gender-roles driven decisions have been replaced by more explicit decisions on task allocation (e.g., Barnett \& Shen, 1997; Wadsworth \& Facer, 2016; Beutell \& O' Hare, 2018; Lomazzi et al., 2019; Cavapozzi et al., 2021). In addition to gender roles, gender match is also considered in this study. An example of gender match is that fathers may prefer to accompany boys to football while mothers may prefer to accompany girls to ballet class (e.g., Han et al., 2020).

As shown in Figure 2.1, the relationship between work schedule arrangement and household task allocation, especially allocation of children-related activities will be discussed in Chapter 5. The model of work schedule arrangements and its estimation results will be discussed in Chapter 6 and Chapter 7.

### 2.4 Conclusions and discussion

This chapter discussed the basic concepts of work schedule arrangement in two-adult household with children, motived the choice of theoretical orientation and outlined a conceptual framework used in this study. The concept of work schedule arrangement refers to decisions how many hours to work per week and how to allocate these working hours across the days of the week and times of day. Random utility maximization theory will be used to model work schedule arrangement choice in this study, assuming that parents choose the work schedule that maximizes their utility, subject to space-time constraints and formal requirements that come with the job.

This thesis develops and presents a conceptual framework that explains how parents in two-adult household with children arrange their work schedule. The conceptual framework distinguishes the job application decision, household task allocation and work schedule arrangement decision. Before arranging work schedules, people need to decide whether or not to apply for a specific job by considering whether attributes of the job can satisfy their preferences and requirements. People will arrange their work schedule under the constraints imposed by the job. In addition, peoples' work schedule arrangements are also influenced by individual/household preferences, some socio-demographic characteristics and gender roles. Moreover, in two-adult household with children, children trigger several children-related activities, some of which are mandatory and need to be conducted at a fixed time and/or fixed location. Correspondingly, these activities will generate particular constraints which may restrict parents' work schedules in time and space. Hence, parents' need to adjust their work schedules to their children's agendas. Based on the conceptual framework, the next chapter presents the design and execution of the data collection for this study.

## Data Collection

### 3.1 Introduction

Based on the conceptual framework, outlined in the previous chapter, this chapter discusses the design of the survey and describes sample characteristics. The aim of this dissertation is to build a model of work schedule arrangements with start time and end time/duration for each parent across the days of the week in two-adult households with children. For this purpose, a web-based data collection instrument was designed. The survey includes questions about the socio-demographic characteristics of parents and their children, parents' weekly work schedules, children's weekly agendas, a stated preference experiment about job application decisions, and questions about attitudes towards work and children.

The structure of this chapter is as follows. First, an outline of the survey design is given. Next, the sample characteristics are described. This chapter ends with summary and conclusion.

### 3.2 Design of the survey

The data collection was developed and conducted online in the Netherlands in January 2015, using a platform that was developed by and for the research group at the Eindhoven University of Technology to design and administer web-based questionnaires. Our target sample was 1000 respondents depending on the experience was used to decide on a sample size that would allow the analyses that we had in mind. The questionnaire consists of four parts: household member sociodemographic characteristics, parents' weekly work schedule, children's weekly agendas and a stated choice experiment of job application decisions.

### 3.2.1 Socio-demographic characteristics

Socio-demographic characteristics are essential for the development of activity-based models. Therefore, the first part of the questionnaire consists of questions about socio-demographic characteristics of the parents. In this part, both personal and household socio-economic characteristics were collected and included gender, age, education level, income, household composition, number of cars and possession of driver licenses in the household. In addition, gender and age of each child in the household were collected.

### 3.2.2 Weekly work schedule

The second part of the questionnaire collected data on the weekly work schedule of each parent. In particular, in case of regular schedules, data were collected about which day of the week the parent works, the departure/arrival time from/to home, start time and end time of work and the commute mode. Considering that some parents have flexible work schedules, respondents were asked first whether they have a flexible work schedule. Depending on their answer, respondents were asked to complete different schedule tables. The schedule table for respondents who have no flexibility included which days they work, departure/arrival time from/to home, start time and end time of work episode, transportation mode and whether they have a break during the day. If they work at home, they just needed to keep blank the departure/arrival time from/to home. Respondents who have a flexible work schedule were asked the total number of working hours per week, transportation mode used, on which days they normally work, and whether they work at home on some days. Respondents were also asked to complete the work schedule of their partner. The work schedule table is shown in Figure 3.1.

### 3.2.3 Children's weekly agenda

Children-related activities tend to play an important role in parents work schedule arrangements. Indeed, there are various children-related activities that parents need to conduct regularly or irregularly, such as escorting children to school/daycare, taking care of their children after school/daycare, accompanying children to leisure activities, escorting children to meet friends, etc. In order to capture the relationship between parents work schedule arrangements and children-related activities, respondents were requested to complete their children's school agendas, daycare agenda and other regular activity agendas.

| Weekly work schedule of $\square$ myself/ $\square$ my partner |  |  |  |  |  |  |  |  |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- |
|  | Monday | Tuesday | Wednesday | Thursday | Friday | Saturday | Sunday |  |
| Work or not | Yes | Yes |  |  |  |  |  |  |
|  | No | Yos | Yes |  |  |  |  |  |
| No | No | Yes | Yes | Yes |  |  |  |  |
| No | No | No | No |  |  |  |  |  |
| Start time | $:$ | $:$ | $:$ | $:$ | $:$ | $:$ | $:$ |  |
| End time | $:$ | $:$ | $:$ | $:$ | $:$ | $:$ | $:$ |  |
| Transportation mode |  |  |  |  |  |  |  |  |
| Departure time from home | $:$ | $:$ | $:$ | $:$ | $:$ | $:$ | $:$ |  |
| Arrival time at home | $:$ | $:$ | $:$ | $:$ | $:$ | $:$ | $:$ |  |
| When do you have a break |  |  |  |  |  |  |  |  |
| From | $:$ | $:$ | $:$ | $:$ | $:$ | $:$ | $:$ |  |
| To | $:$ | $:$ | $:$ | $:$ | $:$ | $:$ | $:$ |  |

Figure 3.1 Example of work schedule table
Several reasons motivated the decision to ask for these agendas. Frist, several studies evidenced that school times influence work commute times. For instance, Saleh \& Farrell (2005) found that escorting children to school can restrict individual's departure time choice options to go to work, even if they have flexible work schedules. Deka (2017) and Ehteshamrad et al. $(2017 a, 2017 b)$ found that departure times of work commutes are influenced by school start times. Therefore, respondents were asked to complete the school agenda of their children. Similar to school, the times that children are brought to daycare, although more flexible than school, need to be synchronized with work schedules if a working parent brings/picks up the child.

Besides school/daycare, parents also need to consider the time their children spend on other activities that require their company. Respondents are therefore asked to provide information about each child's weekly agenda as it relates to other regular activities, focusing on start time and end time of the activity, who escorts the child to the activity, and travel time to the place of the activity. Figures 3.2 to 3.4 are examples of children's agendas used in the questionnaire.

### 3.2.4 Stated choice experiment

The third part of the survey involved a stated choice experiment, which asked respondents to indicate whether they would apply for a specific job considering a set of systematically varied job attributes. The aim of this experiment was to investigate the influence of job attributes, social network and socio-demographics characteristics on the decision to apply for a job of a particular profile. The main advantage of this approach is that it gives the researchers control on the data generation process, and therefore common problems of revealed preference data can be largely avoided.

| School agenda of child__._ |  |  |  |  |  |
| :--- | :---: | :---: | :---: | :---: | :---: |
|  | Monday | Tuesday | Wednesday | Thursday | Friday |
| Start time | $:$ | $:$ | $:$ | $:$ | $:$ |
| End time | $:$ | $:$ | $:$ | $:$ | $:$ |
| Departure from (place) |  |  |  |  |  |
| Travel time | min | min | min | min | min |
| Send by |  |  |  |  |  |
| Transportation mode |  |  |  |  |  |
| Picked up by |  |  |  |  |  |
| Transportation mode |  |  |  |  |  |

Figure 3.2 Example of school agenda table of a child

| Daycare agenda of child __ |  |  |  |  |  |
| :--- | :---: | :---: | :---: | :---: | :---: |
|  | Monday | Tuesday | Wednesday | Thursday | Friday |
| Start time | $:$ | $:$ | $:$ | $:$ | $:$ |
| End time | $:$ | $:$ | $:$ | $:$ | $:$ |
| Who take care of the child |  |  |  |  |  |
| Departure from (place) |  |  |  |  |  |
| Travel time | min | $\min$ | $\min$ | min | min |
| Send by |  |  |  |  |  |
| Transportation mode |  |  |  |  |  |
| Picked up by |  |  |  |  |  |
| Transportation mode |  |  |  |  |  |

Figure 3.3 Example of daycare agenda table of a child

| Other regular activities agenda of child __ |  |  |  |  |  |
| :--- | :---: | :---: | :---: | :---: | :---: |
|  | Activity 1 | Activity 2 | Activity 3 | Activity 4 | Activity 5 |
| On which day |  |  |  |  |  |
| Start time | $:$ | $:$ | $:$ | $:$ | $:$ |
| End time | $:$ | $:$ | $:$ | $:$ | $:$ |
| Departure from (place) |  |  |  |  |  |
| Travel time | $\min$ | $\min$ | $\min$ | min | min |
| Who accompany |  |  |  |  |  |
| Send by |  |  |  |  |  |
| Transportation mode |  |  |  |  |  |
| Picked up by |  |  |  |  |  |
| Transportation mode |  |  |  |  |  |

Figure 3.4 Example of other regular activities agenda of a child
The first step in the design of the experiment concerned the selection of attributes and attributes levels. In this experiment, as shown in Table 3.1, five job attributes and four social influence attributes were selected. Job attributes included the number of working hours/week, flexibility to work from home, general interest in the kind of job, salary/hour and travel distance to work, while social influence attributes were defined as opinions about work and children-related activities, differentiating between parents, relatives, friends and peers. Peers were defined as
other people of the same generation or similar lifestyle. It is likely they read similar magazines, watch the same television shows and hence are exposed to the attitudes of their peers.

The reasons for selecting these attributes and attributes levels are the following. First of all, working hours always play an important role in activity-based models which largely determine individual/household task allocation, related trip organization and travel pattern decisions. For instance, Zhang et al. $(2002,2005)$, and Ettema \& Lippe (2009) found that working hours strongly influence household task allocation related to shopping and escorting children. As discussed in Chapter 2, parents generate income from work to support their daily life. Meanwhile, they have to spend time to organize and conduct different personal and household activities. Owing to the restriction of 24 hours /day, more time spent on work will lead to less time available for other activities. If such time pressure means that some activities are outsourced, more working hours may lead to increasing expenditures on organizing household activities and/or personal activities (Dane et al., 2014). The number of working hours and salary level were therefore selected as the first two variables included in the experiment.

Considering mandatory children-related activities, the third selected variable was flexibility of working hours because flexible working hours may avoid the overlap of activities in time. Vyas et al. (2014) suggested that presence of child/children, and commute distance significantly influence individuals' preferences for flexible work arrangements. For instance, a person works eight hours per day, and escorting children needs to be organized between 8:00 am to 8:30 am. If the eight working hours are flexible, this person can choose not to work during this episode to organize the escorting activity. If there is no flexibility and these activities overlap, parents need to find another solution. Next, distance from home to the job location was selected as the fourth attribute. Generally, increasing distance from home to the work place results in higher commuter time and higher costs. Distance will also affect concerns to return home in case of an emergency. The distance categories were chosen to include the typical commuting distances in the Netherlands.

Finally, personal interest in the job was selected, reflecting the notion that job choice may be influenced by non-monetary reasons. Results from sociology suggest that motivation and interest in the job is another important driver of workers (e.g., Khan et al., 2012; Gupta et al., 2013).

In addition to these job attributes, the experiment varied social influence attributes. Social influence has often been varied in terms of the nature of reviews,

Table 3.1 Selected attributes and attribute levels

| Attribute | Attribute level |
| :---: | :---: |
| Working hours/week | 16 hours <br> 24 hours <br> 32 hours <br> 40 hours |
| Flexibility/ work at home | Non-flexibility <br> Working hours must be at workplace between 9 and 17 on working days <br> You may work at home 1day/week <br> Full flexibility |
| Interest for the job | Opportunity of a lifetime dream job <br> Very interesting job <br> Interesting job, of which there are several OK job, with many similar opportunities |
| Salary/hour (after tax) | 6.25 euros/hour 10.95 euros/hour 15.65 euros/hour 20.35 euros/hour |
| Travel distance to work | $\begin{aligned} & 3 \mathrm{~km} \\ & 10 \mathrm{~km} \\ & 20 \mathrm{~km} \\ & 50 \mathrm{~km} \end{aligned}$ |
| Parents' opinions about work and children care | Stimulate full-time work <br> Stimulate spend more time for work than for children care Stimulate spend more time on children care than work Stimulate give priority to children care |
| Relatives' opinions about work and children care | Stimulate full-time work <br> Stimulate spend more time for work than for children care Stimulate spend more time on children care than work Stimulate give priority to children care |
| Friends' opinions about work and children care | Stimulate full-time work <br> Stimulate spend more time for work than for children care Stimulate spend more time on children care than work Stimulate give priority to children care |
| Peers' opinions about work and children care | Stimulate full-time work <br> Stimulate spend more time for work than for children care Stimulate spend more time on children care than work Stimulate give priority to children care |

and attitudes and adoption of a similar choice alternative (e.g., market share) of social network members (e.g., Zhang et al., 2011; Axsen et al., 2013; Rasouli \& Timmermans, 2016). For instance, Zhang et al. (2011) found that peers' opinions have a significant effect on individuals' choice to buy an EV. Similarly, Rasouli \& Timmermans (2013) estimated the effects of the market share of electric cars among friends and acquaintances, larger family, co-workers and peers. In two-adult households with children, people's job application decision involves the trade-off between work and individual/household activities, especially children-related activities. Hence, the experiment systematically varied opinions about work and child care to measure social influence. Assuming social influence may differ between different types of social networks, hypothetical opinions about work and child care were varied between parents, relatives, friends and peers, following e.g. Rowe (1994), and Rasouli \& Timmermans (2013).

Table 3.1 lists the nine attributes and their levels, which were systematically varied in the experiment. All attributes were defined at 4 levels. Hence, a $4^{9}$ full factorial design would generate all possible job profiles. To reduce the total number of profiles and keep attribute balance at the same time, we used an orthogonal fraction of the full factorial design, generating 128 job profiles. Each level of each attribute appeared 32 times in this design. Respondents were shown eight randomly selected profiles, and were asked to indicate whether they would apply for the job, considering its profile and the opinions/attitudes of the members of their social network, assuming they were looking for a job. In addition, they were told that any other conditions affecting their decision are satisfied. For respondents' reading convenience, the salary (after tax)/month is shown in each profile depending on the number of working hours and salary/hour, instead of salary/hour. Figure 3.5 provides an example of a job profile shown.

| Working hours/week | 40 hours |
| :--- | :--- |
| Flexibility/ work at home | Working hours must be at the workplace between 9 and 17 on working days |
| Interest for the job | OK job, with many similar opportunities |
| Salary (after tax) | 1752 euros |
| Trave/ distance to work | 3 km |
| Parents' opinions about work and child care | Stimulate spending more time on work than on child care |
| Relatives' opinions about work and child care | Stimulate full-time work |
| Friends' opinions about work and child care | Stimulate to give priority to child care |
| Peers' opinions about work and child care | Stimulate spending more time on work than on child care |
| Would you apply for this job? <br> or Yes <br> O No |  |

Figure 3.5 Example of a randomly job profile shown to a respondent

Table 3.2 Sample characteristics ( $\mathbf{N}=1051$ )

|  | Variables | Frequency | \% |
| :---: | :---: | :---: | :---: |
| Gender | Female | 592 | 56.3 |
|  | Male | 459 | 43.7 |
| Age | 18-25 years | 49 | 4.7 |
|  | 26-45 years | 867 | 82.5 |
|  | > 45 years | 135 | 12.8 |
| Partner's age | 18-25 years | 44 | 4.2 |
|  | 26-45 years | 857 | 81.5 |
|  | > 45 years | 150 | 14.3 |
| Number of household members | 3 | 366 | 34.8 |
|  | 4 | 495 | 47.1 |
|  | > 4 | 190 | 18.1 |
| Number of children $\leq 12$ years old | 1 | 540 | 51.4 |
|  | 2 | 418 | 39.8 |
|  | > 2 | 93 | 8.8 |
| Work situation | Only respondent has a job | 141 | 13.4 |
|  | Only respondent's partner has a job | 159 | 15.1 |
|  | Both of them have job | 723 | 68.8 |
|  | None of them has a job | 28 | 2.7 |
| Number of cars | 1 | 590 | 56.1 |
|  | 2 | 413 | 39.3 |
|  | More than 2 | 19 | 1.8 |
|  | None | 29 | 2.8 |
| Driver's license | Respondent has a driver's license | 87 | 8.3 |
|  | Respondent's partner has a driver's license | 58 | 5.5 |
|  | Both have a driver's license | 895 | 85.2 |
|  | None has a driver's license | 11 | 1.0 |
| Income | 0 | 114 | 10.8 |
|  | €1-€1200 | 255 | 24.3 |
|  | € 1201- € 2400 | 514 | 48.9 |
|  | > € $¢ 400$ | 168 | 16.0 |
| Partner's income | 0 | 96 | 9.1 |
|  | €1-€1200 | 250 | 23.8 |
|  | €1201-€2400 | 548 | 52.1 |
|  | > $€ 2400$ | 157 | 15.0 |
| Education level | Primary school | 4 | 0.4 |


|  | Preparatory secondary vocational <br> education (v(m)bo, Its, Ibo, domestic <br> science school) | 58 | 5.5 |
| :---: | :--- | :---: | :---: |
|  | Secondary general education (mavo, <br> (m)ulo) | 87 | 8.3 |
|  | Secondary vocational education (mbo, <br> mts) | 344 | 32.7 |
|  | Higher general and pre-university <br> education (havo, vvwo, hbs) | 75 | 7.2 |
|  | Higher vocational education (HBO, PABO, <br> HTS, HEAO) | 368 | 35.0 |
|  | Academic education (university, PhD) | 115 | 10.9 |

### 3.3 Sample description

In this study, sample size was not calculated a priori but experience was used to decide on a sample size that would allow the analyses that we had in mind. Our target sample was 1000 respondents. Technically, the respondents received a link to our local server, and hence their privacy was protected. The questionnaire was distributed among potential panelists of a national panel in the sense that respondents had to work, belong to two-adult household and have at least one child younger than 12. Once the target number of questionnaires was reached, the data collection ended. The questionnaire was administered in the Netherlands on January 2015 through a website. In the present case, the data collection took just 3 days.

A total of 1051 valid questionnaires were obtained from 1575 respondents who participated in this survey. The basic socio-demographic characteristics are presented in Table 3.2. The percentage of female and male respondents is 56.3 and 43.7 respectively. The frequency distribution of the three age categories is respectively $4.7 \%, 82.5 \%, 12.8 \%$ for respondents and $4.2 \%, 81.5 \%, 11.3 \%$ for respondents' partners, which indicates that most respondents and their partners are $26-45$ years old.

Table 3.2 also shows that more than $80 \%$ of the respondents' households have no more than four household members and more than $90 \%$ of the respondents only have one or two children younger than 12 years. It also indicates that only $2.8 \%$ of the respondents' households do not have a car, $56.1 \%$ has one car. The percentage
of both respondents and their partners having a driver's license is $85.2 \%$, which means that some respondents need to make car allocation decisions.

As shown in Table 3.2, almost 70\% of the respondents and their partners have a job, while in $2.7 \%$ of the cases both adults are non-employed. Nearly $50 \%$ of the respondents earn between 1201 and 2400 euros per month. As for education, the percentage of the respondents with secondary vocational education or professional education is 67.7 , indicating that the majority of the respondents and partners have middle level education. In contrast, the number of respondents with low education or high education is low with $5.9 \%$ and $10.9 \%$ respectively.

### 3.4 Conclusions and discussion

This chapter has presented the design and administration of the questionnaire. This data collection effort tried to capture how parents arrange their work schedule in twoadult household with children. The data collection was conducted online in the Netherlands, through a platform developed by the group to generate and administer web-based questionnaire. The questionnaire consist of basic socio-demographic characteristics, parents' weekly work schedules, the agenda of each child and a stated choice experiment to understand job application decisions.

Although we could not test the representativeness of the sample for the Dutch population due to the lack of published sources about the distribution of sociodemographics of Dutch two-adult households with at least one child younger than 12 years, the sample characteristics show that the sample is sufficiently varied to conduct analyses on the effects of socio-demographic characteristics. There are 1575 respondents participated in this survey and 1051 valid questionnaires, suggest that the valid rate was relatively high. The quality of the data was satisfactory.

## 4

## Job Application Decision

### 4.1 Introduction

Chapter 2 proposed a conceptual framework of work schedule arrangements in twoadult households with children. The job application decision is the first step in negotiating and finalizing work schedule arrangements. People decide whether to apply for a specific job depending on the attributes of job, including the number of working hours, flexibility in working hours, salary, etc. Job profiles affect detailed working time arrangements and choice of transportation mode, but also limit the possibility of people to organize other activities in time and space. Thus, job application decisions affect both work schedule arrangements and household task allocation. Parents can negotiate and coordinate work schedules such that at least one avoids overlap between work and other fixed mandatory activities to ensure that the other mandatory activities can be organized. Otherwise, such mandatory activities need to be outsourced which may lead to an increased expenditure (Dane et al., 2014). An example is sending children to a daycare center instead of taking care of the child oneself. In addition to job attributes and scheduling conflicts, job application decisions may be affected by suggestions from or opinions of social network members about trade-offs between work and household activities, possibly moderated by opinions about gender roles and parenting.

In the previous chapter, we discussed that parents need to trade-off time allocation between work and other household activities, especially children-related activities. The way that two-adult household with children trade-off their time expenditure to different activities and allocate tasks may differ. Heterogeneity may be crucial in sufficiently explaining job application decisions. Such heterogeneity may be
captured using different models. In this chapter, we allow some of the estimated taste parameters to vary across the sample.

The aim of this chapter, therefore, is to estimate the effects of job attributes, social influence and socio-demographic characteristics on job application decisions, allowing for heterogeneity, by using a binary mixed logit model. The estimation results can be used to develop a model of household work schedule arrangements in following chapters.

The chapter is organized as follows. First, relevant literature on job application decisions in transportation research is reviewed. Next, the characteristics of the sample are described. This is followed by a discussion of the estimation results. Finally, the chapter is completed with a conclusion and discussion.

### 4.2 Literature review

Job application decisions is the first step in the process of work schedule arrangement. Work schedule preferences are derived from the assessment of a series of properties such as salary, number of working hours, location, flexibility, etc. The literature on work schedule preferences is rich in social psychology and economics and investigates factors that affect people's job application choices, especially focusing on factors such as salary and interest (e.g., Rynes, 1983; Highhouse et al., 1999; Boswell et al., 2003; Kanar et al., 2010; Reis et al., 2017; Mauger et al., 2019).

In travel behavior research, studies of work schedule preferences mainly focus on the effects of attributes such as working hours, commuting distance/time and flexibility, on activity-travel choices. In activity-based models, working hours are generally considered as given/observed, and largely determine household task allocation, related trip organization and travel pattern decisions. For instance, Zhang et al. (2002, 2005), and Ettema \& Lippe (2009) found that working hours strongly influence household task allocation related to shopping and escorting children. The more hours spend on work, the less time is allocated to other individual/household activities, and vice versa.

In recent years, work schedule flexibility has gained substantial interest. For instance, Saleh \& Farrell (2005) investigated the impact of flexible work time on spreading traffic flows during peak hours, similar to Yoshimura \& Okumura (2001), and Thorhauge et al. (2016). Lari (2012), Haustein et al. (2018) and Hopkins \& Mckay (2019) investigated the impact of flexible work place including teleworking on traffic demand. Several studies took both flexibility of work time and location into account (e.g., Yeraguntla \& Bhat, 2005; Vovsha \& Bradley, 2006; Zhou \& Winters, 2008; Tang
et al., 2008; Singh et al., 2013; Tang et al., 2020). Vyas et al. (2014) studied flexible work arrangement decisions, differentiating between part-time, flexible working places, and communication using high technology such as telephone and online meetings. The estimated results suggested that gender, presence of child/children, and commute distance significantly influence individuals' preferences for flexible work arrangements. Zhou \& Winters (2008) applied a multinomial logit model to analyze compressed work week choices in Washington. Results indicate that many employees prefer a compressed workweek, less working days in a week and longer working hours on a work day, to traditional five work days per week, especially people who face a long distance from home to the work place.

Khan et al. (2012) formulated a multivariate binary probit model to estimate individual work arrangement choices in the San Francisco Bay Area. The estimation results indicate that individuals' work arrangement choices are significantly influenced by socio-demographic, environmental and attitudinal variables. They found that presence of a child/children, and presence of a young child (younger than five years old) lead to different choices. Instead of modeling individual choice of work arrangement, Gupta \& Vovsha (2013) used a hybrid discrete choice-duration model for work schedules with intra-household interaction in multiple-worker households. The estimated results indicate that people from multiple-worker households have a stronger preference to synchronize their work schedules, which proves that in multiple-earner households, work arrangement is a joint decision rather than individual decision.

To better understand the context of the current study, it should be mentioned that workforce participation of women in the Netherlands is low and moreover those who participate tend to work part time. In part, this may be due to the quality of the social support system, but the low rate can also be related to traditional cultural and religious views of the role of women in society. Opinions are changing and therefore differences in attitudes still exist. The topic repeatedly receives attention in the media. Attitudes differ between segments of the population and political parties. These changes triggered our decision to examine the effects of social influence on the decision to apply for a job.

Social influence has recently received increasing attention in travel behavior research (e.g., Dugundji \& Walker, 2005; Wiedmann et al., 2011; Kim et al., 2014; Maness et al., 2015; Cherchi, 2017; Pike \& Lubell, 2018). For example, Pan et al. (2019) developed a model of social influence in the context of city trip itinerary choice, and found that social influence has a modest but significant effect. Manca et al. (2020)
found that peers' attitude is a significant explanatory variable of an individual's attitude, but seems not to directly affect the utility of an alternative. Paez et al. (2008) and Kamargianni et al. (2014) also found that social networks significantly affect decision making processes. Similarly, there is a stream of literature indicating that parents' attitudes and work involvement influence their children's attitudes about work (e.g., Gardner \& LaBrecque, 1986; Marks \& Houson, 2002; Lucas-Thompson \& Goldberg, 2015; Sawitri, 2019). For example, Keith (1988) found that children from a two-career household want a two-career family for themselves. On the other hand, there is also evidence that boys with a higher status working mother tend to wish their future wives stop working after having children. Wiese \& Freund (2011), investigating the influence of parents' work involvement on future work plan involvement of 520 high-school students in Switzerland, concluded that these adolescents' perceptions of parents' work behavior affect their planned work involvement, although they reflect on and modify the role models of their parents according to their own beliefs to balance work and family life. In recent years, with the development of technology and internet, people are exposed to a lot of information and opinions from social media. Correspondingly, several studies demonstrated that peoples' job choice decisions are significantly influenced by social media and social networks (e.g., Stone et al., 2019; Ahamad, 2020). Van Hoye \& Lievens $(2007,2009)$ found that people's job choice is influenced by their friends and family. Kulkarni \& Nithyanand (2013), examining students' job choice decisions under social influence, including the level of friendship, found that the number of respondents who were sensitive to social influence is small. In other words, the extant literature suggests that job applications decisions are made in the context of the opinions of different social networks, but that the strength of social influence may substantially vary.

To summarize, although job applications are the first step in committing to a particular work schedule that strongly influences daily activity-travel behavior, the transportation research community did not investigate this decision in much detail. The decision also affects household time use and task allocation, and thus is relevant in understanding some wider implications on transport and society. Job application decisions are influenced by job attributes, travel implications and, potentially, opinions of members of different social networks.

### 4.3 Selected data

As discussed in Chapter 3, the data were collected in January 2015 in the Netherlands using a national opt-in panel which is representative of the Dutch population. The data selected in this chapter is the total number of 1051 valid questionnaires, the frequency distributions of selected socio-demographic characteristics are shown in Table 3.2.

### 4.4 Results

To estimate the probability of applying for a particular job profile, a binary mixed logit model was estimated. For each job profile, the effects of five job attributes, four social influence attributes and a set of socio-demographic characteristics were estimated. Because the number of variables is high, the estimation of random effects for all variables turned out to be impossible. Thus, a mixed binary logit model with the job attributes as random effects under normal distribution and the remaining attributes as non-random effects was estimated. All variables were effect coded. The estimation results with 500 random draws are shown in Table 4.1. The goodness-of-fit of the model is satisfactory as 0.974 percent as indicatively. McFadden pseudo R-square is 0.3098 .

### 4.4.1 Estimated coefficients for job attributes

Table 4.1 shows that most job attributes significantly affect utility. It indicates that a full-time job and jobs of or less than 16 hours are less preferred than the average. In contrast, jobs between 24 and 32 hours/ week have a higher than average utility. Full time job affects utility negatively, which indicates that respondents prefer to have at least one (week) day to spend with their children and/or conduct non-work activities. Table 4.1 also indicates that the effects of flexible work hours are positive and significant, suggesting that flexibility is an important attribute influencing job applications of people with children. The effect of this attribute on utility is lowest when people have to spend their working hours on the work place between 9 and 17. An explanation may be that people need to spend more time and money on their work commute because of traveling during peak hours, while at the same time the working hours and the commuting time may raise conflicts with mandatory, non-flexible childrelated activities such as escorting children to school. Similarly, utility tend to increase with an increasingly interesting job. As shown in Table 4.1, utility tends to monotonically increase with increasing salary. However, marginal utility increases

Table 4.1 Estimation result of ML (Work attributes with random parameters)

| Attributes | Levels | Coefficient | $P$-value | St. Error |
| :---: | :---: | :---: | :---: | :---: |
| Random parameters in utility function |  |  |  |  |
| Constant |  | -1.9088 | 0.0000 | 0.3580 |
| Working hours/week | 16 hours <br> 24 hours <br> 32 hours <br> 40 hours | $\begin{aligned} & -0.2278 \\ & 0.6792 \\ & 0.2193 \\ & -0.6707 \end{aligned}$ | $\begin{aligned} & 0.0665 \\ & 0.0000 \\ & 0.0131 \end{aligned}$ | $\begin{aligned} & 0.1242 \\ & 0.1062 \\ & 0.0884 \end{aligned}$ |
| Flexibility/ work at home | No flexibility <br> Working hours must be at the workplace between 9 and 17 on working days <br> You may work at home 1day/week <br> Full flexibility | $\begin{aligned} & -0.4458 \\ & -0.5536 \\ & 0.4211 \\ & 0.5783 \end{aligned}$ | $\begin{aligned} & 0.0000 \\ & 0.0000 \\ & 0.0000 \end{aligned}$ | $\begin{aligned} & 0.0985 \\ & 0.0998 \\ & \\ & 0.0898 \end{aligned}$ |
| Interest in the job | Opportunity of a lifetime - dream job Very interesting job Interesting job, of which there are several OK job, with many similar opportunities | $\begin{aligned} & 0.3557 \\ & 0.0867 \\ & -0.1459 \\ & -0.2966 \end{aligned}$ | $\begin{aligned} & 0.0001 \\ & 0.3389 \\ & 0.1016 \end{aligned}$ | $\begin{aligned} & 0.0925 \\ & 0.0907 \\ & 0.0891 \end{aligned}$ |
| Salary/hour (after tax) | 6.25 euros/hour 10.95 euros/hour 15.65 euros/hour 20.35 euros/hour | -3.3180 $-0.5971$ <br> 1.4885 <br> 2.4266 | $\begin{aligned} & 0.0000 \\ & 0.0000 \\ & 0.0000 \end{aligned}$ | $\begin{aligned} & 0.2217 \\ & 0.0990 \\ & 0.1117 \end{aligned}$ |
| Travel distance to work | 3 km 10 km 20 km 50 km | $\begin{aligned} & 0.9322 \\ & 0.6599 \\ & 0.0746 \\ & -1.6667 \end{aligned}$ | $\begin{aligned} & 0.0000 \\ & 0.0000 \\ & 0.4158 \end{aligned}$ | $\begin{aligned} & 0.1071 \\ & 0.0988 \\ & 0.0917 \end{aligned}$ |
| Nonrandom parameters in utility function |  |  |  |  |
| Parents' opinions about | Stimulate full-time work <br> Stimulate spending more time on work than for child care | $\begin{aligned} & -0.0791 \\ & -0.0165 \end{aligned}$ | $\begin{aligned} & 0.3768 \\ & 0.8550 \end{aligned}$ | $\begin{aligned} & 0.0895 \\ & 0.0901 \end{aligned}$ |


| work and child care | Stimulate spending more time on child care than work <br> Stimulate giving priority to child care | $\begin{aligned} & 0.0475 \\ & 0.0481 \end{aligned}$ | 0.5970 | 0.0900 |
| :---: | :---: | :---: | :---: | :---: |
| Relatives' opinions about work and child care | Stimulate full-time work <br> Stimulate spending more time on work than for child care <br> Stimulate spending more time on child care than work <br> Stimulate giving priority to child care | $\begin{aligned} & -0.0079 \\ & -0.0708 \\ & 0.0604 \\ & 0.0183 \end{aligned}$ | $\begin{aligned} & 0.9293 \\ & 0.4265 \\ & 0.5036 \end{aligned}$ | $\begin{gathered} 0.089 \\ 0.0891 \\ 0.0904 \end{gathered}$ |
| Friends' opinions about work and child care | Stimulate full-time work <br> Stimulate spending more time on work than for child care <br> Stimulate spending more time on child care than work <br> Stimulate giving priority to child care | $\begin{aligned} & -0.0041 \\ & 0.0237 \\ & 0.0147 \\ & -0.0343 \end{aligned}$ | $\begin{aligned} & 0.9632 \\ & 0.7958 \\ & 0.8724 \end{aligned}$ | $\begin{aligned} & 0.0894 \\ & 0.0918 \\ & 0.0913 \end{aligned}$ |
| Peers' <br> opinions about work and child care | Stimulate full-time work <br> Stimulate spending more time on work than for child care <br> Stimulate spending more time on child care than work <br> Stimulate giving priority to child care | $\begin{aligned} & 0.0565 \\ & 0.0179 \\ & -0.0820 \\ & 0.0077 \end{aligned}$ | $\begin{aligned} & 0.5344 \\ & 0.8439 \\ & 0.3561 \end{aligned}$ | $\begin{aligned} & 0.0909 \\ & 0.0909 \\ & 0.0889 \end{aligned}$ |
| Gender | Male <br> Female | $\begin{gathered} -0.0395 \\ 0.0395 \end{gathered}$ | 0.7283 | 0.1137 |
| Age | $=<25$ years <br> 26-45 years <br> $>45$ years | $\begin{gathered} 0.7419 \\ -0.1238 \\ -0.6181 \end{gathered}$ | $\begin{aligned} & 0.0137 \\ & 0.4915 \end{aligned}$ | $\begin{aligned} & 0.1362 \\ & 0.1412 \end{aligned}$ |
| Number of children $=<12$ years | 1 <br> 2 $>2$ | $\begin{aligned} & 0.2934 \\ & 0.3622 \\ & -0.6556 \end{aligned}$ | $\begin{aligned} & 0.0313 \\ & 0.0103 \end{aligned}$ | $\begin{aligned} & 0.1362 \\ & 0.1412 \end{aligned}$ |
| Work situation in the family | No one has a job <br> Only respondent has a job <br> Only respondent's partner has a job <br> Both of them have a job | -0.1072 <br> 0.4532 <br> 0.1050 <br> $-0.4511$ | $\begin{aligned} & 0.8165 \\ & 0.0847 \\ & 0.7004 \end{aligned}$ | $\begin{aligned} & 0.4618 \\ & 0.2629 \\ & 0.2729 \end{aligned}$ |


| Education level | Elementary school | 0.9029 | 0.3983 | 1.0689 |
| :---: | :---: | :---: | :---: | :---: |
|  | Lower vocational school | -0.6235 | 0.0895 | 0.3672 |
|  | Middle general education | 0.6158 | 0.0583 | 0.3253 |
|  | Middle specialized education | 0.0152 | 0.9644 | 0.3405 |
|  | Middle vocational education | -0.1251 | 0.6084 | 0.2441 |
|  | Higher vocational education | -0.2877 | 0.2364 | 0.2430 |
|  | University | 0.4976 |  |  |
| Number of cars | 0 | 0.1297 | 0.7472 | 0.4023 |
|  | 1 | -0.0119 | 0.9557 | 0.2139 |
|  | > 1 | -0.1178 |  |  |
| Income of respondents | < 600 euros/month | -0.8789 | 0.0007 | 0.2581 |
|  | 601-1200 euros/month | 0.5208 | 0.0184 | 0.2208 |
|  | 1201-1800 euros/month | 1.1284 | 0.0000 | 0.1824 |
|  | 1801-2400 euros/month | 0.5272 | 0.0098 | 0.2040 |
|  | 2401-3000 euros/month | -0.0571 | 0.8241 | 0.2567 |
|  | > 3000 euros/month | -1.2405 |  |  |
| Income of respondents' partners | < 600 euros/month | -0.1885 | 0.4723 | 0.2624 |
|  | 601-1200 euros/month | 0.3305 | 0.1330 | 0.2199 |
|  | 1201-1800 euros/month | 0.1322 | 0.4578 | 0.1781 |
|  | 1801-2400 euros/month | -0.0942 | 0.6073 | 0.1833 |
|  | 2401-3000 euros/month | -0.5221 | 0.0429 | 0.2579 |
|  | > 3000 euros/month | 0.3422 |  |  |

Scale parameters of random parameters

| Constant |  | 2.2659 | 0.0000 | 0.1544 |
| :---: | :---: | :---: | :---: | :---: |
| Working hours/week | 16 hours | 2.4249 | 0.0000 | 0.1850 |
|  | 24 hours | 1.5171 | 0.0000 | 0.1746 |
|  | 32 hours 40 hours | 0.0368 | 0.9189 | 0.3612 |
| Flexibility/ work at home | No flexibility | 0.7536 | 0.0000 | 0.1791 |
|  | Working hours must be at the workplace between 9 and 17 on working days | 0.5898 | 0.0051 | 0.2104 |


|  | You may work at home 1day/week <br> Full flexibility | 0.2040 | 0.2973 | 0.1957 |
| :---: | :---: | :---: | :---: | :---: |
| Interest in the job | Opportunity of a lifetime - dream job Very interesting job Interesting job, of which there are several OK job, with many similar opportunities | $\begin{aligned} & 0.6882 \\ & 0.0746 \\ & 0.1992 \end{aligned}$ | $\begin{aligned} & 0.0002 \\ & 0.7343 \\ & 0.4815 \end{aligned}$ | $\begin{aligned} & 0.1841 \\ & 0.2198 \\ & 0.2830 \end{aligned}$ |
| Salary/hour <br> (after tax) | 6.25 euros/hour 10.95 euros/hour 15.65 euros/hour 20.35 euros/hour | $\begin{aligned} & 1.9805 \\ & 0.4058 \\ & 0.3259 \end{aligned}$ | $\begin{aligned} & 0.0000 \\ & 0.1336 \\ & 0.1768 \end{aligned}$ | $\begin{aligned} & 0.1841 \\ & 0.2705 \\ & 0.2413 \end{aligned}$ |
| Travel distance to work | 3 km 10 km 20 km 50 km | $\begin{aligned} & 0.9912 \\ & 0.6722 \\ & 0.8635 \end{aligned}$ | $\begin{aligned} & 0.0000 \\ & 0.0022 \\ & 0.0000 \end{aligned}$ | $\begin{aligned} & 0.1663 \\ & 0.2196 \\ & 0.1897 \end{aligned}$ |

much slower between 15.65 and 20.35 euros/ hour than between 6.25 to 10.95 euros/ hour, implying that if the salary is high enough, the increased salary does not tend to affect respondents significantly. Finally, Table 4.1 indicates that the effect of distance from home to work on utility is significant and positive if the range is below approximately 10 km . However, utility drops fast after 20 km , suggesting that respondents seem indifferent when the distance is close enough.

### 4.4.2 Estimated coefficients for social influence attributes

The results of the estimated non-random effects of social influence are listed in the second part of Table 4.1. It shows that social influence from parents, relatives, friends, and peers is less significant for the current sample size compared to job attributes. However, still some small but interesting results can be found. Estimated utility for a job profile decreases when parents and relatives stimulate a full-time job or to spend more time on work than on child care, while utility for a job profile increases if they stimulate spending more time on child care or give priority to children care. Thus, considering job preferences, it seems that the attitudes of parents and relative tend to reinforce personal preferences. For friends, estimated utility increases when they
simulate spending more time on work or child care, which may suggest that people are more influenced by friends' opinions about trade-offs between work and child care. In case of peers, the effects are positive, except when they stimulate spending more time on child care.

### 4.4.3 Estimated coefficients for socio-demographic characteristics

The third part in Table 4.1 lists the effects of the selected socio-demographic characteristics. Although gender differences are insignificant, females are more positively inclined to apply for a new job than males. The effects of age suggest that people younger than 26 years of age are significantly more positively inclined to apply for a new job, whilst people older than 45 years of age are less willing to change their current status. The effects of number of children suggest that if there is only one or two children in the respondents' household, respondents are positively inclined to apply for a new job. In contrast, respondents with more than two children are less willing to apply. Respondents from one-earner households are more positively inclined to apply for a new job, while reversely, respondents from non-earner or dual-earner households are less inclined to apply for a new job. Education and number of cars are less discriminatory. The effects of the personal income of the respondent and of their partners indicate that people with a medium income (601-2400 euros/ month) are significantly and positively inclined to apply for a new job, while people with a low (<600 euros/ month) or high income (>3000 euros/ month) are less inclined to apply for a new job. Compared to the coefficients of respondent income, the effects of partner income are less significant.

### 4.4.4 Estimated scale parameters for job attributes

The last part of Table 4.1 lists the estimated scale parameters which were assumed to follow a normal distribution. The scale parameters are high for the two lower working hours/week ( 16 hour and 24 hour), categories. The scale factors also seem high and significant for lower job flexibility job. Table 4.1 also indicates that the scale is high and significant if the job is a lifetime dream job. Heterogeneity seems much higher in case salary is at the lowest level. Finally, the estimated scale factor is high and significant for distance, suggesting that respondents differ widely in their utility of distance for their work commute.

### 4.5 Conclusions

This chapter answered the research questions which factors influence the decision of parents to apply for a job and are parents' job application decisions significantly affected by social influence. In this chapter, a mixed logit model was presented to estimate the effects of job attributes, social influence and socio-demographic characteristics on job application decisions, allowing for unobserved taste variation.

As the first step of agreeing on a work schedule arrangement, job application decisions influence traffic flows, especially during morning and evening peak hours. The attributes of a job such as working hours, distance and flexibility, may affect peoples' choice of transportation mode, travel time and distance, and thus traffic flows. To manage congestion and protect the environment, the study of job application decision is important. Meanwhile, job application decisions also play an important role in individual/household time use and task allocation. In households with children, parents need to trade-off between work and other individual and household activities, especially children-related activities. In addition, job application decisions may be influenced by attitudes of members of a household's social network. Accordingly, job application decisions are affected by work, social influence and sociodemographic attributes.

The model estimation results lead to some interesting conclusions. First, work attributes and socio-demographic attributes play a more significant role than social influence in job application decisions, which suggests that people's preference of job application decisions are less affected by opinions of members of their social network. Second, flexibility/work at home and number of working hours are most important. Third, the number of children significantly affect peoples' work schedule arrangement. If there are more than two children in a household, the probability of parents to apply for jobs with less working hours is increased, which may be because they need to spend more time on children-related activities. Forth, different attitudes and sensitivity to working hours and salary lead to substantial preference differences. Finally, the probably of applying for a full time job seems low in households with children.

Several policy implications can be derived from the results of this analysis. First, governments should encourage employers to supply more flexibility in working hours and/or work place, especially for people with children so that parents can commute outside peak hours and have more opportunities to conduct children-related activities. This will likely reduce congestion. Second, governments should consider providing more benefits to working parents such as increased child care allowance,
subsidized day care and increased tax refund, to stimulate higher labor force participation rates.

These estimated results can be used in the wider context of work schedule synchronization and coordination between the working adults and constitute the basis for the allocation of non-work household tasks, the focus of this thesis. In the next chapter, the role of household task allocation - another important decision - will be examined.

# Household Task Allocation ${ }^{\mathbf{1}}$ 

### 5.1 Introduction

Work schedules play an important role in household task allocation. Following the conceptual framework, outlined in Chapter 2, this chapter reports the results of an analysis of task allocation in two-adult households with children, considering the parents' work schedule, taking escorting children to school as an example. For this analysis, dual-earner households were selected.

Protagonists of time geography have argued that joint travel arrangements and activity participation exert a strong influence on the scheduling of activities (Rasouli \& Timmermans, 2014a). The reason is that the schedules of the persons involved in joint travel arrangements and activity participation need to be synchronized in time and coordinated in space. Thus, to understand and predict work schedules in activity-travel behavior, processes underlying joint travel and activitytravel participation need to be well understood.

Escorting in this context concerns joint travel in which the child is accompanied by another, generally older person. Usually, escorting is not pre- or proceeded by a joint activity at the same location. Either the accompanying person continues traveling to the next activity location after dropping off the child or waits until the child has completed his/her activity (e.g. sports). Escorting may also involve a group of children, although we do not consider this explicitly in this study.
${ }^{1}$ This chapter is based on the article: Han, B., Kim, J. and Timmermans, H.J.P. Task Allocation and Gender Roles in Dual Earner Households: The Issue of Escorting Children. Travel Behaviour and Society, Vol. 14, 2019, pp. 11-20.

A multinomial logistic regression model is estimated predicting who (father, mother or other) is escorting the children as a function of personal characteristics, work schedules, characteristics of the child, nature of the activity that is conducted, and gender-match. Using a multinomial logit model, the probability of who (father, mother, other or no-escorting) take care of escorting is analyzed as a function of age and gender of the children, personal characteristics of the parents, properties of the activity schedules of the parents, personal interest and gender match.

In this chapter, the effect of gender roles on escorting allocation will be also taken into account. As discussed in Chapter 1, in traditional families, men tend to be responsible for bringing in money, and technical and financial tasks, while women tend to be responsible for running the household and taking care of the children, including escorting tasks. However, in recent decades, with an increasing number of women participating in the workforce, the household decision process has become more complicated in the sense that both parents may be time-pressured and carry with them the burden and anxiety of their jobs and careers. It implies that former more or less habitual, gender-roles driven decisions have been replaced by more explicit decisions on task allocation.

This chapter is organized as follows. We will first provide a brief overview of the literature to support our introductory statements. Next, we provide details of selected sample characteristics. This is followed by an explanation of the analysis that was conducted and a discussion of the results of the analyses. A summary and discussion complete this chapter.

### 5.2 Literature review

The escorting phenomenon points at travel in which a particular individual is cotravelling with one or more other persons for protection or guidance. The concept of escorting is closely related to concepts such as chauffeuring and parenting. Escorting and chauffeuring have been used more or less interchangeably, although some differentiate these concepts based on whether the accompanying person is actually driving. We view the concept of parenting as the set of activities to stimulate and support the multi-faceted development of a child. It thus is a much broader concept, but in some of the transportation literature escorting is seen as a manifestation of parenting.

If we adopt an activity-based perspective, a day can be divided into a consecutive series of activity and travel episodes. An activity episode is a block of time during which a person conducts a particular activity at a particular location. If we rule
out multitasking (Rasouli \& Timmermans, 2014b), a travel episode is a block of time during which an individual travels from one location to another. In both types of episodes, an individual may be accompanied by or may accompany one or more other persons. In case of activity episodes, generally we use the term joint activity participation to indicate that an activity is conducted jointly with others. In case of travel episodes, the general term joint travel arrangement is commonly used to indicate that an individual is traveling jointly with others.

Escorting is a travel episode in which there is an element of protection or guidance. In that sense, it can be viewed as a special case of a travel arrangement. In travel behavior analysis, it often refers to adults traveling with children. Most research is about escorting children to school. In this case, an adult (parent, neighbor, grandparent, etc. or a combination of these) drops off the child at school and then continues to the next activity location, which may be home or office. The concept may also involve travel to other activities as long as the accompanying person is not involved in the activity that follows the travel episode. For example, one of the parents may escort a child to swimming or ballet lessons and may wait there until the child's activity is completed. Chauffeuring points at joint travel involving a car/van or maybe non-regular bus service in which an individual drives one or more other persons to a particular destination. It differs from escorting or drop off/pick up in that the latter concepts are not necessarily tied to driving a vehicle, but may also involve, for example, biking or walking. Thus, chauffeuring can be viewed as a subset of escorting.

The relationship between the escort and the escorted individual(s) can be manifold and involve for example parents, siblings, relatives, neighbors, and professional help. In contrast, parenting implies that parents are involved. As indicated, the term however has a much broader meaning to indicate the process of stimulating and supporting the multi-faceted development of a child. It is less useful in travel behavior analysis.

Research on escorting in travel behavior research has adopted at least three different perspectives. One stream of research has examined parents' activity travel patterns and analyzed to what extent particular choice facets of their trips differ if their trip chain (usually based on a commute trip) involves escorting. Other research has opted for exactly the opposite perspective and analyzed the conditions that affect various facets of children's school trips. A third focus, which is the interest of the present study, has been concerned with task allocation in (dual-earner) households. Although these different perspectives are closely related, they differ in terms of the unit of observation. The first stream of research uses the trips of parents (in particular
commute trips) as observations; the second analyzes the school trips of children, while the third stream is based on task allocation data.

Several studies, including for example McDonald (2008), Deka (2013), and Hsu \& Saphores (2014) have provided evidence to the effect that parents' travel patterns and children's travel to school are co-dependent. Departure times of work commutes have been shown influenced by school start times (Deka, 2017; Ehteshamrad, et al., 2017a, 2017b). Fox et al. (2014) found that the great majority of school escort tours, are made between 08:00-08:59 and 15:00-15:59 when children are traveling to and from school. Escort tours for other purposes are less frequent and more spread out during the day. Typically, non-home-based escort tours and trips involve some detour from the parents' activity location, mostly work.

Examining parents' mode choice for escorting trips, Mehdizadeh et al. (2018) concluded that children's trip-related-variables significantly improved the explained variance of a hierarchical multiple regression analysis. Carver et al. (2013) concluded that most escorting trips involved cars, particularly if the school is located too far from home.

In addition to this stream of research that analyzed aspects of parents' commute trip choice, a second stream of research has examined aspects of children's school trips. The key conceptual considerations underlying these studies do not fundamentally differ from general transportation mode choice studies. They highlight the importance of distance and travel time in the choice of transportation mode in the sense that beyond some distance threshold particular transport mode options are no longer realistic. However, the choice set tends to differ. As young children are not allowed to drive a car (formal age depending on country), the car choice option means they are car passengers and they are being chauffeured. In some countries a school bus is an important option and is added to the choice set. As in other countries mopeds are popular among 16 year olds and higher, depending on whether these children are included in the analysis a refinement of the various types of motorcycles may be relevant.

Several studies (e.g., McMillan et al., 2006; McDonald, 2008; He, 2013; Samimi \& Ermagun, 2012b; Daisy \& Habib, 2013) reported that an increasing distance or travel time from home to school considerably increases the tendency of using the car, simultaneously reducing the probability of walking or cycling to/from school.

Of special interest in studies on children transportation mode choice has been the issue of safety as reflected in distinct features of the built environment and parents general attitudes and concerns with respect to safety and educating children (Eyer \&

Ferreira, 2015). Safety in these studies includes both traffic safety and the risk of being harassed or worse. Examples include Copperman \& Bhat (2007a, 2007b), McDonald \& Aalborg (2009), Fyhri et al. (2011), Giles-Corti et al. (2011), Elias \& Katoshevski-Cavari (2014), Ermagun, et al. (2015), Guliani et al. (2015), Susilo \& Liu (2016), Alkheder et al. (2022). Results of these studies seem to indicate that after some age boys have a lower probability of being accompanied on their way to school, and therefore have a higher propensity traveling alone or with peers as opposed to being escorted (Zwerts et al., 2010; McDonald, 2012). This tendency is amplified by the fact that parents are more concerned about girls traveling independently (Yarlagadda \& Srinivasan, 2008; Samimi \& Ermagun, 2012a). This concern is higher for trips from school to home, since generally school time finishes earlier than work time. Younger children are more likely to be accompanied by their parents or use the school bus, while older children have a higher propensity to travel solo or with peers. Moreover, with increasing age, parents become less concerned about the safety of their children. Other studies concluded that (perceived) safety-inducing characteristics of the built environment induce more independent travel amongst children (e.g., Kyttä 2004; Susilo \& Waygood, 2012; Lam \& Loo, 2014; Kyttä et al., 2015).

Several socio-demographic covariates of the parents' affect escorting patterns. Children from low income families are more likely to travel alone to and from school because parents cannot afford or are less willing to pay for a school bus, and/or do not have access to a car and therefore are more constrained in their ability to escort their children to school, particularly across longer distance (e.g., Vovsha \& Petersen, 2005; McDonald \& Aalborg, 2009). Other studies have shown that parental employment status, work hours and flexibility of work hours are significant factors influencing escorted school trips (Vovsha et al., 2004; Vovsha \& Petersen, 2005; Schwanen et al., 2007; Yarlagadda \& Srinivasan, 2008). Longer work hours tend to be correlated with a lower escorting probability. Similarly, flexible work hours tend to increase escorting probabilities.

Gender and age of parents are other key variables. Ceteris paribus, children tend to be more escorted by their mothers than fathers (e.g. Fyhri \& Hjorthol, 2009; Barker, 2011; Ekert-Jaffé, 2011; Scheiner \& Holz-Rau, 2012; Hjorthol \& Vågane, 2014; Scheiner, 2016a, 2016b). It reflects that mothers still bear the major responsibility for childcare and spend more time in the company of their children than fathers do. This difference is even more pronounced if secondary activities are taken into account because mothers more than fathers tend to combine childcare with other activities such as housework (Scheiner \& Holz-Rau, 2017). Scheiner (2016a) reported that in

Germany women increase escorting until they reach a maximum around the age of 50. In contrast, men reach their maximum only at 65 . Men tend to be responsible for longer, car-based escort trips, while women are more involved in daily routine escorting typically done on foot.

Not only characteristics of the parents have been found significant, personal characteristics of the child also matter. Tetali et al. (2016) concluded that children in the 8th grade were twice as likely to cycle as those in the 6th grade.

A third, but much smaller number of studies in transportation research, directly examined task allocation between parents in multi-parent households. The majority of these studies was only concerned with the two parents and did not consider the effect of others escorting the children (e.g., Motte-Baumvol et al., 2017).

This chapter contributes to the third stream of studies. It focuses on task allocation in double-earner households, addressing the question who is escorting the children to a set of activity destinations in case the child is not travelling independently. Compared to most other studies it does not only include the two parents as possible escorts but also other people.

### 5.3 Sample characteristics

The objective of this chapter is to analyze the effects of co-variates on escorting task allocation in dual-earner households, which special focus on the effects of workrelated attributes and gender match besides socio-demographic characteristics. Correspondingly, data are needed from a sample of dual-earner households with children about the work schedules of the parents, escorting information and contextual information.

This chapter is based on part of the collected data, particularly the part concerned with socio-demographic characteristics of children and parents, the work schedules of the parents, and children-related agendas. The present analysis in this chapter is based on the dual-earner households only. After checking and filtering the data, 624 valid questionnaires of dual-earner households with at least one child were used for analyses.

The frequency distributions of the selected socio-demographic characteristics are shown in Figure 5.1. The share of fathers, respectively mothers is $44.9 \%$ vs. $55.1 \%$. The three age categories represent $3.7 \%, 84.9 \%$ and $11.4 \%$ of the sample. Education level included three categories, primary level, medium level and high level. As shown in Figure 5.1, 33.0\% of the respondents and their spouse both have a high education level, $29.8 \%$ have a middle education level, while in only $1.3 \%$ of the
households both parents have a primary education level. This suggests that the parents in around two thirds of the households have the same level of education. Fathers have a higher education level than mothers in $18.4 \%$ of the sample, while the education level of mothers exceeds the education level of fathers in $17.5 \%$ of the households. The majority of the households have a total income higher than 2801 Euros per month. In contrast, the percentage households with less than 1400 Euro/month and between 1401 Euro and 2800 Euro is $3.9 \%$ and $8.8 \%$ respectively.



Figure 5.1 Sample characteristics $(\mathbf{N}=624)$



(a) Paid working hours/Week


Figure 5.2 Summary statistics parents work arrangements

Note that this relatively high income can be explained in that only dual-earner households were included in the present analyses. The age of the youngest child was classified into <= 4 years, between 5-8 and 9-12 years. This categorization was based on school age requirements in the Netherlands. Children younger than 5 are legally not required to attend school. Figure 5.1 indicates that only $7.5 \%$ of the respondents has more than two children, which means that the majority of the respondents only has one or two children. $55.1 \%$ of the respondents' youngest child is aged less than five years old, while $21.6 \%$ is between $5-8$ and $23.2 \%$ between $9-12$ years of age.

Whereas Figure 5.1 summarizes the socio-demographic profile of the sample, Figure 5.2 shows the distribution of the number of paid working hours per week and the distribution of working days across the weekdays. The percentage of fathers working more than 32 hours per week is $86.2 \%$, which is much higher than the $29.0 \%$ of mothers, conducting paid work for more than 32 hours per week, suggesting that father works longer than mother on average. As shown in Figure 5.2, the percentage fathers working on successive weekdays from Monday to Sunday is $72.9 \%$, $76.1 \%$, $70.8 \%, 74.5 \%, 72.9 \%, 8.8 \%$ and $4.8 \%$ respectively, whilst these percentages for mothers is $62.7 \%, 62.7 \%, 47.8 \%, 60.1 \%, 45.8 \%, 9.0 \%, 5.5 \%$ respectively. Thus, these percentages are higher for fathers than for mothers on weekdays. During weekends, however, the percentage fathers and mothers conducting paid work is almost the same. Wednesdays and Fridays are the days of the week, in addition to the weekend, when less people work. To understand these statistics, it is important
to realize that elementary schools tend to be closed on Wednesday afternoon. Friday is a popular non-working day for people working part-time.

### 5.4 Results

In this study, task allocation among parents in dual earner households in the context of escorting for out-of-home activities is analyzed. To that end, a multinomial logistic regression model was estimated in which the dependent variable was defined as: escorted by father, escorted by mother, escorted by others and no escorting. No escorting served as the basis. The independent variables include the number of working hours of the parents, their flexibility, a set of socio-demographic variables, the kind of activity involved, day of the week and transportation mode. All independent variables were effect-coded.

The estimation results are listed in Table 5.1 (Figure 5.3). For ease of interpretation, we calculated the escorting probabilities of the categories of the dependent variable for each explanatory variable, controlling for the effects of all other independent variables. The results of these escorting probabilities are listed in Table 5.2.

McFadden's pseudo Rho-squared is 0.2414 , indicating a satisfactory goodness-of-fit. The constants for being escorted by father, mother and others are respectively $1.74,1.96$ and 1.73. It indicates that, on average, the escorting task tends to be more frequently conducted by mothers than fathers, and that fathers escort marginally more often than others, such as family, friends and neighbors, whilst the probability that a child travels alone is relatively small. Table 5.1 also shows that the difference in the number of working hours per week between parents significantly affects escorting task allocation, especially between parents. Significant effects on escorting propensity are observed for both fathers and mothers working longer, and on the probability of others escorting the child. This result suggests that if a parent works longer than the other parent, the probability to take charge of escorting is reduced. However, the calculated probabilities listed in Table 5.2 show that even if mothers work longer than fathers, on average, they only have a slightly lower escorting probability compared to mothers working less. Thus, the effect of the number of working hours is not symmetric between parents. If the number of working hours is similar between the parents, mothers are more likely to escort the child than fathers do. This finding may obscure different gender roles between working and non-working fathers.
Table 5.1 Estimated coefficients

| Escorting |  | Father |  | Mother |  | Others |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Attribute | Levels | Coefficient | P -value | Coefficient | P -value | Coefficient | P-value |
| Constant |  | 1.7432*** | 0.0000 | 1.9594*** | 0.0000 | 1.7324*** | 0.0000 |
| Working hours/week across parents | Father works longer Mother works longer Similar | $\begin{gathered} -0.2553^{* * *} \\ 0.0208 \\ 0.2345^{* * *} \end{gathered}$ | $\begin{aligned} & 0.0004 \\ & 0.8493 \\ & 0.0084 \end{aligned}$ | $\begin{gathered} 0.0847 \\ -0.2305^{* *} \\ 0.1458^{*} \end{gathered}$ | $\begin{aligned} & 0.2212 \\ & 0.0339 \end{aligned}$ | $\begin{gathered} -0.1450^{*} \\ 0.2307^{*} \\ -0.0858 \end{gathered}$ | $\begin{aligned} & 0.0674 \\ & 0.0523 \end{aligned}$ |
| Work status on a day | Both work <br> Father works, mother doesn't or flexible Mother works, father doesn't or flexible None works or both flexible | $\begin{gathered} 0.0137 \\ -0.3296 * * * \\ 0.5092 * * * \\ -0.1933 * * \end{gathered}$ | $\begin{aligned} & 0.8399 \\ & 0.0000 \\ & 0.0000 \\ & 0.0317 \end{aligned}$ | $\begin{gathered} 0.0531 \\ 0.3934 * * * \\ -0.5470^{* * *} \\ 0.1005 \end{gathered}$ | $\begin{aligned} & 0.3932 \\ & 0.0000 \\ & 0.0000 \end{aligned}$ | $\begin{gathered} 0.3412^{* * *} \\ -0.0499 \\ 0.3055^{* * *} \\ -0.5968 * * * \end{gathered}$ | $\begin{aligned} & 0.0000 \\ & 0.5621 \\ & 0.0027 \end{aligned}$ |
| Travel time of escort | $\begin{aligned} & <=10 \mathrm{mins} \\ & 11-30 \mathrm{mins} \\ & >30 \mathrm{mins} \end{aligned}$ | $\begin{gathered} 0.5697 * * * \\ 0.1567 \\ -0.7264^{* * *} \end{gathered}$ | $\begin{aligned} & 0.0001 \\ & 0.3077 \\ & 0.0073 \end{aligned}$ | $\begin{gathered} 0.5165^{* * *} \\ -0.1664 \\ -0.3501^{*} \end{gathered}$ | $\begin{aligned} & 0.0000 \\ & 0.1648 \end{aligned}$ | $\begin{gathered} -0.3426 * * * \\ -0.0806 \\ 0.4232 * * \end{gathered}$ | $\begin{aligned} & 0.0006 \\ & 0.4746 \end{aligned}$ |
| Household income | = < 1400 Euro/month <br> 1401-2800 Euro/month <br> 2801-4200 Euro/month <br> > 4200 Euro/month | $\begin{gathered} 0.1313 \\ -0.6459 * * * \\ 0.1349 \\ 0.3797 * * * \end{gathered}$ | $\begin{aligned} & 0.3986 \\ & 0.0000 \\ & 0.1117 \\ & 0.0000 \end{aligned}$ | $\begin{gathered} 0.1989 \\ -0.3366 * * * \\ 0.1271^{*} \\ 0.0106 \end{gathered}$ | $\begin{aligned} & 0.1400 \\ & 0.0024 \\ & 0.0835 \end{aligned}$ | $\begin{gathered} 0.2736^{*} \\ -0.8285^{* * *} \\ 0.3002^{* * *} \\ 0.2548 * * \end{gathered}$ | $\begin{aligned} & 0.0909 \\ & 0.0000 \\ & 0.0011 \end{aligned}$ |

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| Education level | Father higher than mother | $-0.3561^{* * *}$ | 0.0052 | $-0.4405^{* * *}$ | 0.0000 | $-0.5218^{* * *}$ | 0.0000 |
| :--- | :--- | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Mother higher than father | -0.1735 | 0.1903 | 0.1463 | 0.1857 | $-0.3133^{* *}$ | 0.0125 |
|  | Both primary | 0.3363 | 0.3934 | 0.0246 | 0.9372 | $1.1598^{* * *}$ | 0.0001 |
|  | Both middle | 0.1798 | 0.1440 | $0.2416^{* *}$ | 0.0175 | 0.0583 | 0.5954 |
|  | Both high | 0.0135 | 0.9145 | 0.0279 |  | $-0.3830^{* * *}$ |  |
| Number of children | 1 | $-0.3054^{* * *}$ | 0.0000 | $-0.2159 * * *$ | 0.0004 | -0.0755 | 0.3194 |
| $=<12$ years | 2 | 0.0683 | 0.2550 | -0.0475 | 0.3840 | -0.0167 | 0.8066 |
|  | $>2$ | $0.2371^{* * *}$ | 0.0044 | $0.2634^{* * *}$ |  | 0.0922 |  |
| Child's age | $0-4$ years | $1.7321^{* * *}$ | 0.0000 | $1.7637^{* * *}$ | 0.0000 | $0.9344^{* * *}$ | 0.0000 |
|  | $5-8$ years | $0.3440^{* * *}$ | 0.0000 | $0.5037^{* * *}$ | 0.0000 | $0.6691^{* * *}$ | 0.0000 |
|  | $9-12$ years | $-2.0761^{* * *}$ | 0.0000 | $-2.2674^{* * *}$ |  | $-1.6035^{* * *}$ |  |
| Child's gender | Boy | 0.0434 | 0.5797 | $-0.1563^{* *}$ | 0.0392 | -0.0235 | 0.7905 |
|  | Girl | -0.0434 | 0.5797 | $0.1563^{* *}$ |  | 0.0235 |  |
| Type of escorting | Escort to school/daycare | $-0.4991^{* * *}$ | 0.0000 | $-0.3853^{* * *}$ | 0.0000 | $-0.1535^{* *}$ | 0.0412 |
| activity | Escort to other regular activity | $0.4991^{* * *}$ | 0.0000 | $0.3853^{* * *}$ |  | $0.1535^{* *}$ |  |
| Day of the week | Weekday | $-0.7741^{* * *}$ | 0.0000 | $-0.3651^{* *}$ | 0.0235 | $-0.4292^{* *}$ | 0.0312 |
|  | Weekend | $0.7741^{* * *}$ | 0.0000 | $0.3651^{* *}$ |  | $0.4292^{* *}$ |  |
| Transportation mode | Car | $3.5862^{* * *}$ | 0.0000 | $3.4511^{* * *}$ | 0.0000 | $2.7205^{* * *}$ | 0.0000 |
|  | Public transportation | $-0.7507^{* *}$ | 0.0275 | -0.3454 | 0.1826 | $-0.5822^{* *}$ | 0.0222 |
|  | Slow modes | $-0.9858^{* * *}$ | 0.0000 | $-0.9424^{* * *}$ | 0.0000 | $-1.3811^{* * *}$ | 0.0000 |

Household Task Allocation

|  | Other | -1.8498*** | 0.0000 | -2.1633*** |  | -0.7571*** |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Time of escorting | Drop <br> Pick up | $\begin{gathered} 0.0498 \\ -0.0498 \end{gathered}$ | $\begin{aligned} & 0.2339 \\ & 0.2339 \end{aligned}$ | $\begin{gathered} -0.0365 \\ 0.0365 \end{gathered}$ | 0.3350 | $\begin{gathered} 0.0265 \\ -0.0265 \end{gathered}$ | 0.5658 |
| Child's gender and age interaction | $0-4$ years - boy <br> $0-4$ years - girl <br> 5-8 years - boy <br> 5-8 years - girl <br> 9-12 years - boy <br> 9-12 years - girl | $\begin{gathered} -0.3027 * * * \\ 0.3027 * * * \\ 0.0627 \\ -0.0627 \\ 0.2401^{* * *} \\ -0.2401 * * * \end{gathered}$ | $\begin{aligned} & 0.0073 \\ & 0.4252 \\ & 0.0012 \end{aligned}$ | $\begin{gathered} -0.3527 * * * \\ 0.3527 * * * \\ 0.1092 \\ -0.1092 \\ 0.2435 * * * \\ -0.2435 * * * \end{gathered}$ | $\begin{aligned} & 0.0013 \\ & 0.1385 \end{aligned}$ | $\begin{gathered} -0.3767 * * * \\ 0.3767 * * * \\ 0.1557 * \\ -0.1557 * \\ 0.2209 * * * \\ -0.2209 * * * \end{gathered}$ | $\begin{aligned} & 0.0021 \\ & 0.0671 \end{aligned}$ |
| Interaction of type of escorting and gender | Escort to school/daycare - boy <br> Escort to other regular activity - boy <br> Escort to school/daycare - girl <br> Escort to other regular activity - girl | $\begin{gathered} -0.1086^{*} \\ 0.1086^{*} \\ 0.1086^{*} \\ -0.1086^{*} \end{gathered}$ | $\begin{aligned} & 0.0714 \\ & 0.0714 \end{aligned}$ | $\begin{gathered} 0.0756 \\ -0.0756 \\ -0.0756 \\ 0.0756 \end{gathered}$ | 0.1826 | $\begin{gathered} 0.1408 * * \\ -0.1408 * * \\ -0.1408 * * \\ 0.1408 * * \end{gathered}$ | 0.0446 |

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Table 5.2 Probability of escorting
$\left.\begin{array}{l||l||l|l|l}\hline \hline \text { Attribute } & \text { Levels } & \begin{array}{c}\text { Probability } \\ \text { Father escorting }\end{array} & \begin{array}{c}\text { Probability } \\ \text { mother escorting }\end{array} & \begin{array}{c}\text { Probability } \\ \text { other escorting }\end{array} \\ \hline \text { Probability } \\ \text { no escorting }\end{array}\right]$
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|  | Other | 0.1675 | 0.1520 | 0.4942 | 0.1863 |
| :--- | :--- | :--- | :--- | :--- | :--- |
| Time of escorting | Drop | 0.3057 | 0.3481 | 0.2954 | 0.0509 |
|  | Pick up | 0.2817 | 0.3812 | 0.2853 | 0.0518 |
| Child's gender and | $0-4$ years - boy | 0.4123 | 0.4116 | 0.1596 | 0.0165 |
| age interaction | $0-4$ years - girl | 0.3143 | 0.5169 | 0.1612 | 0.0075 |
|  | $5-8$ years - boy | 0.2655 | 0.3317 | 0.3732 | 0.0296 |
|  | $5-8$ years - girl | 0.2399 | 0.4071 | 0.3200 | 0.0331 |
|  | $9-12$ years - boy | 0.2299 | 0.1937 | 0.3348 | 0.2416 |
|  | $9-12$ years - girl | 0.1716 | 0.2140 | 0.2967 | 0.3177 |
| Interaction of Type | Escort to school/daycare - boy | 0.2297 | 0.3145 | 0.3852 | 0.0706 |
| escorting and | Escort to other regular activity - boy | 0.4243 | 0.3203 | 0.2166 | 0.0387 |
| gender | Escort to school/daycare - girl | 0.2599 | 0.3672 | 0.3027 | 0.0702 |
|  | Escort to other regular activity - girl | 0.2696 | 0.4382 | 0.2589 | 0.0333 |

The results also show that the work status of parents is a factor significantly affecting escorting task allocation. The parent who works on the relevant day has a reduced probability of escorting children if the spouse does not work on the same day or has a flexible work schedule. In addition, the probability that others escort the child increases significantly if both parents have a job with nonflexible working hours. This result seems to suggest that parents first tend to try resolving agenda conflicts themselves before involving others. Significant effects on escorting probability are observed if one parent works fixed time and the other has flexible work hours. This effect tends to differ by gender. The marginal effect of this variable is higher for mothers than for fathers. Furthermore, if both parents do not work, mothers have a higher probability of escorting the child. If both parents work and none of their schedules is flexible, the probability of the mother escorting children increases but not significantly. More importantly, the probability that others escort the child increases significantly if the mother works and her work schedule is not flexible. This result may suggest that the work status of mothers plays a more critical role in escorting task allocation than the work status of fathers.

Estimation results for the effects of travel time indicate that fathers and mothers tend to take charge of short time escorting tasks (<= 10 min ), while others tend to become involved in long time escorting (> 30 mins ). The probability of fathers escorting the child to an out-of-home activity decreases rapidly with increasing travel time. The probability of the mother conducting an escorting activity also decreases significantly with increasing travel time, but the marginal effect is lower than for fathers. In contrast, the probability of outsourced escorting increases if the travel time is longer than 10 minutes.

As for household income level, the estimation results suggest that the probability of the father escorting children increases significantly in high-level income households. Because wealthier households are expected to be able to afford hiring professional help, this finding does not seem to reflect a pure income effect. Rather, it more likely indicates different gender roles in high-income households.

As shown in Table 5.1, education level of parents is another significant factor influencing escorting task allocation. Table 5.2 suggests that the probability to have outsourced escorting is highest in households where both parents enjoyed primary education, while in households where the mother had higher education (at least middle level), the probability of the mother escorting the child is higher than the probability of the father or others escorting the child. At first glance, this finding may be counterintuitive as higher income household can afford hiring help. However, one
should realize that observations are influenced by the number of working hours of the parents, start/end times, the ability of parents, other family members and neighbors to help. Full time workers with primary education tend to have earlier/later work start/end times and consequently they may need others to escort their children to school. This finding may also indicate that attitudes towards time spent with children and gender roles may differ by education level.

Estimation results also indicate that escorting depends on the number of children in the household and their age. The probability that others escort the child is higher in single-child households than in multi-child households. The probability of parents escorting young children is much higher than others escorting young children, indicating that parents prefer to escort young children themselves.

One of the most interesting findings of the analysis concerns gender match. Table 5.1 shows evidence of gender match between fathers and boys and mothers and girls. It fuels anecdotes that while fathers do not mind or even enjoy escorting their boys to masculine activities, they are reluctant to escort their girls to typical feminine activities. Meanwhile, if the out-of-home activity concerns a girl, the probability of outsourced escorting is slightly lower than when a boy is involved, which may suggest that parents prefer to escort girls themselves rather than allowing others to escort girls.

The results also indicate that the type of activity has a significant effect on escorting task allocation. The probability of the father escorting the children is lower if they need to bring their children to school/day care. It is higher for other types of activities. An explanation may be that on average fathers have longer working hours than mothers, while school and daycare have fixed times that tend to conflict with their fixed working times.

To better understand how gender match between affects escorting task allocation, we considered the interaction effects of child's gender with child's age and out-of-home activity type, respectively. The estimation results suggest that although the probability of both father and mother conducting escorting activities decreases with increasing age of the child, the influence of gender match tends to become stronger with the growing up of the child. Particularly for fathers, the effect of gender match intensifies when the child becomes older. The results for the interaction between child's gender and out-of-home activity type shows that gender similarity enhances the discrepancies between school/daycare and other regular activities. The probability of the father escorting a boy is dramatically higher for a regular activity than for school/daycare.








Figure 5.3 Graphical display of estimated coefficients

Similarly, the probability of the mother escorting a girl to a regular activity is much higher than the probability of escorting the girl to school/daycare. However, the probability of the mother escorting her son to school is almost the same as escorting her son to a regular activity. Similar results are found between fathers escorting their daughters to school and to regular activities, suggesting that gender similarity generates different effects for different activity types.

Finally, the estimation results indicate that day of the week also significantly affects escorting task allocation. Regardless of gender, parents have less time to escort children during weekdays compared to weekends. This tendency is stronger for fathers than for mothers. Fathers have a lower probability of escorting during weekdays and a higher probability of escorting during the weekend. In contrast, differences in days of the week are much smaller for mothers.

### 5.5 Conclusions and discussion

It is well known that work schedules play an important role in household task allocation decisions, particularly in joint travel arrangements and activity participation as activities need to be synchronized in time and coordinated in space. Hence, in order to better understand the relationship between work schedule arrangements and household task allocation, this chapter reports an analysis of escorting children to school in dual-earner households with children.

Ultimately, understanding individual and household scheduling decisions may improve the specification of activity-based travel demand models, which in turn may lead to better forecasts and therefore improved assessments of the effect of policy decisions. Classic travel demand models fall short in the sense that they can by their very nature only predict particular responses; task allocation is not one of these. Only some contemporary activity-based models of travel demand do explicitly consider task
(re)allocation as a behavioral response to a changing (policy) context (Rasouli \& Timmermans, 2014a).

In this chapter, we focus our attention to the decision who escorts the children to particular activities in dual-earner households. This is a highly interesting task allocation decision in which gender roles, values, personal preferences, social influence and norms, economic considerations and schedule constraints potentially play an important role. The results of our analysis provide ample evidence of the critical influence of gender roles. The basic task allocation is that women are responsible for escorting their children. This tendency becomes less strong with an increasing number of working hours and higher education, but the women's share in escorting is always higher. Gender match is indeed a significant factor in the decision who takes responsibility in escorting children, particularly for fathers. It triggers some degree of selectivity in escorting activities of men. Age is important in the sense that escorting gradually decreases with increasing age.

In part, the results of the present study reinforce findings of earlier research. It differs, however, from most previous research in terms of the direct focus on task allocation and the inclusion of particular variables, which have received less attention in prior research. For example, because we included escorting by others, we found evidence of a differential effect of escorting by others on the escorting probability of each of the parents. The involvement of others escorting children seems to primarily release fathers from escorting, which is a finding that has been less articulated in the literature. The same applies to the findings about gender match, the changing roles of fathers with an increasing age of the children and selectivity in escorting tasks of the father.

Overall, this chapter analyzes task allocation and gender roles in escorting decisions of dual-earner households, taking into account parents' work schedules. The results suggests that both work schedule and gender roles play important roles in household task allocation. The next chapter will focus on the core of this study, modeling parents' work schedule arrangement.

## 6

## Modelling Work Schedule Arrangements

### 6.1 Introduction

Chapters 4 and 5 proposed and reported estimation results of respectively job application decisions and household task allocation that influence parents' work schedule arrangements in two-adult households with children. The aim of this chapter is to develop a new approach for modeling work schedule arrangements in two-adult households with children, which can be used to predict parents' work schedules with start time and number of working hours/end time for each day of the week.

As discussed in the previous chapters, such work schedule arrangement decisions depend on personal preferences and space-time constraints, subject to formal work regulations. In two-adult households with children, however, the schedule of children also plays a potentially important role in parents' work schedule arrangements. In modeling this problem, we assume that the utility of work arrangements is not only a function of duration and other job characteristics, but also of the (dis)utility of joint time to spend with or take care of the children. We therefore differentiate between the states of the children based on children's agendas, identifying six children-related states depending on where a child is at any moment in time and who is co-present with the child.

In order to predict parents' weekly work schedules, we assume that an parent chooses the start time and number of daily working hours/end time of the work activity such as to maximize his/her utility considering children's schedules. The estimated parameters will be used to develop a model that generates synchronized work schedule arrangements in two-adult households with children.

Given the choice of utility maximization theory, we assume that parents tend to arrange their work schedules such that household utility derived from their work
schedules on a weekly basis is maximized depending on the information available on the total number of working hours by individual/household. In this study, we classified five conditions to restrict working hours by individual/household, day/week to predict work schedules under different marginal constraints.

The chapter is organized as follows. The following section reviews previous studies of work schedule arrangements. In section 6.3, the model work schedule arrangements in two-adult households with children will be proposed. This is followed by a description of the data and an interpretation of the estimation results. Finally, the chapter is completed with a conclusion and discussion.

### 6.2 Literature review

Referring to the definition of a work schedule arrangement, it is a complicated problem that involves a series of decisions such as start time, number of working hours per day/week, location of work, whether teleworking is allowed, etc. An abundant volume of studies on work schedules concerned with these different facets can be found in sociology, health studies, and family economics. For instance, several studies (e.g., Fahrbach \& Chanpman, 1990; Tucker et al., 1996; Scandura \& Lankau, 1997; Ye et al., 2007; Bonsdorff et al., 2017; Luger et al., 2019; Wang et al., 2021) suggested that work duration affects people's physical and/or mental health significantly. Hammer et al. (1997) proved that aspects of work schedule arrangements such as flexibility and duration have a strong impact on household conflict and balance especially for dual-earner households. Tausig \& Fenwick (2001), Rau \& Hyland (2002), Day \& Chamberlain (2006), and Yucel (2019) reported similar findings. Focusing on a special group, Fein \& Roe (1998), Kimbro (2006), Mandal et al. (2010) found that female employees with a young baby need short work duration for breastfeeding. In households with children, parents' work schedule arrangements are consequential factors related to child development and well-being (e.g. Strazdins et al., 2006; Hsueh \& Yoshikawa, 2007; Han \& Fox, 2011; Rönkä et al., 2017; Kaiser et al., 2019; Pilarz, 2021; Harknett et al., 2022). These studies revealed that work schedule arrangements play an important role in society, household dynamics and child development.

Compared to this abundant literature in these disciplines, studies related to work schedules in transportation research have gained growing interest, but are still very limited in number. As commuting is a crucial factor contributing to traffic jams, a large share of these studies examined the effects of different facets of work schedules on reducing congestion. For instance, Saleh \& Farrell (2005) investigated
the impact of flexibility of individual's working time choice on spreading traffic flows during peak hours, similar to Hendrickson \& Plank (1984), Yoshimura \& Okumura (2001), and Thorhauge et al. (2016). Meanwhile, several studies tried to investigate flexible work place such as teleworking to decrease traffic demand therefore congestion (e.g., Lari, 2012; Haustein et al., 2018; Hopkins \& Mckay, 2019;), while other studies took both flexibility of working time and space into account to reduce traffic jams from commuting (e.g., Yeraguntla \& Bhat, 2005; Vovsha \& Bradley, 2006; Zhou \& Winters, 2008; Tang et al., 2008; Singh et al., 2013; Tang et al., 2020). The aim of these studies, however, was to investigate the effects of flexible work schedules, not to model the formation of work schedule arrangements.

As discussed in chapters 4 and 5, in travel behavior research, work schedule arrangements play an important role in daily time use and task allocation. In addition, compared to households without children, work schedule arrangements in two-adult households with children are influenced by children's schedules. Considering the critical importance of work schedules arrangement in organizing daily activity-travel patterns, it is surprising that the topic has not generated much interest in transportation research. To the best of our knowledge, only a very limited number of studies addressed the topic of individual/household work schedule arrangement from the perspective of model development. For instance, with the development of technology and society, people have the flexibility to choose their work schedule compared to typical traditional commuters with full time work and fixed workplace and time. Vyas et al. (2014) paid attention to flexible work arrangements by building three interlinked sub-models for this decision process, a strategic long-term (employment type, full-time vs. part-time worker status, number of jobs and usual workplace type), a long-term workplace location choice and a mid-term choice (commuting frequency and flexibility choice) model, were formulated to predict individual's work arrangements of long-term trends as well as possible travel demand management policies. Khan et al. (2012) developed a multivariate binary probit model to estimate individual work arrangement choice, which involved five specific work related decisions: employed or not, work full-time or not, being self-employed or not, holding more than one job or not, and working at home or not. Although the model system is applied for predicting individual's choice of work arrangement, it took household interaction into account to overcome the limitation of independent decisions of household members in previous studies. The results suggested that work arrangement decisions are not only influenced by numerous individual and household demographic and socio-economic characteristics, built environment attributes and
accessibility variables, but also by household interaction. Similar to Vyas et al. (2014), their model can be also used to predict individual's choice of work arrangements. These two studies, however, focused on modeling individual work arrangement but could not predict household work schedule. In addition, time of day was not addressed. As a pioneering study on work schedule arrangements in multi-worker household, Gupta \& Vovsha (2013) formulated a hybrid time-of-day-duration model for work schedules with intra-household interactions in multiple-workers households, accounting for the effects of different aged children. They defined 6 alternatives for departure time periods and 6 arrival time periods on a day, and also distinguished between synchronized and non-synchronized departures and arrivals in order to estimate intra-household interaction, resulting in 42 choice alternatives for each worker, which led to $42 * 42=1764$ choice alternatives in total. The estimation results evidenced significant synchronization to create time overlaps between the work schedules of household members. Nevertheless, the presence of either school or preschool child can break the time overlaps for parents to organize different activities.

Overall, in spite of the importance of work schedule arrangements in transportation, the study of this topic is relatively scarce. Moreover, we did not find any studies which take children's schedules into account. In this chapter, we attempt to fill this gap in the literature by formulating a model of household work schedule arrangements that considers children's day care/school and activity schedules.

### 6.3 Model development

### 6.3.1 Model of work schedule decision making process

The aim of this section is to analyze the influence of children's schedules on the work schedules of parents in two-adult households with children. The estimated parameters can be used to develop a model that generates synchronized work schedule arrangements in these households. We assume that an individual/parent chooses the start time and number of daily working hours/end time of work to maximize his/her utility, which is specified as:

$$
\begin{equation*}
U_{i j d}=V_{i j d}^{W}\left(T_{i j d}^{W}, \boldsymbol{x}_{i}\right)+V_{i j d}^{A}\left(T_{i j d}^{W}, T_{i d}^{S}, T_{i d}^{C}, \boldsymbol{x}_{i}^{S}, x_{i}^{C}\right)+\varepsilon_{i j d} \tag{6.1}
\end{equation*}
$$

where,
$U_{i j d}$ : individual $i$ 's random utility of work schedule $j$ on day $d$ $V_{i j d}^{W}(\cdot)$ : individual $i$ 's systematic utility of work duration of schedule $j$ on day $d$
$V_{i j d}^{A}(\cdot)$ : individual $i^{\prime}$ s additional utility associated with children-related states during work schedule $j$ on day $d$
$T_{i j d}^{W}$ : a set of time components of individual $i$ 's work schedule $j$ on day $d, T_{i j d}^{W}=$ $\left\{t_{i j d}^{W, s}, t_{i j d}^{W, e}\right\}$ where $t_{i j d}^{W, s}$ and $t_{i j d}^{W, e}$ are work start and end times of work schedule $j$ on day $d$, respectively
$T_{i d}^{S}$ : a set of time components of the work schedule of individual $i$ 's spouse on day $d$, $T_{i d}^{S}=\left\{t_{i d}^{S, S}, t_{i d}^{S, e}\right\}$ where $t_{i d}^{S, S}$ and $t_{i d}^{S, e}$ are work start and end times of individual $i^{\prime}$ s spouse on day $d$, respectively
$T_{i d}^{C}$ : a set of time components of a selected school/daycare schedule with respect to the minimum duration of school/daycare activity among individual $i$ 's children on day $d, T_{i d}^{C}=\left\{t_{i d}^{C, s}, t_{i d}^{C, e}\right\}$ where $t_{i d}^{C, s}=\max \left\{t_{i d}^{C_{n, s}} \mid \forall n \in N_{i}\right\}, t_{i d}^{C, e}=\min \left\{t_{i d}^{C_{n, e}} \mid \forall n \in N_{i}\right\}$, and $N_{i}$ is the number of children in individual $i^{\prime}$ s household.
$\boldsymbol{x}_{i}$ : a $(B \times 1)$ vector of socio-demographic characteristics of individual $i$.
$\boldsymbol{x}_{i}^{S}$ : a ( $G \times 1$ ) vector of socio-demographic characteristics of individual $i$ 's spouse.
$x_{i}^{C}:$ a $(Q \times 1)$ vector of socio-demographic characteristics of individual $i$ 's children.
$\varepsilon_{i j d}$ : random distribution term of individual $i$ 's utility of work schedule $j$ on day $d$.

This formulation demonstrates our assumption that individuals have sufficient flexibility in deciding their start and end times of work. Extensions to job with partial flexibility should add scheduling constraints. The systematic utility of work duration $V_{i j d}^{W}(\cdot)$ is assumed to depend on individual $i$ 's work schedule $T_{i j d}^{W}$ and sociodemographic characteristics $\boldsymbol{x}_{i}$. In addition, the utility of work duration is assumed to be mediated by additional utility $V_{i j d}^{A}(\cdot)$ that represents the (dis-)utility for day $d$ stemming from an overlap (or mismatch) of the work schedules of individual $i$ and his/her spouse, and the school/daycare schedules of individual $i$ 's children. Thus, the additional utility is associated with children-related states, and is defined by a function of individual $i$ 's work schedule $T_{i j d}^{W}$, the spouse's work schedule $T_{i d}^{S}$, the children's schedules $T_{i d}^{C}$, and their socio-demographic characteristics $\left(\boldsymbol{x}_{i}^{S}, \boldsymbol{x}_{i}^{C}\right)$.

In order to specify $V_{i j d}^{W}(\cdot)$, let $t^{W}$ denote a time point during work on day $d$, $t_{i j d}^{W, s} \leq t^{W} \leq t_{i j d}^{W, e}$. We assume that individual $i$ derives a certain utility by working at time point $t^{W}$, and that the accumulation of the utilities of each time point from work start time $t_{i j d}^{W, s}$ to work end time $t_{i j d}^{W, e}$ represents the utility of work of day $d$. Hence, the accumulated utility during work hours that varies according to different work schedules $T_{i j d}^{W}$, can be formulated as follows:

$$
\begin{equation*}
V_{i j d}^{W}(\cdot)=\int_{t_{i j d}}^{t_{i j s}^{W W e}}\left[v\left(t^{W}\right)\right] d t^{W}+\boldsymbol{\gamma}^{W} \boldsymbol{x}_{i}+c^{W} \tag{6.2}
\end{equation*}
$$

where,
$v\left(t^{W}\right)$ : the marginal utility of work at a certain time point $t$ during work activity, $t_{i j d}^{W, s} \leq$

$$
t^{W} \leq t_{i j d}^{W, e}
$$

$\boldsymbol{\gamma}^{W}$ : a $(1 \times R)$ vector of parameters representing the effects of socio-demographic characteristics of individual $i$ on the utility of work activity.
$c^{W}$ : a constant of the utility of the work activity.

We assume that the utility of work at time point $t^{W}$ is a function which depends on how long individual $i$ has been working since $t_{i j d}^{W, s}$ and socio-demographic characteristics. More specifically, we assume that the marginal utility is a monotonically decreasing function of work duration. This assumption can be represented in terms of a logarithmic function of work duration. The marginal utility of work duration at a certain time point $t^{W}$ can then be derived as follows:

$$
\begin{equation*}
v\left(t^{W}\right)=\frac{\beta^{W}}{t^{W}-t_{i j d}^{W M}}+\boldsymbol{\alpha}^{W} \boldsymbol{x}_{\boldsymbol{i}} \tag{6.3}
\end{equation*}
$$

where,
$\beta^{W}$ : a parameter representing the effects of the work duration at time point $t^{W}$ on the marginal utility of work.
$\boldsymbol{\alpha}^{W}:$ a $(1 \times R)$ vector of parameters representing the effects of socio-demographic characteristics of individual $i$ on the marginal utility of work.

By substituting equation (6.3) into equation (6.2), the utility of work $V_{i j d}^{W}(\cdot)$ can be represented by the following equation:

$$
\begin{equation*}
V_{i j d}^{W}(\cdot)=\int_{t_{i j d}^{W, s}}^{t_{i j e}^{W}, e}\left[\frac{\beta^{W}}{t^{W}-t_{i j d}^{W, s}}+\boldsymbol{\alpha}^{W} \boldsymbol{x}_{i}\right] d t^{W}+\boldsymbol{\gamma}^{W} \boldsymbol{x}_{i}+c^{W} \tag{6.4}
\end{equation*}
$$

Equation (6.4) can be transformed by solving the definite integral term as follows:

$$
\begin{equation*}
V_{i j d}^{W}(\cdot)=\beta^{w} \ln \left(D_{i j d}^{W}\right)+\boldsymbol{\alpha}^{w} \boldsymbol{x}_{i} D_{i j d}^{W}+\boldsymbol{\gamma}^{W} \boldsymbol{x}_{i}+c^{W} \tag{6.5}
\end{equation*}
$$

where $D_{i j d}^{W}$ is the duration of work schedule $j$ on day $d$, indicating $t_{i j d}^{W, e}-t_{i j d}^{W, s}$.

The additional utility associated with children-related states $V_{i j d}^{A}(\cdot)$ in equation (6.1) is assumed to be associated with the spouse's work schedule and the children's school/daycare schedules. For instance, an individual may be reluctant to work if his/her children stay home alone because his/her spouse also has to work, or if both his/her spouse and children are back home because he/she will lose joint time with the whole family. Therefore, when an individual is deciding about the work schedule, he/she is assumed to consider the children's states during his/her working hours, which vary according to whether or not the spouse work and children's school/daycare schedules overlap.

We classify the state of children into six categories:

State 1: children at home with the spouse for the whole day
State 2: children at school/daycare
State 3: children at home with the spouse before going to school/daycare
State 4: children at home without parents before going to school/daycare
State 5: children at home without parents after school/daycare
State 6: children at home with the spouse after school/daycare

Figure 6.1 depicts an example of a child's state during individual $i$ 's working hours according to the work schedule of the spouse. Individual $i$ 's spouse's work schedule on day $d T_{i d}^{S}$ consists of start time $t_{i d}^{S, S}$ and end time $t_{i d}^{S, e}, T_{i d}^{S}=\left\{t_{i d}^{S, S}, t_{i d}^{S, e}\right\}$, whilst the $n^{\text {th }}$ child's school/daycare schedule on day $d T_{i d}^{C_{n}}$ is represented by start time $t_{i d}^{C_{n}, s}$ and end time $t_{i d}^{C_{n, e}}$ of school/daycare, where $n=\{1, \ldots, N\}$, and $N$ is the total number of children in a household. $T_{i d}^{C_{n}}=\varnothing$ denotes no school/daycare activity of the $n^{t h}$ child on day $d$. As shown in Figure 1, when the work start time of the spouse is earlier than the start time of the $n^{\text {th }}$ child's school/daycare (i.e. $t_{i d}^{S, s}<t_{i d}^{C_{n}, s}$ ), the $n^{\text {th }}$ child stays home without parents from $t_{i d}^{S, s}$ to $t_{i d}^{C_{n, s}}$. Similarly, the child also has to stay home without parents when the work end time of the spouse is later than the end time of the child's school/daycare (i.e. $t_{i d}^{S, e}>t_{i d}^{C_{n}, e}$ ). A child should be in one state at $t_{i d}^{w} \in\left(t_{i d}^{w, s}, t_{i d}^{w, e}\right)$.


Figure 6.1 Example of children state classification

We need to point out that in multi-children households ( $N>1$ ), there will be a large number of states generated by interactions among household members' schedules, $T_{i d}^{w}, T_{i d}^{S}, T_{i d}^{C_{1}}, \ldots, T_{i d}^{C_{n}}, \ldots, T_{i d}^{C_{N}}$, which may lead to some extremely short and meaningless states. Indeed, parents need to decide how to organize children's out-of-school time for various reasons such as security, children's-development, etc. In order to reduce the number of meaningless states and capture the effect of different types of states, the minimum school/daycare time in multi-child household is selected as the children's school/daycare schedule, which ranges from the last child going to school/daycare $t_{i d}^{C, s}=\max \left\{t_{i d}^{C_{n, S}}\right\}$ to the first child coming back from school $t_{i d}^{C_{i d}}=\min \left\{t_{i d}^{C_{n}, e}\right\}$. Based on the classification of states and individual $i^{\prime}$ s additional utility during work schedule $j$ on day $d, V_{i d}^{a}(\cdot)$ equals the sum of the utility of each possible state, which is expressed as follows

$$
\begin{equation*}
V_{i j d}^{A}(\cdot)=\sum_{k \in K_{i j d}} V_{i j d}^{k}\left(T_{i j d}^{k}, \boldsymbol{x}_{i}, \boldsymbol{x}_{i}^{S}, \boldsymbol{x}_{i}^{C}\right) \tag{6.6}
\end{equation*}
$$

where,
$V_{i j d}^{k}(\cdot)$ : the additional utility associated with state $k$ of the children during individual $i$ 's work schedule $j$ on day $d$.
$K_{i j d}$ : a set of individual $i$ 's children's states during work schedule $j$ on day $d, K_{i j d} \subset$ $K$, where $K$ is the whole set including all the possible children's states during a work schedule.
$T_{i j d}^{k}$ : a set of time components of children's state $k$ during individual $i$ 's work schedule $j$ on day $d, T_{i j d}^{k}=\left\{t_{i j d}^{k, s}, t_{i j d}^{k, e}\right\}$ where $t_{i j d}^{k, s}$ and $t_{i j d}^{k, e}$ are start and end times of state $k$, respectively.

Akin to the formulation of the utility of the work function, individual $i$ 's additional utility of children-related state $k$ during work schedule $j$ on day $d$ is formulated as follows

$$
\begin{equation*}
V_{i j d}^{k,}(\cdot)=\int_{t_{i j d}}^{t_{i, j d}^{k, e}}\left[v^{A}\left(t^{k}\right)\right] d t^{k} \tag{6.7}
\end{equation*}
$$

where,
$v^{A}\left(t^{k}\right)$ : the marginal additional utility at a certain time point $t^{k}$ during children's state

$$
\begin{aligned}
& k, t_{i j d}^{k, s} \leq t^{k} \leq t_{i j d}^{k, e} \\
& =\frac{\beta^{k}}{t^{k}-t_{i j d}^{k, s}}+\boldsymbol{\alpha}^{k} \boldsymbol{x}_{i}+\boldsymbol{\alpha}^{k, S} \boldsymbol{x}_{i}^{S}+\boldsymbol{\alpha}^{k, C} \boldsymbol{x}_{i}^{C}
\end{aligned}
$$

$\beta^{k}$ : a parameter representing the effects of the duration of children's state $k$ at time point $t^{k}$ on the marginal additional utility.
$\boldsymbol{\alpha}^{k}$ : a $(1 \times R)$ vector of parameters representing the effects of socio-demographic characteristics of individual $i$ on the marginal additional utility with respect to children's state $k$.
$\boldsymbol{\alpha}^{k, S}:$ a $(1 \times G)$ vector of parameters representing the effects of socio-demographic characteristics of individual $i$ 's spouse on the marginal additional utility with respect to children's state $k$.
$\boldsymbol{\alpha}^{k, C}$ : a $(1 \times Q)$ vector of parameters representing the effects of socio-demographic characteristics of individual $i$ 's child on the marginal additional utility with respect to children's state $k$.

Hence, the equation can be transformed by solving the definite integral term as follows

$$
\begin{equation*}
V_{i j d}^{k}(\cdot)=\beta^{k} \ln \left(D_{i j d}^{k}\right)+\boldsymbol{\alpha}^{k} \boldsymbol{x}_{i} D_{i j d}^{k}+\boldsymbol{\alpha}^{k, S} \boldsymbol{x}_{i}^{S} D_{i j d}^{k}+\boldsymbol{\alpha}^{k, C} \boldsymbol{x}_{i}^{C} D_{i j d}^{k} \tag{6.8}
\end{equation*}
$$

where,
$D_{i j d}^{k}=t_{i j d}^{k, e}-t_{i j d}^{k, s}$ is the duration of additional children-related state $k$.

Based on the utility function of the work schedule, we assume that an individual considers a finite number of possible work schedules when scheduling work activity for a day, and that he/she adopts a schedule that maximizes his/her utility. By assuming that the disturbance term of the utility function $\varepsilon_{i j d}$ is an independent and identically distributed random term and follows an extreme value type 1 distribution, the choice probability function can be expressed as

$$
\begin{equation*}
P_{i j d}=\frac{\exp \left\{V_{i j d}^{W}(\cdot)+V_{i d d}^{A}(\cdot)\right\}}{\sum_{j^{\prime} \in J_{i}} \exp \left\{V_{i j^{\prime} d}^{\prime}(\cdot)+V_{i j^{\prime} d}^{A}(\cdot)\right\}} \tag{6.9}
\end{equation*}
$$

where $J_{i}$ indicates the set of alternatives with respect to individual $i$.

We note that $J_{i}$ includes "not-to-work" on that day $(j=0)$ whose systematic utility is assumed to be zero (i.e. $U_{i(j=0) d}=0+\varepsilon_{i(j=0) d}$ ). It means that the utility of work is assumed to be positive. If the negative additional utility is bigger than the utility of work, people do not work.

### 6.3.2 Model of household work schedule arrangement

As shown in function (6.1-6.9), the utility derived from one of the parent's work schedule is assumed to depend on the other parent's work schedule and children school/daycare agenda. In this regard, the changing of one parent's work schedule on a day will lead to a change of utility derived for the other parent's work schedule, and vice versa. In other words, parents' work schedules in a household are not independent, but interact with each other. Therefore, both parents' work schedules should be generated simultaneously instead of separately.

Given the choice of utility theory, we assume that parents tend to arrange their work schedules such that household utility derived from their work schedules on a weekly basis is maximized. Let $t_{h k d}$ denote a set of time components of parents' work schedule $k$ from household $h$ on day $d, t_{h k d}=\left\{t_{h i k d}, t_{h i}{ }^{\prime} k d=\right.$ $\left\{t_{h i k d}^{s}, t_{h i k d}^{e}, t_{h i k d}^{s}, t_{h i / k d}^{e}\right\}$, where $t_{h i k d}^{s}, t_{h i k d}^{e}, t_{h i k d}^{s}, t_{h i k d}^{e}$ are start time and end time of work schedule alternative $k$ for parent $i$ and the other parent $i^{\prime}$ from household $h$ on day $d$ respectively. $t_{h k d} \in T_{h d}=\left\{t_{h 1 d}, t_{h 2 d}, \ldots, t_{h K d},\right\}$, where $T_{h d}$ is the choice set of all combinations of parents' work schedule alternatives in household $h$ on day $d$, and $K$ is the total number of work schedule alternatives of household $h$ on day $d$.


Figure 6.2 Composition of weekly work schedule choice set of a household

Correspondingly, a set of household weekly work schedule alternatives $t_{h m}$ is composed of work start time and end time of both parents on each weekday across the week, $t_{h m}=\left\{t_{h m d_{1}}, t_{h m d_{2}}, t_{h m d_{3}}, t_{h m d_{4}}, t_{h m d_{5}}\right\}, t_{h m} \in T_{h}=\left\{t_{h 1}, t_{h 2}, \ldots, t_{h M}\right\}$, where $T_{h}$ is the choice set of all combination in terms of both parents' weekly work schedule alternatives in household $h, M$ is the total number of work schedule alternatives of household $h$ on a week. $M=\prod_{d} K_{d}$. The composition of the weekly work schedule choice set $T_{h}$ of a household is shown in Fig.6.2.

Using the model for prediction, we can formulate a family of models on the basis of the utility function (Equations 6.1-6.9). The utility derived from the household's weekly work schedule is equal to the sum of both parents' utility derived from their individual work schedule, which are described by following equations

$$
\begin{align*}
& \text { Maxmize } u_{h m}=\sum_{d} u_{h k d}  \tag{6.10}\\
& =\sum_{d}\left(u_{h i k d}+u_{h i / k d}\right) \tag{6.11}
\end{align*}
$$

Subject to

$$
\begin{gather*}
\sum_{d}\left(t_{\text {hikd }}^{e}-t_{\text {hikd }}^{s}\right)+\left(t_{h i^{\prime} k d}^{e}-t_{h i^{\prime} k d}^{s}\right)=w_{h}  \tag{6.12}\\
\min (w) \leq t_{\text {hikd }}^{W, e}-t_{\text {hikkd }}^{W, S} \leq \max (w)  \tag{6.13}\\
\min (w) \leq t_{h i^{\prime} k d}^{W, e}-t_{h i^{\prime} k d} \leq \max (w) \tag{6.14}
\end{gather*}
$$

where, $w_{h}$ is the given weekly number of working hours of household $h$.

$$
\begin{gather*}
w_{h k d}=\left(t_{h i k d}^{e}-t_{h i k d}^{s}\right)+\left(t_{h i^{\prime} k d}^{e}-t_{h i^{\prime} k d}^{s}\right)  \tag{6.15}\\
w_{h i k d}=t_{h i k d}^{e}-t_{h i k d}^{s}  \tag{6.16}\\
w_{h i k d}=t_{h i k d}^{e}-t_{h i k d}^{s} \tag{6.17}
\end{gather*}
$$

where $w_{h k d}$ is the number of working hours for work schedule alternative $t_{h k d}, w_{\text {hikd }}$ and $w_{h i k d}$ are working hours of parent $i$ and parent $i^{\prime}$ respectively for $t_{h k d}$.

Regarding the composition of weekly household work schedule $T_{h}$, the total number of work schedule choice alternatives $M$ on a week depends on the number of feasible parents work schedule alternatives $K$ on each day, where $M=\prod_{d} K_{d}$, whilst $K$ depends on the number of start time and end time alternatives of work schedule. $K$ and $M$ are directly affected by the definition of range and intervals of work start time and working hours/end time. If the start time and end time choice is a continuous variable (each second on a day is considered as intervals from 0:00 to 23:59), the size of $T_{h}$ is approaching infinity. On the other hand, when people decide a daily start time and end time of work schedule in reality, the distinction between the times in a short period (e.g., 8:00am and 8:01am) might not be very significant and even irrelevant in the sense that contracts are usually decided at the level of half days or maybe number of hours. In this context, in order to make the choice structure manageable, by trading off realistic work arrangements in daily life, and the operability of the model, the range of start times is selected from 6 am to 4 pm , and the range of end time is selected from 11am to 12 pm for each parent and every 0.5 hour intervals.

As for the number of working hours, although the time on a day is strictly restricted to 24 hours per day, people cannot spend all 24 hours working, because of various reasons such as physiological limitation, social needs, institutional restrictions, etc. Generally the number of working hours on a day should be higher than a certain minimum because of job requirements, time efficiency, financial constraints, etc. Hence, considering statistical data of working hours in Netherlands from CBS and rationality, the choice of the number of daily working hour alternative is restricted from 2 hours to 10 hours per day for each parent if they work on that day and every 0.5 hour interval. Let $w$ denotes choice set of individual working hour alternatives on a day including 0 hour as not work, where working hour $w_{\text {hikd }}$ and $w_{h i^{\prime} k d}$ of work schedule alternative $t_{h k d}$ can be formulated as: $w_{h i k d}, w_{h i{ }^{\prime} k d} \in w=$ $\{0$ hour, 2 hours, 2.5 hours, ... 10 hours $\}$. Let $\boldsymbol{w}$ denotes the choice set of all combinations of parents' working hour alternatives on a day, $\boldsymbol{w}_{r} \in \boldsymbol{w}=\left\{\boldsymbol{w}_{1}, \boldsymbol{w}_{2}, \ldots\right.$, $\left.\boldsymbol{w}_{R}\right\}$, where $\boldsymbol{w}_{r}=\left\{w_{r_{i}}, w_{r_{i}}\right\}$ denote a set of parents' working hour combination, $w_{r_{i}}$ and $w_{r_{i^{\prime}}}$ denote working hours of alternative $r$ for parent $i$ and $i^{\prime}$ respectively.

Under random utility maximization theory, we assume that parents will select the work schedule alternative which generate the maximum utility depending on the information available on the total number of working hours by individual/household. It means that the parents' predicted total working hours per week should satisfy the
observed/assumed marginal constraints. The constraints of number of working hours can be defined in several ways. In this thesis, we classified five conditions to restrict working hours by individual/household, day/week: condition 1, no total working hour constraints; condition 2, household weekly working hours are subjected to observed household weekly working hours; condition 3, each parent's weekly working hours are subjected to observed weekly working hours of each parent's respectively; condition 4, household working hours on each day is subjected to observed household working hours on the same day; condition 5, each parent's working hours on each day is subjected to observed working hours on the same day of each parent respectively. According to the definition of different working hour constraints, the optimized solution can be formulated as follows

Condition 1,

$$
\begin{equation*}
\text { Maximize } u_{h m}=\sum_{d} \max \left(u_{h i k d}+u_{h i^{\prime} k d}\right) \tag{6.18}
\end{equation*}
$$

Condition 2,

$$
\begin{align*}
& \text { Maximize } u_{h m}=\max \left(\sum_{d}\left(u_{h i k d}+u_{h i^{\prime} k d}\right)\right)  \tag{6.19}\\
& \sum_{d}\left(t_{h i k d}^{e}-t_{h i k d}^{s}\right)+\left(t_{h i^{\prime} k d}^{e}-t_{h i^{\prime} k d}^{s}\right)=\boldsymbol{w}_{h} \tag{6.20}
\end{align*}
$$

Condition 3,

$$
\begin{gather*}
\text { Maximize } u_{h m}=\max \left(\sum_{d} u_{h i k d}\right)+\max \left(\sum_{d} u_{h i^{\prime} k d}\right)  \tag{6.21}\\
\sum_{d}\left(t_{h i k d}^{e}-t_{h i k d}^{s}\right)=\boldsymbol{w}_{h i}  \tag{6.22}\\
\sum_{d}\left(t_{h i^{\prime} k d}^{e}-t_{h^{\prime} k d}^{s}\right)=\boldsymbol{w}_{h i^{\prime}} \tag{6.23}
\end{gather*}
$$

Condition 4,

$$
\begin{gather*}
\text { Maximize } u_{h m}=\sum_{d}\left(\max \left(u_{h i k d}+u_{h i^{\prime} k d}\right)\right)  \tag{6.24}\\
\left(t_{h i k d}^{e}-t_{h i k d}^{s}\right)+\left(t_{h i^{\prime} k d}^{e}-t_{h i^{\prime} k d}^{s}\right)=\boldsymbol{w}_{h d} \tag{6.25}
\end{gather*}
$$

Condition 5,

$$
\begin{gather*}
\text { Maximize } u_{h m}=\sum_{d} \max \left(u_{h i k d}\right)+\sum_{d} \max \left(u_{h i^{\prime} k d}\right)  \tag{6.26}\\
t_{h i k d}^{e}-t_{h i k d}^{s}=\boldsymbol{w}_{h i d}  \tag{6.27}\\
t_{h i^{\prime} k d}^{e}-t_{h i^{\prime} k d}^{s}=\boldsymbol{w}_{h i^{\prime} d} \tag{6.28}
\end{gather*}
$$

where $\boldsymbol{w}_{h}$ is the observed number of weekly working hours of household $h, \boldsymbol{w}_{h i}$ and $\boldsymbol{w}_{h i^{\prime}}$ are observed weekly working hours of parent $i$ and parent $i^{\prime}$ in household $h$ respectively, $\boldsymbol{w}_{h i d}$ and $\boldsymbol{w}_{h i^{\prime} d}$ are observed working hours of parent $i$ and parent $i^{\prime}$ in household $h$ on day $d$ respectively.

### 6.4 Data description

The questionnaire used in this chapter included questions about the weekly work schedule of both the respondent and his/her spouse (e.g. start time and end time of work, departure time to work and arrival time to work, etc.), about the schedules (e.g. school/daycare agenda) of each child, and about the socio-demographic characteristics (e.g. gender of respondent, age of respondent and the spouse, education level, number of children, age and gender of each child, etc.) of household members. On the basis of the work situation, respondents were classified into both respondent and spouse have a job, only the respondent has a job, only the spouse has a job, neither respondent or spouse has a job. Depending on the flexibility of work, respondents were classified into work with fixed work schedule, work with flexible work schedule and non-work. In this chapter, unemployed were excluded from model estimation. Furthermore, because the start time and end time of work are needed, respondents with a fully flexible work schedule were not taken into account.

Table 6.1 Sample description

|  |  | Value | Percent (\%) |
| :--- | :--- | :---: | :---: |
| Gender | Male | 345 | 51.0 |
|  | Female | 331 | 49.0 |
| Number of children | 1 | 358 | 53.0 |
|  | 2 | 264 | 39.0 |
|  | $>2$ | 54 | 8.0 |
| Household income | $=<1400$ | 27 | 4.0 |
| (Euro/month) | $1401-2800$ | 95 | 14.0 |
|  | $2801-4200$ | 284 | 42.0 |
|  | $>4200$ | 270 | 40.0 |
| Education level | Primary level | 21 | 4.0 |
|  | Middle level | 297 | 44.0 |
|  | High level | 352 | 52.0 |
| Youngest child's age | $0-4$ years | 379 | 56.0 |
|  | $5-8$ years | 135 | 20.0 |
|  | $9-12$ years | 162 | 24.0 |
| Youngest child's | Boy | 352 | 52.0 |
| gender | Girl | 324 | 48.0 |

As a result, 676 respondents were selected for model estimation.
The frequency distributions of the selected socio-demographic characteristics are shown in Table 6.1. Regarding the sample characteristics, the frequency distribution of male and female respondents shows that they are almost equally represented in the sample ( $49 \%$ and $51 \%$ respectively). More than $90 \%$ of the respondents has one or two children, whilst only $8 \%$ has more than two children. Moreover, more than $50 \%$ of the respondents has a medium income. By contrast, respondents with a low household income level of less than 1200 Euro/month represent only 4\%.

The percentage respondents with a primary, middle and high level of education is $4 \%, 44.0 \%$ and $52 \%$ respectively, which indicates that most respondents at least have medium level education. In addition, $56 \%$ of the respondents has a young child (younger than the five year old/school age), $20 \%$ of the youngest children is between $5-8$ years of age, while $24 \%$ of the youngest children is between $9-12$ years of age.

Regarding the distributions of work start and end times, the peak start time is between 7am and 9:30am, while the end time for work has a small peak between noon and 1 pm , and a bigger peak between 4 pm and 7 pm .

### 6.5 Results

To estimate the proposed utility function (6.1), we created a choice set of work schedules for each respondent. The created choice set consists of 2 work schedules and non-working (i.e. there are 3 alternatives in each choice set). When a respondent worked on a certain day of the week, the reported start and end times were used to describe the chosen work schedule in the choice set. We randomly generated a work schedule and non-working that represent the non-chosen alternatives. As for a respondent who did not work on a certain day of the week, the non-working was used to describe the chosen alternative in the choice set. We randomly generated two different work schedule that present the non-chosen alternatives. Variables related to time, such as duration and time point are continuous, whilst the remaining variables were effect-coded. The estimation results are shown in Table 6.2. For a better understanding, Figures 6.3 depicts the interaction effects between socio-demographic characteristics and the duration of work.

### 6.5.1 Utility of work duration

The estimated parameter for work duration is significant and positive, indicating that the utility of work increases with increasing duration of the work episode. Due to the

Table 6.2 Estimation results

| Attributes |  |  |  | Estimate | P-value |
| :---: | :---: | :---: | :---: | :---: | :---: |
| Work activity utility: Constant |  |  |  | -3.5778 | 0.0000 |
| SocioDemographics | Gender |  | Male <br> Female | $\begin{gathered} -1.4283 \\ 1.4283 \end{gathered}$ | $\begin{aligned} & 0.0000 \\ & 0.0000 \end{aligned}$ |
|  | Household income <br> (Euro/month) |  | $\begin{aligned} & =<1400 \\ & 1401-2800 \\ & 2801-4200 \\ & >4200 \end{aligned}$ | $\begin{gathered} 0.4754 \\ 1.0561 \\ 0.1258 \\ -1.6572 \\ \hline \end{gathered}$ | $\begin{aligned} & 0.4131 \\ & 0.0047 \\ & 0.6791 \\ & 0.0000 \end{aligned}$ |
|  | Education level |  | Primary level <br> Middle level <br> High level | $\begin{gathered} 1.8557 \\ -1.2606 \\ -0.5952 \\ \hline \end{gathered}$ | 0.0000 <br> 0.0000 <br> 0.0617 |
|  | Day of the week |  | Monday <br> Tuesday <br> Wednesday <br> Thursday <br> Friday | $\begin{gathered} 0.2252 \\ -0.1030 \\ -0.3883 \\ 0.4184 \\ -0.1524 \end{gathered}$ | $\begin{aligned} & 0.5359 \\ & 0.7818 \\ & 0.2780 \\ & 0.2640 \\ & 0.5603 \end{aligned}$ |
|  | Number of children |  | $\begin{array}{\|l\|} \hline 1 \\ 2 \\ >2 \\ \hline \end{array}$ | $-0.5336$ <br> $-0.5174$ <br> 1.0510 | 0.0598 <br> 0.0596 <br> 0.0059 |
|  | Youngest child's age |  | 0-4 years <br> 5-8 years <br> 9-12 years | $\begin{gathered} -1.3614 \\ 0.8660 \\ 0.4954 \end{gathered}$ | $\begin{aligned} & 0.0000 \\ & 0.0052 \\ & 0.1931 \end{aligned}$ |
|  | Youngest child's gender |  | Boy Girl | $\begin{gathered} 0.6896 \\ -0.6896 \end{gathered}$ | $\begin{aligned} & 0.0003 \\ & 0.0003 \end{aligned}$ |
|  | $\log$ (Duration of Work) |  |  | 2.1001 | 0.0000 |
|  | Interaction between Duration of Work and: | Gender | Male <br> Female | $\begin{gathered} 0.2596 \\ -0.2596 \\ \hline \end{gathered}$ | $\begin{aligned} & 0.0000 \\ & 0.0000 \end{aligned}$ |
|  |  | Household income <br> (Euro/month) | $\begin{aligned} & =<1400 \\ & 1401-2800 \\ & 2801-4200 \\ & >4200 \end{aligned}$ | $\begin{aligned} & \hline-0.0007 \\ & -0.2027 \\ & -0.0203 \\ & 0.2236 \end{aligned}$ | $\begin{aligned} & 0.9957 \\ & 0.0680 \\ & 0.7534 \\ & 0.0026 \\ & \hline \end{aligned}$ |
|  |  | Education level | Primary level <br> Middle level <br> High level | $-0.2099$ <br> 0.1832 <br> 0.0268 | 0.0661 <br> 0.0074 <br> 0.4832 |
|  |  | Day of the week | Monday <br> Tuesday | $\begin{gathered} -0.0339 \\ 0.0658 \end{gathered}$ | $\begin{aligned} & 0.6225 \\ & 0.3881 \end{aligned}$ |


|  |  |  | Wednesday <br> Thursday <br> Friday | $\begin{gathered} \hline 0.0474 \\ -0.0698 \\ -0.0096 \\ \hline \end{gathered}$ | $\begin{aligned} & 0.4688 \\ & 0.3661 \\ & 0.9980 \\ & \hline \end{aligned}$ |
| :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | Number of children | $\begin{aligned} & 1 \\ & 2 \\ & >2 \end{aligned}$ | $\begin{gathered} 0.2168 \\ 0.0523 \\ -0.2691 \end{gathered}$ | $\begin{aligned} & 0.0000 \\ & 0.2331 \\ & 0.0000 \end{aligned}$ |
|  |  | Youngest child's age | $0-4$ years <br> 5-8 years <br> 9-12 years | $\begin{aligned} & -0.2126 \\ & 0.0269 \\ & 0.1857 \end{aligned}$ | $\begin{aligned} & 0.0003 \\ & 0.7100 \\ & 0.1149 \end{aligned}$ |
|  |  | Youngest child's gender | Boy Girl | $\begin{aligned} & -0.0886 \\ & 0.0886 \end{aligned}$ | $\begin{aligned} & 0.0007 \\ & 0.0007 \end{aligned}$ |
| State 1 during work: Children at home with spouse for the whole day | $\log$ (Duration of State 1) |  |  | 1.7523 | 0.0000 |
|  | Interaction between Duration of State 1 and: | Gender (of respondent) | Male <br> Female | $\begin{gathered} 0.0744 \\ -0.0744 \end{gathered}$ | $\begin{aligned} & 0.0242 \\ & 0.0242 \end{aligned}$ |
|  |  | Household income (Euro/month) | $\begin{aligned} & =<1400 \\ & 1401-2800 \\ & 2801-4200 \\ & >4200 \end{aligned}$ | $\begin{aligned} & -0.0107 \\ & 0.0046 \\ & -0.0084 \\ & 0.0146 \end{aligned}$ | $\begin{aligned} & 0.9111 \\ & 0.9626 \\ & 0.8752 \\ & 0.7593 \end{aligned}$ |
|  |  | Education level (of respondent) | Primary level <br> Middle level <br> High level | $\begin{aligned} & \hline-0.1270 \\ & 0.0441 \\ & 0.0828 \\ & \hline \end{aligned}$ | $\begin{aligned} & 0.2025 \\ & 0.4559 \\ & 0.2590 \end{aligned}$ |
|  |  | Day of the week | Monday <br> Tuesday <br> Wednesday <br> Thursday <br> Friday | $\begin{gathered} 0.0311 \\ -0.0117 \\ -0.0177 \\ -0.0003 \\ -0.0015 \\ \hline \end{gathered}$ | $\begin{aligned} & 0.5859 \\ & 0.8516 \\ & 0.7337 \\ & 0.9965 \\ & 0.9290 \end{aligned}$ |
|  |  | Number of children | $\begin{aligned} & 1 \\ & 2 \\ & >2 \end{aligned}$ | $\begin{aligned} & -0.1967 \\ & 0.0029 \\ & 0.1938 \end{aligned}$ | $\begin{aligned} & 0.0147 \\ & 0.9720 \\ & 0.3479 \end{aligned}$ |
|  |  | Gender match of spouse and the youngest child | Yes No | $\begin{aligned} & -0.0102 \\ & 0.0102 \end{aligned}$ | $\begin{aligned} & 0.5926 \\ & 0.5926 \end{aligned}$ |
| State 2 during work: Children at school/ daycare | $\log$ (Duration of State 2) |  |  | 1.4206 | 0.0000 |
|  | Interaction between Duration of State 2 and: | Gender (of respondent) | Male <br> Female | $\begin{array}{r} 0.0011 \\ -0.0011 \\ \hline \end{array}$ | $\begin{aligned} & 0.9772 \\ & 0.9772 \end{aligned}$ |
|  |  | Household income | $\begin{aligned} & =<1400 \\ & 1401-2800 \end{aligned}$ | $\begin{aligned} & \hline-0.2189 \\ & 0.1833 \\ & \hline \end{aligned}$ | $\begin{aligned} & 0.0495 \\ & 0.0843 \end{aligned}$ |


|  |  | (Euro/month) | $\begin{aligned} & 2801-4200 \\ & >4200 \end{aligned}$ | $\begin{gathered} -0.0200 \\ 0.0556 \end{gathered}$ | $\begin{aligned} & 0.7479 \\ & 0.5443 \end{aligned}$ |
| :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | Education level (of worker) | Primary level <br> Middle level High level | $-0.2673$ <br> 0.0828 <br> 0.1845 | 0.0124 <br> 0.2035 <br> 0.0189 |
|  |  | Day of the week | Monday <br> Tuesday <br> Wednesday <br> Thursday <br> Friday | $\begin{gathered} 0.0666 \\ -0.0639 \\ 0.0393 \\ 0.0298 \\ -0.0718 \end{gathered}$ | $\begin{aligned} & 0.3352 \\ & 0.3660 \\ & 0.5718 \\ & 0.6759 \\ & 0.2231 \end{aligned}$ |
|  |  | Number of children | 1 <br> 2 $>2$ | $\begin{aligned} & \hline-0.1067 \\ & 0.0942 \\ & 0.0125 \\ & \hline \end{aligned}$ | 0.0359 <br> 0.0305 <br> 0.1560 |
|  |  | Youngest child's age | $0-4$ years <br> 5-8 years <br> 9-12 years | $\begin{aligned} & 0.49407 \\ & -0.1457 \\ & -0.3484 \end{aligned}$ | $\begin{aligned} & 0.0000 \\ & 0.0234 \\ & 0.0017 \end{aligned}$ |
|  |  | Youngest child's gender | Boy <br> Girl | $\begin{gathered} 0.0349 \\ -0.0349 \\ \hline \hline \end{gathered}$ | $\begin{aligned} & 0.1817 \\ & 0.1817 \\ & \hline \end{aligned}$ |
| State 3 during work: Children at home with spouse before school/daycare | $\log$ (Duration of State 3) |  |  | -2.5933 | 0.0000 |
|  | Interaction <br> between <br> Duration of <br> State 3 and: | Gender (of respondent) | Male <br> Female | $\begin{gathered} 0.1428 \\ -0.1428 \\ \hline \end{gathered}$ | $\begin{aligned} & 0.0521 \\ & 0.0521 \\ & \hline \end{aligned}$ |
|  |  | Household income <br> (Euro/month) | $\begin{aligned} & =<1400 \\ & 1401-2800 \\ & 2801-4200 \\ & >4200 \end{aligned}$ | $\begin{aligned} & 0.1912 \\ & 0.1381 \\ & -0.0326 \\ & -0.2967 \\ & \hline \end{aligned}$ | $\begin{aligned} & 0.4947 \\ & 0.4007 \\ & 0.7681 \\ & 0.0300 \\ & \hline \end{aligned}$ |
|  |  | Education level (of worker) | Primary level <br> Middle level <br> High level | $\begin{aligned} & 0.2970 \\ & -0.1206 \\ & -0.1764 \\ & \hline \end{aligned}$ | $\begin{aligned} & 0.0688 \\ & 0.2421 \\ & 0.1174 \end{aligned}$ |
|  |  | Day of the week | Monday <br> Tuesday <br> Wednesday <br> Thursday <br> Friday | $\begin{gathered} 0.1830 \\ -0.1277 \\ -0.1464 \\ 0.0098 \\ 0.0814 \end{gathered}$ | $\begin{aligned} & 0.1776 \\ & 0.3276 \\ & 0.2620 \\ & 0.9493 \\ & 0.5032 \end{aligned}$ |
|  |  | Number of children | $\begin{aligned} & 1 \\ & 2 \\ & >2 \end{aligned}$ | $\begin{gathered} -1.2929 \\ 0.5876 \\ 0.7053 \end{gathered}$ | $\begin{aligned} & 0.0000 \\ & 0.0000 \\ & 0.0000 \end{aligned}$ |
|  |  | Youngest child's age | $0-4$ years <br> 5-8 years | $\begin{gathered} 0.5276 \\ -0.2509 \\ \hline \end{gathered}$ | $\begin{aligned} & 0.0000 \\ & 0.0533 \end{aligned}$ |


|  |  |  | 9-12 years | -0.2767 | 0.2542 |
| :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | Gender match of spouse and youngest child | $\begin{aligned} & \text { Yes } \\ & \text { No } \end{aligned}$ | $\begin{gathered} 0.01838 \\ -0.01838 \end{gathered}$ | $\begin{aligned} & 0.7745 \\ & 0.7745 \end{aligned}$ |
| State 4 during work: Children at home without parents before school/daycare | $\log$ (Duration of State 4) |  |  | 1.8029 | 0.4137 |
|  | Interaction between Duration of State 4 and: | Gender (of respondent) | Male <br> Female | $\begin{gathered} 1.5000 \\ -1.5000 \end{gathered}$ | $\begin{aligned} & 0.0222 \\ & 0.0222 \end{aligned}$ |
|  |  | Household income (Euro/ month) | $\begin{aligned} & \hline=<1400 \\ & 1401-2800 \\ & 2801-4200 \\ & >4200 \\ & \hline \end{aligned}$ | $\begin{gathered} 18.477 \\ -5.6694 \\ -8.2893 \\ -4.5183 \\ \hline \end{gathered}$ | $\begin{aligned} & 0.0054 \\ & 0.0173 \\ & 0.0007 \\ & 0.0496 \\ & \hline \end{aligned}$ |
|  |  | Education level (of worker) | Primary level <br> Middle level <br> High level | $\begin{gathered} -1.7054 \\ 2.5587 \\ -0.8533 \end{gathered}$ | $\begin{aligned} & \hline 0.1538 \\ & 0.0022 \\ & 0.2165 \end{aligned}$ |
|  |  | Day of the week | Monday <br> Tuesday <br> Wednesday <br> Thursday <br> Friday | $\begin{aligned} & 0.8246 \\ & -0.5300 \\ & -0.3774 \\ & -0.4690 \\ & 0.5519 \\ & \hline \end{aligned}$ | $\begin{aligned} & 0.5138 \\ & 0.5009 \\ & 0.5786 \\ & 0.5178 \\ & 0.4791 \end{aligned}$ |
|  |  | Number of children | $\begin{aligned} & 1 \\ & 2 \\ & >2 \end{aligned}$ | $\begin{aligned} & \hline-10.776 \\ & 4.9932 \\ & 5.7831 \\ & \hline \end{aligned}$ | $\begin{aligned} & 0.0002 \\ & 0.0004 \\ & 0.0023 \end{aligned}$ |
|  |  | Youngest child's age | $0-4$ years <br> 5-8 years <br> 9-12 years | $\begin{gathered} \hline 3.4014 \\ -1.2105 \\ -2.1909 \\ \hline \end{gathered}$ | $\begin{aligned} & 0.0000 \\ & 0.0576 \\ & 0.0004 \\ & \hline \end{aligned}$ |
|  |  | Youngest child's gender | Boy <br> Girl | $\begin{gathered} -0.8436 \\ 0.8436 \end{gathered}$ | $\begin{aligned} & 0.0428 \\ & 0.0428 \end{aligned}$ |
| State 5 during work: Children at home without parents after school/ daycare | log(Duration of State 5) |  |  | -2.2808 | 0.0000 |
|  | Interaction <br> between <br> Duration of <br> State 5 and: | Gender (of respondent) | Male <br> Female | $\begin{gathered} 0.1814 \\ -0.1814 \end{gathered}$ | $\begin{aligned} & \hline 0.1229 \\ & 0.1229 \end{aligned}$ |
|  |  | Household income (Euro/month) | $\begin{aligned} & =<1400 \\ & 1401-2800 \\ & 2801-4200 \\ & >4200 \\ & \hline \end{aligned}$ | $\begin{gathered} \hline-0.2537 \\ 0.1226 \\ 0.2707 \\ -0.1397 \end{gathered}$ | $\begin{aligned} & 0.7131 \\ & 0.6819 \\ & 0.3021 \\ & 0.6950 \end{aligned}$ |
|  |  | Education level (of worker) | Primary level Middle level High level | $\begin{gathered} 0.0056 \\ -0.1812 \\ 0.1756 \end{gathered}$ | $\begin{aligned} & \hline 0.9849 \\ & 0.3256 \\ & 0.3815 \end{aligned}$ |


|  |  | Day of the week | Monday <br> Tuesday <br> Wednesday <br> Thursday <br> Friday | $\begin{gathered} -0.0069 \\ 0.1590 \\ -0.3126 \\ -0.0080 \\ 0.1685 \end{gathered}$ | $\begin{aligned} & 0.9743 \\ & 0.4531 \\ & 0.0501 \\ & 0.9669 \\ & 0.2437 \end{aligned}$ |
| :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | Number of children | $\begin{aligned} & 1 \\ & 2 \\ & >2 \end{aligned}$ | $\begin{aligned} & \hline-0.1674 \\ & 0.1005 \\ & 0.0669 \\ & \hline \end{aligned}$ | $\begin{aligned} & \hline 0.3475 \\ & 0.5835 \\ & 0.6978 \\ & \hline \end{aligned}$ |
|  |  | Youngest child's age | $0-4$ years <br> 5-8 years <br> 9-12 years | $\begin{aligned} & 0.3072 \\ & -0.4702 \\ & 0.1630 \end{aligned}$ | $\begin{aligned} & 0.0198 \\ & 0.0039 \\ & 0.2027 \end{aligned}$ |
|  |  | Youngest child's gender | Boy <br> Girl | $\begin{gathered} 0.1437 \\ -0.1437 \\ \hline \end{gathered}$ | $\begin{aligned} & 0.1225 \\ & 0.1225 \end{aligned}$ |
| State 6 during work: <br> Children at home with spouse after school/daycare | $\log$ (Duration of State 6) |  |  | -0.7220 | 0.0003 |
|  | Interaction between Duration of State 6 and: | Gender (of respondent) | Male <br> Female | $\begin{gathered} 0.0091 \\ -0.0091 \end{gathered}$ | $\begin{aligned} & 0.8122 \\ & 0.8122 \end{aligned}$ |
|  |  | Household income <br> (Euro/month) | $\begin{aligned} & =<1400 \\ & 1401-2800 \\ & 2801-4200 \\ & >4200 \end{aligned}$ | $\begin{aligned} & -0.0499 \\ & -0.0147 \\ & 0.0823 \\ & -0.0177 \\ & \hline \end{aligned}$ | $\begin{aligned} & 0.6979 \\ & 0.8975 \\ & 0.2153 \\ & 0.4834 \end{aligned}$ |
|  |  | Education level (of worker) | Primary level <br> Middle level <br> High level | $\begin{aligned} & 0.0842 \\ & -0.1291 \\ & 0.0449 \end{aligned}$ | $\begin{aligned} & 0.4456 \\ & 0.0544 \\ & 0.4874 \end{aligned}$ |
|  |  | Day of the week | Monday <br> Tuesday <br> Wednesday <br> Thursday <br> Friday | $\begin{gathered} 0.0467 \\ -0.0501 \\ 0.0984 \\ -0.0741 \\ -0.0209 \end{gathered}$ | $\begin{aligned} & 0.5126 \\ & 0.5168 \\ & 0.1184 \\ & 0.3535 \\ & 0.7466 \\ & \hline \end{aligned}$ |
|  |  | Number of children | $\begin{aligned} & 1 \\ & 2 \\ & >2 \end{aligned}$ | $\begin{aligned} & -0.1640 \\ & 0.0895 \\ & 0.0745 \end{aligned}$ | $\begin{aligned} & 0.0017 \\ & 0.0645 \\ & 0.0812 \end{aligned}$ |
|  |  | Youngest child's age | 0-4 years <br> 5-8 years <br> 9-12 years | $\begin{gathered} 0.3792 \\ -0.1598 \\ -0.2195 \\ \hline \end{gathered}$ | 0.0000 <br> 0.0193 <br> 0.0550 |
|  |  | Gender match of spouse and youngest child | $\begin{aligned} & \text { Yes } \\ & \text { No } \end{aligned}$ | $\begin{gathered} 0.0909 \\ -0.0909 \end{gathered}$ | $\begin{aligned} & 0.0007 \\ & 0.0007 \end{aligned}$ |
| Goodness-of-fit | Log likelihood $=-964.89686$ |  |  |  |  |

chosen logarithmic function, the marginal utility monotonically decreases. This tendency varies according an individual's socio-demographic characteristics. The estimated results are listed in the first and second part of Table 6.2 and are depicted in Figure 6.3. As shown in Figure 6.3(a), for a relatively short number of working hours (approximately less than 6 hours), females gain more utility than males, implying that the probability of women choosing a work schedule of shorter duration is higher than for males.

On the other hand, the utility of long working hours is significantly higher for males than for females. Regarding income, the increase in utility of work by working longer is much higher for people in high-income households than for people in the other income categories (Figure 6.3(b)). In addition, as shown in Figure 6.3(c), the utility of work duration for low-educated people does not increase with an increasing number of working hours when the number of working hours is higher than 5 . On the other hand, work duration utility of middle- and high-educated people increases continuously with an increasing number of working hours. Figure 6.3(d) indicates that the utility of work duration does not vary significantly by day of the week. While the utility of work duration generally increases with an increasing number of working hours, the utility for people with more than two children tends to be dramatically decrease with an increasing number of working hours, as shown in Figure 6.3(e). An explanation of this effect may be that people need to spend more time on child-related activities when they have more than two children.

Regarding children's socio-demographic characteristics, people living with a child younger than five years old are more likely to work fewer hours than people who do not (Figure 6.3(f)). One of the reasons may be that, in the Netherlands, children older than five are legally required to attend school. Parents need to spend more time on childcare before their school age. As shown in Figure 6.3(g), the utility of work duration is slightly higher for people whose youngest child is a boy than for people whose youngest child is a girl. However, this effect is not statistically significant.

### 6.5.2 Utility of state 1 : children stay at home with the spouse the whole day

As listed in the third part of Table 6.2, the estimated parameter of work duration for state 1 is significant and positive, suggesting that the utility of work duration of an


Figure 6.3 Utility of work duration by working hours and sociodemographic characteristics
individual increases when the spouse stays home the whole day to take care of the children. In other words, people are more likely to work longer when their spouse can take care of the children for the whole day. This tendency varies by socio-demographic characteristics of the individual, his/her spouse and the children. Males are more likely to work longer than females when their spouse stays home to take care of the
children. This difference increases with increasing duration of this state. Regarding the effects of education level, well-educated people tend to derive more additional utility than relatively low-educated people when the spouse stays home to take care of the children during work hours. The estimated parameter for the interaction between the duration of state 1 and the number of children staying at home during state 1 reveals an interesting result: the number of children is positively associated with the additional utility. It means that a spouse taking care of more than one child at home at the same time generates more utility than when the spouse takes care of only one child. An explanation may be that the efficiency of child care is higher. As for the effects of household income, day of week and parent-youngest child gender match, these effects are not significant.

### 6.5.3 Utility of state 2: children at school/daycare

The fourth part of Table 6.2 demonstrates that the utility of work increases when the children are in state 2 , suggesting that parents likely choose a work schedule that has more overlap with their children's school/day care schedule. The estimated results indicate that the interaction between the duration of state 2 and gender is not significant. It is also not significant for household income, day of the week and gender of the youngest child, which means that the choice of overlap between an individual's work schedule and children's school/daycare schedule is not affected (extended or shortened) by these variables. The interaction effect between education level and duration of children at school during work hours suggests that people with higher education are more likely to synchronize their work schedule with their children's school/daycare schedule than people with low education. A plausible reason might be that there tend to be more opportunities for highly educated people to get a position with flexible working time (including start and end times, and/or working hours) than for less educated people. The additional utility shows a less positive effect on the utility of work duration when there is only one child in school/daycare. Table 6.2 also suggests that children younger than five years old have a higher marginal effect on an individual's utility of work duration, which may be because people do not need to worry about their young children when they are at school/daycare.

### 6.5.4 Utility of state 3 : children at home with spouse before school/daycare

As shown in the fifth part of Table 6.2, a longer duration of state 3 decreases the utility of work, indicating that people are more likely to start work not earlier than the
start time of their children's school/daycare. There may be several plausible reasons for this tendency. First, they may have the opportunity to escort their children to school or take care of their children at home before they go to school. Second, there is the loss of shared time with family members in the morning. Therefore, it may suggest that people tend to adjust their work schedule to have more shared time with their whole family. Third, because school starts between 8 am and 9 am, a longer duration of this state implies an earlier start time for work. Therefore, the result may reflect the fact that people tend to avoid working too early.

This tendency tends to vary according to individual's socio-demographic characteristics. Females tend to be more negatively influenced by this state compared to males. This result may imply that mothers tend to feel more responsible preparing children for school/daycare in the morning. People with a primary level of education have a smaller marginal effect on the utility of work than others. One of the reasons may that the possibility to start work earlier in the morning is higher for them.

The results also reveal that the negative additional utility associated with this state strongly depends on the number of children staying at home. If there is only one child staying at home with the spouse in this state, the utility of work duration during this state dramatically decreases with increasing duration of this state. This negative impact is reduced if more than one child is in this state. Table 2 also indicates that the estimated effect of the youngest child's age decreases with an increasing age of the child.

### 6.5.5 Utility of state 4: children staying home without parents before school/daycare

As shown in the fifth part of Table 6.2, the results indicate that the duration of children staying at home without parents before going to school/daycare does not have a significant effect on work schedules. Taking into account the limited number of observations for this state and the short duration (few mins) of this state in the data, this finding may suggest that people try to avoid going to work before children go to school, especially when the spouse already departed to work.

In spite of the non-significant additional utility associated with this state, many interesting effects can be observed. First, mothers seem less willing to work if their children are home alone. Second, children staying home alone seems more acceptable for low income respondents, whilst less acceptable for the remaining household income categories. Third, more disutility is generated if there is only one child in this state. Finally, young children (<=4 years old) in this state is associated with a positive
additional utility. Again, this unexpected effect may be generated by the limited number of observations for this state.

### 6.5.6 Utility of state 5: children staying home without parents after school /daycare

In the sixth part of Table 6.2, the estimated parameter of the duration of this state is significantly negative, indicating that state 5 generates substantial disutility. Therefore, people are likely to choose the work schedule, which has less overlap between their work schedule and state 5 to avoid children staying home alone after school/daycare.

Table 6.2 also shows that mothers tend to be less willing to work than fathers if their children already went back home from school/daycare but their spouse did not. The negative effect of this state on the utility of work duration tends to be bigger on Wednesdays than on other days of the week, which seems caused by the fact that elementary schools are closed on Wednesday afternoon, and school time on Wednesday is shorter than on other weekdays. The negative utility caused by this state tends to be higher if there is only one child at home alone. It may imply that the negative utility can be reduced if older brothers/sisters can take care of their younger siblings. In addition, this state tends to generate a great disutility on the utility of work when the age of the youngest child in this state is under 8 years old.

Table 6.2 also reveals that a higher disutility is generated if the youngest child in this state is a girl, suggesting that people are more likely to avoid being at work when their children are home alone, especially if the youngest child is a girl.

### 6.5.7 Utility of state 6: children at home with spouse after school/daycare

The seventh part of Table 6.2 lists the estimated parameters of work duration when children are at home with a spouse after school/daycare. It indicates that this state induces a significant disutility on the utility of work. Similar to state 3 , this result may reflect the desire or need to escort children from school/daycare or take care of them after coming back from school/daycare. In addition, working when both the spouse and children stay at home after school/daycare means a loss of shared time with the whole family. Therefore, this result may imply that people prefer to enjoy more shared time with their family.

Most parameters show a similar tendency as those estimated for state 3: for example, the number of children and the age of the youngest child. We need to point out, however, that less disutility will be generated in state 6 if the spouse's gender is the same as that of the youngest child. A possible reason may be that the available joint time is much longer after school/daycare (normally in the afternoon/evening) than in the before school/daycare (normally in the morning). Parents normally organize child-centered activities, such as the father playing football with his son, or the mother accompanying her daughter to dance, etc., in the afternoon or evening, implying any true or perceived necessity of gender match is more significant in this state. Interestingly, gender match is not significant in state 1.

### 6.6 Conclusions and discussion

This chapter developed an activity-based model of work schedule arrangements in two-adult household with children, which will be used to predict parents' work schedules with start time and working hours/end time for each day of the week. To this end, we first investigated the effects of social demographic characteristics and children's schedules on parents' work schedule decisions. We suggested a random utility model to represent the work schedule decision-making process under different states of children in two-adult households, assuming that parents' work schedule decisions are influenced by the schedule of their children.

Our empirical results reveal that the utility of work during a particular hour of the day depends on whether the child is home alone, accompanied by the spouse, or at school/daycare. Therefore, the probability of working on a particular time of the day is influenced by the schedule of the children. In particular, parents prefer to choose to work when their child(ren) are at school/daycare, which indicates that they would like to have more overlap between their work schedule and children's school/daycare schedule. In contrast, parents have a lower preference to start work earlier or finish work later than their children's school/daycare schedule, as in that case, they not only cannot escort their children, but also lose the joint time with their whole family. Indeed, parents try to avoid their children stay at home without parents, especially in case of young children.

In light of these empirical findings, a random utility model of household work schedule arrangements is developed under the hypothesis that parents will select the work schedule which generate the maximized utility which includes the overlap with the schedules of the children and the other parent. The work schedule choice set for
a household is composed of all alternatives for different combinations of work start time and end time of both parents on each day of the week.

The formulated model of work schedule arrangements can predict people's start time, work duration and end time in two-adult household with children and, therefore, help in formulating and assessing policies to solve congestion during morning and evening peak hours. In addition, it can serve as a useful extension of activity-based models of travel demand. The next chapter is the application of modelling work schedule arrangement which will evaluate whether the model can accurately predict the weekly work schedule.

## 7

## Work Schedule Prediction

### 7.1 Introduction

In Chapter 6, we developed an activity-based model of work schedule arrangements in two-adult households with young children which can predict parents' work schedules with start time and number of working hours/end time for each day of the week considering the effects of socio-demographic characteristics and children's agendas. This chapter is to evaluate the accuracy of the model. Therefore, the difference between predicted and observed work schedules will be compared for the sample households. The chapter is organized as follows.

Following this section, we first predict parents weekly work schedules under five difference conditions, based on the results reported in Chapter 6. Next, we discuss how to evaluate whether the model can accurately predict household work schedules, as different data represent different conditions and different marginal distributions define the degrees of freedom left in the generation of work schedule arrangements. The power of prediction is evaluated by comparing predicted work schedules against observations in terms of predicting work vs. non-work days, work start time and working hours. The chapter ends with a conclusion and discussion of findings.

### 7.2 Predicting work schedules

In Chapter 6, we defined five different working hour conditions in order to find the global optimal solution. It implies we need to derive the utility of all alternatives (feasible work schedules) in choice set $T_{h}$ under different constraints (Equations 6.186.28). The number of work schedule alternatives under conditions 1,4 and 5 is equal to $\sum_{d} K_{d}$, where $K_{d}$ is the total number of work schedule alternatives on day $d$ in the household, whilst under condition 2 and 3, the number of work schedule alternatives
is $\prod_{d} K_{d}=\prod_{d}\left(R_{i d} * R_{i^{\prime} d}\right)$, where $R_{i d}$ and $R_{i^{\prime} d}$ are the total number of work schedule alternatives of parents $i$ and $i^{\prime}$ on day $d$. Regarding the definition of start time and end time/duration alternatives, the total number of household work schedule alternatives under conditions 2 and 3 is very large. The number of work schedule alternatives is greatly reduced under conditions 2 and 3.

As shown in Figure 7.1, depending on parents' work hours combination $\boldsymbol{w}_{r}=$ $\left\{w_{r_{i},}, w_{r_{i}{ }^{\prime}}\right\}$ of parents $i$ and $i^{\prime}$ on a day, the choice set of a household's daily work schedule $T_{h d}$ can be divided into $R$ subsets, denoted as $T_{h d}^{r} \in T_{h d}=$ $\left\{\left\{T_{h d}^{1}\right\}, \ldots,\left\{T_{h d}^{r}\right\}, \ldots,\left\{T_{h d}^{R}\right\}\right\}$. Let $t_{h k d}^{r}$ denote a work schedule alternative in subset $T_{h d}^{r}$, $T_{h d}^{r}=\left\{t_{h 1 d}^{r}, \ldots, t_{h k d}^{r}, \ldots, t_{h K d}^{r}\right\}$. All work schedule alternatives in subset $T_{h d}^{r}$ have different start and end times but the same combination of number of working hours $\left\{w_{r_{i}}, w_{r_{i}{ }^{\prime}}\right\}$, which is formulated as $w_{\text {hikd }}^{r}=w_{r i}$ and $w_{\text {hikd }}^{r}=w_{r i}$. All work schedule alternatives are unique in each subset $T_{h d}^{r}$.

Based on the utility functions, the utility of work schedule alternatives in each subset varies by different start time and end time of the parents with the same working hours combination $\left\{w_{r_{i}}, w_{r_{i}}\right\}$ on day $d$. Correspondingly, there is a maximum utility derived from a specific start time and end time of parents in subset $T_{h d}^{r}$. Under the hypothesis of utility maximization, parents will select the work schedule which generates the maximum utility. In other words, for spending the same working hours of each parent, they will choose the best start time/end time to generate the maximum utility. Hence, in each subset $T_{h d}^{r}$, only the work schedule alternative $t_{h d}^{r, \max }$ which generates the maximum household utility will be retained whilst those schedules generating less utility are excluded. The utility derived from $t_{h d}^{r, \max }$ is denoted as $u_{h d}^{r, \max }$. The reduced work schedule choice set $T_{h d}^{\max }=\left\{t_{h d}^{1, \max }, \ldots, t_{h d}^{r, \max }, \ldots, t_{h d}^{R, \max }\right\}$.

Let $T_{h}^{\max }$ denotes the reduced weekly work schedule choice set, which is composed of all combinations of $t_{h d}^{r, m a x}$ on each day across the week. Let $t_{h m}^{\max }$ denote an alternative in the reduced weekly household work schedule choice set $T_{h}^{\max }$, $t_{h m}^{\max }=\left\{t_{h m d_{1}}^{\max }, t_{h m d_{2}}^{\max }, t_{h m d_{3}}^{\max }, t_{h m d_{4}}^{\max }, t_{h \boldsymbol{m} d_{5}}^{\max }\right\}$, where $t_{h m}^{\max } \in T_{h}^{\max }=\left\{t_{h 1}^{\max }, t_{h 2}^{\max }, \ldots, t_{h M}^{\max }\right\}$, $t_{h m d_{1}}^{\max } \in T_{h d_{1}}^{\max }, t_{h m d_{2}}^{\max } \in T_{h d_{2}}^{\max }, t_{h m d_{3}}^{\max } \in T_{h d_{3}}^{\max }, t_{h m d_{4}}^{\max } \in T_{h d_{4}}^{\max }, t_{h m d_{5}}^{\max } \in T_{h d_{5}}^{\max }, \boldsymbol{M}$ is the total number of alternatives in $T_{h}^{\max }$. According to definition that the range of working hours of each parent is between 2 hours to 10 hours with 0.5 hour intervals, and taking into account the non-work schedule (working hours is equal to zero), there are $R=306$ working hours combination alternatives in each day. Therefore, the total number of alternatives $\boldsymbol{M}=\sum_{d} R_{d}$ in the reduced choice set $T_{h}^{\max }$ is mathematically
equal to $306^{\wedge} 5$. In this study, an exhaustive method is used to find the global optimal solution.


Figure 7.1 Reduce the number of work schedule alternatives by branch and bound method


Figure 7.2 Process of finding solution

Overall, the process of finding the optimal solution is illustrated in Figure 7.2.
Step 1: generate daily work schedule choice set $T_{h d}$ across the week;
Step 2: divide $T_{h d}$ into $R$ subsets which denoted as $T_{h d}^{r}$ according to working hours combination alternative of parents' $w_{r}=\left\{w_{r_{i}}, w_{r_{i}}\right\}$, where $T_{h d}^{r} \in T_{h d}=$ $\left\{\left\{T_{h d}^{1}\right\}, \ldots,\left\{T_{h d}^{r}\right\}, \ldots,\left\{T_{h d}^{R}\right\}\right\}$, and $T_{h d}^{r}=\left\{t_{h 1 d}^{r}, \ldots, t_{h k d}^{r}, \ldots, t_{h K d}^{r}\right\} ;$

Step 3: calculate the utility of each work schedule alternative $t_{h k d}^{r}$ in each subset $T_{h d}^{r}$;

Step 4: select the work schedule alternative $t_{h d}^{r, \max }$ which generates the maximum utility in each subset $T_{h d}^{r}$;

Step 5: generate the reduced weekly household work schedule choice set $T_{h}^{\max }$ of all combination in terms of the maximum utility work schedule $t_{h d}^{r, \text { max }}$ across days of the week, where $t_{h m}^{\max } \in T_{h}^{\max }=\left\{t_{h 1}^{\max }, t_{h 2}^{\max }, \ldots, t_{h m}^{\max }, \ldots, t_{h M}^{\max }\right\}$;

Step 6: select a weekly household work schedule alternative $t_{h m}^{\max }$ from $T_{h}^{\max }$;
Step 7: check if alternative $t_{h m}^{\max }$ satisfies the constraints, if yes, go step 8, else go back to step 6, $\boldsymbol{m}=\boldsymbol{m}+1$;

Step 8: calculate the utility $u_{h m}^{\max }$ derived from $t_{h m}^{\max }$ on the basis of utility function (10);

Step 9: if $\boldsymbol{m}=1$, save $\boldsymbol{u}_{h m}^{\max }=u_{h m}^{\max }$ and $\boldsymbol{t}_{h m}^{\max }=t_{h m}^{\max }$, else check if $u_{h m}^{\max }>$ $\boldsymbol{u}_{h(\boldsymbol{m} \mathbf{- 1})}^{\max }$, if yes, save $\boldsymbol{u}_{h m}^{\max }=u_{h m}^{\max }$ and $\boldsymbol{t}_{h m}^{\max }=t_{h m}^{\max }$, else save $\boldsymbol{u}_{h m}^{\max }=\boldsymbol{u}_{h(\boldsymbol{m} \mathbf{- 1})}^{\max }$ and $\boldsymbol{t}_{h m}^{\max }=\boldsymbol{t}_{h(\boldsymbol{m}-\mathbf{1})}^{\max }$, where $\boldsymbol{u}_{h m}^{\max }$ is the maximized utility after $\boldsymbol{m}$ times of loop, and $\boldsymbol{t}_{h m}^{\max }$ is the work schedule which generates the maximum utility $\boldsymbol{u}_{h m}^{\max }$ after $\boldsymbol{m}$ iterations;

Step 10: if $\boldsymbol{m}=\boldsymbol{M}$, go to step 11, else go back to step $6, \boldsymbol{m}=\boldsymbol{m}+1$.
Step 11: Output the $\boldsymbol{u}_{h m}^{\max }$ and $\boldsymbol{t}_{h m}^{\max }$ after $\boldsymbol{M}$ times of iteration, where $\boldsymbol{t}_{h M}^{\max }$ is the optimal solution which generate the maximized household utility $\boldsymbol{u}_{h M}^{\max }$ on a week of a household in the choice set $T_{h d}$.

### 7.3 Results

The proposed model can generate work schedule arrangements of two-adult households, especially for dual earner households with young children. In turn, such schedules can be the cornerstones of an activity-based travel demand forecasting model, which typically assumes that work and home are the anchors of daily activitytravel patters (Rasouli \& Timmermans, 2015). Similar to the classic spatial interaction models, prediction of work schedules can be subjected to a set of constraints, depending on the data collected in the travel survey. One extreme is that only the total number of working hours for the complete household is known for say a week.

Another extreme is that a multi-day travel survey is available that contains information about the number of working hours for each parent per day of the week. These different data represent the different conditions mentioned. At the same time, these different marginal distributions also define the degree of freedom left in the generation of work schedule arrangements. Thus, one would expect that the more detailed the data, the closer the generated schedules will fit the marginal distributions of the number of working hours per day per individual/household. If number of working hours per day per household members are known, the model can only predict the start/end time of the work episode. If these constraints are relaxed, the model can also generate error in the number of working hours per day and allocation of hours to individual household members.

With the aim of validating the model and assessing its predictive power, we followed five conditions classified in section 6.3 .2 to restrict working hours by individual/household, day/week: condition 1, no total working hour constraints; condition 2 , household weekly working hours are subjected to observed household weekly working hours; condition 3, each parent's weekly working hours are subjected to observed weekly working hours of each parent's respectively; condition 4, household working hours on each day is subjected to observed household working hours on the same day; condition 5 , each parent's working hours on each day is subjected to observed working hours on the same day of each parent respectively.

Tables 7.1-7.3 show the generated work schedule arrangements under the different conditions. The power of the prediction is evaluated by comparing predicted work schedules against observations in terms of predicting work vs. non-work days, work start time and working hours. The results are shown in Tables 7.1 to 7.3. In each table, the results are listed by male, female and the average, across day of the week under each condition. Owing to the definition of working hour constraints in the previous section, households that do not meet constraints 2 hours $\leq w_{\text {hikd }} \leq$ 10 hours and 2 hours $\leq w_{h i{ }^{\prime} k d} \leq 10$ hours were removed. As a result, 658 households were selected for work schedule prediction and model evaluation.

### 7.3.1 Predicting work vs. non-work days

Table 7.1 describes the number/percentage of correctly predicted working day for each day of the week under the five conditions. A prediction is correct if the prediction work day respectively non-work day is the same as the observation. The results under condition 5 have not been listed because the working hours is subjected to each
parent on each day, the predictions are always the same with observations. The average percentage of correct predictions under conditions 1, 2, 3 and 4 are respectively $75.9 \%, 79.3 \%, 87.3 \%$ and $84.8 \%$, suggesting that the model predict parents' work day well. As shown in Table 7.1, results also suggest that the percentage of correct working day predictions of males is higher than of females under all conditions. The average percentage correctly predicted working days of males ( $88.6 \%, 85.5 \%, 91.6 \%, 91.4 \%$ ) is higher than for females ( $64.2 \%, 73 \%, 83.1 \%$, $78.2 \%$ ) under conditions $1,2,3$ and 4 . An explanation of this difference may be that the average number of weekly working hours of males is higher than those of females, and therefore there is less flexibility in predicting work days.

Table 7.1 Percentage correctly predicted working days ( $\mathrm{N}=658$ )

|  |  |  | Mon | Tue | Wed | Thu | Fri | Average |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Constraint 1 | M | N | 575 | 594 | 558 | 589 | 568 | 88.6 |
|  |  | \% | 87.4 | 91.5 | 86.0 | 90.8 | 87.5 |  |
|  | F | N | 454 | 450 | 386 | 431 | 392 |  |
|  |  | \% | 69.0 | 68.4 | 58.7 | 65.5 | 59.6 | 64.2 |
|  | A | \% | 78.2 | 79.3 | 71.7 | 77.5 | 72.9 | 75.9 |
| Constraint 2 | M | N | 575 | 600 | 543 | 564 | 532 | 85.5 |
|  |  | \% | 87.4 | 91.2 | 82.5 | 85.7 | 80.9 |  |
|  | F | N | 498 | 518 | 443 | 489 | 454 |  |
|  |  | \% | 75.7 | 78.7 | 67.3 | 74.3 | 69.0 | 73.0 |
|  | A | \% | 81.5 | 85.0 | 74.9 | 80.0 | 74.9 | 79.3 |
| Constraint 3 | M | N | 613 | 616 | 592 | 607 | 586 | 91.6 |
|  |  | \% | 93.2 | 93.6 | 90.0 | 92.2 | 89.1 |  |
|  | F | N | 578 | 574 | 520 | 553 | 508 |  |
|  |  | \% | 87.8 | 87.2 | 79.0 | 84.0 | 77.2 | 83.1 |
|  | A | \% | 90.5 | 90.4 | 84.5 | 88.1 | 83.1 | 87.3 |
| Constraint 4 | M | N | 593 | 612 | 589 | 612 | 601 | 91.4 |
|  |  | \% | 90.1 | 93.0 | 89.5 | 93.0 | 91.3 |  |
|  | F | N | 515 | 535 | 510 | 522 | 493 |  |
|  |  | \% | 78.3 | 81.3 | 77.5 | 79.3 | 74.9 | 78.2 |
|  | A | \% | 84.2 | 87.2 | 83.5 | 86.2 | 83.1 | 84.8 |

Table 7.2 Start time difference between predicted and observed work schedules under five conditions

|  |  | Monday | Tuesday | Wednesday | Thursday | Friday | Average |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- | :---: |
| Constraint 1 | M(h) | 0.49 | 0.80 | 0.73 | 0.47 | 0.65 | 0.63 |
|  | F(h) | -0.84 | -0.46 | -0.51 | -0.73 | -0.57 | -0.56 |
|  | A(h) | -0.16 | 0.16 | 0.21 | -0.04 | 0.21 | 0.07 |
| Constraint 2 | M(h) | -0.01 | 0.14 | 0.10 | -0.03 | 0.00 | 0.04 |
|  | F(h) | -0.61 | -0.37 | -0.18 | -0.49 | -0.33 | -0.39 |
|  | A(h) | -0.33 | -0.07 | -0.07 | -0.30 | -0.20 | -0.18 |
| Constraint 3 | M(h) | -0.02 | 0.23 | 0.20 | -0.02 | 0.06 | 0.09 |
|  | F(h) | -0.61 | -0.32 | -0.18 | -0.43 | -0.33 | -0.37 |
|  | A(h) | -0.32 | -0.05 | 0.01 | -0.23 | -0.27 | -0.14 |
| Constraint 4 | M(h) | -0.08 | 0.04 | 0.06 | -0.07 | 0.00 | -0.01 |
|  | F(h) | -0.56 | -0.42 | -0.27 | -0.52 | -0.35 | -0.42 |
|  | A(h) | -0.32 | -0.19 | -0.11 | -0.30 | -0.17 | -0.22 |
| Constraint 5 | M(h) | -0.10 | 0.01 | 0.08 | -0.08 | 0.02 | -0.01 |
|  | F(h) | -0.56 | -0.37 | -0.31 | -0.51 | -0.31 | -0.41 |
|  | A(h) | -0.33 | -0.18 | -0.12 | -0.30 | -0.14 | -0.21 |

### 7.3.2 Predicting start times

Accuracy in predicting start times is measured in terms of the difference between predicted and observed start times of the work schedule. The results are shown in Table 7.2. The average start time difference for the five conditions are respectively 0.07 hour, -0.18 hour, -0.14 hour, -0.22 hour and -0.21 hour, which suggests that the model predicts parents' work start times accurately under all conditions, but slightly earlier than the observations in most cases. All females' start time differences are negative, indicating that the model predicts females' work start times earlier than their observed start times. In contrast, the results for males show the opposite tendency. Most males are predicted to start work later than observed. Results in Table 4 also suggest that the model predicts male's start times more accurately (all less than 0.1 hour on average) than the work start times of females ( -0.39 hour, -.037 hour, -0.42 hour, -0.41 hour) across the week under conditions $2,3,4$, and 5 . The accuracy of predicted work start times of females is only higher than the predicted work start times of males under condition 1 when there are no working hour constraints.

Table 7.3 Differences between predicted and observed work schedules by days of the week under five conditions

|  |  | Mon | Tue | Wed | Thu | Fri | Average | Average |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- |
| (week) | (day) |  |  |  |  |  |  |  |
| Constraint 1 | M(h) | 1.54 | 1.75 | 1.64 | 1.13 | 1.58 | 7.64 | 1.53 |
|  | F(h) | 2.22 | 2.45 | 1.97 | 2.05 | 2.41 | 11.1 | 2.22 |
|  | A(h) | 1.88 | 2.10 | 1.81 | 1.59 | 2.00 | 9.38 | 1.87 |
| Constraint 2 | M(h) | 0.45 | 0.81 | 0.18 | -0.78 | -0.96 | -0.30 | -0.06 |
|  | F(h) | 0.27 | -0.08 | 0.04 | 0.07 | -0.01 | 0.30 | 0.06 |
|  | A(h) | 0.36 | 0.37 | 0.11 | -0.36 | -0.49 | 0.00 | 0.00 |
| Constraint 3 | M(h) | 0.50 | 0.43 | 0.42 | -0.85 | -0.51 | 0.00 | 0.00 |
|  | F(h) | 0.33 | -0.08 | -0.22 | 0.02 | -0.04 | 0.00 | 0.00 |
|  | A(h) | 0.42 | 0.18 | 0.11 | -0.42 | -0.28 | 0.00 | 0.00 |
| Constraint 4 | M(h) | 0.32 | 0.64 | 0.19 | 0.08 | -0.11 | 1.12 | 0.22 |
|  | F(h) | -0.32 | -0.64 | -0.19 | -0.08 | 0.11 | -1.12 | -0.22 |
|  | A(h) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

### 7.3.3 Predicting number of working hours

The accuracy of predicted number of working hours is reported in Table 7.3. It shows that the average working hours difference under condition 1 is 9.38 hours/week, with 7.64 and 11.1 hours/week for respectively males and females. This suggests that the model overpredicts parents' working hours if there are no constraints on the number of working hours. An explanation of these differences may be that the utility increases with an increasing number of working hours, implying parents can work longer to maximize the utility if there is no limitation on the number of working hours.

Under condition 2, household number of weekly working hours are subjected to observed household number of weekly working hours. Therefore, the average difference between predicted and observed number of weekly working hours is 0 hours/week, with -0.30 hours/week for males and 0.30 hours/week for females respectively, indicating that the model can allocate working hours rather precisely between parents for a week. Males' differences for the average daily number of working hours from Monday to Friday are respectively 0.45 hours, 0.81 hours, 0.18 hours, -0.78 hours and -0.96 hours, while the corresponding differences for females
are respectively 0.27 hours, -0.08 hours, 0.04 hours, 0.07 hours and -0.01 hours, which suggests that the model predicts the daily number of working hours of females more accurately than for males.

Under condition 3, each parent's weekly working hours are subjected to their observed weekly working hours. Correspondingly the average number of weekly working hours difference is 0 hours/week, for both males and females. Similar as the results under condition 2 , the differences by day of the week for males $(0.50,0.43$, $0.42,-0.85$ and -0.51 hours) are bigger than for females ( $0.33,-0.08,-0.22,0.02$ and -0.04 hours), suggesting that the model predicts more accurately for females than males under condition 3.

As shown in Table 5, under condition 4, the average working hour differences of males and females indicate that the predicted working hours of males are slightly higher than the observations ( 1.12 hours/week) and the opposite for females. Overall, the average difference under conditions 1, 2, 3 and 4 indicate that the model predicts parents' working hours accurately and that the prediction becomes more precise with increasing constraints.

### 7.4 Conclusions and discussion

The aim of this chapter was to validate the model and assess its predictive power. To this end, work schedules were predicted by using the model developed in Chapter 6 and compared against observations in terms of number/percentage of correctly predicted working days, start times and number of working hours for each day of the week under five different conditions classified in section 6.3.2.

The results of work vs. non-work days suggest that the accuracy of predicting working day correctly is higher for males than females under all five conditions, which may be caused by the different average number of weekly working hours and less flexibility in predicting working days. As for predicting work start times, the results suggest that the model predicts parents' start times accurately under all conditions, but predicts males' start times more accurately than females' start times across the week under conditions $2,3,4$, and 5.

In this study, we proved that the model can predict parents' work schedules accurately when parents working hours are subjected to their observed number by day or week. Model predictions tend to become more precise with increasing strength of constraints. Another important and interesting finding is that the model can allocate working hours precisely between parents (male and female) on a week when
household weekly working hours are subjected to observed household weekly working hours. Consequently, the model can be used to contribute to transportation demand analysis and investigate to reduce traffic congestions

Overall, the results suggest that the model can predict working days, start times and working hours for each day of the week accurately, especially when the strength of constraints increases. The next chapter summarizes this study and discusses possible future work.

## 8

## Conclusions and Discussion

### 8.1 Summary and findings

Work schedule arrangements influence traffic volumes and therefore congestion, especially during the morning and evening peak hours. Despite the critical importance of work schedules arrangements in organizing daily activity-travel patterns, studies on this topic are relatively rare, especially in transportation research. Moreover, extant studies do not explicitly consider children's schedules. Therefore, the aim of this dissertation was to contribute to the understanding of the formation of work arrangements by developing a new approach to modeling weekly work schedule arrangements in the context of activity-based models of transport demand, predicting work start time and end times/duration for each weekday. The focus is on two-adult households, mainly dual-earner households, with children.

In order to achieve this objective, six research questions have been addressed:

1. How can household work schedule arrangement decisions in two-adult households with children be conceptualized?
2. What kind of information we need to collect to operationalize the conceptual framework?
3. Which factors influence the decision of parents to apply for a job?
4. Are parents' job application choices significantly affected by social influence?
5. To what extent do children's schedules affect parents' choice of work schedule? Is this effect gendered?
6. Can we develop a model that predicts parents' weekly work schedule (start time and end times/working hours on each day of the week)?
7. Is the predictive model valid and what is its predictive power?

To answer these questions, first, we developed a conceptual framework of work schedule arrangements in two-adult households with children that explains how parents in two-adult households with children arrange their work schedule. The concept of work schedule arrangement referred to decisions how many hours to work per week and how to allocate these working hours across the days of the week and times of day. We assumed that parents choose the work schedule that maximizes their utility, subject to space-time constraints and formal requirements that come with the job.

The framework of work schedule arrangements involved job application, work schedule arrangement and household task allocation. Before arranging work schedules, people need to decide whether to apply for a specific job by considering whether attributes of the job can satisfy their preferences and requirements. Correspondingly, their work schedule will be arranged under the constraints imposed by the job. In addition, peoples' work schedule arrangements are also influenced by individual/household preferences, some socio-demographic characteristics and gender roles. Moreover, in two-adult households with children, parents' need to adjust their work schedules to their children's agendas in time and space, owning to the particular constraints which generated by children related activities.

Based on the conceptual framework, with the aim to understand modelling how parents arrange their work schedule in two-adult households with children, Chapter 3 presented the design and administration of the questionnaire. The data collection was conducted online in the Netherlands, through a platform that is developed in the Design and Decision Support Systems (DDSS) group, The questionnaire consists of basic socio-demographic characteristics, parents' weekly work schedules, the agenda of each child and a stated preference experiment about a parent's decisions to apply for a specific job.

Compared to standard activity-based questionnaires of socio-demographic characteristics, such as gender, age, education level, income, household composition, the data collection in this study involved more detailed information about respondents' household socio-demographic characteristics such as gender and age of each child, etc. Moreover, the work schedule of both parents and regular agendas of each child were collected with detailed information including activity type, start time and end time, travel time of the activity, transport mode, etc. For children's agendas, information such as who escorts/accompanies the child to the activity was collected. As a result, 1575 respondents participated in this survey and 1051 valid questionnaires were obtained.

Chapter 4 presented the estimation results of a mixed logit model about the effects of job attributes, social influence and socio-demographic characteristics on job application decisions, allowing for unobserved taste variation. The job application decision is the first step of agreeing on a work schedule arrangement. On the one hand, the attributes of a job such as working hours, distance and flexibility, may affect peoples' choice of transportation mode, travel time and distance, and thus traffic flows, especially during morning and evening peak hours. On the other hand, job application decisions play an important role in individual/household time use and task allocation. In households with children, parents need to trade-off between work and other individual and household activities, especially children-related activities. In addition, job application decisions may be influenced by attitudes of members of a household's social network. Accordingly, job application decisions are affected by work, social influence and socio-demographic attributes.

The estimated results indicated that work attributes and socio-demographic attributes play a more significant role than social influence in job application decisions, which suggests that people's job application decisions are less affected by opinions of members of their social network. Flexibility/work at home and number of working hours are most important. Peoples' job application decisions are significantly affected by the number of children. The probability of respondents to apply for jobs with less working hours is increased when there are more two children in the household, as they may need to spend more time on children-related activities. Moreover, different attitudes and sensitivity to working hours and salary lead to substantial preference differences. Finally, the probably of applying for a full time job seems low in households with children. These results can be used in the wider context of work schedule synchronization and coordination between the working adults and constitute the basis for the allocation of non-work household tasks, the focus of this thesis.

The objective of Chapter 5 was to analyze choices of escorting children to school in dual-earner households with children. In this chapter, we focused our attention to the decision who escorts the children to particular activities in dual-earner households, taking into account parents' work schedules. This is a highly interesting task allocation decision in which gender roles, values, personal preferences, social influence and norms, economic considerations and schedule constraints potentially play an important role. This chapter was based on part of the collected data which concerned socio-demographic characteristics of children and parents, the work schedules of the parents, and children-related agendas. The analysis in this chapter was based on the dual-earner households only.

The estimation results provided ample evidence of the critical influence of gender roles. The basic task allocation is that women are responsible for escorting their children. However, this tendency showed less strong with an increasing number of working hours and higher education, but the women's share in escorting is always higher. Gender match significantly affected escorting task allocation, especially for fathers. It triggered some degree of selectivity in escorting activities of men. Age of children also played an important role in the sense that escorting gradually decreases with increasing age.

Chapters 6 and 7 are the core chapters of this dissertation. Chapter 6 developed an activity-based model of work schedule arrangements in two-adult household with children, which is used to predict parents' work schedules with start time and working hours/end time for each day of the week. To this end, we first investigated the effects of social demographic characteristics and children's schedules on parents' work schedule decisions. We suggested a random utility model to represent the work schedule decision-making process under different states of children in two-adult households, assuming that parents' work schedule decisions are influenced by the schedule of their children.

The questionnaire used in this chapter included the weekly work schedule of both the respondent and his/her spouse, agendas of each child, and sociodemographic characteristics of household members. In this chapter, unemployed were excluded from model estimation. Furthermore, because the start time and end time of work are needed, respondents with a fully flexible work schedule were not taken into account. As a result, 676 respondents were selected for model estimation in this chapter.

The estimation results revealed that the probability of parents working on a particular time of the day is influenced by the schedule of the children. In particular, parents prefer to choose to work when their child(ren) are at school/daycare, indicating that they would like to have more overlap between their work schedule and children's school/daycare schedule. In contrast, parents have a lower preference to start work earlier or finish later than their children's school/daycare schedule, as in that case, they not only cannot escort their children, but also lose the joint time with their whole family. Indeed, parents try to avoid their children stay at home without parents, especially in case of young children.

In light of these empirical findings, a random utility model of household work schedule arrangements is developed under the hypothesis that parents will select the work schedule which generate the maximum utility which includes the overlap with
the schedules of the children and the other parent. The work schedule choice set for a household is composed of all alternatives for different combinations of work start time and end time of both parents on each day of the week.

The formulated model of work schedule arrangements can predict people's weekly work schedule with start time, work duration and end time in two-adult household with children and, therefore, help in formulating and assessing policies to solve congestion during morning and evening peak hours. In addition, it can serve as a useful extension of activity-based models of travel demand.

The aim of chapter 7 was to validate the model and assess its predictive power. To this end, work schedules were predicted by using the model developed in Chapter 6 and compared predictions against observations in terms of number/percentage of correctly predicted working days, start times and number of working hours for each day of the week under five different conditions (condition 1, no total working hour constraints; condition 2, household weekly working hours are subjected to observed household weekly working hours; condition 3, each parent's weekly working hours are subjected to observed weekly working hours of each parent's respectively; condition 4, household working hours on each day is subjected to observed household working hours on the same day; condition 5, each parent's working hours on each day is subjected to observed working hours on the same day of each parent respectively).

The results suggest that the model can predict the number of working days, start times and number of working hours for each day of the week accurately. As for predicting work vs. non-work days, the results suggested that the accuracy of predicting working day correctly is higher for males than females under all five conditions. The results of predicting work start times suggested that the model predicts parents' start times accurately under all conditions, but predicts males' start times more accurately than females' start times across the week under conditions 2, 3,4 , and 5 .

In this study, we proved that the model can predict parents' work schedules accurately when parents working hours are subjected to their observed number by day or week. Model predictions tend to become more precise with increasing strength of constraints. Another important and interesting finding is that the model can allocate working hours precisely between parents (male and female) on a week when household weekly working hours are subjected to observed household weekly working hours.

### 8.2 Discussion and future research

Section 8.1 summarized the findings and results of analysis that has been carried out in this dissertation. In this section, we will draw conclusions and discuss what can be improved in future research. The results of analysis suggested that parents' work schedule arrangement are strongly linked with children's daily agendas. Moreover, females tend to have part time jobs, and they still seem the primary person responsible for children-related activities (we took escorting as an example). However, gender match significantly affects this children-related task allocation, especially for fathers. Also, flexibility of work is very important for parents' work schedule. As children-related activities generate temporal and spatial constraints, they prefer have flexible work times/place when arranging their work schedule.

Several policy implications can be derived from the results of analyses. First, governments should encourage employers to supply more flexibility in working hours and/or work place, especially for people with children so that parents can commute outside peak hours and have more opportunities to conduct children-related activities. This will likely reduce congestion. Second, in order to stimulate higher labor force participation rates, governments should consider providing more benefits to working parents such as increased child care allowance, subsidized day care and increased tax refund. In addition, the model can be used to apply parents working start time and end time, therefore can contribute to transportation demand analysis and investigate how to reduce traffic congestions.

Although this research yielded valuable findings, still some limitations were encountered. First, we did not explicitly consider the degree of flexibility that individual workers have. To the extent that the lack of flexible working hours co-varies with particular socio-demographics, its effect is confounded with the effect of the sociodemographic variables. We need to also mention that due to the Covid-19 since 2020, work from home tended to be popular all over the world, the flexibility of working time/place should be interesting for our future work.

Second, we did not explicitly consider the work commute in the utility function. If an individual has a longer work commute or the available transportation mode requires the individual to leave home earlier, the individual will experience additional constraints to synchronize his/her work schedules with the children's agendas.

Third, in this study, we analyzed household task allocation, focusing on escorting only. A wider perspective including task allocation for all activities needed to run a household would enhance our understanding of gender roles and task allocation in dual-earner and other types of dual-parent households. It would provide
more insight into the role of escorting in the full set of household activities that could potentially be allocated among the parents and others.

Last but not the least, this study of modeling work schedule arrangement focused on two-adult households with child(ren). Therefore, future research should collect data and develop a model of work schedules in households without children.

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## List of Publications

## Journal articles

Han, B., Kim, J. and Timmermans, H.J.P. 2020. Turn taking behavior in dual earner households with children: a focus on escorting routines. Transportation, Vol. 47, pp. 203-222.
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