Journal of Soft Computing in Civil Engineering 5-1 (2021) 62-79

Contents lists available at SCCE

Journal of Soft Computing in Civil Engineering

Journal homepage: www.jsoftcivil.com

Escort Patterns in Dual-Worker Households with Students

Y. Rahmati[1], A. Samimi[2*]

1. Ph.D. Candidate, Department of Civil and Environmental Engineering, University of Illinois at Urbana-Champaign, Urbana, United States

2. Associate Professor, Department of Civil Engineering, Sharif University of Technology, Tehran, Iran

Corresponding author: *asamimi@sharif.edu*

https://doi.org/10.22115/SCCE.2021.257897.1261

ARTICLE INFO

Article history:
Received: 18 November 2020
Revised: 17 January 2021
Accepted: 18 January 2021

Keywords:
Group decision-making;
Interactions;
Escort patterns;
School trips.

ABSTRACT

Individuals have been regarded as independent decision makers in majority of transportation analysis. However, agents' behaviors are usually affected by the interactions among the members in a group; and therefore, individual decision-making paradigms may result in unrealistic outcomes and erroneous interpretations of the results. In light of this, the present study develops discrete choice models in individual and group levels and compares their prediction power in predicting the choice of escort pattern in dual-worker households with at least one under-18-year-old student. The main purpose is to reveal the efficiency of each approach in analyzing parent-child joint activities and highlight the effect of model misspecification in predicting group decisions using a quantifiable measure. The results reveal that more than 25 percent of correct predictions in school trips will be missed when the conventional individual decision-making procedure, rather than a group decision-making paradigm, is adopted. Also, 20 percent of the observed reduction in the explanatory power of the model was associated with trips from school. The findings of this study underscore the significance of implementing group decision-making paradigms when the context requires.

How to cite this article: Rahmati Y, Samimi A. Escort patterns in dual-worker households with students. J Soft Comput Civ Eng 2021;5(1):62–79. https://doi.org/10.22115/scce.2021.257897.1261.

1. Introduction

While the accurate prediction of travel demand decisions is pivotal for successful evaluation of associated transportation policies, it is usually hard to realize mainly due to the inevitable simplifications in modeling approaches and also overlooking the effect of unobserved factors that might influence the decision-making process.

A good example of such simplifications can be shown in modeling group decisions in a conventional way, while real-world contexts suggest that some decisions are not made individually. In a conventional decision modeling framework, the choice behavior is regularly considered to be influenced by the characteristics of the decision maker and his/her available alternatives. In order to model group decisions using this approach, one of the group members is usually selected to serve as the representative decision maker of the whole group. Apparently, such mechanism ignores the existing interdependencies between the group members, and therefore, undermines the predictive power of the resulted model. On the other hand, a random selection process over individual decision makers seems essential in selecting the representative decision maker of the target group. However, as Badoe [1] argued in his study, the initial data used for travel demand modeling is typically derived from household-level surveys in which households are selected randomly as the sampling units. Under such circumstances, selecting a household would result in selecting all of its members, which is obviously not a random sampling over individual decision makers.

To further investigate the efficacy of the group versus individual, decision-modeling methods in approximating multi-agent decisions, the present study has focused on the decisions made by household members regarding the accompaniment patterns in trips to/from school. Family members share common concerns and resources such as living space, household income, and vehicles. Consequently, each member's behavior would be affected by the decisions of other members. These intra-household interactions can be observed both in long-term decisions, such as residential location choice, car ownership, etc., and also the short-term decisions such as mode choice and accompaniment patterns. The existence of such interactions among the household members indeed motivates the consideration of group rather than individual decision makings in order to maximize the overall utility of the family.

Most of the studies in the context of households' group-based behavior incorporate dual-worker families and analyze the interactions between working couples. Such households face more constraints in choosing residential and work locations to maximize the overall family's utility considering home-to-work commuting distances. In addition, the effect of both father's and mother's work-related variables (e.g., employment status and work schedule) on households' choice behavior can be examined in dual-worker families. The presence of school-going children in such households complicates the decision process even more. Children's dependency in mobility in addition to the temporal, spatial, and modal linkage between parents' work trips and students' school trips affects the activity patterns of the family members. This effect can also be observed in the choice of children's escort patterns *to* and *from* school. As Clifton [2] stated,

“children’s inability to travel independently and the resulting chauffeuring responsibilities of adults have contributed to the examination of the interdependencies that exist between household members in organizing activities and travels.”

According to the above discussion, dual-worker households with at least one under-18-year-old student are considered for the purpose of this study. Individual and group-based modeling frameworks are adopted to predict the accompaniment patterns of the household in trips to and from school. The findings of the study can reveal the accuracy and efficiency of group decision-modeling methods versus conventional individual frameworks in predicting multi-agent decisions.

The remainder of this paper is organized as follows. Next section provides a review of the studies that have focused on adults' work trips and students' escort patterns in school trips. It is continued by introducing the dataset used for the purpose of this research. The proposed modeling framework is discussed next, followed by presenting the parameter estimation results. Section 5 presents a detailed discussion considering the findings of the study. The paper concludes with summary remarks and future research directions.

2. Literature review

Group decision-making mechanism has been underscored in various aspects of household travel behavior. Despite numerous studies which incorporate individual-based process in transportation planning arena, there are relatively limited number of studies in the context of group behavior. Modeling multi-agent decisions have been developed since the 1990s, via considering the existing interactions among group members [1,3,4].

Focusing on family groups, intra-household interactions have shown to be an important factor in determining whether a family will conduct a parent-child joint activity [5,6]. Parental employment status and the presence of school-going children are known to be among the pivotal factors affecting households’ decisions about making joint trips [7–11]. In this regard, escorting children to and from school, which can be represented as a group decision [12,13], is one the most common activities performed jointly by adults and children in a household [14]. Table 1 identifies a list of major studies on households’ decisions on whether/how to escort students. Various factors, including demographics and built environment characteristics, are identified to be effective in the way that parents accompany their children on their school trips. In most of these studies, existing interactions among the members are captured by applying a household-level approach and taking into account the characteristics of the children and those of parents, notably parents’ employment status and gender difference role in child caring. For example, Yarlagadda [15] has addressed the connection among the activities performed by adults and children considering the influence of parents' employment and work flexibility on children's school-trip mode choice. His results suggest that intra-household interdependencies can affect the activity patterns of the household members. In a recent study, Weiss and Habib [16] have developed a generalized formulation for modeling students' escort and travel mode choices as a

group decision. A parallel constrained choices logit model is proposed allowing for both individual and household-level decisions to be jointly modeled. The results of the study indicate an altruistic behavior by adults toward their children, meaning that parents may intentionally select a sub-optimal behavior for the benefit of their children.

Despite the recognition of mutual influence in group decisions, most of the studies on parents' work trips have applied an individual-based approach without accounting for the effect of existing interdependencies among the household members. Indeed, the related studies in this field have often focused on personal characteristics of the worker, as well as the trip-related variables such as travel time/cost when analyzing the commute timing and mode choice decisions of parents in work trips. Irfan et al. [17], for example, have developed a behavioral choice model to predict adults work-trip mode preference focusing on the associated cost of existing travel modes and commuters' income level. The model is then used to evaluate users' response to potential transportation policies like transit improvement and congestion pricing. Aiming to address the interactions among partners, McQuaid [18] investigated the length of time that parents are willing to travel to an existing or new job. He showed that workers whose partner is unemployed, are more willing to travel longer distances potentially due to the possibility of relegating child care responsibilities to their unemployed spouse and also the greater need for income. Table 2 shows a number of studies on parents' work trips.

The review of the aforementioned studies provides significant evidence on how intra-household interactions can affect the individual behavior of the adults in a family. Many individual decisions in a household may indeed be inherently a group decision as members usually tend to consider the betterment of the whole family. Accounting for these interactions is even more necessary when evaluating parents' behavior (as in their work trip decisions) because they often tend to sacrifice their own optimality for the betterment of their children. In these circumstances, adopting individual decision-making frameworks to model group-based decisions can lead to unrealistic outcomes and erroneous interpretations of the results. In light of this, the present study conducts a comparison between the prediction power of the individual and group-based frameworks in estimating the choice of escort patterns in dual-worker households. The main purpose is to reveal the efficiency of each approach in analyzing parent-child joint activities and highlight the effect of model misspecification in predicting group decisions using a quantifiable measure. The findings of this study would indicate the significance of addressing intra-household interdependencies when predicting the activity patterns of the household members, particularly parents' work trips and students' school trips.

3. Data

Data used for the purpose of this study is extracted from the Chicago Regional Household Travel Inventory (CRHTI), which is a comprehensive study of travel behavior characteristics of the residents in the greater Chicago area. Travel information of 14,390 households in 8 counties of Illinois (Cook, DuPage, Grundy, Kane, Kendall, Lake, McHenry, and Will) and three counties of Indiana (Lake, LaPorte, and Porter) were collected from January 2007 to March 2008.

Table 1
List of the Studies on Households' Choice of Escorting Students.

First author	Country	Year	Decision	Method	Individual/ household level approach	Significant Variables													
						Household structure	Household vehicles	Household income	Ethnicity	Child's age	Child's gender	Child's school mode	Parents' age	Parents' gender difference	Parents' work mode	Parents' employment	Parents' education level	Distance/ travel time	Built environment
Vovsha [19]	U.S.	2005	Escort patterns in school trips	A formulated choice model with nested structure	Household	-	×	×	-	×	-	-	×	×	×	×	-	×	×
Schwanen [20]	Netherlands	2007	Escort patterns in school trips	Regression	Household	×	-	-	-	×	-	-	-	×	×	×	-	×	×
Yarlagadda [15]	U.S.	2008	Mode choice and escort patterns in school trips	MNL	Household	×	×	-	×	×	×	-	-	×	×	×	-	×	×
McDonald [21]	U.S.	2009	Escort patterns in school trips	Statistical analysis		-	-	×	×	×	×	-	-	-	-	-	-	×	×
Yoon [22]	U.S.	2011	Escort patterns in school trips	Binary Logit	Household	×	×	×	×	×	×	×	-	×	-	×	×	×	×
He [23]	U.S.	2013	Escort patterns in school trips	MNL	Household	×	×	×	×	×	×	-	-	×	-	×	-	×	×
Deka [14]	U.S.	2013	A joint model for adults' travel mode to work and children's travel mode to school	MNL and Heckman Probit	Household	×	-	×	×	×	×	×	-	-	×	-	-	×	×
Gupta [24]	U.S.	2014	Escort patterns in school trips	ABM with MNL specification	Household	-	×	×	-	×	-	-	×	×	-	-	×	×	×
Weiss [16]	Canada	2018	Escort patterns and mode choice in school trips	Generalized parallel constrained choice model	Household and Individual	×	×	-	-	×	-	-	×	-	×	×	-	×	-
Note: Dash (-) implies that the variable is not analyzed in the related study.																			

Table 2
List of the Studies on Work Trips.

First author	Country	Year	Decision	Method	Individual/ household level approach	Significant Variables																				
						Age	Gender	Weight	Ethnicity	Disability	Education	Type of job	Employment status	Partner characteristics	Accommodation	Private car availability	Household income	Household size	Number of children	Child's age	PT characteristics	Distance/ travel time	Flexibility of departure time	Trip cost	Parking cost	Built environment
Liu [25]	China	2007	Work-trip mode choice	MNL	Individual	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	×	-	×	-	-
McQuaid [18]	Scotland	2009	Commuting time in work trips	Regression	Household	×	×	-	×	×	×	×	×	×	×	×	-	-	×	×	×	-	-	×	-	×
Habib [26]	Canada	2009	Commuting Trip Timing and Mode Choice	A joint discrete-continuous model	Individual	×	×	-	-	-	-	-	×	-	×	×	×	×	-	-	×	×	-	×	×	×
Belz [27]	US	2012	Factors influencing ride-share	MNL and NL	Individual	×	×	-	-	-	-	-	-	-	-	×	-	-	-	-	-	×	-	-	-	×
Habib [28]	Canada	2012	Commuting mode choice, start time, and duration of work	Trivariate discrete–continuous–continuous model	Individual	×	×	-	-	-	-	-	×	-	×	×	×	×	-	-	×	×	-	×	×	×
Panter [29]	UK	2013	Incorporation of active modes in work trips	Regression	Individual	×	×	×	-	×	×	×	-	-	×	-	-	-	×	-	-	×	-	-	×	×
Almasari [30]	Palestine	2013	Work-trip mode choice	MNL	Individual	×	×	-	-	-	-	-	-	-	-	×	×	-	-	-	-	×	-	×	-	-
Tushara [31]	Indiana	2013	Work-trip mode choice	MNL	Individual	×	×	-	-	-	-	-	-	-	-	×	×	-	-	-	×	×	-	×	-	-
Waerden [32]	Netherlands	2015	Change from car to carpooling in work trips	ML	Individual	-	-	-	-	-	-	-	-	-	-	×	-	-	-	-	×	×	×	-	×	-
Irfan [17]	Pakistan	2018	Work-trip mode choice	MNL	Individual	-	-	-	-	-	-	-	-	-	-	×	×	-	-	-	×	×	-	×	×	-

The dataset provides household demographics along with some travel information of all household members during a randomly assigned 24-hour or 48-hour period. This includes locations of all visited places, mode, travel time, and various trip purposes. About 33 percent of the data include households in which both parents are workers, referred to as dual-worker households in this manuscript. As illustrated in Figure 1, about 44 percent of dual-worker households have at least one under 18-year-old student, which accounts for 1041 households whose intra-household interactions and escort patterns in school trips are investigated in more detail.

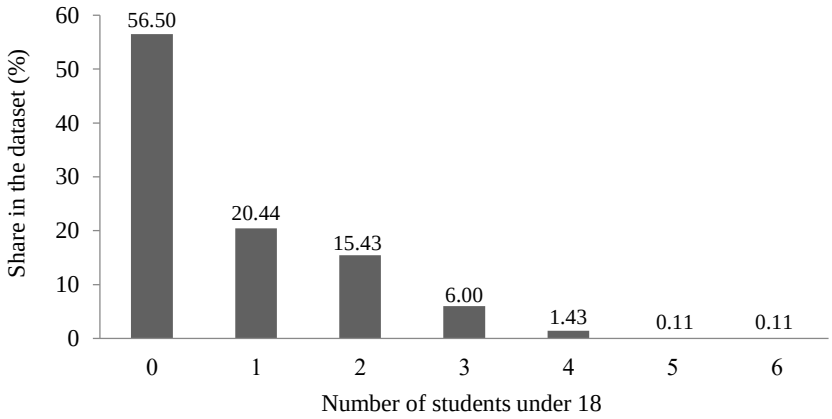

Fig. 1. Number of students under 18 in dual-worker households.

This study defines three mutually exclusive escort patterns in school trips: 1) independent travel, 2) children escorted only by father, and 3) children escorted by mother (also includes the scenarios in which both parents escort their children). Note that an independent trip implies that the child is not escorted by his/her parent(s). It should be noted that in households with more than one student, the youngest child is considered in identifying the escort pattern as he/she is arguably more dependent on parents for mobility purposes. Table 3 illustrates the distributions of these three patterns among the households in trips *to* and *from* school. As shown, 45 percent of the students have independent trips *to* school; however, this percentage increases to 56 in trips *from* school. In addition, mothers' share in escorting children *to* and *from* school is relatively higher than that of fathers.

Table 3
Escort Patterns in Trips *To* and *From* School.

Escort patterns	*To* school		*From* school	
	No. of households	Share (%)	No. of households	Share (%)
Independent travel	470	45.1	582	55.9
Escorted only by father	151	14.5	112	10.8
Escorted by mother	420	40.3	347	33.3
Total	1041	100	1041	100

4. Methodology and modeling

This study adopts discrete choice models to describe agents' decision making when choosing among multiple alternatives. These models are usually derived under the assumption of utility maximization, based on which agents try to choose those alternatives that maximize their overall utility. Considering that an external observer cannot identify all the determinants in one's decision making, discrete choice modeling frameworks define a stochastic utility function. Accordingly, the associated utility of each alternative consists of 1) a deterministic component to reflect the effect of observed factors, and 2) an error term to account for unobserved factors, such as the heterogeneity across decision makers.

McFadden's [33] multinomial logit (MNL) model is the most common discrete choice model due to its low computational complexity and ease of result interpretation. Considering that the utility function of each alternative consists of a deterministic part and an error term, the logit probabilities in this modeling framework are calculated using Eq. 1, where P_{ni} denotes the probability of choosing alternative *i* by decision maker *n*, V_{ni} denotes the observed component in alternative *i*'s utility, and *C* denotes the choice set.

$$P_{ni} = \frac{e^{V_{ni}}}{\sum_{j \in C} e^{V_{nj}}} \tag{1}$$

The key assumption in MNL models is that the error components of the utility functions are Independently and Identically Distributed (IID) extreme value. This assumption results in a well-known property of the logit models, i.e., Independence from Irrelevant Alternatives (IIA), which may lead to biased estimations when the IID assumption is violated. In light of this and to avoid potential biases, Nested Logit (NL) models [34] are established based on the idea that alternatives with some degrees of correlation in unobserved factors are grouped into a nest. Thereby, the IIA property is held only for the alternatives in the same nest and relaxed to Independence from Irrelevant Nests (IIN) for those in different nests. The probability of choosing alternative *i* by decision maker n among the alternatives grouped in K nests is given by Eq. 2, where B_k denotes the set of alternatives in nest k. The parameter θ_k then measures the degree of independence between unobserved utilities of the alternatives in nest k where lower values (near 0) indicate a higher correlation among the associated error terms. McFadden showed that NL models are consistent with the utility-maximizing behavior for $0 \leq \theta_k \leq 1$ (34).

$$i \in B_k : \qquad P_{ni} = \frac{e^{V_{ni}/\theta_k} \times \left(\sum_{j \in B_k} e^{V_{ni}/\theta_k}\right)^{\theta_k - 1}}{\sum_{l=1}^{k} \left(\sum_{j \in B_l} e^{V_{ni}/\theta_k}\right)^{\theta_l}} \tag{2}$$

For the purpose of this study, logit models are used to develop individual and group decision-making frameworks to estimate the escort patterns chosen by household members in school trips. To this end, a household-level model is proposed to predict the selected escort patterns by families. Then, an individual model is adopted for each of the parents to identify whether they decide to escort their children. The results from both models are compared with households' observed choice in real-world scenarios to evaluate the accuracy of each approach in approximating group decisions.

4.1. The household-level model

NL model is used to predict escort patterns of the households in trips *to* and *from* school. Three alternatives, namely: *independent travel*, *escorted only by father*, and *escorted by mother,* are defined. The last two choices are set into the e*scorting* nest (Figure 2). After cleaning the missing observations, the information of 1,041 households were available for modeling purposes.

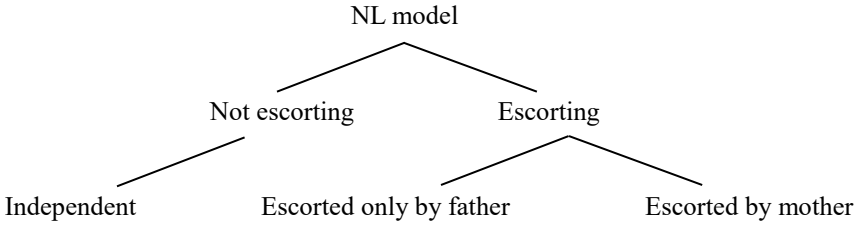

Fig. 2. Structure of the NL model.

Table 4 presents the definition of the variables that turned out to be significant at 1%, 5%, or 10% confidence level in the proposed household-level model. As shown, two main categories can be defined for the variables: 1) socio-economical characteristics, including the household size, number of driving licenses in the household, age, and parents' work status; and 2) trip characteristics, such as travel distance, number of daily trips, and school travel modes.

Table 5 shows the estimation results of NL model for trips *to* and *from* school. It is observed that in line with previous studies, socio-economical and trip characteristics turned out to be significant in households' choice of escort pattern. According to Table 5, as the number of household members increases, students are more likely to make independent trips *to* and *from* school. This could be due to the presence of siblings or grandparents who can take the responsibility of escorting students instead of parents. Older students are more often allowed to have independent trips *to* and *from* school, perhaps due to their desire for freedom. It is also observed that students aged 6-15 years old tend to be escorted by their fathers. This might reflect the dependency of the preschoolers (under 6 years old) to their mothers, and also the relatively more independent characteristics of the students over 15 years old. Children's gender, however, has not significantly affected the choice probabilities.

Model estimation results indicate that parental employment arrangements are among pivotal factors in households' decision for joint work-school trips. It seems that mothers who have reported "home" as their work location, face lower time constraints and find it more convenient to accompany their children *to* and *from* school. Flexibility in fathers' work schedule also helps mothers to relegate the responsibility of escorting children *to* school; however, this option decreases fathers' utility for escorting in trips *from* school. Moreover, mothers who work full-time are less likely to escort their children, arguably due to time constraints from longer work hours. These results also support the gender-based difference in childcare, as discussed in (6 and 19). Mothers are often considered as the main caregivers and seek ways to balance their mother-work responsibilities. Consequently, mothers' work-related variables, such as the work location and employment status, would directly affect the households' choice of escorting patterns.

Table 4
Definitions of the Variables Used in the Household-Level Model.

Variable	Description	Mean	Std. error
	Socio-economical characteristics		
HHSIZ	Household size	3.8867	0.7797
CHAVGAG	The average age of the children [(1)]	10.2311	0.7193
AGEL	Age of the youngest child	9.2277	0.8838
AGE0	1= If at least one of the children is under 6 years old/ 0= otherwise [(2)]	0.2776	0.4480
AGE6	1= If at least one of the children is 6-15 years old/ 0= otherwise	0.7041	0.4565
WLOCF	1= If father works at home/ 0= otherwise	0.0865	0.2811
WLOCM	1= If mother works at home/ 0= otherwise	0.0893	0.2853
FLEXF	1= If father has a flexible work schedule/ 0= otherwise	0.6722	0.4695
PARTF	1= If father is a part time employee/ 0= otherwise [(3)]	0.0327	0.1778
FULM	1= If mother is a full-time employee/ 0= otherwise	0.5793	0.4938
VEH2	1= If there are less than 2 vehicles in the household/ 0= otherwise	0.0903	0.2867
SAMES	1= If children (2 or 3 of them) are going to the same school/ 0= otherwise	0.3477	0.4763
	Trip characteristics		
DISTM	Distance between home and mother's work place [(4)]	0.1218	0.1350
DSTFCL	Distance between father's work place and the youngest child's school	0.2004	0.1784
DSTMCL	Distance between mother's work place and the youngest child's school	0.1218	0.1336
HTRIPS	Household daily trips	16.6206	0.7158
TRIPSF	Number of father's daily trips	4.3612	0.8744
TRIPSM	Number of mother's daily trips	5.6907	0.2435
TRIPSL	Number of the youngest child's daily trips	3.4736	0.9268
ONESPT	1= If trip mode *to* school for at least one of the children is public transit/ 0= otherwise	0.3734	0.4838
ONESCAR	1= If trip mode *to* school for at least one of the children is car/ 0= otherwise	0.6343	0.4817

[(1)] All of the age-related variables are defined in years.
[(2)] Three categories of AGE0, AGE6, and AGE15 are defined for children to represent 0-6, 6-15, and 15-18 age groups, respectively.
[(3)] Part-time employment is defined as working less than 30 hours per week.
[(4)] All distances are computed using the latitude and longitude of the origin and destination (the straight-line distance).

Table 5 also shows that the likelihood of escorting students *to* school by their mothers increases in households with less than two vehicles. However, this variable doesn't have a significant effect on households' escort patterns in trips *from* school. It is also observed that going to the same school as other siblings would increase the probability of independent school trips as students may travel together.

Table 5
Household-Level NL Model for Escort Patterns in Trips *To* and *From* School.

Variable		*To* school			*From* school		
		Independent travel	Escorted only by father	Escorted by mother	Independent travel	Escorted only by father	Escorted by mother
Constant		-	6.9945	8.2529**	-	8.2491**	11.0845***
Socio-economical characteristics	HHSIZ	0.2852*** (0.1422)	-	-	0.6832*** (0.1350)	-	-
	CHAVGAGE	-	-	-	-	-	-0.1796** (0.0366)
	AGEL	0.1732*** (0.0183)	-	-	0.1839*** (0.0219)	-	-
	AGE6	-	0.6648** (0.2842)	-	-	-	-
	WLOCF	-0.7186** (0.2837)	-	-	-	-	-
	WLOCM	-	-	1.0690** (0.5083)	-	-	1.5626** (0.6349)
	FLEXF	-	-	-0.5097** (0.2574)	-	-0.5229** (0.3091)	-
	PARTF	-	-	-	-	1.5648** (0.7003)	-
	FULM	-	-	-0.7210*** (0.2695)	-	-	-0.6843** (0.3052)
	VEHL2	-	-	0.8921** (0.4149)	-	-	-
	SAMES	0.5417*** (0.2019)	-	-	-	-	-
Trip characteristics	DISTM	1.2265** (0.6177)	-	-	-	-	-
	DSTFCL	-	-1.9885*** (0.7581)	-	-	-2.2135** (0.9471)	-
	AGE0×DSTMCL	-	2.8280** (0.3036)	-	-	4.8757*** (0.5319)	-
	HTRIPS	-0.0874*** (0.0169)	-	-	-0.0888*** (0.0171)	-	-
	TRIPSF	-	0.2921*** (0.0433)	-	-	0.3547*** (0.0564)	-
	TRIPSM	-	-	0.2625*** (0.456)	-	-	0.3451*** (0.0575)
	TRIPSL	0.2272*** (0.0573)	-	-	0.1986*** (0.0574)	-	-
	ONESPT	0.8968*** (0.1885)	-	-	0.4846** (0.1939)	-	-
	ONESCAR	-1.0518*** (0.1843)	-	-	-1.1306*** (0.1927)	-	-
IV parameters							
Not Escorting		1			1		
Escorting		0.2546*** (0.0935)			0.2742*** (0.0758)		
Log likelihood (Constant only)		-999.5182			-948.9158		
Log likelihood (Model)		-700.1158			-628.4986		
ρ^2		0.2995			0.3377		
Percent correctly predicted		60.1			64.9		

(1) ***, ** and * = Significance at the 1%, 5% and 10% level.
(2) Numbers in the parenthesis are standard error of the coefficient.
(3) Dash (-) implies that the variable is not used in the utility function of the alternative.

According to Table 5, the variable *Distance* has also turned to be significantly effective in households' choice of escort patterns in two folds. First is the distance between home and parents' work location. The increase in mother's home-to-work commute distance causes the household to choose the independent travel alternative for their children in trips *to* school. The next distance-related variable is associated with the work-school relative location. According to Table 5, the further the father's work location is from home, the less likely he is to take the responsibility of escorting children. This variable also affects households' choice of escorting students by mothers in the same way, but only when there are preschoolers in the household. A noteworthy point here is that morning trips are more sensitive to distance, as the start time of work/school activities is usually inflexible.

The number of daily trips is another parameter that affects the choice of escort patterns. An increase in the number of household's daily trips results in a lower probability of independent trips. For both parents, more daily trips mean that they are more likely to accompany their children in school trips. On the other hand, students with more daily trips tend to have independent travels to and from school.

The last group of variables used in the models is associated with the travel modes to school. Table 5 implies that when the reported school mode is public transit for at least one of the children in the household, it is more likely that the youngest child is not escorted by his/her parents in school trips (i.e., independent trip). An opposite effect is, however, observed for the case where at least one of the children in the household has reported car as his/her school mode.

4.2. The individual-level model

For the individual-level, parents' choice of escorting students is estimated by MNL models. Two choices are proposed for each parent in the model: (1) Escorting the student(s), and (2) Not escorting the student(s). Table 6 presents the definition of the variables that turned out to be significant in the proposed individual-level model.

Table 6
Definitions of the Variables Used in the Individual-Level Model.

Variable	Description	Mean	Std. error
	Socio-economical characteristics		
MOTHER	1= mother/ 0= otherwise	0.5000	0.5001
HHSIZ	Household size	3.8867	0.7797
HHLIC	Household driving licenses	2.2469	0.5610
CHAVGAG	The average age of the children	10.2311	0.7191
AGEL	Age of the youngest child	9.2277	0.8838
WLOC	1= if this person works at home/ 0= otherwise	0.0893	0.2853
TELEW	1= if this person teleworks/ 0= otherwise	0.2036	0.3030
FUL	1= If this person is a full-time employee/ 0= otherwise	0.7719	0.4197
	Trip characteristics		
DISTWSL	Distance between work and the youngest child's school	0.1606	0.1621
TRIPS	Number of daily trips for this person	5.0259	0.1357
TRIPSL	Number of the youngest child's daily trips	3.4736	0.9267
ONESPT	1= If trip mode *to* school for at least one of the children is public transit/ 0= otherwise	0.3734	0.4838
ONESCAR	1= If trip mode *to* school for at least one of the children is car/ 0= otherwise	0.6343	0.4817

Estimation results of 2,082 individuals (fathers and mothers in the 1041 households) are presented in Table 7 for trips *to* and *from* school. As expected, mothers are more involved in escorting their children *to* and *from* school, as they play the main role in child caring. Among socio-economical characteristics, it can be observed that more driving licenses in a household positively affects the utility of not escorting the students in morning trips. It is likely that working parents relegate the responsibility of escorting students to other household members who have driving permission.

Consistent with the household-level model, the age of the children plays an important role in parent's escorting decisions. An increase in the average age of children decreases the probability of escorting them *to* school. This variable is only significant for mothers in trips *from* school. In addition, as the age of the youngest child increases, fathers are less likely to accompany children on their way back home.

Parental work arrangements have been also significant in the individual model. Mothers who work at home are more likely to pick up their children from school. Similarly, teleworking fathers have more tendencies to escort their children *to* school as they face less difficulty in implementing work-school temporal coordination. Moreover, working as a full-time employee decreases the likelihood of escorting.

Similar to the household-level model, constraints of work and school locations affect the choice of escorting by parents. Longer distances between the parent's work location and child's school makes it less likely that the parent chooses to escort his/her children *to* and *from* school. Table 7 also indicates that escorting is more probable for parents with higher number of daily trips. Further, if public transit is used by at least one of the students, independent trips would have a higher choice probability. Similar to previous findings, school trips are more likely to be made under parents' escort if at least one of the students have reported car as his/her school mode.

5. Discussion

As alluded to, the main motivation of the present study is to investigate the accuracy and efficiency of individual decision modeling frameworks in modeling multi-agent decisions. This section adopts logit models to compute the power of the proposed household and individual-level models in predicting the households' observed choice of escort patterns in school trips.

A random-based process is used to determine the prediction power of the proposed individual and household-level models for the purpose of this study. Consider, for example, a discrete choice scenario where agents can choose an option among three possible alternatives. Using MNL or NL models, the probability of choosing each alternative can be calculated using Eq. 1 or Eq. 2, respectively. Assuming that the proposed modeling framework has generated the choice probabilities of 0.2, 0.5, and 0.3 in this scenario, three intervals of [0-0.2], [0.2-0.7], and [0.7-1] can be formed to represent each choice alternative. In order to determine model predictions, a random number is then generated for each decision scenario and compared to the associated choice probability intervals. A random number of 0.4, for instance, implies that the second alternative in the above example would be predicted by the model as the optimal choice of the

decision maker. Once model predictions are identified, the accuracy of the model is evaluated by comparing the predicted and observed choices of each decision maker in the dataset. For model robustness, these steps are repeated 10 times, and an average percent correct value is then reported. Note that the procedure is conducted for trips *to* and *from* school, separately.

Table 7
Individual-Level Model for Escort Patterns in Trips *To* and *From* School.

Variable		*To* school		*From* school	
		Escorting	Not escorting	Escorting	Not escorting
Constant		-	-1.3580***	-	-2.5341***
Socio-economical characteristics	MOTHER	1.3418*** (0.1517)	-	3.6734*** (0.5261)	-
	MOTHER×HHSIZ	-	-	-	0.2794** (0.1135)
	HHLIC	-	0.2432** (0.1447)	-	-
	CHAVGAG	-0.0929*** (0.0154)	-	-	-
	MOTHER×CHAVGAG	-	-	-0.2306*** (0.0195)	-
	(1-MOTHER) ×AGEL	-	-	-0.0481** (0.0228)	-
	MOTHER×WLOC	-	-	0.6236** (0.2759)	-
	(1-MOTHER) ×TELEW	0.7086*** (0.2353)	-	-	-
	FUL	-	-	-	0.4636** (0.1684)
Trip characteristics	DISTWSL	-2.3000*** (0.4851)	-	-2.3320*** (0.5521)	-
	TRIPS	0.2614*** (0.0226)	-	0.2808*** (0.0236)	-
	TRIPSL	-	0.1485** (0.0356)	-	0.1608** (0.0390)
	ONESPT	-0.4936*** (0.1548)	-	-	-
	ONESCAR	0.7563*** (0.1573)	-	1.1082*** (0.1561)	-
Log likelihood (Constant only)		-1100.8906		-1036.2711	
Log likelihood (Model)		-824.3635		-719.2182	
ρ^2		0.2512		0.3060	
Percent correctly predicted		72.3		78.1	

Tables 5 and 7 present the percent correct values for each of the modeling frameworks. It can be observed that 60.1 percent and 64.9 percent of the observed escort patterns are correctly predicted by the household-level model in trips *to* and *from* school, respectively (Table 5). On the other hand, considering the escorting decisions made by each of the parents (rather than the household), the individual-level model has resulted in prediction powers of 72.3 percent and 78.1 percent when estimating individual choices (Table 7).

To evaluate the credibility of the individual-level model and verify its ability in predicting the escort decisions of the whole family, parents' predicted choices are used to determine the escort pattern of the associated household, as shown in Table 8. Once families' decisions are estimated

based on the results of the individual model, a new percent correct value is computed to reflect the prediction power of the proposed individual-level modeling framework in estimating the households' group decisions.

Table 8
Household Escort Patterns Determined by Individual Model.

Individual escort pattern		Household's escort pattern
Father	Mother	
Not escorting	Not escorting	Independent travel
Escorting	Not escorting	Escorted only by father
Not escorting	Escorting	Escorted by mother
Escorting	Escorting	Escorted by mother

According to the results presented in Table 9, only 44.8 percent (51.8 percent) of the household's escort patterns are correctly predicted by the individual-level model in trips *to* (*from*) school. These findings suggest that using individual-level instead of household-level models to predict families' escort patterns would result in losing more than 25 percent of the correct predictions in trips *to* school, as well as more than 20 percent in trips *from* school.

Table 9
Comparison of the Household and Individual-Level Models' Prediction Accuracy.

Modeling level	Correct prediction values for households' escort pattern (%)	
	To school	*From* school
Household-level (NL)	60.1	64.9
Individual-level (MNL)	44.8	51.8

The noticeable differences in the accuracy of the household and individual-level models in predicting the escort patterns in school trips indeed highlight the crucial role of intra-household interdependencies in decisions jointly made by family members. The desire to maximize the utility of the entire group can result in an interactive behavior among the members that, in turn, affects individual decision makings. In some scenarios, group utility may prevail over, or even be in contrast to, individual benefits. Modeling these group decisions based on the conventional individual frameworks would then ignore the existing desire toward group utility maximization and consequently result in less accurate and/or unrealistic predictions.

6. Summary and conclusion

Different members in a group may have different opinions and preferences, which can, in turn, lead to complexities in making group decisions as members' behavior might be affected by others' opinions. In such circumstances, individual decisions may change due to the interdependencies among the members and the desire to maximize the group rather than individual utilities. Adopting individual decision modeling mechanisms can thus result in less

accurate and/or unrealistic outcomes. Motivated by this, the present study aims at investigating the accuracy of the conventional individual-level approaches in predicting multi-agent decisions. In particular, the choice of escort patterns in school trips is selected in dual-worker households with at least one under 18-year-old student.

Adopting multinomial and nested logit models in both individual and group levels, the escort patterns of households in a selected dataset are estimated in trips *to* and *from* school. Household size and driving licenses, parents' employment status, work schedules, and their role in child caring, children's age, school mode and location, travel distance, and the number of daily trips were among the main descriptors in determining the escort patterns. A comparison between the prediction power of the proposed modeling frameworks revealed that individual decision-making mechanism leads to more than 25 percent decrease in model's ability to correctly predict the selected escort patterns of the households in trips *to* school. The reduction in the explanatory power of the model was also 20 percent in trips *from* school. These findings support the idea that the joint modeling approach better addresses the intra-household interdependencies and highlights the importance of the interactions between the group members when predicting joint activity patterns.

The findings of this study have important policy implications, as well. Analysis of the results indicates that relaxing temporal and spatial constraints among parental employment and children's schooling can help parents better coordinate their work-family life. It is indeed in support of some of the existing policies such as the "school choice program" and "childcare near parents' work location", which aim at relaxing the work-school distance constraints. The effect of parental work arrangements on children's escort patterns also demonstrates that the implication of specific work-related policies such as teleworking and flexible work hours may affect school trip patterns. In addition, chauffeuring children to school can lead to complex trip chains, and in turn, affect parents' responses to some policies, particularly those associated with transit improvement [35,36]. In line with previous studies, this research also indicates that mothers are more involved in escorting responsibilities as they often play the main role in child care. Given the increasing number of working mothers, programs that help women facilitate the family-work balance may find wider acceptance; however, further studies are needed to identify a certain trend in childcare and possible shifts in the parental role for escorting students. Evaluating such policies in a group decision framework can pave the way for more successful policy assessments.

The present study has also faced some constraints and can be improved in the future. Due to data limitations, only three escort patterns are defined for household-level modeling purposes. More patterns may better highlight the efficiency of the individual and group-based mechanisms in estimating households' escort patterns. Besides, as spatial constraints play a vital role in households' choice of escort patterns, the actual distances between the locations, and even more precisely, distances by different modes of transportation may better approximate the real-world choice behavior. Implementing the new methodologies for joint behavior modeling developed by recent studies [29–32] is also suggested to estimate the choice of escort patterns and investigate potential differences between conventional and group decision modeling frameworks.

References

[1] Badoe D. Modelling Work-Trip Mode Choice Decisions in Two-Worker Households. Transp Plan Technol 2002;25:49–73. doi:10.1080/03081060290032051.

[2] Clifton KJ. Independent Mobility Among Teenagers: Exploration of Travel to After-School Activities. Transp Res Rec J Transp Res Board 2003;1854:74–80. doi:10.3141/1854-08.

[3] Timmermans H, Borgers A, van Dijk J, Oppewal H. Residential Choice Behaviour of Dual Earner Households: A Decompositional Joint Choice Model. Environ Plan A Econ Sp 1992;24:517–33. doi:10.1068/a240517.

[4] Borgers A, Timmermans H. Transport facilities and residential choice behavior: A model of multi-person choice processes. Pap Reg Sci 1993;72:45–61. doi:10.1007/BF01538349.

[5] Gliebe JP, Koppelman FS. A model of joint activity participation between household members. Transportation (Amst) 2002;29:49–72.

[6] Gliebe JP, Koppelman FS. Modeling household activity–travel interactions as parallel constrained choices. Transportation (Amst) 2005;32:449–71. doi:10.1007/s11116-005-5328-0.

[7] Kostyniuk LP, Kitamura R. An empirical investigation of household time space paths. Recent Adv Travel Demand Anal 1983:266–89.

[8] Bhat CR. A model of post home-arrival activity participation behavior. Transp Res Part B Methodol 1998;32:387–400. doi:10.1016/S0191-2615(98)00006-X.

[9] Jones PM, Dix MC, Clarke MI, Heggie IG. Understanding Travel Behaviour (No. Monograph) 1983.

[10] Niemeier D, Morita J. Duration of trip-making activities by men and women. Transportation (Amst) 1996;23. doi:10.1007/BF00223061.

[11] Srinivasan KK, Athuru SR. Analysis of within-household effects and between-household differences in maintenance activity allocation. Transportation (Amst) 2005;32:495–521. doi:10.1007/s11116-005-5355-x.

[12] Bhat CR, Pendyala RM. Modeling intra-household interactions and group decision-making. Transportation (Amst) 2005;32:443.

[13] Timmermans HJP, Zhang J. Modeling household activity travel behavior: Examples of state of the art modeling approaches and research agenda. Transp Res Part B Methodol 2009;43:187–90. doi:10.1016/j.trb.2008.06.004.

[14] Deka D. An explanation of the relationship between adults' work trip mode and children's school trip mode through the Heckman approach. J Transp Geogr 2013;31:54–63. doi:10.1016/j.jtrangeo.2013.05.005.

[15] Yarlagadda AK, Srinivasan S. Modeling children's school travel mode and parental escort decisions. Transportation (Amst) 2008;35:201–18. doi:10.1007/s11116-007-9144-6.

[16] Weiss A, Habib KN. A generalized parallel constrained choice model for intra-household escort decision of high school students. Transp Res Part B Methodol 2018;114:26–38. doi:10.1016/j.trb.2018.05.008.

[17] Irfan M, Khurshid AN, Khurshid MB, Ali Y, Khattak A. Policy Implications of Work-Trip Mode Choice Using Econometric Modeling. J Transp Eng Part A Syst 2018;144:04018035. doi:10.1061/JTEPBS.0000158.

[18] McQuaid RW. A model of the travel to work limits of parents. Res Transp Econ 2009;25:19–28. doi:10.1016/j.retrec.2009.08.001.

[19] Vovsha P, Petersen E. Escorting Children to School. Transp Res Rec J Transp Res Board 2005;1921:131–40. doi:10.1177/0361198105192100115.

[20] Schwanen T. Gender Differences in Chauffeuring Children among Dual-Earner Families. Prof Geogr 2007;59:447–62. doi:10.1111/j.1467-9272.2007.00634.x.

[21] McDonald NC, Aalborg AE. Why Parents Drive Children to School: Implications for Safe Routes to School Programs. J Am Plan Assoc 2009;75:331–42. doi:10.1080/01944360902988794.

[22] Yoon SY, Doudnikoff M, Goulias KG. Spatial Analysis of Propensity to Escort Children to School in Southern California. Transp Res Rec J Transp Res Board 2011;2230:132–42. doi:10.3141/2230-15.

[23] He SY. Will you escort your child to school? The effect of spatial and temporal constraints of parental employment. Appl Geogr 2013;42:116–23. doi:10.1016/j.apgeog.2013.05.003.

[24] Gupta S, Vovsha PS, Livshits V, Maneva P, Jeon K. Incorporation of Escorting Children to School in Modeling Individual Daily Activity Patterns of Household Members. Transp Res Rec J Transp Res Board 2014;2429:20–9. doi:10.3141/2429-03.

[25] LIU G. A behavioral model of work-trip mode choice in Shanghai. China Econ Rev 2007;18:456–76. doi:10.1016/j.chieco.2006.09.001.

[26] Nurul Habib KM, Day N, Miller EJ. An investigation of commuting trip timing and mode choice in the Greater Toronto Area: Application of a joint discrete-continuous model. Transp Res Part A Policy Pract 2009;43:639–53. doi:10.1016/j.tra.2009.05.001.

[27] Belz NP, Lee BHY. Composition of Vehicle Occupancy for Journey-to-Work Trips. Transp Res Rec J Transp Res Board 2012;2322:1–9. doi:10.3141/2322-01.

[28] Nurul Habib KM. Modeling commuting mode choice jointly with work start time and work duration. Transp Res Part A Policy Pract 2012;46:33–47. doi:10.1016/j.tra.2011.09.012.

[29] Panter J, Desousa C, Ogilvie D. Incorporating walking or cycling into car journeys to and from work: The role of individual, workplace and environmental characteristics. Prev Med (Baltim) 2013;56:211–7. doi:10.1016/j.ypmed.2013.01.014.

[30] Almasri E, Alraee S. Factors Affecting Mode Choice of Work Trips in Developing Cities—Gaza as a Case Study. J Transp Technol 2013;03:247–59. doi:10.4236/jtts.2013.34026.

[31] Tushara T, Rajalakshmi P, Bino IK. Mode choice modelling for work trips in Calicut City. Int J Innov Technol Explor Eng ISSN 2013:2278–3075.

[32] van der Waerden P, Lem A, Schaefer W. Investigation of Factors that Stimulate Car Drivers to Change from Car to Carpooling in City Center Oriented Work Trips. Transp Res Procedia 2015;10:335–44. doi:10.1016/j.trpro.2015.09.083.

[33] McFadden D. Conditional logit analysis of qualitative choice behavior 1973.

[34] McFadden D. Modelling the choice of residential location 1978.

[35] Strathman JG, Dueker KJ. Understanding trip chaining. Spec Reports Trip Veh Attrib 1990.

[36] Mauch M, Taylor BD. Gender, Race, and Travel Behavior: Analysis of Household-Serving Travel and Commuting in San Francisco Bay Area. Transp Res Rec J Transp Res Board 1997;1607:147–53. doi:10.3141/1607-20.