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You'll Never Walk Alone: Parental active escorting as an alternative to car travel to school☆,☆☆

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A R T I C L E I N F O

Dataset link: https://nhts.ornl.gov/downloads, https://github.com/vibe-lab-gsd/never-walk-alone

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A B S T R A C T

Introduction: Active travel can contribute to children meeting recommended levels of physical activity. Independent travel may also increase children's mental and emotional health by increasing feelings of autonomy. The purpose of this study is to determine (1) what predicts households' joint choice of mode and parental escorting for the journey to school, and (2) how the structure of this joint choice is best described.

Methods: Using data from the 2009 and 2017 National Household Travel Surveys in the United States, we estimated several discrete choice models jointly predicting the choice of mode and escorting. We tested alternative model structures representing mode-escorting combinations as independent alternatives, nested alternatives, or cross-nested alternatives.

Results: The cross-nested model structure best fits the data. The cross-nested model is consistent with the conception of escorted active travel as a compromise between motorized travel and unescorted active travel. Lower vehicle access, a later survey year, and the presence of a nonworking mother in the household are associated with lower utility of both motorized travel and unescorted active travel, relative to escorted active travel.

Conclusions: While the physical activity benefits of active travel are available regardless of parental escorting, additional mental and emotional health benefits may come when travel is both active and independent. Since there is less substitution from motorized travel to unescorted active travel than to escorted active travel, we conclude with a call for strategies that not only facilitate active travel to school, but also enable children to safely travel independently of their parents.

1. Introduction

A primary benefit of non-motorized travel for children is the ability to travel independently from adults. However, both independent travel and non-motorized travel by children have declined in recent decades across multiple countries (Fyhri et al., 2011; Rich et al., 2023). Characteristics of the physical, cultural, or policy environment may require children's trips to take place by car. Even in contexts where efforts have been made to encourage active travel, explicit requirements or cultural norms requiring children to be escorted by adults may circumvent those efforts to the extent that the choice of mode for children's travel is related to whether a child is able to travel independently.

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The purpose of this paper is to examine the relationship between choice of mode and choice of independence (whether a child travels with a parent). We focus our analysis on the journey to school because this is a trip that is constrained in terms of whether and when it will take place, and it takes place at a time of day that frequently corresponds with other non-discretionary trips by adult household members. Our results suggest that escorted travel to school by active modes may be appropriately described as a compromise between motorized travel and unescorted active travel. Lower vehicle access, a later survey year (2017 rather than 2009), and the presence of a non-working mother in the household are all associated with a lower likelihood of both motorized travel and active travel without a parent (relative to active travel with a parent).

In the following section, we summarize existing literature on independent and active travel to school. This is followed by a description of the dataset and modeling approach we used to address the questions of which individual, household, and trip characteristics are associated with the choice of mode and the choice of independence, and whether and in what way the choice of mode and choice of escorting are interdependent. After summarizing our results, we conclude with a call for further research that focuses not only on strategies to facilitate active travel to school, but to enable children to safely travel independently of adult escorts.

2. Background

Substantial research has been published on the correlates with, causes of, and barriers to active travel to school. Reviews of this literature include McMillan (2005), Davison et al. (2008), Sirard and Slater (2008), Stewart (2011), Rothman et al. (2018), Aranda-Balboa et al. (2020).

2.1. Factors that affect level of active travel to school

Distance is the strongest predictor of mode choice for the trip to school. Studies seeking to identify a threshold distance beyond which the likelihood of walking to school decreases substantially have found that distance to be 0.71 miles (1.14 kilometers) for primary school children in California (Voulgaris et al., 2021), 0.78 miles (1.25 kilometers) for seven- to eleven-year-old children in urban areas of Spain (Rodríguez-López et al., 2017), and 0.88 to 1.89 miles (1.42 to 3.05 kilometers) for ten- to fourteen-year-old children in Norfolk, United Kingdom (with distances increasing with age) (Chillón et al., 2015). Travel time is closely related to distance. In a study of 1104 trips by caregivers escorting children to school in the Andalusia region of Spain, Chica-Olmo and Lizárraga (2022) have found that escorted school trips are more likely to take place by car for longer distances, but that caregivers' mode choice for escorting children to school is less sensitive to distance for trips that are shorter than 10 min by the mode that was ultimately selected. Their interpretation of this finding focuses on the potential that travel time has to influence mode choice rather than on the more obvious explanation that trips by foot are slower than trips by car, and will generally have longer travel times when distances are equal.

McMillan (2005) has proposed a framework for explaining the mode choice for children's journey to school in terms of the built environment, mediated by household resources and real and perceived safety and moderated by parental attitudes, sociodemographics, and social norms. Subsequent literature reviews have generally confirmed the greater importance of sociodemographics and parental attitudes and perceptions, relative to built environment characteristics (and controlling for trip distance) (Davison et al., 2008; Sirard and Slater, 2008; Stewart, 2011; Rothman et al., 2018; Aranda-Balboa et al., 2020).

McDonald (2012, 2008) has found important relationships between active travel to school and the genders of both a school child and their parents. Girls are less likely to travel to school by active modes than boys are, and most of this difference is from a gender gap in cycling (McDonald, 2012). Moreover, she has found the work status of a child's mother, but not their father, to be a significant predictor of a child's mode of travel to school (McDonald, 2008).

2.2. Initiatives to promote active travel to school in USA

Formal efforts in increase active travel to school, especially in the United States context, are classified as Safe Routes to School (SRTS) programs. As research has confirmed the importance of sociocultural factors relative to built environment factors, SRTS programs have shifted their focus accordingly. When they were first introduced to in the mid-1990s, SRTS programs generally emphasized improvements to pedestrian and cycling infrastructure, but have since expanded to include non-infrastructure strategies, with efforts typically characterized in terms of four elements, described as the four 'E's: Education (e.g., teaching drivers to yield to pedestrians and cyclists); Encouragement (e.g., Walk to School Day events); Enforcement (e.g., the use of police officers and community volunteers to enforce traffic laws); and Engineering (e.g., sidewalk and crosswalk improvements) (Pedestrian and Bicycle Information Center, 2015). In more recent years, the Safe Routes Partnership, a non-profit organization that promotes and supports SRTS programs in the United States, has added two additional 'E's (Equity and Evaluation) to create their "Six 'E's" framework (Isidro, 2020). In June 2020, in response to nationwide protests against police violence, the Safe Routes Partnership revised their "Six 'E's" framework to replace Enforcement with Engagement, where engagement represents community engagement (Isidro, 2020).

2.3. Health benefits of active travel

Much of the research on active commuting by children is situated in the public health literature and frames the importance of active transportation in terms of its potential physical activity benefits. This emphasis on the health benefits of active travel to school is underscored by Jing et al. (2021) finding that, among journals that had published on the topic of active travel to school (as of the publication of that review in 2021), Journal of Transport and Health had done so the most frequently. Literature reviews specifically addressing the relationship between active travel to school and health benefits associated with physical activity include Lubans et al. (2011) and Davison et al. (2008). These reviews have found some consensus that walking and cycling to school is associated with increased physical activity and greater physical fitness, and more mixed results relating active travel to school to obesity and body-mass index.

Fewer studies have framed active travel to school in terms of benefits and risks that extend beyond children's physical activity. Wilson et al. (2007) discusses the environmental impact of school choice policies that increase student commute distances and car-reliance. Bierbaum et al. (2021) discuss the equity implications of school choice policies where access to better schools is conditional on access to private, motorized transportation.

A review by Schoeppe et al. (2013) takes a broader scope than the literature reviews discussed above by including studies of travel by all trip purposes rather than focusing exclusively on school trips and by examining the effects of both active travel and independent mobility. They focus on physical activity benefits and find that active travel and independent mobility are both associated with greater physical activity in children.

2.4. Intensive parenting

A systematic literature review by Ferreira et al. (2024) on the effects of children's independent mobility on their cognitive and social-emotional benefits finds that effects of independent travel beyond physical health are understudied, but that the available studies do suggest that independent mobility is associated with cognitive and socio-emotional development. Increases in parental escorting may be understood in terms of a general cultural shift toward more intensive parenting in the United States and the United Kingdom, as described by Faircloth (2014). Work by Yerkes et al. (2021) has suggested that although intensive parenting has a demonstrated postive effect on children's physical health, it may have a negative effect on their psychological health. In a commentary in the Journal of Pediatrics, Gray et al. (2023) review available evidence to suggest that a decline in children's independent activity (which would include independent travel) might be an important explanation for the recent decline in children's mental health. Indeed, Ortiz and Fastman (2024) have suggested that daily participation in independent activities may be an effective treatment for childhood anxiety.

2.5. The relation between active travel and independent mobility

Only a few studies directly address the relationship between active travel and independent mobility, although the presence of a relationship between independence and motorized travel is obvious: Children are generally prohibited from operating motor vehicles independently. However, travel by active modes can be either independent or escorted. Walking school buses, in which schools or parent organizations organize groups of children to walk to school together escorted by an adult volunteer, offer an approach to facilitating active travel to school by reducing the need for parents to escort their children on the journey to school (Kearns et al., 2003; Mendoza et al., 2009; Kingham and Ussher, 2007; Kong et al., 2009; Heelan et al., 2009).

He and Giuliano (2017) and Yarlagadda and Srinivasan (2008) both apply a multinomial logistic regression to jointly predict mode and escorting for the journey to school by children younger than 18, and both represent this choice in their model as being among a set of independent alternatives. He and Giuliano (2017) use data from a 2001 household travel survey in Southern California and Yarlagadda and Srinivasan (2008) use data from a 2000 household travel survey in the San Francisco Bay Area. The focus of both of these studies is on the relationship between parental work schedules and the joint mode/escort choice for the journey to school. He and Giuliano (2017) find that women who work longer hours are less likely to chauffer their children, and Yarlagadda and Srinivasan (2008) find that mothers with inflexible work schedules are more likely to drive their children to school than mothers who are not workers or have flexible work schedules.

While both He and Giuliano (2017) and Yarlagadda and Srinivasan (2008) mention having tested nested model structures (which would account for some correlation among related alternatives), they find that these model structures do not improve the fit of the model relative to an unnested model that assumes independent alternatives. This may be explained in part by their inclusion of older adolescents in their study and a study area in which children between sixteen and eighteen can be licensed to drive.

Ermagun and Samimi (2016) test nested and unnested models of the escorting choice for the journey to school for children between the ages of 12 and 17 in Iran. In their nested model, they include nests for escorted and unescorted travel, with escorted travel further divided into two nests: one for school buses, and one for travel by other modes. They find that the nested model performs better and that the choice of a unnested model leads to substantially different coefficient estimates, including some coefficients that change direction depending on whether a nested model is used. While the separate consideration of school bus travel might qualify this study as one that jointly predicts mode and escorting, they frame school bus travel as a specific category of escorted travel rather than as a mode choice. The classification of trips as being by car or by active modes is included in the model as a predictor rather than as an alternative. In a separate study using the same study sample of adolescents in Iran, Ermagun et al. (2015) compare the performance of a copula-based model to that of a nested logit model (but not a cross-nested model) for the joint choice of mode and escorting for the journey to school, and they find that the copula-based model offers the best performance.

2.6. Research gap

In this study, we test unnested, nested, and cross-nested models to predict the joint choice of mode and escorting for children younger than fifteen. This focus on younger children is in contrast to other analyses that have jointly predicted mode and escorting (Yarlagadda and Srinivasan, 2008; Ermagun et al., 2015; He and Giuliano, 2017). Ermagun, Rashidi, and Samimi note (Ermagun et al., 2015) justify the exclusion of primary school children by citing (McMillan, 2005) to note that “they have a totally different travel behavior due to their high level of dependency” (p. 275). For similar reasons, and to exclude children who may be able to drive themselves in the United States context, we limit our analysis to primary school children (and those who may be in the earliest years of secondary school). This work also represents a contribution to the existing literature that jointly predicts mode choice and escorting by incorporating a nation-wide sample that includes households from across at least 49 different metropolitan areas rather than focusing on a single region, as Yarlagadda and Srinivasan (2008) do on the San Francisco Bay Area, He and Giuliano (2017) do on the Los Angeles region, and Ermagun et al. (2015) do on Tehran. To the best of our knowledge, ours is also the first study to apply a cross-nested logit model to the problem of jointly predicting mode choice and escorting for the journey to school.

3. Data and methods

This analysis draws on the 2009 and 2017 samples of the National Household Travel Survey conducted by the Federal Highway Administration (FHWA) of the United States Department of Transportation (Federal Higway Administration, 2009; Federal Highway Administration, 2017). Both surveys invite participating households to complete a travel diary documenting all trips taken by all household members over the age of five during a 24-hour period on an assigned travel day. The 2009 survey included a sample of 150,147 households and the 2017 survey included a smaller sample of 129,686 households. The FHWA also completed a National Household Travel Survey in 2022 with a much smaller sample (7893 households) (Federal Higway Administration, 2022). None of these three most recent surveys provide publicly-available data with detailed residential locations of survey respondents, although the 2009 and 2017 surveys do include a variable indicating the population density of the census tract in which the survey respondent lives.

We conducted our analysis at the trip level, and used several criteria for inclusion in the analysis. Fig. 1 summarizes the reduction in sample size that results from the successive application of each criterion. We discuss each criterion in greater detail below.

Age criterion: We excluded children younger than seven (for whom parents might commonly consider unescorted travel to be outside the choice set) and people older than 14 (who can operate a motor vehicle independently in some states). Across all three survey years, this criterion eliminated 88 percent of all households, 92 percent of all individuals, and 93 percent of all trips. The proportion eliminated was similar (within one or two percentage points) for each survey year.

Trip purpose criterion: We identified trips to school as those that begin at home and end at school with an arrival at school before 10 a.m. If a child made multiple trips from home to school before 10 a.m., we only included the first such trip. Once this criterion was applied, there was no more than one trip per person, so the number of people in the sample was the same as the number of trips. This criterion eliminated 56 percent of all households with children between the ages of seven and fourteen and 59% of all children in that age range. This is a reasonable proportion, given most states in the United States require public schools to provide 180 instructional days per year (National Center for Education Statistics, 2018). The proportions eliminated from the 2009 and 2017 samples are similar, but the proportions of people and households eliminated from the 2022 survey are higher (68 percent of households and 70 percent of children), probably because of ongoing school closures and absences due to illness during the COVID-19 pandemic.

Distance criterion: We sought to construct a sample of trips for which walking was a reasonable alternative. As we have discussed, studies seeking to identify a threshold distance beyond which the likelihood of walking to school decreases substantially have found that distance to range from 0.71 miles (1.14 kilometers) to 1.89 miles (3.05 kilometers), depending on national context and children’s ages (Voulgaris et al., 2021; Rodríguez-López et al., 2017; Chillón et al., 2015). We limited the analysis to trips shorter than one mile (1.6 kilometers). This eliminated 81 percent of households with school trips and 80 percent of all school trips.

The next two criteria removed trips from the sample based on their use of modes that were presumed not to be unavailable to most students living within walking distance of their schools. Table 1 shows the share of school trips taken by foot, bike, car, school bus, public transit for trips longer and shorter than one mile (1.6 kilometers) in each of the three survey years, and across all three survey years.

School bus criterion: Of the full sample of school trips (before filtering out trips that are beyond a reasonable walking distance), school bus trips represented about a third of trips across the three survey years. Policies determining eligibility for school bus service (and whether families must pay a fee for such service) are determined at the state or local level and can vary widely. (Taylor, 2014; Speroni, 2023). In general, the distance a child lives from their assigned school is a primary determinant of eligibility for school bus service in localities where school transportation is provided, with the understanding that school bus service should only be provided to students for whom walking to school is not a reasonable option. McDonald and Howlett (2007) reviewed policies for pupil transportation funding in six states in the United States and found that 1.5 miles (2.4 km) and two miles (3.2 km) were common thresholds for determining eligibility for school bus service. From a survey of school districts in the state of California, Speroni et al. (2025) estimate that, for students attending their assigned public neighborhood school and living within one mile of that school, 4.5 percent of school districts in California offered school bus service for elementary-school students and 0.9 percent offered service to middle-school students. For students attending a choice school (one that they were not assigned to based on residential location), these percentages are 2.6 percent and 1.4 percent for elementary and middle-school students, respectively.

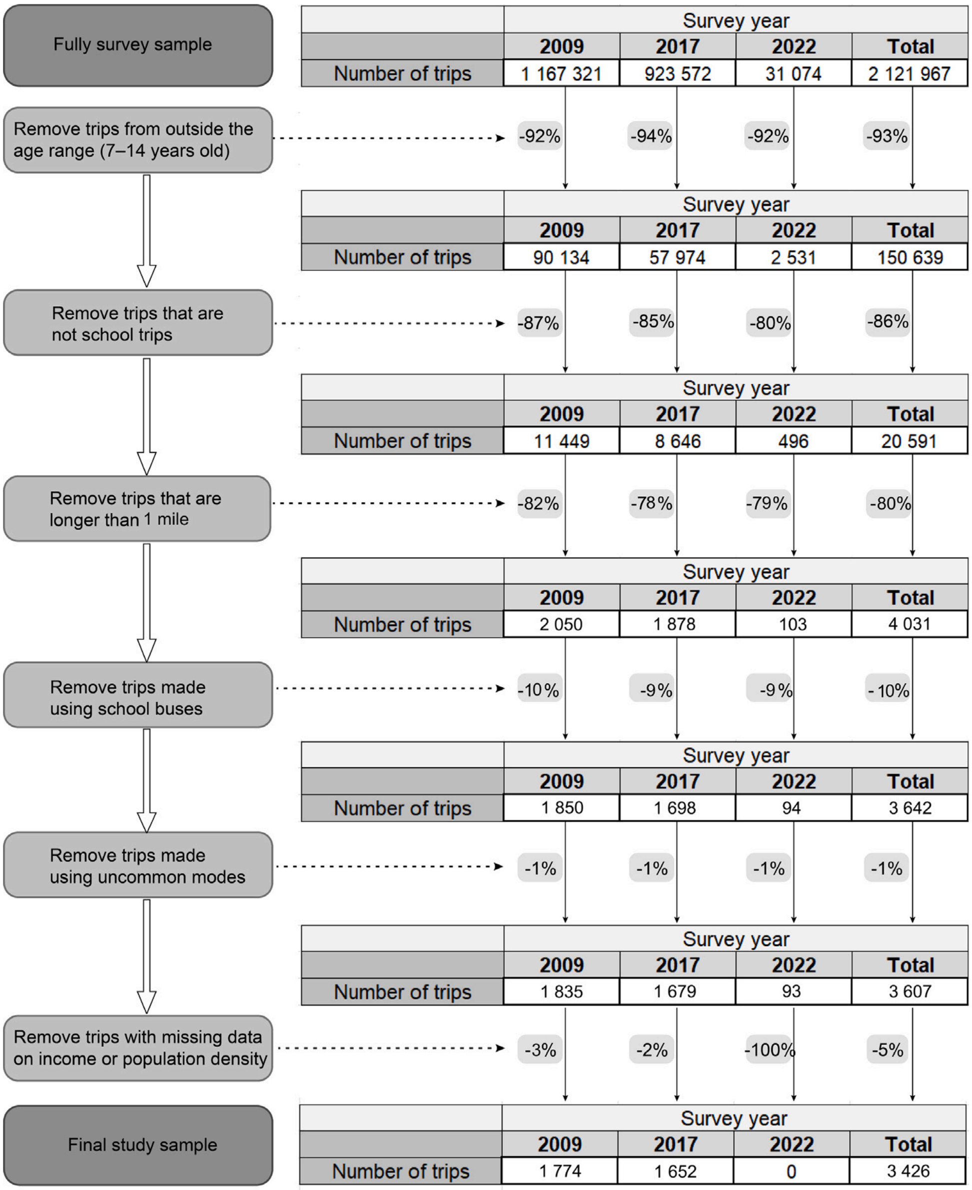

Fig. 1. Sample sizes from successive application of inclusion criteria.

Table 1
Mode shares for the journey to school by trip distance and year.

Trip distance:	Less than 1 mile (1.6 km)			More than 1 mile (1.6 km)			All school
	2009	2017	2022	2009	2017	2022	trips
Car	43%	52%	53%	56%	61%	58%	56%
School bus	10%	10%	9%	40%	36%	38%	33%
Walk	43%	31%	31%	2%	1%	2%	8%
Bike	4%	6%	7%	1%	1%	2%	2%
Public transit	0%	0%	0%	1%	1%	0%	1%
Other	0%	1%	1%	1%	0%	0%	1%
Total	100%	100%	100%	100%	100%	100%	100%

Table 2
Mode of travel by independence and year for journey to school.

	Car	Parental active escorting[a]	Active without parent[a]	Total
2009, n	856	38	880	1774
2009, %	48%	2%	50%	100%
2017, n	967	256	429	1652
2017, %	59%	15%	26%	100%
Total, n	1823	294	1309	3426
Total, %	53%	9%	38%	100%

[a] All household adults are classified as parents.

Federal law requires schools to provide school bus service to some students who live within such thresholds, including some students with disabilities and students experiencing homelessness. About fifteen percent of public school students in the United States have a documented disability that entitles them to public school accommodations, and these accommodations may or may not include transportation services (National Center for Education Statistics, 2024). In our sample of students ages seven to fourteen with trips to school that were shorter than one mile (1.6 km), about ten percent traveled to school by school bus. Given how rare it is for school districts to offer transportation services to students living within one mile of their school, we assumed that the majority of that ten percent were likely to be students who were eligible for school bus services based on a disability and that a minority of them were students living in districts that offered school bus services to students living within one mile of their school. We assumed that school bus service was not available to the remaining 90 percent of students living within one mile of their school. In general, since school bus eligibility policies are designed to only offer school bus service to students for whom walking is not a reasonable option (and the distances students in our sample biked to school were generally even shorter than the distances they walked), we assume that school bus travel does not compete with active travel for the journey to school. We removed students who used a school bus to get to school in order to limit our analysis to a set of students for whom active travel is a reasonable alternative.

Uncommon mode criterion: An additional one percent of students who traveled to school using less common modes (including public transit) were also removed from the sample.

Missing data criterion: The public dataset from the 2022 survey does not include a residential density variable, and we determined that the value of including population density in our analysis outweighed the value of including the 93 remaining trips from the 2022 survey, so we limited our analysis to the 2009 and 2017 surveys. We also removed 87 trips (61 from 2009 and 26 from 2017) with missing values for household income. Our final sample included a total of 3426 trips to school, including 1774 from 2009 and 1652 from 2017.

We categorized all trips in the sample into one of three combined mode-escort categories:

- Car (categorized as escorted).
- Parental active escorting: Walking or biking with a parent (defined as any household adult).
- Active without parent: Walking or biking without a parent.

Active-mode trips without a parent may be escorted or accompanied by a non-household adult, and the survey data do not indicate the ages of any non-household members who are present on a trip. We categorize all car trips as escorted, reasoning that parents may consider children confined to the private space of a car to require a lower standard of supervision than children traversing public streets by active modes. Moreover, non-household members or older siblings driving children in a car are presumably licensed to operate a motor vehicle and may thus be presumed by parents to be capable escorts.

Table 2 shows the number of trips in each of the above categories, with values disaggregated by survey year. Between 2009 and 2017, there was an increase from 48 percent to 59 percent in the share of the sample traveling to school by car, and a corresponding reduction from 52 percent to 41 percent in travel by active modes. Among the children who traveled to school by active modes, the share of students who were escorted by a parent increased dramatically between 2009 and 2017, from four percent of all active trips to 36 percent.

There were substantial differences in macroeconomic conditions between 2009 and 2017: The 2009 survey was conducted during an economic recession, and the 2017 survey was conducted during a period of economic growth. There was also a difference in the sampling method between the two years. The 2009 survey sample was based on random-digit dialing and did not include mobile phones, so households without a landline were not included in the survey. The 2017 survey sample was drawn from a random sample of addresses. Neither of these differences offers an obvious explanation for why parents would be so much more likely to escort their children to school by active modes in 2017 than in 2009. It is possible that this change is part of a broader cultural shift toward more intensive parenting (Faircloth, 2014; Yerkes et al., 2021) and an associated reluctance to leave children unsupervised.

We estimated a set of multinomial logistic regression models jointly predicting travel mode and independence for survey-day trips to school. All three alternatives (travel by car and active travel with and without parental escorting) were modeled as being available to all children in the sample. About three percent of children in the sample lived in households without a car. However, since about five percent of children in zero-vehicle households nevertheless traveled to school by car, we included car travel as an available alternative for all children, and included a vehicle-availability variable as an independent predictor.

Table 3
Independent variables included in regression models.

Variable	2009 (n = 1774)		2017 (n = 1652)	
	Mean or proportion	Standard deviation	Mean or proportion	Standard deviation
Household characteristics				
Household income[a]	\$83,248	\$52,660	\$100,736	\$78,152
Number of vehicles per driver	1.08	0.46	1.09	0.54
Presence of a non-working father[b]	12%	NA[f]	11%	NA
Presence of a non-working mother[c]	39%	NA	36%	
Individual characteristics				
Age	10.0	2.2	9.9	2.1
Female	49%	NA	47%	NA
Has a younger sibling[d]	60%	NA	48%	NA
Has an older sibling	49%	NA	44%	NA
Trip characteristics				
Trip distance (miles)	0.42	0.21	0.58	0.24
Population density (per mi^2)[e]	6315	6451	5884	5797

[a] The 2009 survey recorded household income in one of seventeen income categories and the 2017 survey recorded it in one of eleven income categories. We converted this to a continuous variable by assigning each household an income at the midpoint of its respective category. For the highest income category (greater than \$100,000 USD per year in the 2009 survey and greater than \$200,000 USD per year in the 2017), we calculated the median income of households in the United States with children between the ages of 7 and 14 and incomes above the threshold, based on microdata from the American Community Survey published by IPUMS (Ruggles et al., 2024). The value assigned to the highest income category based on this method was \$140,000 for the 2009 survey and \$281,360 for the 2017 survey. 2009 income values were inflation-adjusted to 2017 dollars.
[b] All male household adults are classified as fathers.
[c] All female household adults are classified as mothers.
[d] All household children are classified as siblings.
[e] Of the home block group (the trip origin).
[f] NA = "Not applicable".

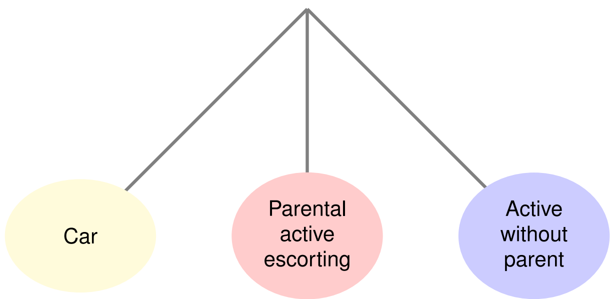

Fig. 2. Choice structure for non-nested model.

The independent variables we included in our model are listed in Table 3 along with basic descriptive statistics for both 2009 and 2017. Average values for the independent variables across the two years are broadly similar. The biggest difference is that children in the 2017 sample are somewhat less likely to have an older sibling (defined as any older child in the household) than those in the 2009 sample.

Using the data described above, we estimated a set of seven multinomial logistic regression models using Biogeme (Bierlaire, 2023). The first was an unnested model representing all alternatives as independent from one another, and is illustrated in Figs. 2.

The remaining models used various nesting structures to account potential relationships among alternatives. One includes a nest for active modes, as illustrated in Fig. 3(a). An alternative nesting structure groups alternatives by escorting, with a nest for travel by car and parental active escorting, as illustrated in Fig. 3(b).

Of the three mode-escort alternatives, parental active escorting places the greatest demand on the time of the escorting parent. Thus, a third alternative for a nested model would group alternatives based on their demand on parental time, where travel by car and active travel without a parent are classified as low parental time demand, as illustrated in Fig. 3(c).

Each nest m in a nested logit model includes a parameter μ_m that estimates the correlation of unobserved errors between alternatives within the nest as $1 - (\mu/\mu_m)^2$. To be consistent with random utility theory, the ratio $0 < \mu/\mu_m < 1$. Otherwise, this would imply inverse correlation of errors and therefore unnatural out-of-nest substitution. Biogeme by default constrains the scale parameter in the numerator $\mu = 1$, meaning that estimated nest parameters $\mu_m > 1$ for random utility theory to hold. If μ is not significantly different from 1, this indicates no within-nest substitution as in the unnested model, while a higher value of μ, indicates

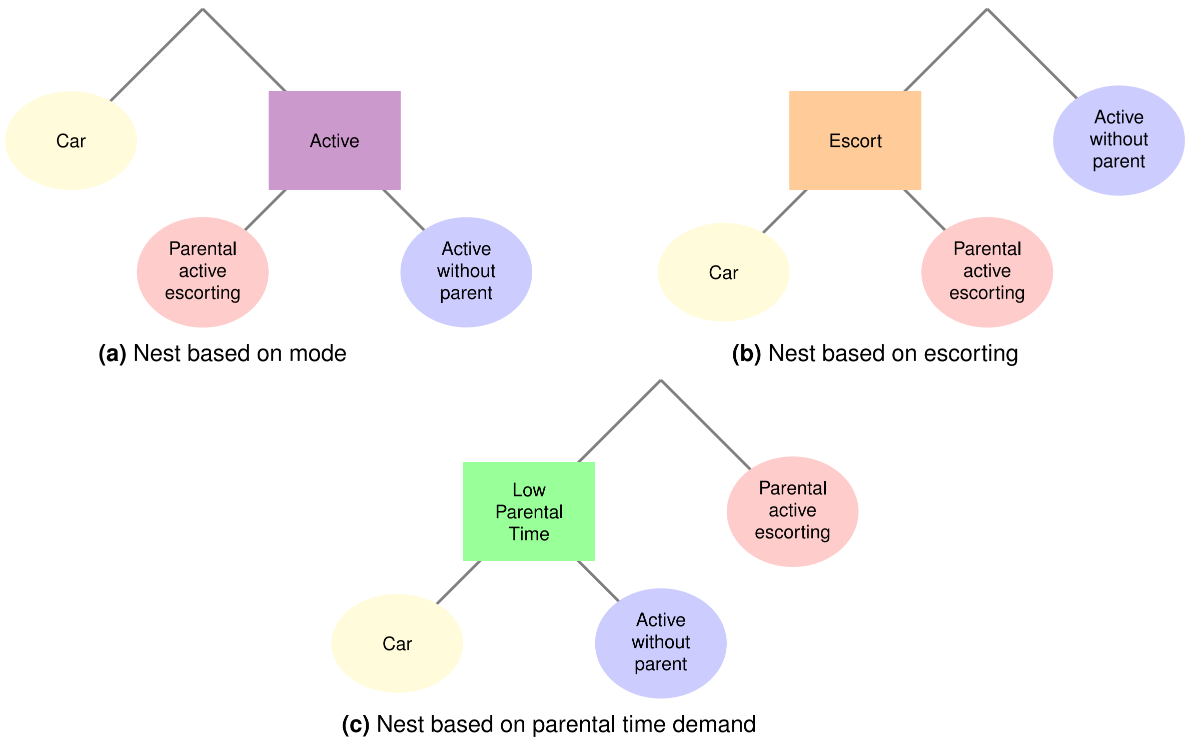

Fig. 3. Nested choice model structures.

a higher level of within-nest substitution.[1] A cross-nested model, allows an alternative to belong to multiple nests. For an alternative assigned to two different nests, the model includes a parameter α indicating the degree to which the alternative is a member of each nest.

With three possible sets of nests (one based on mode, one based on escorting, and one based on parental time demands), there are three possible cross-nested model structures that allow an alternative to belong to multiple nests. The first of these is illustrated in Fig. 4(a) and has two nests: one for escorted trips and one for trips by active modes. Trips by car are included in the "escorted" nest; active trips without a parent were included in the "active" nest; and parental active escorted trips were included in both nests.

Fig. 4(b) illustrates an alternative cross-nested model structure with one nest for escorted trips and one for trips with low parental time demand. Parental active escorted trips are included in the "escorted" nest; active trips without a parent were included in the "low parental time demand" nest; and car trips were included in both nests.

Finally, Fig. 4(c) illustrates a cross-nested model structure with one nest for active trips and one for trips with low demand on parental time. Parental active escorted trips are included in the "active" nest; car trips were included in the "low parental time demand"nest; and active trips without a parent were included in both nests.

4. Results

Table 4 summarizes the model fit and nesting validity of each of the seven models. The first column of the table indicates whether all nests included in the model had nesting scale parameters (μ) that were significantly greater than one, at a 95-percent confidence level. The unnested model meets this standard because it has no nesting scale parameters. The only nested model for which all nesting scale parameters were significantly greater than one was the cross-nested model with nests based on mode and escorting (illustrated in Fig. 4(a)). Of the two models with valid μ parameters, the cross-nested model with nests based on mode and escorting offers the best model fit, based on its log-likelihood.

Tables 5 and 6 show results of the two models with valid (or no) nesting structures. Coefficients in both tables are relative to the escorted active alternative. As shown in Table 5, neither household income nor the presence of a non-working father in the household were observed to have a significant effect on the mode-escort choice for the journey to school, controlling for other predictors. In fact, this was the case across all four models.

[1] Some software instead constrains the denominator of the ratio μ/μ_m, leading to estimates of values of nest parameters that are between zero and one; the ratio is all that matters for utility consistency.

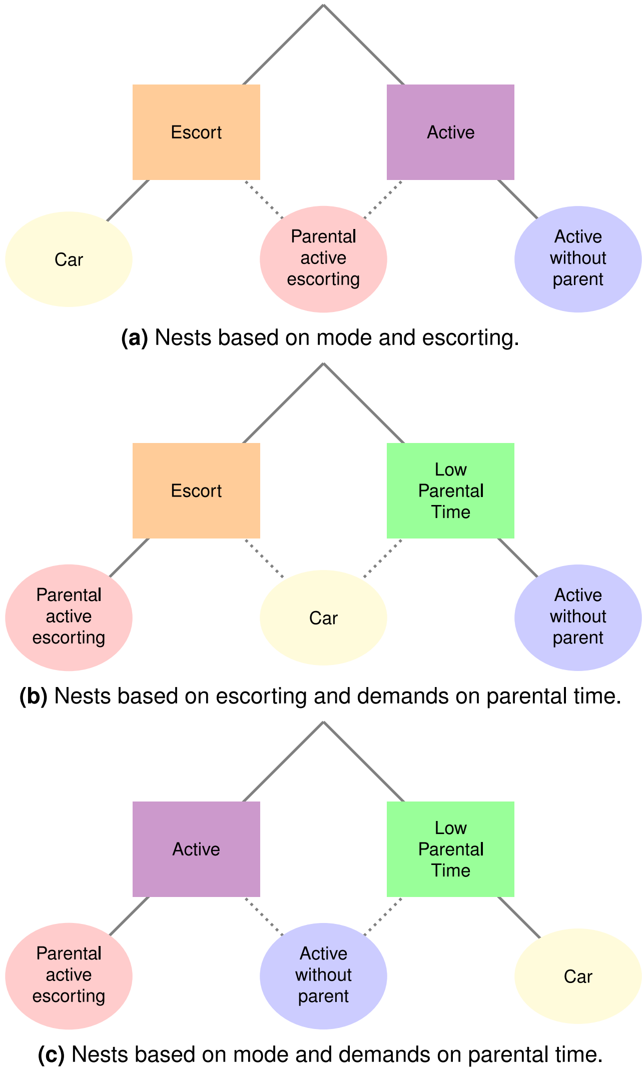

Fig. 4. Choice structures for cross-nested models.

Table 4
Summary of nesting validity and model fit for all models.

Model	$\mu > 1$ for all nests (95% confidence)	Number of parameters	Log likelihood
Unnested	Yes	24	−2564.123
Mode-based nest	No	25	−2559.917
Escort-based nest	No	25	−2562.938
Time-demand-based nest	No	25	−2564.123
Cross-nested (mode and escorting nests)	Yes	27	−2552.336
Cross-nested (time demand and escorting nests)	No	27	−2544.442
Cross-nested (time demand and mode nests)	No	27	−2559.917

Table 6 shows the results of the cross-nested model with three alternatives. The membership parameter, α_{active}, was 0.39, indicating that the alternative of traveling by an active mode with a parent had a somewhat stronger association with the "escorted" nest than with the "active" nest.

Fig. 5 compares the variable coefficients from the two models. In general, the model that represents the motorized travel, unescorted active travel, and escorted active travel as independent alternatives overestimates model coefficients relative to the cross-nested model: Of the 24 variable coefficients estimated in both models, 21 had a greater magnitude in the unnested model than in the cross-nested model. Of the three coefficient estimates that had a greater magnitude in the cross-nested model, one (the

Table 5
Results of unnested model.

Log likelihood: -2564.123 (24 parameters)					
Variable	Alternative (relative to active parental escorting)	Coefficient estimate	Standard Error	p-value	
Intercept	Car	6.40	0.91	< 0.001	***
	Active without parent	1.68	0.95	0.077	
Year 2017 (relative to 2009)	Car	−2.48	0.20	< 0.001	***
	Active without parent	−2.89	0.20	< 0.001	***
log(household income)	Car	−0.08	0.08	0.268	
	Active without parent	−0.11	0.08	0.175	
Vehicles per driver	Car	0.99	0.22	< 0.001	***
	Active without parent	0.77	0.23	0.001	***
Non-working father	Car	−0.26	0.20	0.203	
	Active without parent	−0.30	0.22	0.162	
Non-working mother	Car	−0.35	0.15	0.019	*
	Active without parent	−0.51	0.15	0.001	***
Age	Car	0.25	0.04	< 0.001	***
	Active without parent	0.48	0.04	< 0.001	***
Female	Car	0.15	0.14	0.283	
	Active without parent	−0.11	0.15	0.430	
Has younger sibling	Car	−0.27	0.15	0.067	
	Active without parent	−0.07	0.15	0.622	
Has older sibling	Car	0.01	0.14	0.939	
	Active without parent	0.31	0.15	0.038	*
log(trip distance)	Car	1.45	0.13	< 0.001	***
	Active without parent	0.13	0.13	0.324	
log(density)	Car	−0.52	0.08	< 0.001	***
	Active without parent	−0.35	0.08	< 0.001	***

* = 95-percent confidence, ** = 99-percent confidence, *** = 99.9-percent confidence.

effect of having an older sibling on the utility of car travel) was not significantly different from zero in either model at a 95-percent confidence level. The other two (the effects of gender and trip distance on the utility of unescorted active travel) were significantly different from zero in the cross-nested model but not in the unnested model, due to the larger standard errors in the unnested model.

We calculated the significance of the difference in coefficients between the two models based on the Z-score, calculated using Eq. (1) (Clogg et al., 1995), where β is the coefficient estimate and SE_β is its standard error.

$$Z = \frac{|\beta_1 - \beta_2|}{\sqrt{SE_{\beta1}^2 + SE_{\beta2}^2}} \tag{1}$$

Differences with Z-scores greater than 1.96 are statistically significant at a 95-percent confidence level. The difference in coefficients between the two models is statistically significant for twelve coefficients: the alternative-specific constants, the effect of the survey year, the effect of age, the effect of vehicle availability, the effect of distance, and the effect of density, each on the utility of both car travel and unescorted active travel.

Even controlling for individual, household, and trip characteristics, the utility of escorted active travel was substantially higher in 2017 than in 2009, relative to both unescorted active travel and car travel. Accounting for the cross-nested structure of the mode/escorting choice leaves about half as much unexplained difference between those two years as the unnested model does.

Older children are more likely than younger children to travel to school unescorted by active modes, relative to escorted active travel, but age is not associated with a greater likelihood of traveling by car, relative to active escorted travel. Longer trip distances are associated with a greater likelihood of traveling by car, but are not associated with a difference in the likelihood that active trips will be unescorted rather than escorted.

5. Discussion

By testing various model structures, including unnested, nested by mode, nested by escorting, nested by demands on parental time, and three cross-nesting structures, we have sought to answer the question of whether the choice to escort a child to school using an active mode might be more appropriately considered as an alternative to driving a child to school or as an alternative to sending a child to travel by an active mode without a parent. The failure of the nested models without a parameter for cross-nesting suggests that escorted active travel to school serves as a substitute to both motorized travel and unescorted active travel to school. Escorted active travel to school might thus be seen as a compromise between unescorted active travel and motorized travel.

Table 6
Results of cross-nested model.

Log likelihood: -2552.336 (27 parameters)					
Variable	Alternative (relative to active parental escorting)	Coefficient estimate	Standard Error	*p*-value	
Intercept	Car	3.04	0.76	< 0.001	***
	Active without parent	−1.22	0.66	0.064	
Year 2017 (relative to 2009)	Car	−0.90	0.18	< 0.001	***
	Active without parent	−1.29	0.16	< 0.001	***
log(household income)	Car	−0.04	0.04	0.301	
	Active without parent	−0.06	0.04	0.147	
Vehicles per driver	Car	0.44	0.11	< 0.001	***
	Active without parent	0.20	0.11	0.059	
Non-working father	Car	−0.11	0.09	0.225	
	Active without parent	−0.12	0.11	0.256	
Non-working mother	Car	−0.10	0.07	0.137	
	Active without parent	−0.23	0.07	0.001	**
Age	Car	0.06	0.02	0.007	**
	Active without parent	0.26	0.03	< 0.001	***
Female	Car	0.10	0.06	0.126	
	Active without parent	−0.14	0.07	0.042	*
Has younger sibling	Car	−0.13	0.07	0.087	
	Active without parent	0.02	0.07	0.768	
Has older sibling	Car	−0.04	0.06	0.515	
	Active without parent	0.25	0.07	< 0.001	***
log(trip distance)	Car	0.79	0.19	< 0.001	***
	Active without parent	−0.35	0.14	0.009	**
log(density)	Car	−0.25	0.06	< 0.001	***
	Active without parent	−0.08	0.05	0.097	
Scale parameter for active nest, μ_{active}		3.43	0.71	< 0.001	***
Scale parameter for escorted nest, μ_{escort}		2.56	0.68	< 0.001	***
Active without parent membership in active nest, α_{active}		0.39	0.10	< 0.001	***

* = 95-percent confidence, ** = 99-percent confidence, *** = 99.9-percent confidence

We do not find any differences between the cross-nested and unnested models in the direction of any effects. However, the differences we do find lead to different inferences about the effect of residential density, vehicle availability, maternal employment, trip distance, and gender on the mode/escorting choice.

Density: The estimated effect of residential density on the utility of unescorted active travel (relative to escorted active travel) is significant in the unnested model (with children living at higher densities having a lower utility of unescorted travel). This effect becomes insignificant in the cross-nested model.

Vehicle availability: Unsurprisingly, greater vehicle availability is associated with a greater utility of car travel, relative to escorted active travel. More surprisingly, the unnested model suggests that greater vehicle availability is also associated with a greater utility of unescorted active travel, relative to escorted active travel. However, this latter difference becomes insignificant in the cross-nested model.

Maternal employment: Escorted active travel is the most time-consuming option for the parent who would be responsible for escorting, which may explain why the presence of a non-working mother in the household is associated with a lower likelihood of both of the less time-consuming alternatives in the unnested model. In the cross-nested model, the presence of a non-working mother only reduces the predicted utility of unescorted active travel (the least time consuming of any of the three alternatives).

Distance: The unnested model suggests that longer trip distances are associated with a greater likelihood of travel by car, but do not effect the likelihood that a walking or biking trip will be escorted. In the cross-nested model, distance effects both the choice of mode and the choice of escorting, where shorter trips are more likely to be independent.

Gender: The unnested model shows no significant relationship between gender and the utility of unescorted active travel, but the results of the cross-nested model suggest that the girls are somewhat less likely than boys to walk or bike to school without an adult rather than with an adult.

In contrast to findings by He and Giuliano (2017) and by Yarlagadda and Srinivasan (2008) we find that model fit improves when a nesting structure is applied to account for the interdependence among alternatives. An important explanation for the difference between our findings and those from those previous studies is that our sample is drawn exclusively from children who cannot drive themselves to school, while theirs included adolescents as old as sixteen and seventeen years old in geographies where children are permitted to drive at those ages. We would suggest that household decision-making about mode choice and escorting would be

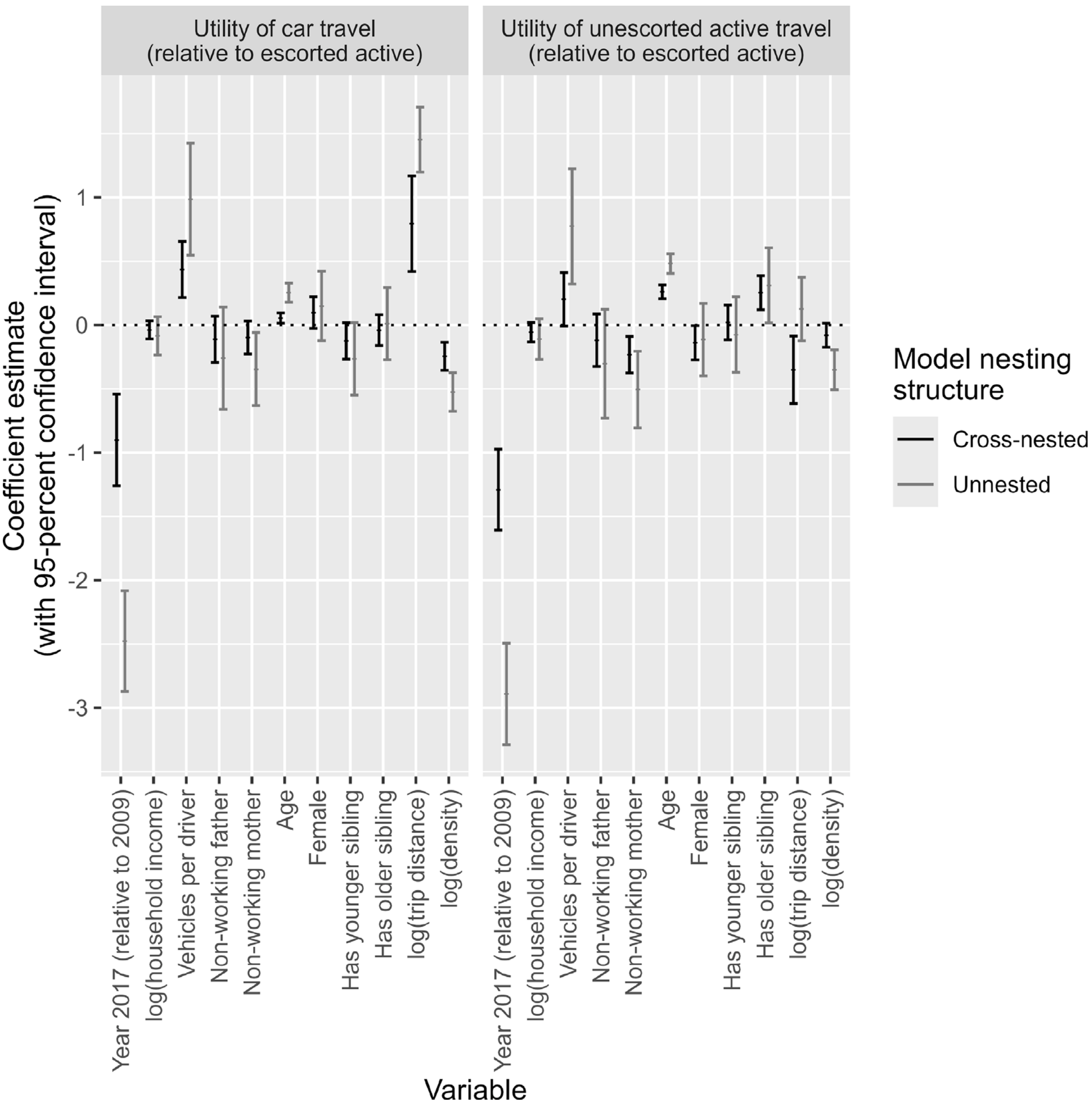

Fig. 5. Comparison of model coefficients for unnested and cross-nested models with three alternatives.

quite different for older adolescents than for younger children (especially in contexts where adolescents can drive) and that separate analyses for these two populations is appropriate.

Previous studies found a higher level of escorted trips in urban areas and for shorter distances (Scheiner, 2016). This is in contrast to our finding that car trips (which are always escorted) are generally longer and that, among active trips, shorter trips are more likely to be independent.

It is well documented in the literature that women are more involved in escorting trips than men. Motte-Baumvol et al. (2017) suggest that, in dual-earner households, women more often than men have jobs that are compatible with escorting, and Chica-Olmo and Lizárraga (2022) likewise find that women disproportionately escort children to school. Our finding that the mode/escorting choice is associated with the presence of a non-working mother in the household (but not with the presence of a non-working father) further indicate that the employment status and job characteristics of mothers influence their children's travel in ways that fathers' employment and job characteristics do not. This is generally consistent with findings by McDonald (2008), by He and Giuliano (2017), and by Yarlagadda and Srinivasan (2008).

6. Limitations and further research

The authors acknowledge that there might be important interactions that have been overlooked or not available in the data used. Despite the inclusion of a high number of explanatory variables that could account for household and geographical differences over the years, we still found a significant and negative parameter for Year 2017 relative to 2009. This difference can be due to changes in sampling method or differences in macroeconomic conditions. While the result aligns with research indicating a reduction in active travel among children, there is a need for further research that analyze this tendency further. Relevant topics to analyze further are intensive parenting and broader cultural shifts that affect transport.

7. Conclusion

This study has implications for the practice of modeling the travel behavior of children and for creating policies to improve children's health and other outcomes by creating safer and more comfortable environments for the journey to school.

With regard to modeling, we find that failing to account for the interdependency among alternative combinations of mode and escorting for the journey to school, in this case, generally leads to an overestimation of model coefficients and might therefore lead to an overstatement of the influence that individual and household characteristics might have on the joint choice of mode and escorting for the journey to school.

With regard to policy, we argue that interventions that are effective in shifting school trips from cars to escorted active travel are a step in the right direction, but they should not stop there. Some of the health benefits of active travel to school, such as the cognitive and socio-emotional benefits that children may receive from having the autonomy to independently navigate their neighborhoods, are only available to children whose active travel to school does not rely on parental escorts. Moreover, our finding that the there is a significant relationship between the presence of a non-working mother in the home and the likelihood of making mode/escort decisions that place greater demands on parental time highlights the importance of considering parental time burdens in designing school transportation policies.

The alpha coefficient for the mode-based nest of 0.39 in the cross-nested model suggests that, in the joint choice of mode/escorting, the escorting aspect of the choice might be somewhat more salient to parents than the mode aspect. Safe Routes School programs should thus target not only those students who rely on private cars to get to school, but also those who already travel by active modes but require better infrastructure, support, or education in order for their caregivers to be comfortable allowing them to travel to school without an adult escort. Additional strategies such as bicycle or walking "buses" with groups of children in a neighborhood traveling en masse might help resolve household-level time constraints in escorting or hesitation to permit independent travel.

CRediT authorship contribution statement

Carole Turley Voulgaris: Writing – review & editing, Writing – original draft, Visualization, Methodology, Formal analysis, Data curation, Conceptualization. **Anders Fjendbo Jensen:** Writing – review & editing, Methodology, Conceptualization. **Gregory S. Macfarlane:** Writing – review & editing, Methodology, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

This research uses publicly available data from https://nhts.ornl.gov/downloads. Analysis code is available at https://github.com/vibe-lab-gsd/never-walk-alone.

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