The influence of external factors on children's travel mode: A comparison of school trips and non-school trips

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Abstract:

This study examined travel patterns of pupils from four secondary schools in Austria and Germany. Their mobility behavior was examined using a one-week travel diary in a typical school week. This paper examines objective determinants (in particular settlement pattern and trip characteristics) of mode choice. We used a Bayesian approach for nonlinear Structural Equation Modeling (SEM) of binary response variables to assess the effects of external factors on the choice of travel modes. The focus lies on the competitiveness between car and transit. The results indicate that children's modal choices are influenced by trip length and the service quality of motorized modes. A key finding is that school trips and non-school trips are very different. School trips are quite affine to transit even in rural areas, given a sufficient service quality, which can easily be provided by a school bus system. Long school trips increase the frequency of transit use. Non-school trips, however, are much more affine to car ridership, if trip length exceeds the range for walking and cycling.

Keywords: Mode choice; Children; School trips; Non-school trips; Structural equation modeling; Bayesian approach

1 Introduction

The causalities between the built environment and mobility behavior are a recurrent topic in urban and transportation planning. A wide range of studies examined the effects of different attributes of the built environment on travel behavior. They were systematically reviewed and summarized by several authors. They found that a dense and diverse urban form with good accessibility to local destinations leads to less car use, more transit use, and also more use of the active modes walking and cycling (Badoe & Miller, 2000; Ewing & Cervero, 2001; Ewing & Cervero, 2010; Stead & Marshall, 2001; Whalen et al., 2013). A lot of these studies refer to adults. However, the travel decision making process and framework of children differs fundamentally from the adults' perspective. Children have limited scope of when, where and how they travel, and they are more dependent on adults giving them a lift (e.g. Mackett, 2013; Yarlagadda & Srinivasan, 2008). Nevertheless, during the phase of childhood individual preferences for a certain mode of transport are already developing. For example, a pro-car orientation seems to be acquired from the age of 12 (Flade and Limbourg, 1997). When growing up they get more control over their choices of transport options (Mitra, 2013). The age group in this paper (7th school grade) represents a "transition phase" between childhood and late adolescence: They are much more independent in their mobility decisions than younger children are, but their travel behavior is still influenced by their parents' travel decisions. This is evidenced among other things by the fact that our target group made 49% of the travel decisions by themselves; only 5% were other directed (46% joint decisions).

It is very important to better understand influencing factors on mode choice in this young age group, because the experiences at young age influence travel decisions at adulthood (Mackett, 2001). The last decade has indeed shown an increasing interest in the mobility behavior and mobility needs of children; most of them examined school trips with focus on active modes. Fewer studies took non-school-trips into account (*reference blended*; Fyhri & Hjorthol, 2009; Hjorthol & Fyhri, 2009; Broberg et al., 2013; Villanueva et al., 2012). Several surveys found that the distance between home and school is a key influencing factor on mode choice (Fyhri & Hjorthol, 2009; Ewing et al., 2004; McDonald, 2008; McMillan, 2007; Mitra & Buliung, 2012; Schlossberg et al., 2005; Schlossberg et al., 2006; Wilson et al., 2007; Yarlagadda & Srinivasan, 2008). This is also confirmed by Müller et al. (2008), who revealed that the mode choice of young people aged between 10 and 19 in Germany is most influenced by distance, car availability, and weather conditions. In view of the growing public health concerns such as obesity and inadequate physical maturation, medical researchers also put an emphasis on the mobility at a young age, primarily with a focus on active travel modes such as walking and cycling (D'Haese et al., 2011; Larsen et al., 2009; Panter et al., 2008; Pont et al., 2009; Timperio et al., 2006; Van Dyck et al., 2010).

Overall, when compared to walking or cycling, the circumstances of transit choice among children and young adolescents are less known. However, when children get older, their action radius increases

(Daschütz, 2006). In this context, it has to be considered that above a certain trip length the use of non-motorized modes is not an option anymore. For this age group also the allowances of parents play an important role. Parents may be especially concerned about cycling because of traffic safety. It should be noted, that the use of transit for longer trips is preferable to escorted trips by car - mainly for environmental reasons, but also because (i) it encourages independent (unsupervised) mobility and (ii) transit trips almost always include at least short stages of walking trips. In this context, the service quality of transit is a critical factor for children's mode choice and also interesting from the planning point of view. Ewing & Cervero (2010) consider the distance to transit as one of six main criteria describing the quality of the built environment relevant to mobility (along with density, diversity, design, accessibility, and parking management). But, the service quality of transit is difficult to measure. The literature suggests several approaches for indirect measurement. Dense population structures are often associated with good transit supply. Goeverden and Boer (2013) draw this conclusion, but cannot prove it empirically. Yarlagadda and Srinivasan (2008) found that children living in areas with high employment rates use transit more often and conclude that these areas have better transit services. A more disaggregate indicator is the distance from home to the next transit station, the transit route density, the distance between transit stops, or the number of stations per unit area (Ewing & Cervero, 2010). However, none of these approaches considers the service quality for particular trips. The existence of a transit stop near home does not necessarily mean that one can reach the desired destination at the required time in a convenient way. On the other hand, a properly scheduled school bus can provide a very good service for school trips in an otherwise poorly served area. In response to this problem, we calculated the door-to-door speed for each reported trip using a route planning web application. It yields an indicator for the service quality at the level of single trips.

The research reported here is part of a study which explored (changes of) attitudes and the mobility behavior of pupils over a period of two years. This paper explores how external factors like settlement pattern, trip purposes in terms of school trips and non-school trips, trip length, and service quality of motorized modes influence mode choice and how they affect each other. In the models we controlled for gender and household characteristics in order to remove possible confounding effects with these variables. In particular, this analysis hypothesizes that

- School trips and non-school trips (mainly leisure trips) of children’s everyday mobility follow different rules; as a result, the determining factors of mode choice are also different.
- The trip length has an influence on the used mode of transportation; a longer trip increases the need of motorized means of transport.
- The trip specific service quality of private car use and transit use (or the ratio between the two) influences the decision as to which of the two motorized modes is chosen.

- The settlement pattern influences both aforementioned factors; urban areas have a shorter average trip length, a better service quality of transit, and a worse service quality of private car use.
- Trip length and service quality of motorized modes capture only a part of the variability of mode choice between different locations, because a location stands for many more differences that may influence children's mode choice.

Our interest in the interdependencies between different exogenous factors suggests using the approach of structural equation modelling (SEM), which allows analyzing the causes and effects in a networked sense.

The paper is structured as follows. In Section 2 we describe the sample, data collection as well as the methodology. Section 3 presents the descriptive data analysis and structural equation models examining the relationship between the exogenous variables as predictors and the outcome variables (mode choice). This section also describes detailed analyses e.g. with regard to home-school and school-home relations and with regard to accompaniment. The model results are discussed in context to the research hypotheses. The paper closes with conclusions on the study methodology and results (Section 4).

2 Data and Methods

2.1 Sample

Our sample includes 186 children in the 7th grade (average age 13.1) of eight classes, coming from four different secondary schools of a comparable type. The schools were selected along a gradient from central-urban to rural areas (Table 1): School A is located in the densely built city center of Vienna; it is very well accessible with metro, tram and bus. School B at the edge of Vienna is less accessible with metro, but some central tram lines are in short distance; the neighborhood is affluent and less densely built. Regular transit can be used for both school trips and non-school trips. School C is in Tulln, a small town in Lower Austria of 15,000 inhabitants, but with a large catchment area; the school is located about one kilometer from the railway station and is accessible with a very few school bus connections. In the city of Tulln a city bus serves the area (mainly weekday), single regional bus lines serve the wider area. School D is located in Itzehoe, North Germany, a city of 32,000 inhabitants; the school is comparable with Tulln, the catchment area also covers neighboring rural municipalities within a radius of about 20 kilometers. At School D, there are very few bus connections and the next railway station is about 1.5 kilometers away. The region is socially and culturally similar to Austria. With a view to the schools’ catchment areas there are no major differences in terms of altitude profiles. One difference with regard to mobility is that the bicycle plays an important role as an everyday means of transport.

It should be noted that there are no explicit 'school busses', although some regular busses serve mainly as feeder busses for schools according to their specific schedule. School children at school sites C and D can use a bus for their school trips; the transit option for non-school trips is in most cases poor or not existing.

Table 1: Spatial characteristics of the studied schools.

School	A	B	C	D
Country	Austria	Austria	Austria	Germany
Location	center of town (Vienna)	edge of town (Vienna)	small town in rural area (Tulln)	small town in rural area rural area (Itzehoe)
Density [inhabitants/km²]	4,983 (urban district)	1,361 (urban district)	107 (district)	126 (district)
Accessibility with transit	very good connections (metro, tram, bus)	good connections (metro, tram)	very few connections (busses)	very few connections (busses)

2.2 Data collection

The survey conducted in April 2013 was based on travel diaries the pupils of eight classes filled in during a period of seven days *(reference blinded)*. Before, a travel diary was developed in cooperation with the children to ensure comprehensibility and practicability for this target group. For example, questions about restrictions to mode choice and the level of information about alternative modes were included in the diary. The children were supported in completing the questionnaire throughout the survey period, e.g., in finding the right addresses of trip origins and destinations. Such intensive cooperation was only possible because the four schools were partners in the project and provided lessons for supervision of the pupils. Therefore, a response rate of 97% could be reached.

The collected data include some context information about the household and peers, personal information, trip-based information, and information about trip-stages. During data input, all of the trip origins and destinations were encoded with GPS coordinates to allow geo-referenced analysis. Moreover, we generated the 'objective door-to-door travel time' for each reported trip with four different modes (walking, cycling, transit, and car) using a web journey planning software[1].

2.3 Analysis method

The data preparation started with a grouping of the sample according to two criteria: First, the school location with four nominal categories. This variable shall capture the influences of spatial and other

[1] For the Austrian schools: http://www.anachb.at; for the German school: http://reiseauskunft.bahn.de

structural features on mode choice and on other variables with predictive power on mode choice. Secondly, the trip purpose with two nominal categories. Trips originating at home and ending at school location (home-to-school) and vice versa are referred to as 'school trips'; all non-school trips are referred to as 'non-school trips'; these are predominantly leisure trips. For a detailed analysis further sub-groups were defined to consider possible influences (i) of trip direction on school trips (school-home, home-school) and (ii) of accompaniment on non-school trips. We also analyzed if trip purpose may impact the model results. Gender and household characteristics were included in the analysis as control variables.

The analysis proceeds in two steps: The first step is a descriptive analysis which includes amongst others a visualization of school trips, a modal split chart, and a pairwise comparison of means of the possible predictors of mode choice at different school locations. The second step is the development of structural equation models (SEM) to examine the relationships between the exogenous variables and the outcome variables (mode choice).

3 Results

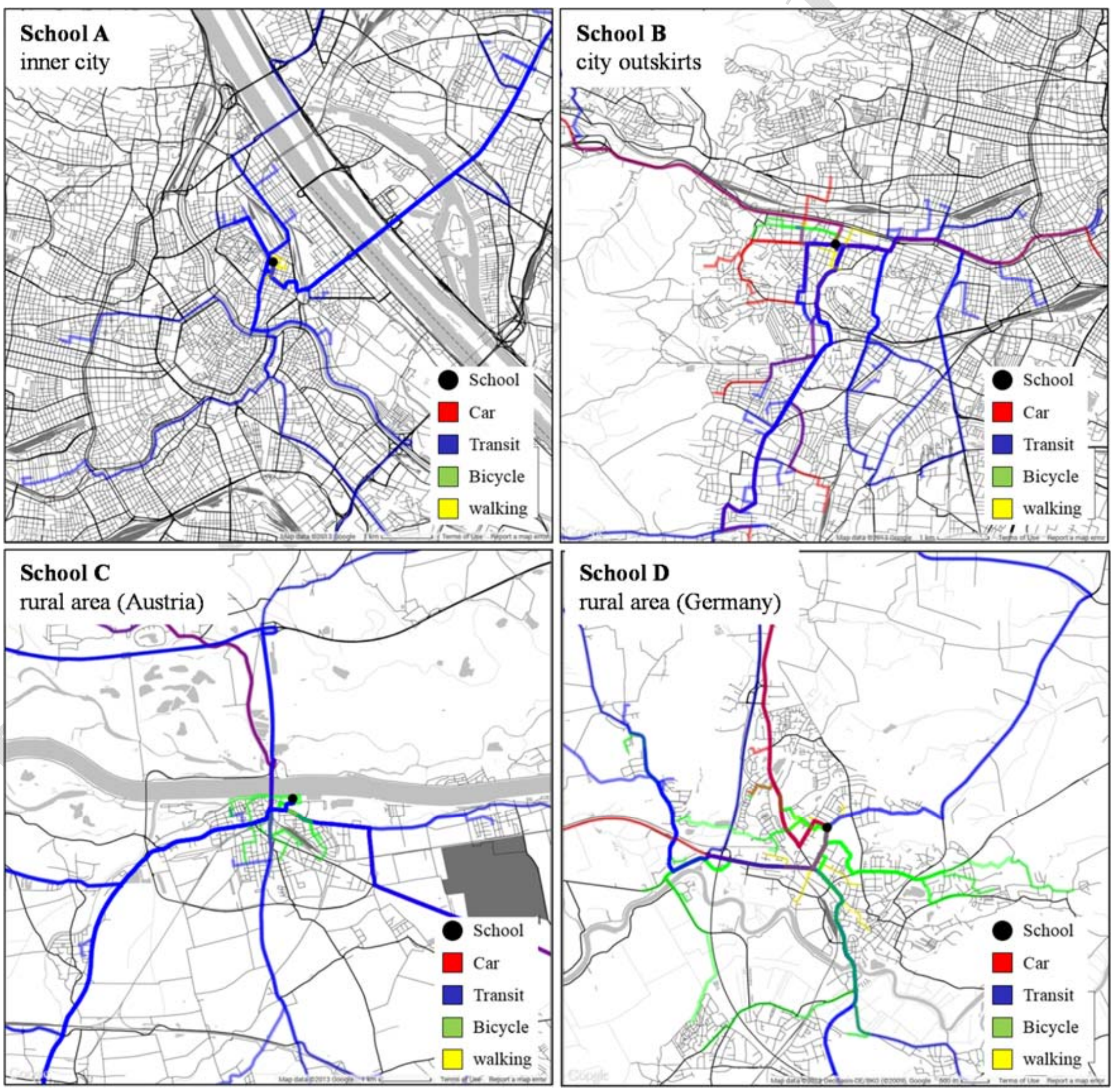
The 186 school children, who participated in the survey, reported 3,522 trips with 6,015 trip stages during the one week survey period. We excluded trips longer than 50 km from the analysis (this refers to 38 trips, mostly recreational) to focus on everyday mobility; therefore the basic model finally contains 1,682 school trips (trips from home-to-school respectively school-to-home) and 1,802 non-school trips (Table A- 1). As outlined above, the focus of the following analysis lies on how external factors influence mode choice. Sample characteristics on person and household level were included as control variables and are presented in Table A- 2 of the appendix.

3.1 Descriptive analysis

Of course, school trips play a key role in the everyday mobility of the children: they account for almost half of all trips and have a strongly recurrent pattern. We used these trips to provide a visual impression of the spatial situation at the different school locations and how this situation affects trip length and mode choice (Figure 1). The school trips were mapped using the Google Maps Application Programming Interface (Google, 2013). The geo-referenced locations of the schools and the home locations of the children were connected using the 'Directions Service' object provided by the application programming interface along with the reported travel modes. The visualization gives an impression of the schools' catchment areas: School A in the inner city has a maximum distance of 11 km (mean: 3.2 km), whereas school B at the outskirts has a maximum of 16 km (mean: 4.1 km). The schools in the rural areas show comparable larger catchment areas (C: maximum 20 km, mean 9.2 km; D: maximum 19 km, mean 5.0 km). It must be considered that this calculation is only based on the places of residence of the students in this sample and is not valid for the entire school.

The colors in Figure 1 represent the different modes of transportation (yellow – walking, green – cycling, red – car, blue – transit, including school bus). Walking trips can only be seen in a very small radius. The map for school D indicates a strong affinity of the children to the bicycle; it is used for much longer trips than at the other three locations. Transit is the preferred long-distance mode for school trips at all four locations, but school B and D show a somewhat stronger affinity to car ridership.

Figure 1: School locations (black spots) and sections of their catchment areas displaying the mode choice on school trips. Top left: inner city school (Vienna, Austria), top right: city outskirts (Vienna, Austria), down left: school in rural area (Tulln, Austria), down right: school in rural area (Itzehoe, Germany).



We assume that school trips and non-school trips of children’s everyday mobility follow different rules. Most of the trips other than school-home and home-school relations are leisure trips such as sports and social activities (68.7%). For 6.4% of the leisure trips the children were not able to define a specific destination.

Further non-school trips are shopping trips (9.3%) and education out of school (6.0%). Our data collection was conducted in close contact with the children. In this way, we were able to find out that a reported trip destination “shopping facility” does not necessarily mean that the children bought something but rather use it as a place where they chill out and hang out in the afternoon.

Figure 2 shows the modal split per school location, each divided according to school trips (ST) and non-school trips (OT). This analysis is based on a nominal variable indicating a single "main mode" for each trip. The figure reveals a very strong variation of children’s mode choice with regard to location (School A to D) and trip purpose (ST/OT). Particularly striking is School D with the highest share of cyclists, the lowest share of transit users, and almost no difference between school trips and non-school trips with regard to the share of walking and cycling. The high share of cyclists is typical for Northern European regions (Vaismaa et al., 2012; Pucher & Buehler, 2010). It seems to result from a positive feedback loop: The good “cycling climate” leads to a better development of cycling infrastructures, which may lead in turn to an increased use of bicycles and positive attitudes towards cycling, which leads in turn to a good cycling climate. We assume that travel socialization within the bicycle-friendly environment made the bicycle to an everyday mode even for longer trips for children from school D.

The Austrian locations (school A to C) are more similar to each other. The school trips have a very high share of transit use even in the rural area. But for non-school trips the share of transit users decreases in favor of walking, cycling, and car ridership. The increase in car ridership is strongest in the rural area and lowest in the city center. The high car use for leisure trips confirms the findings of Hjorthol and Fyhri (2009) who analyzed leisure activities of children in the age group of 6 to 12. The children’s average trip rates (number of trips per person/day) also differ between the locations: Whereas children living in the urban area had 2.8 (A) respectively 2.9 trips per day, those living in rather rural areas had 3.2 (D) to 3.4 (C) trips per day. These differences are not in the focus of our study and we have no specific explanation, but they are remarkable and worth of further exploration with bigger samples.

Figure 2: Modal split according to school location and trip purpose (ST – school trips, OT – non-school trips).

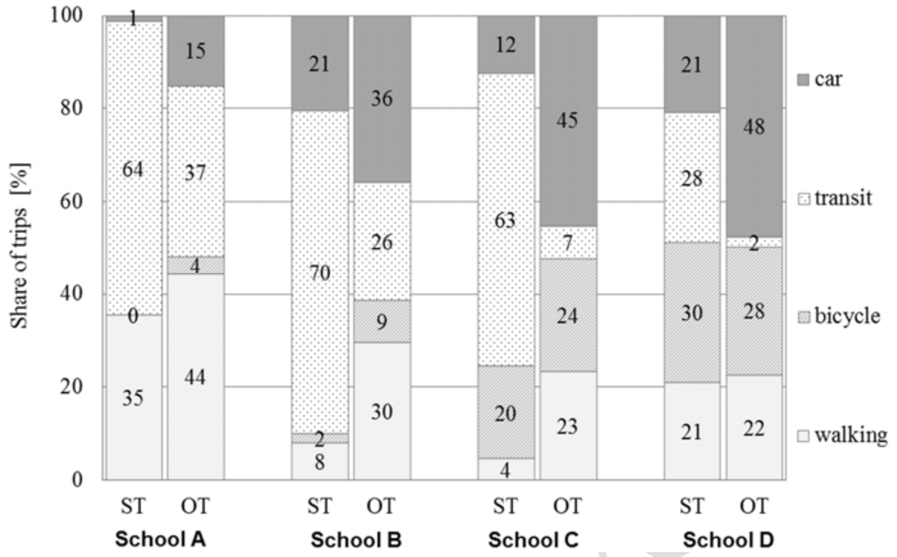


Table 2 and Table 3 show descriptive statistics of trip characteristics for variables used in the structural equation models (SEM). These are (i) the presumed external factors influencing mode choice according to our hypotheses (exogenous variables), and (ii) the modal share of transit use and car ridership (outcome variables). The tables include the mean values for the school locations (upper part) as well as the results of ANOVAs with a post-hoc comparison of means using Bonferroni correction. The results show more significant than insignificant differences, most of which are in line with our expectations. Some results should however be noted, which are important for the model: For school trips, both car speed and transit speed increase from the city center to the peripheral area and further to the rural area (Table 2). However, the average car speed rises stronger, so that the ratio between transit speed and car speed decreases from the city center to the rural areas.

The particularly high transit speed in the rural area of Austria (School C) is somewhat surprising. It results from the bus, which serves the school trips very well: the bus drives on roads with high speed limit, few stops in direct connection. The transit network in the city center is indeed dense, but not so fast, because trams and buses drive on crowded roads and most trips require changes. The transit speed in the rural area decreases strongly when it comes to leisure trips, which are more diverse in space and time and are not served by a dedicated bus (Table 3). The urban areas show a more similar transit speed of school and non-school trips than the rural area in Germany (School D).

In all four schools, the school trips are much more likely to be traveled by transit than non-school trips. This outcome correlates with the higher transit speeds for school trips than the mean transit speeds for non-school trips (Schools B, C and D), which are not located directly in the city center.

Table 2: Means and pairwise comparison of means between different school locations with regard to several trip characteristics of school trips (p ≤.001, *p ≤ .05).**

	School locations	trip length (km)	Speed transit (km/h)	Speed car (km/h)	Transit use	Car use
Mean	A	3.19	7.14	8.02	0.64	0.01
	B	4.10	8.89	19.61	0.70	0.23
	C	9.21	16.89	44.22	0.63	0.18
	D	5.04	9.65	29.67	0.28	0.23
Δ Mean	A-B	–0.90*	–1.74**	–11.58**	–0.06	–0.22**
	A-C	–6.01**	–9.75**	–36.20**	0.00	–0.16**
	A-D	–1.85**	–2.51**	–21.65**	0.36**	–0.22**
	B-C	–5.11**	–8.00**	–24.61**	0.06	0.06
	B-D	–0.94**	–0.76	–10.06**	0.42**	0.00
	C-D	4.17**	7.24**	14.55**	0.35**	–0.06

Table 3: Means and pairwise comparison of means between different school locations with regard to several trip characteristics of non-school trips (p ≤ .001, *p ≤.05).**

	School locations	trip length (km)	Speed transit (km/h)	Speed car (km/h)	Transit use	Car use
Mean	A	3.86	7.34	10.42	0.37	0.17
	B	5.44	7.48	17.89	0.26	0.38
	C	7.83	7.57	35.12	0.07	0.46
	D	4.98	7.61	27.23	0.02	0.48
Δ Mean	A-B	–1.59	–0.14	–7.48**	0.11**	–0.20**
	A-C	–3.97**	–0.23	–24.71**	0.29**	–0.29**
	A-D	–1.12	–0.28	–16.81**	0.35**	–0.30**
	B-C	–2.39**	–0.09	–17.23**	0.18**	–0.08*
	B-D	0.47	–0.14	–9.34**	0.24**	–0.12**
	C-D	2.86**	–0.05	7.89**	0.05	–0.02

3.2 Structural equation models

Structural equation models were used to test our hypotheses about the influence of external factors on the travel mode of children along with interdependencies between the external factors. A main advantage using this structural equation modeling is that effects between the variables are displayed separately. The resulting models for school trips (N = 1,682) and non-school trips (N = 1,802) are shown in Figure 3 and Figure 4. The models include the following variables:

- The four different school locations from A (city center) to D (rural); they are represented by dummy variables with school A as reference category.
- The trip length is the road trip length between origin and destination obtained from a route planning web application (continuous variable).
- The service quality of motorized modes, indicated by the speed ratio between transit and car; a higher score indicates a better performance of transit compared to car use (continuous variable).
- The mode choice is represented by two binary variables serving as outcome variable of the model. The variable indicates for each single trip, if the corresponding mode (transit and car) was used (1) or not used (0). From this results that each observed trip is represented in the model. A low share of transit use (or car use) causes a low mean value of the binary variable. The modes walking and cycling are not represented in the model for the sake of clarity; these modes will be analyzed in separate models, in which we intend to use partly different explanatory variables.

As outlined above, we did not distinguish between school bus and public bus in the transit option, because at the school locations there is no explicit "school bus", although some regular busses serve mainly as feeder busses for schools according to their specific schedule. From this follows that the difference between "school feeder bus" and other transit is indirectly covered by the combination of school location and kind of trip (school trip, non-school trip) as follows: children outside the city of Vienna (school locations C and D) have a bus available for their school trips; the transit option for non-school trips is in most cases poor or not existing; children in the urban area (school locations A and B) have a dense transit system (bus, tram, or metro) available for all their trips. They use the regular transit for both school trips and non-school trips without a difference.

Following from the categorical scale of our response variables we used a Bayesian approach for nonlinear Structural Equation Modeling of dichotomous variables (Lee et al. 2010). Within this approach, all unknown parameters are treated as uncertain and therefore described by a probability distribution. The standardized solutions (correlations and standardized regression weights) are presented (Figure 3, Figure 4). All displayed coefficients are significant ($p \leq 0.01$) except those marked with brackets (see also Table A-3 and A-4 in the Appendix). The posterior predictive p value is 0.4, which seems adequate for a correct model. We also calculated a pseudo-r^2 for our categorical response variables using an approach for ordinal level variables (McKelvey & Zavoina, 1975), which also applies to binary responses. It calculates the R^2 of a linear model, which predicts the actual underlying continuous probabilities of the probit link function using the estimated parameters.

The model parameters confirm all of our hypotheses and have throughout the expected signs. A rural school location comes along with (i) a decreasing quality of transit compared to car and (ii) longer school trips. The trip length of non-school trips is more similar between the school locations. Another difference between school-trips and non-school trips is that longer school trips lead to a higher use of transit, whereas longer non-school trips strengthen the use of car.

In order to control for socio-demographic influences on mode choice in the model, we tested gender as explanatory variable for car use and transit use. A significant effect could be found for a higher use of car of girls on school trips. Age was excluded as predictor because of lacking variability (all children of the same grade). We also found significant effects of the number of cars per household, the number of persons per household, and the personal ownership of a transit ticket (parents' occupation and their ownership of transit ticket was not influential in our model). We also tested the influence of trip purpose by including relevant trip purposes as dummy variables in the model. However, no significant influence could be found for both the school-trip-model and the non-school-trip-model. Not all socio-demographic variables are significant for both response variables in both models (school trips and non-school trips), but we used the same set of predictors in all models for the sake of consistency.

It should be noted that the mode choices stem from repeated observations from the same individuals and are therefore not fully independent. Each individual reported 10 mode choices on average, and 60.5% of the children chose the same mode for their school trips in the survey week. From that follows that the standard errors of the parameters are under-estimated due to intra-individual correlation. Fixing this problem would require mixed model approach, which accounts for the pseudo-panel structure of the data, but this option is not available in the AMOS software package that we have used for model estimation.

Figure 3: Structural equation model of factors influencing the use of transit and car on school trips (ST). Values on paths are standardized regression weights. All displayed paths are significant ($p \leq 0.01$) except those in brackets. N_{ST} = 1,682 trips.

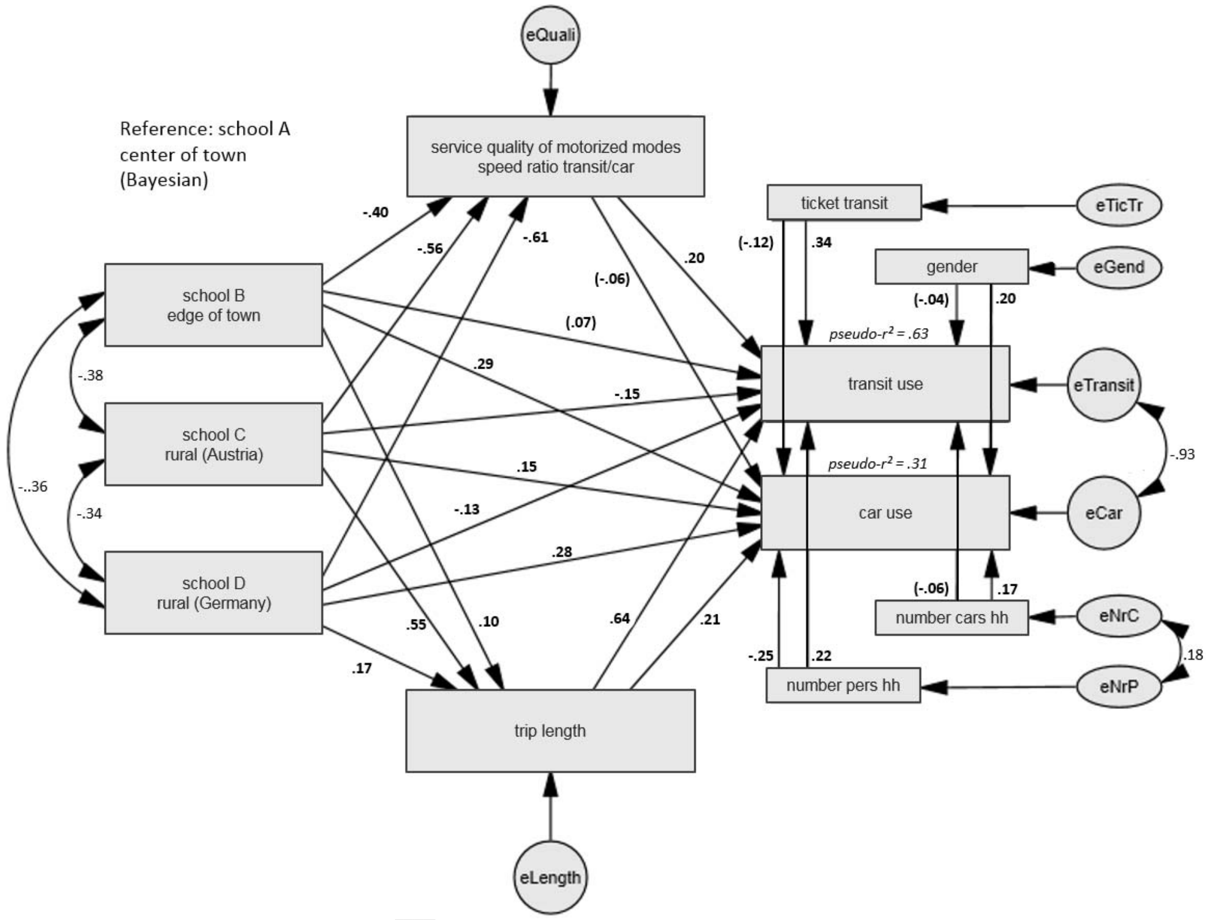
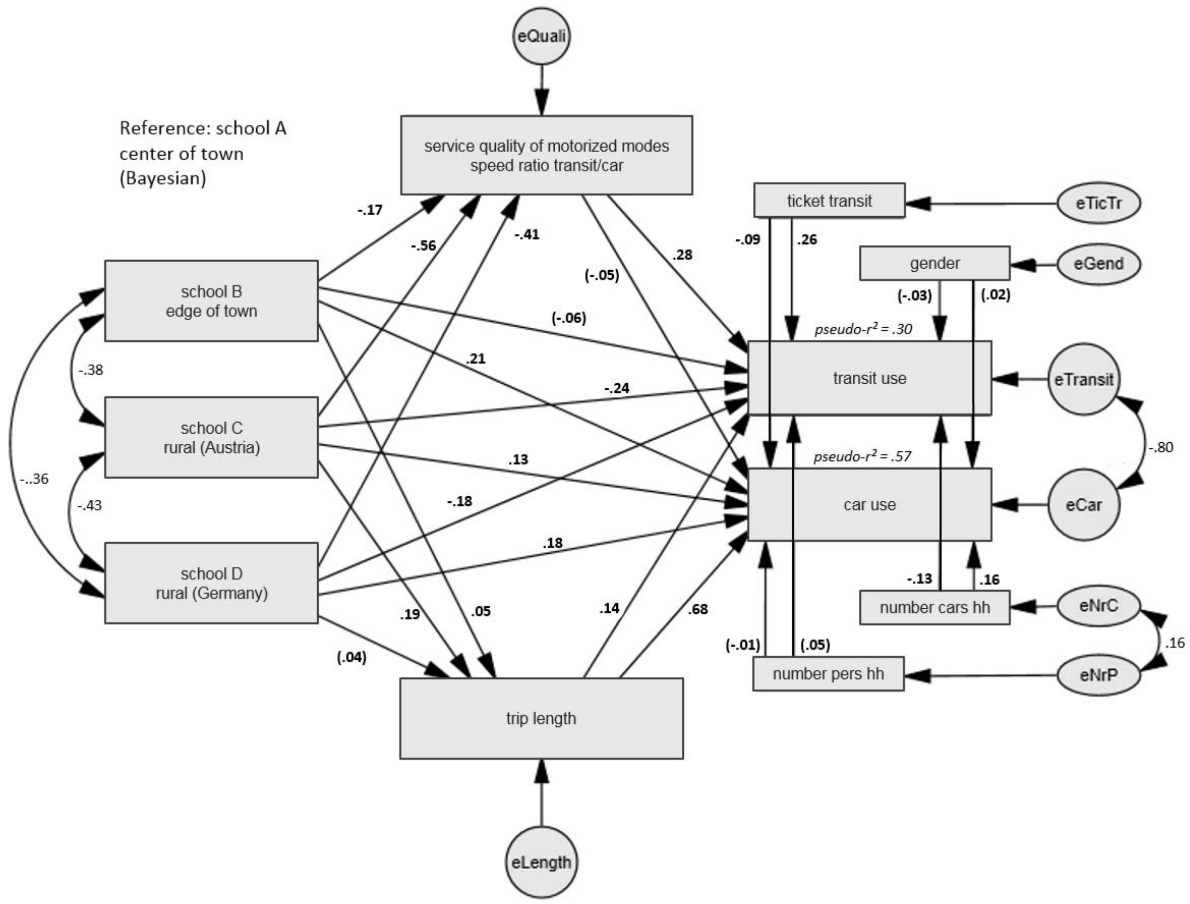


Figure 4: Structural equation model of factors influencing the use of transit and car on non-school trips (OT). Values on paths are standardized regression weights. All displayed paths are significant ($p \leq 0.01$) except those in brackets. N_{OT} = 1,802 trips.



Based on the models in Figure 3 and 4 we conducted more detailed analyses to test further hypotheses. In a first step, we tested by means of separate sub-models whether home-to-school trips differ from school-to-home trips. This test followed the findings of previous studies (e.g. Yarlagadda & Srinivasan, 2008) that mode choice of children can differ depending on the direction (home-to-school trips vs. school-to-home trips), largely due to different levels of parental availability. However, we found hardly any differences between these directions. One explanation might be that in our sample supervision is very similar in both directions and on low level. Children of our age group are less dependent than younger age groups; according to their own statements, only 5% of mode choices were “other directed”.

However, non-school trips have higher levels of accompaniment by supervisors than school trips. In order to test, whether escorting by supervisors makes a difference on the mode choice of non-school trips, we split this group into two sub-groups by means of a binary variable that takes the value one, if a supervisor (parents in the most cases) joined the child at least on half of the trip ($N_{OT\text{-}ws}$=844 trips) and zero otherwise ($N_{OT\text{-}wos}$=958 trips). The results of both sub-groups are displayed in Figure 5 and Figure 6.

It turned out that "escorting by supervisors" is strongly confounded with trip length and the use of motorized modes: accompanied trips are in most cases longer (average length 9.4 km) than trips without supervision (average length 2.7 km). Accompanied trips (Figure 5) show a strong path from trip length to car use, indicating that long accompanied trips are typically trips on which the car is used. The path from trip length to transit use is insignificant, because long transit trips are in most cases unaccompanied; they are not included in this model, but in the model of non-school trips without supervision (see Figure 6).

Unaccompanied trips show a strong path from trip length to both motorized modes (Figure 6). The strong path to transit use (compared to the other model) indicates that long transit trips do not require supervision (unlike car trips). The even stronger path from trip length to car use is caused by few long trips, on which a car was used on at least one trip stage[2]; because of our age group, the vast majority of trips on which a car is used was supervised at least on half of the trip and is thus included in Figure 5.

An overview of the standardized and unstandardized direct effects of the sub-models is provided in Table A-5 (Appendix). The posterior predictive p value is .38. However, the sub-models show in general lower p-values due to the lower sample size.

2 According to our definition of supervision (yes, if a supervisor joined at least half of the trip) car use on trips without supervision is only possible if transit or a non-motorized modes was also used for the larger part of the trip; for example, if parents escort their child a short distance to the railway station. In very few cases, a child with a driving license used a motorcycle in the free-time, which was allocated to car use (motorized individual transport).

Figure 5: Structural equation model of factors influencing the use of transit and car on non-school with supervision. Values on paths are standardized regression weights. All displayed paths are significant ($p \leq 0.01$) except those in brackets. $N_{OT\text{-}ws}$ = 844 trips.

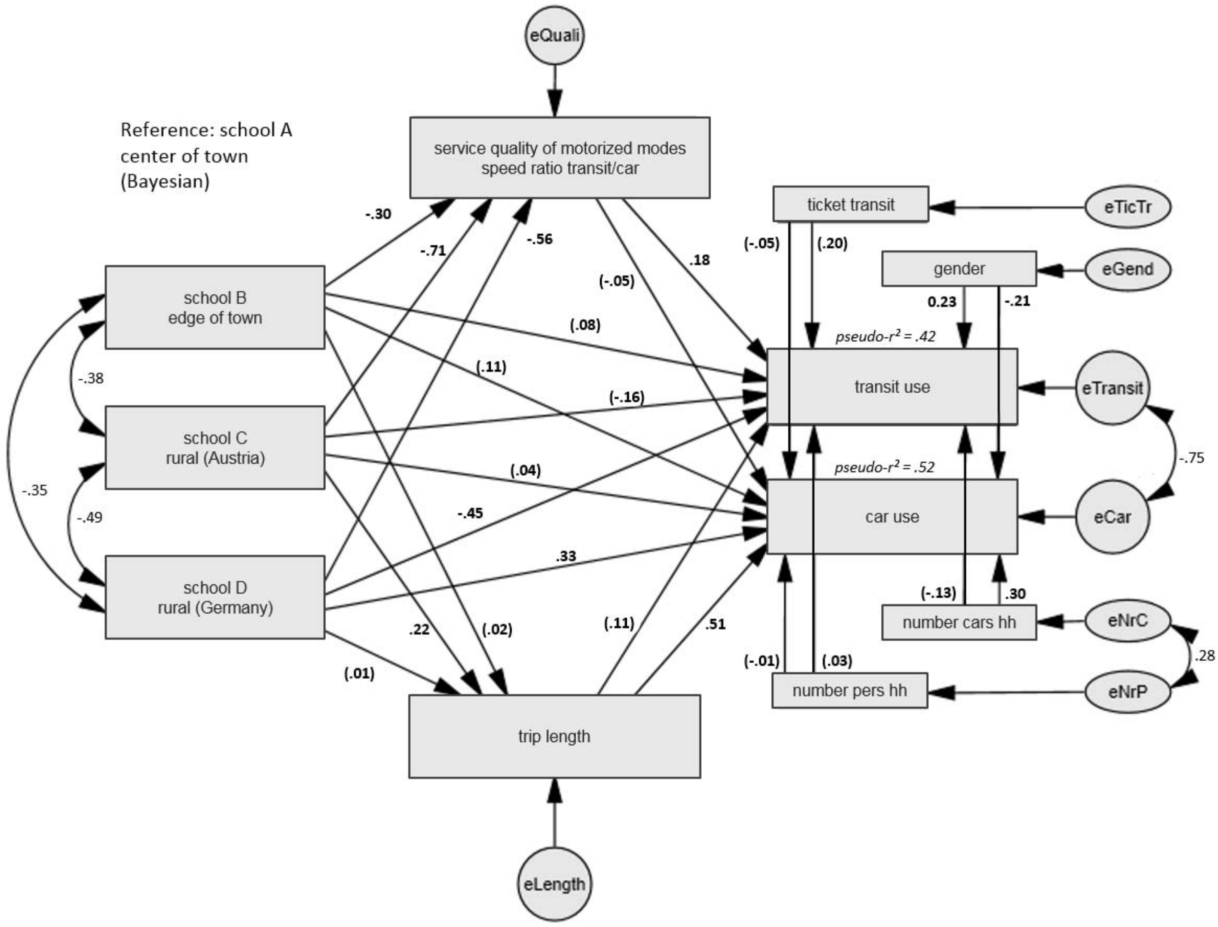
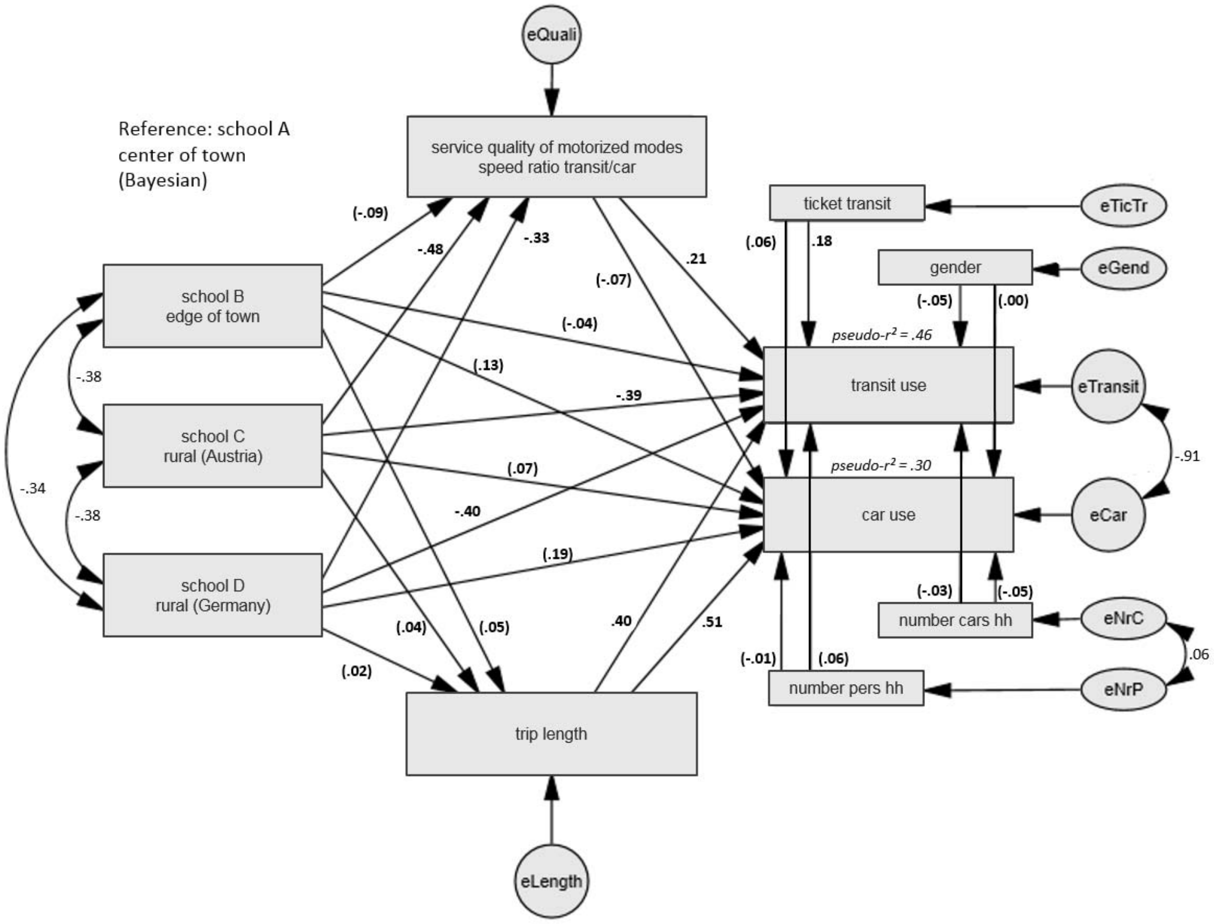


Figure 6: Structural equation model of factors influencing the use of transit and car on non-school without supervision. Values on paths are standardized regression weights. All displayed paths are significant ($p \leq 0.01$) except those in brackets. $N_{OT\text{-}wos}$ = 958 trips.



4 Discussion and conclusion

In our study we emphasized on objective (infra-)structural factors as predictors of children's travel mode choice. The structural factors include school location, trip purpose (school trips vs. non-school trips), trip length, and service quality of motorized modes. For all we know there are no comparable results reported in the literature. There is only a similar model of Fyhri & Hjorthol (2009), who investigated the influence of a range of background variables on mode choice for Norwegian children’s transport to school or leisure activities. Although the focus lies on structural factors, we controlled for gender and various household characteristics in our models. Psychosocial factors such as parental concerns and inter-relation between parents’ travel mode to work may also have an impact (Lopes et al., 2014; Deka, 2013), but were not included as we have no information about this. It should be noted that the results were derived from data of four schools with particular environment. Given that every neighborhood is different in some respects, a large sample representing diverse built environments would be desirable to confirm our findings.

Following from the categorical scale of our response variables we used a Bayesian approach for nonlinear Structural Equation Modeling of dichotomous variables, R square cannot be calculated. Therefore, pseudo-r^2 is provided lying between 0.30 (car ridership on non-school trips without supervision) up to 0.63 (transit use on school trips) with an average of 0.44 over all four estimates. As mentioned above, it should not be equated with the classic R^2, because it estimates the R^2 of a linear model, which predicts the actual underlying continuous probabilities of the probit link function. One reason for the high explanatory power is probably the disaggregated measurement of the service quality of motorized modes by means of the door-to-door speed of individual trips. The corresponding variable (ratio between transit and car speed) contributes significantly to the explanation of children's use of modes. It confirms the findings of Yarlagadda and Srinivasan (2008) as well as Ewing & Cervero (2010) that the service quality of transit is critical for children's mode choice. Our model derived from data at four school locations reveals that a better service quality of transit in relation to the car increases the use of transit for both school and non-school trips, but it has little impact on car use. The additional transit riders are not necessarily former car riders; they are also recruited from former cyclists and pedestrians. This behavioral pattern explains in particular, (i) why transit is more often used in the urban areas than in rural areas; (ii) why the rural school in Austria has twice the share of transit use for school trips than the rural school in Germany; and (ii) why both rural locations show a low share of transit use on non-school trips. The answer is that school trips in the rural area are very well served by a dedicated bus, so that the transit can seriously compete with car and cycling, whereas leisure trips do not enjoy this service. This should be considered in transit planning policy: improvements in the transit service quality, in terms of speed, planned and regulated offer, leads to a higher probability of children using this mode.

The structural equation models of school trips and non-school trips confirm our hypotheses by means of significant path coefficients, all of which have the expected signs. The effects have throughout the same direction for school trips and non-school trips. It reveals some similarities across both kinds of trips:

- The gradient from the city center to rural areas comes along with an increasing trip length and a decreasing service quality of transit in relation to the car.
- Longer trips argue for using a motorized mode instead of walking or cycling. It confirms the finding of other authors that the trip length is a crucial factor for children's mode choice (e.g., Ewing et al., 2004; Schlossberg et al., 2006; McDonald, 2008; Mitra & Buliung, 2012, *reference blinded*).
- A better service quality of transit increases the use of transit, but it has little impact on car use (as stated above).

Beyond these similarities, there are also strong differences between school trips and non-school trips in our sample, indicated by significantly different effect sizes:

- A rural settlement pattern increases mainly the length of school trips, whereas the length of non-school trips is more similar in urban and rural areas.
- Long school trips increase the frequency of transit use, whereas long non-school trips increase the frequency of car use. This result confirms the findings of Fyhri & Hjorthol (2009) that the car is the most typical mode of travel to leisure activities.
- Accompaniment by supervisors also makes a difference on children’s mode choice on non-school trips. Unaccompanied trips are on average shorter than accompaniment trips and involve a higher freedom of choice between walking and cycling (for short distances) and transit use (for longer distances).
- Accompanied non-school trips are in most cases long trips, which include car use on some or all trip stages. It illustrates that a high level of car use not only burdens the environment but also the parents in terms of time requirement.

Using structural equation modelling proved to be a valuable method to reveal the effects of several structural factors on children's mode choice simultaneously, although the absence of individual factors causes some limitations. Integrated approaches such as Klinger et al. (2013) for German cities show that further socio-demographic characteristics and attitudes would probably account for further variability in individual mobility patterns. The socio-demographics include variables determining individual options and necessities for mobility activities; subjective characteristics include values, norms and attitudes such as estimations of transport modes, which affect preferences and habits for specific activities, destinations, routes and modes of transport.

Finally, in view of the decreasing levels of physical activity in children’s everyday life, we would like to draw the attention to the non-school trips, which should be subject to awareness raising activities to promote active travel. Besides the continuation of existing AST campaigns, this potential should be addressed from multiple levels.

5 Appendix

Table A- 1: Number of children and trips per school location.

	A	B	C	D	Total
Children	37	52	47	50	186
School trips	337	504	427	414	1,682
Non-school trips	294	417	579	512	1,802

Table A- 2: Household and socio-demographic characteristics of children and parents in the sample (N=186 children).

Children's characteristics			
Gender			
	female		54.3%
	male		45.7%
Age			
	average		13.1%
	12		23.1%
	13		46.2%
	14		23.7%
	15		7.0%
Own bicycle = yes			91.2%
Season ticket for public transport = yes			77.7%
Parents' characteristics			
Parents' occupation		mother	father
	full time	40.2%	79.7%
	part time	40.2%	14.6%
	no	19.5%	5.7%
Driving license (car) = yes		84.4%	98.3%
Season ticket for public transport = yes		31.3%	27.7%
Household characteristics			
Number of persons per household			4.1
Number of vehicles per household			
	scooter		1.4
	bicycle		3.8
	motorcycle		0.4
	car		1.7

Table A- 3: Standardized and unstandardized direct effects (school trips).

Path	standardized direct effects	unstandardized direct effects	CR	p value
trip length<-- school B	0.0957	1.0199	3.7156	0.0002
service quality<-- school C	-0.5572	-0.4802	-27.5715	0.0000
car use<-- school B	0.2886	0.7456	6.7948	0.0000
transit use<-- school D	-0.1348	-0.4719	-3.8725	0.0001
car use<--service quality	-0.1186	-0.1805	-2.1160	0.0343
service quality<--school B	-0.3970	-0.3286	-15.8281	0.0000
trip length<-- school C	0.5483	6.0835	20.1070	0.0000
trip length<-- school D	0.1699	1.9153	6.2673	0.0000
service quality<-- school D	-0.6094	-0.5338	-24.4166	0.0000
transit use<-- school B	0.0714	0.2373	1.8909	0.0586
transit use<-- school C	-0.1530	-0.5278	-3.7675	0.0002
car use<-- school C	0.1460	0.3933	2.6546	0.0079
car use<-- school D	0.2846	0.7784	5.4609	0.0000
car use<--trip length	0.2065	0.0501	5.3825	0.0000
transit use<--trip length	0.6350	0.1977	17.4547	0.0000
transit use<--service quality	0.2026	0.8114	6.8662	0.0000
car use <--nr persons household	-0.2493	-0.2345	-5.0399	0.0000
car use <--gender	0.1969	0.4631	5.7465	0.0000
transit use <-- gender	-0.0378	-0.1142	-1.3995	0.1617
transit use <-- nr cars household	-0.0593	-0.0879	-1.8060	0.0709
car use <--nr cars household	0.1671	0.1920	4.4545	0.0000
car use <--ticket transit	-0.1186	-0.1801	-2.5482	0.0108
transit use <-- ticket transit	0.3355	0.6543	9.2373	0.0000
transit use <-- nr persons household	0.2234	0.2695	5.9725	0.0000

Table A- 4: Standardized and unstandardized direct effects (non-school trips).

Path	standardized direct effects	unstandardized direct effects	CR	p value
trip length<-- school B	0.0497	1.0141	3.7217	0.0002
service quality<-- school C	-0.5553	-0.4807	-27.9110	0.0000
car use<-- school B	0.2144	0.7725	8.2072	0.0000
transit use<-- school D	-0.1832	-1.0535	-10.5945	0.0000
car use<--service quality	-0.0492	-0.2241	-2.6626	0.0078
service quality<-- school B	-0.1650	-0.1565	-6.4167	0.0000
trip length<-- school C	0.1940	3.6328	7.1234	0.0000
trip length<-- school D	0.0409	0.7888	1.5028	0.1329
service quality<-- school D	-0.4075	-0.3627	-15.4232	0.0000
transit use<-- school B	-0.0551	-0.1517	-1.3031	0.1925
transit use<-- school C	-0.2394	-0.6004	-4.4650	0.0000
car use<-- school C	0.1283	0.4066	3.2834	0.0010
car use<-- school D	0.1835	0.5983	4.3642	0.0000
car use<--trip length	0.6846	0.1160	19.8199	0.0000
transit use<--trip length	0.1377	0.0185	4.0181	0.0001
transit use<--service quality	0.2795	0.8102	8.3566	0.0000
car use <--nr persons household	0.0142	0.0203	0.5170	0.6052
car use <--gender	0.0154	0.0481	0.6498	0.5158
transit use <-- gender	0.0273	0.0672	0.7252	0.4683
transit use <-- nr cars household	-0.1281	-0.1530	-3.0662	0.0022
car use <--nr cars household	0.1561	0.2356	5.5903	0.0000
car use <--ticket transit	-0.0860	-0.1668	-2.6284	0.0086
transit use <-- ticket transit	0.2592	0.3973	5.4480	0.0000
transit use <-- nr persons household	0.0505	0.0568	1.4821	0.1383

Table A- 5: Standardized and unstandardized direct effects - non-school trips with ($N_{OT\text{-}ws}$ = 844 trips) and without ($N_{OT\text{-}wos}$ = 958 trips) supervision. All displayed paths are significant (p ≤0.01) except those in brackets.

	standardized direct effects		unstandardized direct effects	
Path	with supervision	without supervision	with supervision	without supervision
trip length<-- school B	(0.0190)	(0.0478)	(0.4982)	(0.4982)
service quality<-- school C	-0.7097	-0.4842	-0.4871	-0.4871
car use<-- school B	(0.1147)	(0.1328)	(0.3807)	(0.3807)
transit use<-- school D	-0.4474	-0.3958	-1.2296	-1.2296
car use<--service quality	(0.0258)	(-0.0691)	(-0.1846)	(-0.1846)
service quality<--school B	-0.3031	(-0.0864)	-0.2385	(-0.0928)
trip length<-- school C	0.2189	(0.0397)	4.9958	(0.3875)
trip length<-- school D	(0.0116)	(0.0197)	(0.2746)	(0.1955)
service quality<-- school D	-0.5564	-0.3309	-0.3991	-0.3388
transit use<-- school B	(-0.0816)	(-0.0417)	(-0.2426)	(-0.1353)
transit use<-- school C	(-0.1614)	-0.3857	(-0.4186)	-1.1776
car use<-- school C	(0.0385)	(0.0738)	0.1098	(0.1996)
car use<-- school D	0.3345	(0.1942)	1.0128	(0.5343)
car use<--trip length	0.2976	-0.0463	0.0647	0.1409
transit use<--trip length	(-0.1325)	-0.0259	(0.0126)	0.1243
transit use<--service quality	-0.0074	0.0595	0.6953	0.6415
car use <--ticket transit	(-0.0476)	(0.0648)	(-0.0895)	(0.1017)
transit use <-- ticket transit	0.1952	0.1804	0.3352	0.3157
car use <--gender	-0.2052	(-0.0521)	-0.6076	(-0.1343)
transit use <-- gender	0.2337	(0.0029)	0.6300	0.0079
car use <--nr cars household	0.2976	(-0.0463)	0.3899	(-0.0657)
transit use <-- nr cars household	(-0.1325)	(-0.0259)	(-0.1572)	(-0.0405)
transit use <-- nr persons household	(-0.0074)	(0.0595)	(-0.0095)	(0.0761)
car use <-- nr persons household	(0.0258)	(-0.0097)	(0.0367)	(-0.0109)
school B <--> school C	-0.3810	-0.3780	-0.0749	-0.0749
school C <--> school D	-0.4909	-0.3828	-0.1062	-0.0798
school B <--> school D	-0.3535	-0.3419	-0.0665	-0.0667

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