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Children's mode choice for trips to primary school: a case study in German suburbia

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ABSTRACT

Research on children's school travel behaviour has grown tremendously in the past decade, although Germany has remained amazingly silent. At the same time the interplay between various factors that affect child travel is not yet fully understood. The paper reports results from a survey in the medium-sized suburban town of Lünen, Germany. Mode choice of children to and from primary school is studied using multinomial logistic regression. The models include a large variety of variables that capture child and household sociodemographics, parents' mode use, trip distance, parental concerns, attitudes and perceptions, and the built and transport environment. Some of our results confirm previous studies (e.g. on the role of age, gender, and trip distance), while others differ. For instance, we found no effects of household socioeconomic status or of the social environment on mode choice. Concerning the role of the transport environment, we want to highlight two findings. Firstly, narrow pavements along the route increase the odds of being driven rather than walking. Secondly, traffic calming is associated with higher odds of cycling against walking. Parental attitudes and concerns also play a significant role in child mode choice.

1. Introduction

Children's travel to and from school has been the subject of research since the 1970s (Rigby, 1979, see for a comprehensive review of early studies EPPI, 2001). But the past decade has seen a tremendous increase in research on children's trips (see Helbich, 2017; Moran et al., 2016; Race et al., 2017; Sharmin and Kamruzzaman, 2017; Leung and Loo, 2017; Buliung et al., 2017, for recent studies). This is paralleled by increasing debate in the general media about problems associated with driving to school and traffic at school sites (Vollmuth 2017; Prengel, 2018), and the autonomous mobility of children in a wider sense (Batthyany, 2016). This growing interest is motivated by a number of concerns (see Waygood et al., 2017). Child obesity, deficits in motor skills, a lack of physical activity (Lau et al., 2017; Race et al., 2017) and issues with cognitive development (Appleyard, 2017) have been associated with a lack of independent mobility and active travel (walking and cycling); children's decreased independence and knowledge about their environment have both been linked to children being increasingly driven by their parents (Fang and Lin, 2017), while attention has also been paid to the negative environmental, social and financial effects of driving to school (Lu et al., 2017; Rothman et al., 2017; He and Giuliano, in print).

Children's travel has substantially changed over the past decades, the most striking changes being probably the shift from active modes, especially walking, to being driven by car, and the associated decline in independent travel (McDonald, 2007, for the US; Shaw et al., 2013 for the UK and Germany; Kyttä et al., 2015, for Finland; Schoeppe et al., 2016, for Australia; Mitra et al., 2016, for Toronto).

Research on children's travel has become a wide arena that includes multiple perspectives in terms of motivation, scope, methododology, and target variables. Two basic distinctions can be made. Firstly, a large number of studies inquire into characteristics of trips made by children and, hence, employ a 'child travel' perspective, while other studies look at trips made by parents to accompany their children. These latter studies often take a gender perspective and consider child escorting as an integral part of intra-household or intra-family worksharing.

Secondly, while the majority of studies – especially in the transport realm – use standardised data to study either children's mode choice or independent mobility (without being accompanied by parents or other adults), or in some cases other measures of travel such as trip distances (e.g., Andersson et al., 2012; van Goeverden and de Boer, 2013), a smaller but notable number use qualitative methods to better understand children's or/and parents' subjective mobility experiences, motives and rationales (e.g., Ahern et al., 2016; Race et al., 2017). These

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Table 1
Examples of studies in the field.

	Quantitative	Qualitative	Mixed method
Focus on children	Buliung et al. (2017)	Race et al. (2017)	Romero, (2015)
Focus on parental escort	Manz et al. (2015)	Ahern et al. (2016)	Kramer (2009)

studies often have their roots in cultural sciences.

Neither of these two distinctions is a subgroup of the other. Qualitative as well as quantitative studies may pay attention to parents' and/or children's travel. Nor is either of the two distinctions exclusive; rather there is overlap to some extent, although the majority of studies can still be clearly located in one field. Table 1 gives some examples.

This paper uses standardised data collected in 2017 in a questionnaire survey in the mid-sized suburban town of Lünen, Germany. It studies children's mode use on the trip to primary school and back home. Hence, the paper can be filed in the upper left-hand field of the table. The study was motivated by the observation that there is a striking lack of research on the topic in Germany. This is despite the early contribution of Germany to research about child mobility (Hillman et al., 1990). More specifically, to the best of our knowledge this is the first study from Germany that investigates child mode use using multivariate methods to simultaneously include multiple factors (see Scheiner, 2016, for a study on children's independent travel). Hence, this paper asks for sociodemographic, attitudinal and environmental factors that may affect children's trips to school in Germany.

The next section provides a brief overview of literature on children's mode use. Section 3 introduces data and methods, and Section 4 presents the results. The paper concludes with a summary and draws conclusions for policy and research.

2. Background – children's mode use

Research on child travel has matured to the extent that literature reviews have been conducted for various sub-fields including children's mode use (Rojas Lopez and Wong, 2017; Rothman et al., in print), independent mobility (Sharmin and Kamruzzaman, 2017), environmental factors that affect the use of active modes (Pont et al, 2009; D'Haese et al., 2015), interventions to promote active travel (Smith et al., 2015; Pang et al., 2017; Larouche et al., 2018), associations between child travel and child health status (Schoeppe et al., 2013), methods of capturing children's independent mobility (Bates and Stone, 2015), and children's mobility/school travel in general (McDonald, 2005; McMillan, 2005; Curtis et al., 2015). This also includes multiple review sections in empirical studies on mode use (Wilson et al., 2010; Zhang et al., 2017; Hatamzadeh et al., 2017) or independent mobility (Shaw et al., 2013; Kyttä et al., 2015; Buliung et al., 2017).

Hence, this section focuses – though not exclusively – on studies of mode use employing standardised data that have been published in the past few years. There is, however, much overlap between studies of mode use and studies of independent mobility. In strongly car-based environments independent mobility coincides largely, though not strictly, with the use of active modes (Carver et al., 2014, for Australia; Hsu and Saphores, 2014, 550 for California), while in less car-based environments parents may accompany their children on foot or by bicycle (Scheiner, 2016, for Germany; Buliung et al., 2017, for Toronto). The literature on children's independent mobility is somewhat different from the mode use literature as the latter tends to use measures of realised travel, while the former is often based on surveys asking for 'mobility licences', i.e. parental allowances for travelling or being outside without supervision (Hillman et al., 1990; see Kyttä et al., 2015, and Schoeppe et al., 2016 for the use of both types of measures). Further, it should be noted that most studies focus on school travel, while there is less research on other trip purposes (see for a comparison between the two, Stark et al., 2018).

One needs to point out that children's mode use is not necessarily a preferential choice as it is for adults. Children, particularly at younger ages, are largely dependent on their parents' choices though they develop strategies to resist and strive for autonomy (Barron, 2014). Hence, their travel is constrained by parental considerations, daily needs, resources, attitudes and fears. Generally, children's mode use may be understood in the context of seven dimensions that can be modelled using a large number of variables: (1) trip characteristics, (2) child characteristics, (3) the household context, (4) subjective concerns, attitudes and perceptions, (5) the transport environment, (6) the built environment and (7) the social environment.

2.1. Trip characteristics

Studies consistently report that longer distances to school are associated with less active (non-motorised) travel (Wilson et al., 2010; Hsu and Saphores, 2014; all for the US; Mitra and Buliung, 2012; Mitra and Faulkner, 2012; Stone et al., 2014; Rothman et al., 2015; Guliani et al., 2015; Mitra et al., 2016; and Larsen et al., 2016, for Toronto, Canada; Clark et al., 2016; and Ahern et al. 2016 for the UK; Hatamzadeh et al., 2017, for Iran; Zhang et al., 2017; and Jing et al., 2017, for China; Helbich, 2017, for the Netherlands; Mehdizadeh et al., 2017, for Iran; van Goeverden and de Boer, 2013, for the Netherlands and Flanders; Easton and Ferrari, 2015, for Sheffield, UK; Waygood and Susilo, 2015, for Scotland; Moran et al., 2016, for Israel; Stark et al., 2018, for Austria). Thresholds for the acceptance of active travel may vary with cultural norms or constraints set by the environment (see Waygood and Susilo, 2011, for a comparison between Japan and the UK; van Goeverden and de Boer, 2013, for the Netherlands and Flanders). In Germany, two thresholds can be identified. The share of primary school children walking drops from 85% to about 60% when the distance to school is longer than 600 m, and to 34% at a distance of 1.2 km. The share of the bicycle has its maximum in the range from 1.2 to 2.0 km (14%) (Mobilität in Deutschland, own analysis, unpublished).

Over and above distance, mode choice is affected by topography (slope) along the route (Lin and Chang, 2010, for independent travel) and climatic or (more short-term) weather variations (van Goeverden and de Boer, 2013; Oxford and Pollock, 2015; Kamargianni et al., 2015). Mitra and Faulkner (2012) do not find significant effects of (weekly) weather conditions on mode choice.

The homebound trip from school is more often conducted independently of parents than the morning trip to school, and this is associated with less car travel (Lin and Chang 2010, for Taiwan; Schlossberg et al., 2006; Wilson et al., 2010; and McDonald and Aalborg, 2009, for the US). This may reflect parental work schedules and safety considerations which preclude parents from letting their children walk in the rush hour or on dark winter mornings.

2.2. Child characteristics

Children become more independent as they grow up. Hence, age has been found to be one of the most important factors to explain children's mode use, as can also be seen in effects of school stages that reflect age (Zhang et al., 2017). The probability of walking or cycling to school increases with age (Wilson et al., 2010; Yoon et al., 2011; Helbich, 2017), and the same has been found to be true for using public transport (Wilson et al., 2010), while the probability of being driven decreases (Wilson et al., 2010; van Goeverden and de Boer, 2013; see He and Giuliano, 2017, for a joint mode and escort model). Conversely, Easton and Ferrari (2015) find that teenagers are less likely to walk to school than younger children, once distance is taken into account, and rather use motorised modes. Pabayo et al. (2011) and Manz et al. (2015) also find that from the age of ten walking decreases and, hence, forms a bell-shaped age curve.

Environmental conditions may mediate age effects. Lopes et al. (2014) find that children in highly urbanised environments in Portugal are allowed to be independently mobile only at a greater age than those living in more rural environments. Scheiner (2016) confirms this for Germany, but adds that older children tend to be escorted less often by their parents in cities.

Boys use active modes and the bus more often than girls (Mitra and Faulkner, 2012; Stone et al., 2014; Guliani et al., 2015; Easton and Ferrari, 2015; Larsen et al., 2016; Zhang et al., 2017; Jing et al., 2017), and they are driven less often (van Goeverden and de Boer, 2013, for the Netherlands and Flanders) which is probably due to parental concerns about harassment and the vulnerability of girls (Zhang et al., 2017). Other studies find no significant effects of gender on mode choice (Helbich, 2017; Frater et al., 2017, for the intention to cycle) or independent travel (He, 2013).

2.3. The household context

The family in which a child lives affects the child's mode use in a myriad of ways. These include more objective factors such as household and parental resources, needs, activity patterns, the existence, gender and age of siblings, and their school trips, as well as subjective parental attitudes, concerns and fears. These factors may intersect in multiple and complex ways. For instance, parents may be inclined to let their 7-year-old son walk to school without parental escort as long as the elder daughter takes the same route. The elder daughter, however, may prefer to walk with her friends rather than looking after her younger brother. Finally, the father may take the son to school by car and drop him off on the trip to work. The interactions between household members have been studied by Ermagun and Levinson (2016) using a group decision making approach that captures intra-household bargaining.

Various studies found that children living in high-status households are less likely to use public transport (Wilson et al., 2010, for the US; Ermagun and Samimi, 2015, for Iran; Zhang et al., 2017 for China), less likely to use active modes (Mehdizadeh et al., 2017, for Iran), and more likely to be driven (Zhang et al., 2017) and travel less independently (Yoon et al., 2011; Pabayo et al., 2012; He, 2013; Hsu and Saphores, 2014). Socioeconomic status is reflected in various variables in these studies, such as income, parental education, or home ownership. There is no ultimate theoretical mechanism to explain this. Privileged households may be more protective (Yoon et al., 2011; Kamargianni et al., 2015), or they may live more distant from the school, e.g. because parents are more likely to choose the 'best' school for their children (rather than the nearest), if the school system allows this (e.g., Andersson et al., 2012, for Sweden). High-status households are also more likely to include two employed parents and have multiple cars, which facilitates dropping a child off at school on the commute, as long as the work schedule is flexible or fits school start time (and location) (Oxford and Pollock, 2015; Zhang et al., 2017). On the other hand, time constraints are more severe when both parents are in full-time employment. Parents being 'unavailable' early in the morning due to their own work schedules may motivate their child to walk alone (Mitra and Buliung, 2012). Mothers with longer working hours and/or longer commutes are less likely to escort their children, resulting in an increased probability of alternative options (He and Giuliano, 2017), while flexible work schedules may increase the propensity of escorting their child (Buliung et al., 2017; He and Giuliano, 2017). Carver et al. (2013) find that in Australia the likelihood for a child to be driven home from school increases when at least one parent is not employed full-time (and, hence, may have the option to pick up the child).

Household car ownership is a key resource for travel that may operate over and above its link to social status. It has consistently been found to increase the chance of being driven (van Goeverden and de Boer, 2013; Zhang et al., 2017) at the expense of active modes (Mitra and Faulkner, 2012, Guliani et al., 2015; Rothman et al., 2015; Waygood and Susilo, 2015; Mitra et al., 2016; Moran et al., 2016; Mehdizadeh et al., 2017; Stark et al., 2018).

Household composition may be important in various ways. Single parents may have less chance to escort their children due to time constraints (He and Giuliano, 2017). Pabayo et al. (2012) report that having an older sibling increases the likelihood of active travel, as joint travel with older siblings may reduce parental fear. On the other hand, having to drop off another child at the same or another school along the route may increase the chance that the sibling child is driven (Stone et al., 2014; Oxford and Pollock, 2015).

Parents' general travel behaviour also affects children's travel. Henne et al. (2014), Susilo and Liu (2016) and Jing et al. (2017) find a positive association between parents' and their children's use of active modes. This may contribute to longer-term mobility biographies.

2.4. Subjective concerns and attitudes

Safety and security concerns may lead to more parental escort (Alparone and Pacilli, 2012; Hsu and Saphores, 2014; Waygood and Susilo, 2015) and have been found to reduce cycling as well as walking among children (Guliani et al., 2015; Rothman et al., 2015; Kamargianni et al., 2015; Curtis et al., 2015; Moran et al., 2016). Parental or children's fears may refer to traffic safety or security from crime and harassment ('stranger danger'). Parental concerns, however, are themselves to some extent a function of the environment (Evers et al., 2014; Guliani et al., 2015). For instance, heavy traffic levels may encourage parents to protect their child, thus preventing the child from developing travel competence, which in turn may lead to a negative parental perception of the child's competence (Hüttenmoser, 1995). The interrelations between subjective perceptions and the actual environment may lead to unexpected results, which are not easy to interpret. For instance, Waygood and Susilo (2015) find that the parental perception that traffic is slow and safe has a negative effect on the probability that their child walks to school. They suggest that this perception 'may be associated with neighbourhoods that have low congestion, thus making it easier for the parent to drive their child' (Waygood and Susilo, 2015, 128).

Another dimension of parental attitudes is that driving is perceived to be convenient and fast (McDonald and Aalborg, 2009; Stone et al., 2014), and a welcome opportunity for parents to spend time with their child (Carver et al., 2013). Parental pressure based on their mode attitudes has been found to affect adolescents' willingness to cycle to school (Stone et al., 2014; Frater et al., 2017). What is more, parental mode habits have been found to exhibit a strong impact on child mode use in China (Jing et al., 2017).

2.5. The transport environment

High traffic density, high speed levels, wide streets, a lack of pavements, the need to cross (major) intersections and, more generally, stress resulting from motorised traffic on the trip to school may prevent parents from allowing their children to walk or cycle independently (Stone et al., 2014; Rothman et al., 2015; Ahern et al. 2016; Larsen et al., 2016; Zhang et al., 2017; see Ghekiere et al., 2018, for an experimental study of the traffic and infrastructure design factors that increase parents' willingness to let their children cycle). Conversely, factors such as the existence of pavements and/or bicycle paths, traffic calming measures, good road connectivity and the existence of shortcuts have been reported to positively affect walking and/or cycling (Noland et al., 2012; Stone et al., 2014, Guliani et al., 2015; Kamargianni et al., 2015; Clark et al., 2016). On the other hand, Helbich (2017) finds no significant associations between objective traffic safety and mode choice to school in the Netherlands, which may be due to the omnipresence of bike lanes and pavements.

It is often difficult to draw consistent conclusions from the multitude of attributes of the transport network and their possible effects. For instance, Guliani et al. (2015) find that the need to cross major roads increases the likelihood of walking. This sounds counterintuitive as the need to cross intersections should increase parental safety concerns (e.g., Stone et al., 2014). The authors suggest that the presence of major intersections may represent good connectivity in the road network which may in turn increase active and independent travel (similarly: Schlossberg et al., 2006).

2.6. The built environment

More general measures of urbanity, such as population density, land-use diversity, city population size and a generally urban (as opposed to suburban or rural) location encourage active and independent travel (van Goeverden and de Boer, 2013; Hsu and Saphores, 2014; Curtis et al., 2015; Waygood and Susilo, 2015; Mitra et al., 2016). On the other hand, urbanity is typically associated with parental traffic safety and security concerns (Lopes et al., 2014) and, hence, results on the role of the built environment are not fully consistent (see Kyttä et al. 2015, for discussion). Inconclusive results may also be due to simplified coding of modes (e.g. mashing up walking and cycling into active modes) and/or purposes. For instance, Moran et al. (2016) find that density encourages walking to school in Israel, but discourages cycling to neighbourhood destinations or for leisure purposes. Helbich (2017) supports the separate treatment of walking and cycling.

2.7. The social environment

Intra-neighbourhood social interaction may affect mode use, e.g. children are more likely to walk to school in neighbourhoods where other people walk. This may reflect a sense of pedestrian safety or a collectively shared walking culture. Neighbourhood social capital, social trust or a sense of community may also motivate parents to not drive their children on short trips (McDonald, 2007; Alparone and Pacilli, 2012; Carver et al., 2013; Lopes et al., 2014; Kyttä et al., 2015). Conversely, walking may increase the chance for a child to see friends or other known people on the trip and, thus, increase incidental community connections (Waygood and Friman, 2015). Social pressure by peers has been found to strongly affect adolescents' willingness to cycle to school (Frater et al., 2017).

Taken overall, a rich array of factors that contribute to understanding children's mode choice to school have been studied, though there is arguably no single study that integrates all the relevant factors in a comprehensive way. Additionally, there are inconsistencies between findings in various studies, and between findings and their interpretation. For Germany, this is the first study that simultaneously models associations between children's mode choice on the school trip and a large number of variables that reflect all the dimensions discussed above.

3. Data and method

3.1. Survey and study site

The data used for this paper were collected in January 2017 in a questionnaire survey. Parents of children in one of seven primary schools (forms 1–4, age 6–10, out of a total of 14 primary schools) in Lünen, North Rhine-Westphalia, were asked to complete a questionnaire that was distributed via teachers in the classrooms and collected a week later (with a second round of collection two weeks later to account for late responses). All children in the seven schools (n = 1763) received a questionnaire. Separated parents were informed that the questionnaire should be completed by the parent where the child spends most of his/her time on schooldays. A response rate of 60.3 percent resulted in n = 1064 completed questionnaires. This unusually large response rate testifies to the strong motivation of schools and parents to support studies of school trips (as can also be seen from parental comments written on the questionnaires).

Lünen is a medium-sized town located at the border between the metropolitan Ruhr area and the more rural Münsterland. It has a distinct suburban character, and it can be considered a somewhat typical representation of mid-to-late 20th century developments in low-to-middle-class regions.

The weather at the time of survey was cool but sunny and dry (no snow), with daytime temperatures slightly exceeding the freezing point. The following information was collected:

- the child's trip to and from school: usual mode in the week prior to the survey and in summertime, accompanying persons (separate for outward and return trip, respectively), reasons for accompaniment, distance to school
- child sociodemographics: age, gender, school form
- household sociodemographics: household type, age of other children in the household, household income, the respondent's and his/her partner's age, gender, nationality, education level (school and job training), employment situation
- travel behaviour of the responding parent and her/his partner: license possession, number of cars, mode choice to work (or education, if applicable),
- the responding parent's attitudes and concerns about safety, security, the social environment, and the transport environment on the trip to school. This included 20 items that captured the level of trust in other traffic participants, neighbourhood trust, trust into the capabilities of the child, fears related to the child when (s)he is outside, and seven items related to perceived transport infrastructure design and traffic dangers on the route to school
- the responding parent's attitudes about gender role worksharing in the household (four items)
- the household residential address.

Privacy concerns led to a questionnaire instruction explicitly stating that information on the home address and household income was not mandatory (though this is a matter of course). We received full information for regression modelling in 581 cases (morning trip) and 576 cases (afternoon trip), with 477 respondents omitting the income question, and 385 respondents omitting their address. The net sample of n = 576 still reflects a good response rate of 33 percent of the gross (n = 1763).

3.2. The transport and built environment

The survey data were matched with detailed information that was extracted from digital sources and collected on site in August 2017. Route information was collected for the shortest walking route including paths and tracks suitable only for non-motorised transport. These formal or informal shortcuts (see Clark et al., 2016) were detected manually on site.

The geodata used includes information on speed limits, the classification of roads, pavement designs, pedestrian crossing facilities, parking regulations, right-of-way regulations at intersections, land-use along the trip, and traffic safety. The survey of parking regulations was limited to intersections where it is most likely that parked vehicles restrict the view for crossing pedestrians. Information on traffic loads was not available, but it can be assumed that the classification of a road is strongly associated with traffic loads. Similarly, industry and trade areas taken from the detailed on-site survey are associated with heavy traffic loads. Various kinds of artifacts (plants, street furniture, vehicles etc.), some of them temporary, restrict the view at road crossings. An attempt to reduce bias was made by surveying only on weekdays during working hours. Still, the variables may include arbitrary information.

This vast amount of information was used in two different ways. Most research in the field relies heavily on 'variable approaches', i.e. the effects of a number of separate variables on child travel are estimated simultaneously. As many geographical variables correlate with each other, this procedure may mask interactions between the variables, i.e. it does not provide a holistic picture of a route. On the other hand, working with 'holistic' variables that capture the 'total' of a route does not allow a detailed examination of the effects of certain land-use or road attributes.

We therefore use ha combined approach. We assume that two issues are particularly relevant for parental concern: the need to cross roads and/or walk along insufficient pavements, and traffic safety. The latter is particularly true in small or medium-sized towns where people may recall severe accidents including the places where they occurred. Therefore, we work with original measures here, while we reduce other geographical variables in a principal component analysis to account for the general character of the route.

3.2.1. Traffic safety

We use accident data covering the period 2008–2016 that distinguish victims by age group, mode and injury severity. We tested several measures and found that accident hot spots contribute to explain mode choice better than the mere number of injuries along a route. This is especially true with respect to hot spots where pedestrian injuries (regardless of age) or child injuries (pedestrian or cyclist) have occurred. These two types of hot spots lead to very similar results, but are only moderately correlated. We merged both into one binary variable that captures whether or not the child needs to pass a site which can be defined as either of these two hot spot types. We define a 'hot spot' as a place where at least four pedestrians were injured or killed in the observation period, or at least three children were injured or killed as pedestrians or cyclists. These thresholds result in 16 and 15 hot spots, respectively, and 26 hot spots overall. All hot spots are intersections. The operational definition includs a radius of 30 m around the centre of the intersection.

3.2.2. Road crossings and pavement width

Data on road infrastructure along the route does not necessarily refer to the exact route a child actually takes. For instance, there may be a convenient pavement on one side of the road, but not on the other. However, the child may need to cross the road an extra time to use the convenient pavement.

We manually reconstructed the 'optimal' route based on local knowledge and plausibility considerations. We extracted width of pavement (none, < 1 m, 1–1.5 m, > 1.5 m) and number of road crossings required by type (light signal, zebra crossing, pedestrian refuge island, other pedestrian facility, no facility (which mainly refers to low-speed residential roads). Two variables exhibited significant effects in bivariate regression: the number of zebra crossings that need to be crossed, and length of road sections with narrow pavements (< 1 m). These two variables are used for analysis. Interestingly, the length of road sections with no pavement did not show any effect, probably because these mainly refer to tracks at a distance from roads.

3.2.3. Other built environment variables

A total of 31 variables (excluding traffic safety and the need to cross roads or use narrow pavements) were inspected with regard to bivariate correlations. Strong correlations led to the decision to reduce the variables using principal component analysis. Using Varimax rotation (Eigenvalue > 1) resulted in eight dimensions explaining 75.1 percent of the variance of the initial variables (Table 2). This procedure has been used before in related research (e.g., Broberg et al., 2013). A stepwise modelling process in which we exclude and re-include various factors resulted in four out of eight factors that exhibited significant effects on mode choice. These are included in the final model. The use of factors is in line with findings by Helbich (2017). He compares various measures of land-use in child mode choice models, and achieves the best explanation of variance with the use of principal components, as compared to individual variables or composite measures.

The first factor may require some explanation. The term 'general residential area' is a formal term taken from German land-use planning. It refers to a residential area with some limited non-residential use, such as retail, services and businesses, but not industrial use. These areas may be located either close to a city centre or – as in our case – in more remote, former villages that have become part of an urban area. Given their historical growth, they are often characterised by irregular parking and sub-standard pedestrian and cycling facilities that fail to meet today's planning standards.

Tables 4 and 5 give an overview of the variables finally used in the models.

3.3. Parental concerns, attitudes and perceptions

We also used principal component analysis with Varimax rotation (Eigenvalue > 1) to reduce the 20 items that captured the respondents' attitudes and concerns. This resulted in eight attitudinal dimensions explaining 61.5 percent of the variance of the initial variables (Table 3). This procedure has also been used before in related studies (Guliani et al., 2015). As there is complete attitudinal information in only 851 cases, we use the factors to group variables into mean value scales as indicated by the horizontal lines in Table 3 that show when at least two valid answers are available for any scale. Three items were excluded to achieve higher scale validity. Cronbach's alpha ranges between 0.60 and 0.86 for all scales but the last ('child is competent'), which has a Cronbach alpha value of only 0.31. After some discussion of this issue we decided to use the scale anyway for theoretical reasons, as it may be expected to exhibit an important effect on child travel (e.g., Villanueva et al., 2013).

Only three factors show significant effects and are thus retained in the model. This means that some concerns and attitudes are insignificant despite having been shown to be significant in previous research, including fear of nuisance, neighbourhood social capital, and a generally strong wish to protect one's child. This may be due to the geographical setting where the study was conducted, and where there may be little variation in these variables.

3.4. Sociodemographics

We tested a variety of sociodemographic variables. The following turned out insignificant in various modelling stages and were excluded from the final models: household type (traditional family, lone parent, other), parental education level (either separately or combined), household income and equivalent income, household car ownership. Mothers' and fathers' employment (full-time, part-time, none; either separate or combined) was only significant in the return trip model. Further, we use child age and gender, mother's age (that was consistently significant), presence of a sibling of primary-school age, and parental car use for the commute (that may to some extent capture employment effects).

3.5. Trip distance

Trip distance is known to be among the strongest determinants of mode use. However, it is likely that trip distance does not affect mode use in a linear fashion. For instance, the probability to cycle rather than walk may increase with distance, but decrease in higher distance ranges. Hence, we include trip distance as a quadratic function.

3.6. Travel modes

The mode normally used for three types of situations was recorded in the questionnaire: the outward trip and the return trip in the week prior to the survey (January), and the school trip in summertime. Respondents could state more than one mode for each of the trips. This would typically refer to short-term variations in mode use but may

Table 2
Built environment. Principal component analysis results.

	General residential area 1	Centre area 2	Industry and trade area 3	Major road with restrict-ed view 4	Woodland 5	Play street 6	Traffic calming 7	High speed road 8
Housing dominates (1, 3)	**0.88**	−0.02	0.07	0.05	−0.08	0.19	0.23	−0.07
Kerb-side parking (2)	**0.83**	0.29	0.01	0.15	0.04	0.15	0.21	−0.08
Speed limit 30 km/h (1)	**0.78**	−0.14	0.19	0.24	0.16	0.26	0.16	−0.12
Parking on pavement (2)	**0.76**	0.29	0.03	−0.11	0.04	−0.05	−0.11	0.04
Well-lit (1)	**0.71**	0.28	0.14	0.10	0.23	0.21	**0.45**	0.16
Cross parking (2)	**0.69**	−0.01	−0.02	0.10	0.08	−0.20	0.00	0.08
Right of way reg.: Yield sign (2)	**0.66**	**0.44**	0.15	−0.16	0.00	0.17	0.24	0.23
Shopping (minor) (1, 3)	**0.66**	0.14	**0.31**	−0.02	−0.14	−0.08	0.19	0.36
Parking on carriageway (2)	**0.65**	−0.05	0.11	**0.36**	0.02	0.17	−0.22	−0.01
Right of way reg.: Priority to the right (2)	**0.64**	−0.22	−0.05	**0.40**	0.12	0.11	**0.37**	−0.10
Pavement width < 1.5 m, side 1 (1)	**0.64**	−0.04	0.04	**0.34**	0.01	0.03	**−0.35**	−0.17
Shopping dominates (1, 3)	0.01	**0.86**	0.05	0.08	0.02	0.01	−0.01	0.04
Angle parking (2)	0.10	**0.80**	−0.09	**0.33**	−0.01	0.04	0.02	−0.11
Right of way reg.: Light signal (2)	0.26	**0.72**	0.05	0.05	0.16	−0.04	−0.10	**0.39**
Route crosses industrial area (1)	0.05	0.00	**0.80**	0.07	**0.31**	0.02	−0.06	−0.18
Route crosses trade/retail area (1)	0.08	−0.04	**0.71**	0.17	−0.07	0.02	−0.02	0.26
Trade and industry dominates (1, 3)	−0.01	0.11	**0.68**	−0.01	0.12	−0.06	0.13	**−0.31**
Trade and industry (minor) (1, 3)	**0.36**	0.00	**0.62**	0.01	0.05	0.15	0.11	0.24
Restricted view (number)	0.13	**0.31**	0.15	**0.86**	−0.07	0.19	0.01	0.06
Major road (1)	0.13	**0.31**	0.15	**0.86**	−0.07	0.19	0.01	0.06
Pavement width < 1,5m, side 2 (1)	**0.31**	−0.09	−0.02	**0.65**	0.27	**−0.30**	0.02	−0.07
Woodland dominates (1, 3)	0.00	0.10	0.00	−0.08	**0.84**	0.02	0.08	0.05
Track separate from road (1)	0.08	0.00	0.18	0.08	**0.72**	**0.45**	0.06	0.09
Route crosses woodland (1)	0.03	−0.03	**0.54**	0.09	**0.67**	0.08	−0.04	0.13
Green area dominates (1, 3)	0.18	0.09	0.19	0.06	**0.61**	**0.48**	0.28	0.28
No pavement, side 2 (1)	0.09	−0.12	−0.07	0.07	0.11	**0.82**	0.00	0.09
Speed limit 10 km/h (1)	0.06	0.17	0.05	0.05	0.14	**0.76**	−0.02	−0.06
No pavement, side 1 (1)	**0.35**	−0.10	0.28	0.15	**0.31**	**0.45**	**0.37**	0.10
No parking (2)	**0.32**	0.02	−0.07	−0.04	0.20	0.23	**0.81**	0.14
Right of way reg.: roundabout (2)	0.02	−0.05	0.10	0.02	0.00	−0.12	**0.77**	−0.13
Speed limit > 50 km/h (1)	−0.06	0.12	−0.01	0.02	0.25	0.07	−0.02	**0.79**
R^2	75.1							

(1) measured in meters along the route.
(2) number of intersections where this is the case.
(3) Land-use functions were manually surveyed in addition to using the local land-use plan, as a manual inspection provides more detail. A distinction was made between dominant and minor (additional) land uses in a road section linking two junctions. The dominant or minor character was rated by trained student staff and confirmed by a second person. Loadings exceeding |0.3| shown in bold.

involve intermodal trips. We separately model the morning and afternoon trip, as is frequently done in related studies (see discussion in Buliung et al., 2017). We omit mode choice in summertime. We consider this information less reliable, as the respondents refer to their child being either half a year younger or older than (s)he is at the time of survey, which can be quite a difference, given the young age.

The application of a choice model requires a full set of relevant alternatives. Distinguishing between walking, bicycle, scooter, school bus, other bus, and car passenger, plus combinations of any two would result in fifteen alternatives of any two, of which most are very rare. The use of three different modes is even rarer. A descriptive inspection suggests that only two combinations occur to some relevant extent: walking and another active mode, and walking and the car.

Many child mode choice studies merge walking and cycling into one category, but there is no reason to assume that the two are affected by the same variables. This was reflected in the considerable loss in explained variance, when we tentatively merged walking and cycling into one mode. Hence, we consider walking and other active modes to be different choices, but we merge cycling and the use of scooters into one mode. Both have similar speeds, and their use has similar age distributions. Hence, bicycles and scooters appear to fulfil similar functions. We consider multiple choices of the car and any active mode as a separate category, but make no distinction here between the type of active mode due to limited sample size.

Another decision had to be made in cases of walking plus cycling or use of a kick scooter. These cases were coded as ‘cycling/scooter’ as the child would obviously be permitted to cycle or use the scooter, which is more critical from a parental perspective than walking (as reflected in the higher ages of children cycling or using scooters). Hence, we finally consider five alternatives: walking, other active mode, car, public transport, car and active mode.

3.7. Analysis method

Various methods have been used to study children's mode use, including standard percentage and mean value comparisons, binary logistic regression (Henne et al., 2014; Stone et al., 2014; Waygood and Susilo, 2015; Larsen et al., 2016; Hatamzadeh et al., 2017; Mehdizadeh et al., 2017), multinomial logit regression (van Goeverden and de Boer, 2013; Helbich, 2017; Zhang et al., 2017, with decision trees beforehand, see He and Giuliano, 2017, for a joint mode and escort modelling), mixed logit regression that accounts for repeated choices (Noland et al., 2012), and structural equation modelling (Guliani et al., 2015; Susilo and Liu, 2016; Stark et al., 2018). The most common method is binary or multinomial logistic regression that accounts for the categorical nature of mode choice information.

This paper also uses multinomial logistic regression. Perceptions and attitudes towards the transport environment may be endogenous to sociodemographics and especially the objective environment itself. This may lead to biased coefficient estimations. Hence, we enter sociodemographics and built environment variables in a first model. In a second model we include attitudinal variables and check the

Table 3
Parental attitudes and concerns. Principal component analysis results.

	Trust in other road users 1	Neighbourhood social capital 2	Diffuse fear 3	Stranger danger 4	Pavements and lighting in good condition 5	Major roads and cars 6	Strong protective attitude 7	Child is competent 8
Other road users give priority to my child at a pedestrian crossing	**0.83**	0.02	−0.02	−0.07	0.08	0.00	0.04	0.09
Drivers are careful when they drive close to my child	**0.81**	0.07	−0.11	0.01	0.08	−0.10	0.04	−0.02
Cyclists watch out for my child	**0.80**	0.10	0.04	−0.08	0.08	0.00	0.05	0.03
I trust that drivers see my child	**0.73**	0.01	0.03	0.02	0.04	−0.04	−0.04	0.03
Most neighbours know me	0.06	**0.92**	0.00	0.01	0.03	−0.01	−0.02	0.05
I know most of my neighbours	0.09	**0.90**	0.00	0.01	0.03	−0.01	−0.02	0.11
In our neighbourhood we care for our neighbours' children	0.07	**0.79**	0.01	0.05	0.00	0.05	−0.09	0.03
I feel uncomfortable when my child walks along dark paths	−0.04	−0.03	**0.79**	0.18	0.01	0.10	−0.03	−0.08
My child should be accompanied by an adult in the dark	−0.03	0.04	**0.75**	0.09	0.00	0.09	0.14	−0.13
I feel safer when my child plays close to our residence when (s)he is outside	−0.03	0.03	**0.64**	0.12	−0.03	−0.03	0.24	−0.04
I feel uncomfortable when my child walks on narrow pavements	−0.04	−0.03	**0.54**	0.21	−0.14	0.06	**0.38**	0.02
My child is accompanied more often in winter than in summer	*0.12*	*−0.05*	***0.41***	*0.03*	*−0.16*	*−0.02*	*−0.03*	*0.34*
My child could be bullied by adolescents or other children	−0.03	0.01	0.18	**0.87**	−0.03	0.03	0.11	0.04
My child could be harassed or hurt by adolescents or other children	−0.02	0.03	0.06	**0.82**	−0.02	0.00	0.19	−0.03
My child could be harassed by adults	−0.06	0.01	0.28	**0.76**	0.03	0.05	0.02	−0.07
The street lighting on the route to school is sufficient	0.11	0.03	−0.06	−0.01	**0.83**	0.03	0.01	0.03
The pavements on the route to school are wide and in good condition	0.16	0.06	0.03	0.00	**0.80**	0.02	0.04	0.00
Walking and cycling paths on the route to school are dark and lonesome	*0.07*	*0.02*	*0.09*	*−0.02*	***−0.54***	*0.11*	***0.37***	*−0.03*
I consider the route to school safe	*0.28*	*0.01*	*−0.21*	*−0.09*	***0.49***	***−0.37***	*0.08*	*0.29*
There are roads with high traffic levels on the route to school	−0.14	0.06	0.05	0.01	−0.02	**0.79**	−0.01	−0.08
Roads with high traffic levels on the route to school have light signals	0.15	−0.11	0.07	−0.01	0.15	**0.69**	0.03	0.14
Cars on the route to school are parked in dense lines	−0.11	0.07	0.02	0.07	−0.20	**0.67**	0.07	0.07
I do not want my child to go anywhere without an adult	0.06	−0.06	0.32	0.08	0.03	0.05	**0.71**	−0.13
I want to know exactly what my child is doing at any time	0.02	−0.02	0.24	0.25	−0.02	0.02	**0.66**	0.22
My child is careless in road traffic*	0.03	−0.11	−0.07	0.09	−0.08	−0.01	**0.53**	**−0.46**
My child is used to getting around in an urban environment	0.12	0.00	−0.15	0.06	0.03	0.09	−0.07	**0.63**
My child knows how to behave with strangers	−0.07	**0.35**	−0.03	−0.13	0.12	0.01	0.11	**0.56**
R^2	61.5							

Loadings exceeding |0.3| shown in bold.
Items shown in italics were not used for scales.
* Used for 'child is competent' scale, inverted.

Table 4
Categorical variables used in regression: descriptive statistics.

		Morning trip (January)	Return trip (January)	Trip in summertime
Travel mode	On foot	38.0	38.7	37.9
	Bicycle, scooter	11.9	11.8	27.4
	Bus	10.0	8.0	9.1
	Car passenger	31.7	31.6	20.7
	Car and active	8.4	9.9	4.8
Child gender	Male		50.6%	
	Female		49.4%	
Primary-school-aged (6–10 years) sibling			28.4%	
Mother drives to work			63.5%	
Father drives to work			69.0%	
Accident hot spot on the route to school (pedestrian or non-adult non-motorised victim)			54.6%	
Mother: full-time employed			15.6%	
Mother: part-time, side job, training			61.6%	
Mother: not employed or no mother in household			22.7%	
Father: full-time employed			78.0%	
Father: not full-time employed or not in household			22.0%	

Including mode choice in summertime for information. All binary variables are coded as yes = 1, no = 0.

Table 5
Continuous variables used in regression: descriptive statistics.

	Min	Max	Mean	Std deviation
Distance (km)	0.01	11	1.7	1.4
Distance (km), squared	0.0001	121	4.8	10.6
Child's age	6	11	7.9	1.3
Mother's age	24	63	38.6	5.4
Built and transport environment				
Factor 1 – general residential area	−1.63	3.46	0.0	1.0
Factor 3 – industry and trade area	−1.53	3.69	0.0	0.6
Factor 4 – major road with restricted view	−2.62	5.31	0.0	1.0
Factor 7 – traffic calming	−2.06	5.78	0.0	1.0
Route to school along a road with narrow pavement (< 1 m) (km)	0	0.978	0.1	0.2
Zebra crossings that need to be crossed (number)	0	4	0.6	0.9
Concerns, attitudes, perceptions				
Factor 3 – diffuse fear	1	5	3.9	0.8
Factor 5 – pavements and lighting in good condition	1	5	3.2	1.0
Factor 8 – child is competent	1.67	5	3.8	0.7
n	581			

estimations for stability.

4. Findings

4.1. Descriptives

We begin with descriptive statistics to provide an overview of the data. Table 4 shows mode use for the morning and the afternoon trips. Mode use in summertime is also included for information.

About 38 percent of children walk to school, 32 percent are driven by car, just under 12 percent cycle or use a scooter, 10 percent take the bus (split evenly between school buses and public busses, not reported in the table), and 8 percent combine or alternate between the car and an active mode. Differences between the morning and afternoon trip are only minor, but in summertime there is considerably more cycling (27 percent), while fewer children are driven by car (21 percent). The combination of the car and an active mode is less frequent as well.

These figures differ somewhat from a trip-based analysis of trips to and from school made by children of the same age (6–9) based on nationwide data. Manz et al. (2015, 95) report a higher share of walking trips (44 percent) and trips made by public transport (20 percent), but less cycling (8 percent) and less car use (28 percent). As this study uses data collected in 2008, one may suspect that car use has increased in the meantime, but it appears more likely that the stronger car use and lower level of walking and public transport use in Lünen reflects the suburban character of the study area and increased car use in winter.

A comparison between the schools reveals striking differences, which are shown for the morning trip in Table 6.

The Kardinal-von-Galen school has the highest share of walking, while other modes are below average. This corresponds with short trips to school, i.e. a small catchment area, which may be because the school is positioned close to the town centre.

The Leo and Lüserbach schools show the highest shares of car use, while the Lüserbach school still has a strong share of walking children. Long mean distances travelled to both schools contribute to this finding, while the distance median travelled to the Lüserbach school is low. This implies that a strong share of students live in proximity to the school, while others travel long distances. The long distances travelled to the Leo school may have to do with the school's attractiveness for some German-born parents. The school has a strikingly low share of immigrant students. Only 2 percent of the students do not speak German at home, as compared to 15 percent for all schools taken together (values for 2016/17 provided by the City of Lünen, unpublished). What is more, the Leo school is located very close to an overly wide main road with a heavy traffic load, which is reflected in low subjective safety. The statement 'I consider the route to school safe' reaches a low 2.73 agreement on a scale ranging from one to five, as compared to 3.08 for all schools considered together (difference significant, $p < 0.001$).

The Elisabeth school has an almost zero share of the bus, while the share of cycling is above average. Students in this school also travel short distances on average. Virtually all students live in Brambauer, the

Table 6
Mode use for the morning trip by school.

	Gottfried school	Kardinal-von-Galen school	Leo school	Matthias-Claudius school	Heiken-berg school	Lüserbach school	Elisabeth school
Walking	26.7	55.4	28.7	28.6	36.1	40.4	36.5
Bicycle, scooter	17.1	9.8	12.4	8.9	13.1	5.9	17.4
Bus	18.5	3.1	7.9	31.3	13.9	4.3	0.9
Car passenger	33.6	23.3	41.0	27.7	31.1	40.4	35.7
Car + active	4.1	8.3	10.1	3.6	5.7	9.0	9.6
Trip distance (mean)	1.83	1.37	2.13	2.01	2.11	1.91	1.50
Distance (median)	1.5	1.1	2.0	1.8	1.5	1.0	1.2
n	146	193	178	112	122	188	115

Table 7
Multinomial regression analysis of mode use: morning trip.

	Bicycle, scooter			Bus			Car passenger			Car and active		
	B	OR	p	B	OR	p	B	OR	p	B	OR	p
Constant	−2.81			−2.04			−1.24			−2.79		
Child age	0.43	1.53	**	0.02	1.02		0.00	1.00		−0.02	0.98	
Child gender female	−0.79	0.45	**	−0.16	0.86		−0.16	0.85		−0.60	0.55	
Primary school age sibling	−0.09	0.91		0.33	1.39		−0.58	0.56		−0.28	0.76	
Mother's age	−0.09	0.91	**	−0.08	0.93	(*)	−0.06	0.94	*	−0.02	0.98	
Mother commutes by car	−0.11	0.89		0.61	1.83		1.61	5.01	**	0.72	2.06	(*)
Father commutes by car	−0.03	0.97		−0.32	0.72		0.26	1.30		0.48	1.62	
Attitudes, concerns												
Diffuse fear	−0.09	0.91		−0.34	0.71		0.47	1.61	*	0.12	1.13	
Pavements and lighting in good condition	−0.35	0.71	*	−0.15	0.86		−0.20	0.82		−0.08	0.93	
Child is competent	0.34	1.41		−0.51	0.60		−0.44	0.64	*	0.00	1.00	
Trip distance (km)	1.27	3.57	*	4.97	144.15	**	2.66	14.36	**	1.70	5.48	**
Trip distance, squared	−0.17	0.85		−0.55	0.58	**	−0.20	0.82	**	−0.13	0.88	*
Environment (factors)												
General residential area	0.36	1.44		0.69	1.98	**	0.41	1.51	*	0.25	1.28	
Industry and trade	−0.08	0.93		−1.00	0.37	**	−0.13	0.87		−0.25	0.77	
Main road with restricted view	0.24	1.27		0.11	1.12		0.31	1.37	(*)	0.05	1.05	
Traffic calming	0.62	1.87	*	1.10	3.01	**	0.23	1.26		−0.09	0.91	
Narrow pavement (< 1m, length)	2.93	18.73	**	1.80	6.03		2.35	10.47	*	0.91	2.48	
Zebra-crossings (number)	−0.29	0.75		−0.17	0.84		0.59	1.81	*	0.57	1.76	*
Accident hot spot (pedestrians or children)	−0.54	0.58		−1.44	0.24	**	−0.44	0.64		0.54	1.72	
Pseudo R^2 Cox & Snell	0.62											
Pseudo R^2 Nagelkerke	0.65											
Pseudo R^2 McFadden	0.34											
n	581											

All binary variables are coded as yes = 1, no = 0. Reference mode is walking. OR: odds ratio. Significance levels: ** $p < 0.01$; * $p < 0.05$, (*) just fails to reach significance (p = 0.05–0.07)

neighbourhood that hosts the school in its periphery. This location contributes both to not using the bus and to cycling.

The Gottfried school has high shares of cycling and bus use, while walking is below average. The Matthias-Claudius school has an extremely large share of bus use, while all other modes are below average. Two-thirds of the bus travellers use a school bus here. Both schools are located in the same place, a comparatively affluent residential area at the edge of town. Distances travelled are longer to the Matthias-Claudius school than to the Gottfried school, which explains the strong use of the bus, while the remote location also helps explain the high shares of cycling and bus use in the Gottfried school.

The Heikenberg comes closest to the average of all schools, although trip distances are somewhat higher than average. This is again due to the school being located at the edge of town.

4.2. Regression models

We start by presenting the morning trip model (Table 7) and add findings from the afternoon trip model (Table 8) where there are notable differences. It should be noted that in all cases where an effect is significant in one of the models, but insignificant in the other, the effect sign is in the same direction. Walking serves as a reference category. Both models show a good fit, with Pseudo R-square values ranging between 0.33/0.34 (McFadden) and 0.65 (Nagelkerke).

4.2.1. Sociodemographics

As expected, the odds of cycling as opposed to walking increase with child age. Children receive an informal cycling license in the fourth form after a test supervised by the police. Other modes are less distinctly different from walking, as regards age. Girls are less likely to cycle as opposed to walking (effect is insignificant in the afternoon trip model). Having a sibling of primary school age (who may possibly attend the same school, although we cannot conclusively determine this) reduces the odds of being driven home from school.

Interestingly, having an older mother reduces the odds of cycling or being taken to school by car, as opposed to walking (car use effect insignificant in the afternoon trip model). We have no clear interpretation for this finding, but we want to point out that the associations between maternal age and mode use turned out significant in all modelling stages. Older mothers (with children of a young age) tend to have fewer children, and we suspect that this may motivate them to walk their child to school more than other mothers do.

Parental employment status was excluded from the morning trip model due to a lack of significance. From the afternoon trip model it can be seen that mothers being unemployed is associated with lower odds of bus use and car use (the latter just fails to reach significance). Part-time employment among mothers does not show a significant effect that differs from full-time employment. Also, paternal employment does not have any effect on child mode use, no matter which categories are distinguished.

4.2.2. Commute mode

Mothers driving to work strongly increase the odds of their child being driven to school. The father's mode to work does not exhibit any significant effect.

4.2.3. Attitudes

Three dimensions of parental concerns show some significant effects. Firstly, a general diffuse feeling of fear increases the odds of being driven, rather than walking to school. In the afternoon model the same association is found for combined use of active modes and the car, but just fails to reach significance. Secondly, the more the parents judge pavements (sidewalks) and lighting on the school route to be in good condition, the more likely it is that their child may cycle to school, rather than walk. On the afternoon trip, this perception is also significantly associated with lower odds of car use. Thirdly, the more a

Table 8
Multinomial regression analysis of mode use: afternoon trip.

	Bicycle, Scooter			Bus			Car passenger			Car and active		
	B	e^B	p	B	e^B	p	B	e^B	p	B	e^B	p
Constant	−3.68			−7.69		*	−1.65			−4.11		
Child age	0.48	1.61	**	0.30	1.35		−0.17	0.84		0.05	1.05	
Child gender female	−0.37	0.69		−0.09	0.91		−0.05	0.95		−0.36	0.70	
Primary-school-age sibling	−0.29	0.75		0.83	2.30		−0.78	0.46	*	−0.53	0.59	
Mother's age	−0.07	0.93	*	−0.04	0.96		−0.01	0.99		0.01	1.01	
Employment (ref. full-time)												
Mother: part time/side job/training	−0.07	0.94		−1.15	0.32	(*)	−0.07	0.93		0.59	1.80	
Mother: not employed	−0.94	0.39		−1.76	0.17	*	−0.93	0.39	(*)	−0.72	0.49	
Father: not full-time	−0.34	0.71		−0.31	0.73		−0.10	0.91		−0.11	0.89	
Mother commutes by car	−0.26	0.77		0.22	1.25		1.36	3.88	**	0.58	1.79	
Father commutes by car	−0.32	0.73		−0.98	0.38		−0.24	0.79		0.54	1.71	
Attitudes, concerns												
Diffuse fear	−0.02	0.98		−0.32	0.73		0.52	1.68	**	0.43	1.54	(*)
Pavements and lighting in good condition	−0.44	0.65	*	0.12	1.13		−0.38	0.68	**	−0.07	0.93	
Child is competent	0.10	1.10		−0.87	0.42	*	−0.48	0.62	*	−0.40	0.67	
Trip distance (km)	1.09	2.99	(*)	5.39	218.92	**	2.33	10.28	**	1.45	4.25	**
Trip distance, squared	−0.14	0.87		−0.56	0.57	**	−0.17	0.84	**	−0.11	0.90	*
Environment (factors)												
General residential area	0.49	1.63	*	0.46	1.58		0.61	1.84	**	0.22	1.24	
Industry and trade	−0.09	0.92		−0.96	0.38	**	−0.13	0.88		−0.13	0.88	
Main road with restricted view	0.18	1.20		0.08	1.08		0.19	1.21		−0.09	0.92	
Traffic calming	0.59	1.81	*	1.42	4.14	**	0.49	1.63	*	0.38	1.47	
Narrow pavement (< 1m, length)	2.48	11.93	*	0.53	1.70		1.12	3.07		1.08	2.94	
Zebra-crossings (number)	−0.32	0.73		−0.95	0.39	**	0.25	1.28		0.14	1.15	
Accident hot spot (pedestrians oder children)	−0.23	0.80		−0.52	0.60		0.04	1.04		0.38	1.47	
Pseudo R^2 Cox & Snell	0.61											
Pseudo R^2 Nagelkerke	0.65											
Pseudo R^2 McFadden	0.33											
n	576											

All binary variables are coded as yes = 1, no = 0. Reference mode is walking.

parent considers the child competent, the less likely it is that the child is driven to school, rather than being allowed to walk. On the afternoon trip, this attitude is also significantly associated with lower odds of bus use.

Attitudes and concerns may be endogeneous to sociodemographics and the built environment. Additional models were estimated excluding attitudes (available from the authors upon request). These largely confirm the results of the models presented here and, thus, there do not seem to be notable biases in estimations.

4.2.4. *Trip distance*

Trip distance has a non-linear relationship with mode use, as expressed in significant quadratic functions. The effects of distance and squared distance need to be considered in tandem. They suggest that the odds for any mode against walking increase with distance, but the slopes decrease. The maximum increase for car passenger and, even more so, for bus travel, is at a lower distance than for cycling. The bicycle reaches its maximum odds against walking at a distance of about four kilometres.

4.2.5. *Built environment*

Four general factors describing the built environment along the route affect child mode use. Firstly, routes along ‘general residential areas’ are associated with higher odds of bus and car use against walking. Bus use is insignificant in the afternoon model. On the other hand, the afternoon model suggests higher odds of cycling in general residential areas. These associations can be linked to the remote location of the residential areas that score high on this factor.

Secondly, routes in areas characterised by industrial land uses are associated with lower odds of bus use. This relates to an industrial area close to the Kardinal-von-Galen school (low level of bus use) on the one hand, and the Gottfried and Matthias-Claudius schools on the other hand. Both schools are located in a somewhat remote residential area (i.e. very low values of industrial land use), and characterised by high shares of bus use.

Thirdly, routes along main roads with a restricted view may be associated with higher odds of car use (but note that the effect just fails to reach significance, and is clearly insignificant in the afternoon model). Fourthly, areas with traffic calming are associated with higher odds of cycling, but also bus use and, in the afternoon, car use. Neighbourhoods with high values on this dimension are Nordlünen and Lünen-South. In Lünen-South children typically attend either the Leo or Lüserbach school, which may explain the positive effect on car use. The Lüserbach school is located somewhat remote in a low-density area, where driving is more common, while the Leo school – as pointed out above – has a large catchment area due to its attractiveness, which results in long distances travelled. In Nordlünen things are somewhat more mixed. Children mostly attend the Kardinal-von-Galen school or Gottfried school. The Gottfried school is located in a somewhat remote area, and it scores high on the traffic calming factor. It has the lowest share of walking in all schools, but high shares of cycling and bus use. The Matthias-Claudius school is located at the same site, and has the strongest bus use among all schools, which also contributes to the positive bus effect. The Kardinal-von-Galen school is centrally located and scores very low on traffic calming, while many children walk. All these local circumstances may contribute to the association between traffic calming and mode use.

Over and above these broad factors, three more specific variables exhibit significant effects. Firstly, route length along roads with narrow pavements is associated with higher odds of cycling and car use. The latter effect is insignificant in the afternoon model. While the effect on car use is in line with expectations, the cycling effect may again be due to local circumstances. Two residential neighbourhoods score low on the narrow pavements variable, and at the same time many children from these neighbourhoods attend the Lüserbach school where the share of cycling is low.

Secondly, the number of zebra crossings that need to be crossed is positively associated with both regular car use and occasional car use (combined with an active mode). Both effects are insignificant in the afternoon model, while in this model the need to cross zebra crossings is associated with lower odds of bus use. Thirdly, accident hot spots along the route are negatively associated with bus use. Again, this effect is insignificant in the afternoon model. The Leo and Lüserbach schools (and, less so, the Kardinal-von-Galen school) stand out with above-average shares of students who need to pass an accident hot spot, and at the same time these schools are characterised by low bus use. Conversely, the Gottfried and Heikenberg schools have a low prevalence of accident hot spots, while bus use is strong.

5. Summary and conclusions for policy and research

This paper is one of the few studies of children's mode use for school trips in Germany. It is arguably the first one in Germany that simultaneously looks at the full range of dimensions that may help understandings of mode use: (1) trip characteristics, (2) child characteristics, (3) the household context, (4) subjective concerns, attitudes and perceptions, (5) the transport environment, (6) the built environment and (7) the social environment. In constrast to the majority of studies in the field, an attempt was made to capture a holistic picture of the transport and land-use environment along the route, while at the same time some key attributes of the route were used as separate variables.

The results are largely in line with existing research in terms of distance effects, age and gender differences. It is also well-known that mothers' attributes affect child travel, but fathers' attributes less so (here in terms of car use, employment and age). The reason for the significant effects of mothers' age is not clear and warrants further consideration.

In contrast to much other research we found no direct effects of income or parental education, nor did we find evidence for effects of the social environment (as reflected in subjective judgements of parents). It has also been found before that the probability of walking and cycling increases with age while we found only a significant increase in the odds of cycling against walking. An important conclusion is thus that it may not be reasonable to merge cycling and walking into one mode category, as the two modes have distinctly different characteristics.

The impact of urban form and the transport system along the trip is of particular interest from the perspective of urban development and transport planning. A number of points may be highlighted.

One dimension of parental attitudes clearly refers to the transport environment. Parents who state that pavements and lighting are in a good condition seem to be more inclined to let their child cycle rather than walk, and they have lower odds of picking their child up by car after school. The link between pavements and cycling is not obvious, but note that primary-school children are allowed to cycle on pavements in Germany up to their 10th birthday (and are legally supposed to do so until their 8th birthday). This is clearly supported by reasonably wide paths to avoid conflicts between cycling children and pedestrians. This effect suggests that good infrastructure helps.

The other significant attitudes rather suggest broader concerns that may or may not refer to the local environment along the route. Parents who exhibit fears in a broad sense have stronger odds of driving their child to and from school. The opposite is the case for parents who consider their child competent. While the first of these effects seems to refer to a psychographic attribute of the responding parent, the second may well refer to inter-individual differences between children over and above 'naturally' increasing competence emerging with age. Both associations, however, do not necessarily preclude policy interventions, as the concerns expressed may well be addressed by interactive concepts.

The general attributes of the areas along the route differ between the morning and afternoon trip in terms of significance, but are consistent in terms of effect signs. Nonetheless, some of them are not easy to interpret. Routes along general residential areas seem to increase the odds of cycling, bus use and being driven as opposed to walking. One reason for this may be that these areas are often characterised by remote post-war developments with mixed land-use, but dominant housing, often with little dedication in terms of upgrading pedestrian networks.

Traffic calming is associated with higher odds of cycling, which is in line with expectations, and bus use or being driven (back home), which is less in line with expectations, but may be due to local circumstances. Having to walk along main roads with a restricted view may also increase the likelihood to be driven, but the effect is only moderate and just fails to reach significance.

The prevalence of narrow pavements along the route increases the odds of car use, but also cycling, against walking. This is again probably due to local circumstances in two residential neighbourhoods. The need to use zebra crossings shows increased odds of car use. This may well indicate parental concern about letting their child cross the road at a site where the child has the right of way but drivers may not always give it to them (which is different from a light signal). Objective traffic safety is found to affect mode use very moderately at best. The only significant effect is the reduced odds of using the bus for routes that cross accident hot spots. This may again be due to local situations.

Two more transport-related parameters deserve attention for policy, although they are not strictly related to the transport environment. Firstly, distance belongs to the most consistent variables that affect children's mode use. Reducing distances to schools (or at least maintaining the existing distances) by providing a decentralised network of schools thus contributes to stronger use of active modes. Secondly, any attempt to reduce parental car use may also reduce the likelihood that a child is driven to or from school.

Taken overall, the results provide a rich, but mixed picture. Some environment variables have notable significant effects that generally confirm other studies and/or are in line with reasonable expectations and may be generalised, while other significant effects are more likely due to specific local circumstances that make straightforward interpretation difficult in some cases.

For future research, this means that there still seems to be a lot to do even though the field has increased tremendeously in the past few years. We struggled with the strong correlations between various built environment and transport environment variables that preclude the identification of clear-cut isolated variables that help understand the effects of the environment. What is more, we suspect that there are very nuanced details of the environment that motivate parents to let their child walk or cycle, or not (as studied by Ghekiere et al., 2018, using an experimental approach). Such nuances may relate to the social environment (e.g., temporal meeting places of elder children along the route), to parental activity patterns (e.g. timing of work trips), and to interactions between parents and their children, e.g. when children pressurise parents to drive them.

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