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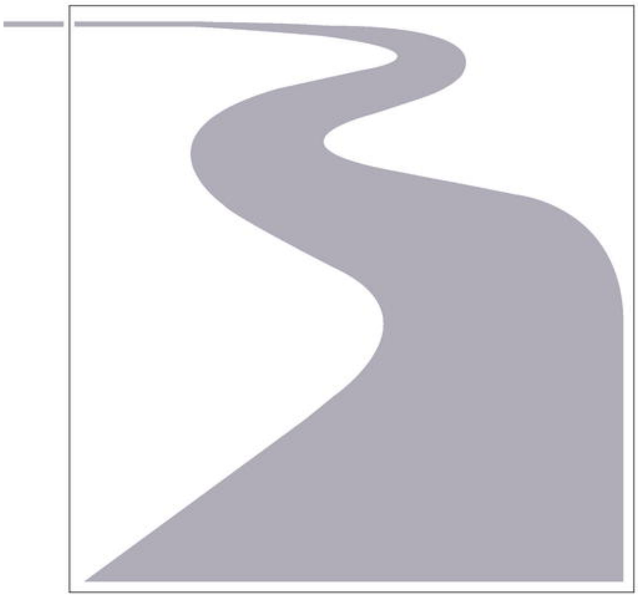

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How to obtain a healthy journey to school

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Abstract

Danish children walk and cycle a lot and at the same time have one of the best child road safety records in the western part of world. Based on several studies, the paper describes how Denmark has obtained a good child road safety and why Danish children choose to walk and cycle. Child road safety has predominantly been improved due to higher seat belt use and many implemented local safety measures such as campaigns and physical safe routes to school projects. It is mostly safe routes to school projects that include speed reducing measures and signalisation of junctions that are successful. The distance from home to school is an important factor in children's transport mode choice. Since about half of Danish children have less than 1.5 km to school the decentralised school structure with many fairly small schools is an important reason to the many walking and bicycle journeys. Road design and motorised traffic volumes do influence children's mode choice, but to a rather limited extent.

Keywords: Children; School; Road safety; Safe routes to school; Travel behaviour; Transport mode choice

1. Introduction

The paper focuses on road safety and travel among school children in Denmark. Being one of the richest countries of the world, one may think that Danish children seldom use non-motorised transportation. This is not true. About 60% of the journeys to school are done by foot and bicycle in Denmark (Jensen and Hummer, 2002).

Risk studies often conclude that walking and cycling is less safe than car and bus travel, so one may think that Danish children relatively often are killed in road traffic. This is neither true. Risk values from 2002 show that 1.3 per 100,000 children of 0–14 years of age are killed in Danish road traffic, which places Denmark as the fourth safest country for children among 28 OECD countries (OECD, 2005).

These facts raise several questions. What makes children choose to walk and cycle to school? How has Denmark attained such a high level of child road safety? The paper presents three different Danish studies (Andersson and Jensen, 2002; Jensen, 2005; Jensen and Hummer, 2002). The three studies answer to some

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degree the two questions raised above using different study objects and methodologies. The first study describes safety effects of more than 100 safe routes to school projects, see Section 2.3. The second study shows the detailed impacts of road and traffic characteristics and travel time on school children's choice of transport mode, see Section 3.2. The third study is described in the other sections and reveals national safety and travel trends and to some degree gives backgrounds to these trends in various ways.

It is important to view the studies in the context of which they exist. Denmark is rather special regarding structure of primary and lower secondary schools and governance of school children transport compared to many other developed countries. A typical Danish school has 300–500 pupils of which most are 6–16 years of age. This highly decentralised school structure means that about half of the school children have less than 1.5 km to school from their home (Jensen and Hummer, 2002).

The municipal reform in 1970 entailed that Danish municipalities became responsible for primary and lower secondary schools, bus transport of school children and the majority of roads, and that they should pay for these services through their tax revenue. Creation of safer routes to schools will benefit the municipality due to reduced costs to school buses and accident victims. Moreover the municipality has many options to improve children's road safety and change their travel behaviour, e.g., through physical measures on roads, campaigns, physical changes of schools and changes of school hours and management.

The Danish Road Traffic Act has since 1976 joined the police and road administrations to implement measures that protect children against moving vehicles on their journey to and from school. The law for primary and lower secondary schools was changed in 1977. Municipalities must provide free travel between school and home for pre-school to class 3 children who have school route journeys longer than 2.5 km. The distance is 6 km for children in class 4–9 and 7 km for children in class 10. Municipalities must also provide free travel for children who have shorter school journeys, if concerns related to child road safety make it particularly necessary. A circular from the Ministry of Justice in 1978 specified the concept of school route and when such a route should be classified as dangerous. In short, the legislation means that school children must be provided with relatively safe routes to school. If the municipality assesses a school route as dangerous, it must, if possible, make the route safer by implementing physical measures, or otherwise provide free travel. In practice, the municipality can choose the number of roads to be classified as dangerous. The legislation does not set a specific minimum level of safety.

Size and placement of schools, safer routes to schools and school transport services are therefore almost entirely a local policy issue in Denmark. School, road and social administrations are managed by the same municipal council.

2. Child road safety

It is widely assumed that child road accidents result from inadequate knowledge and skills. A review of studies of children and traffic shows that, overall, three factors are important to the accident rate (Jensen and Hummer, 2002):

- cognitive and meta-cognitive skills;
- the level of dependent and independent activity in traffic areas and
- motivational and personality factors, e.g., low adherence to responsible social values.

The number of minutes and km that children travel increases with age, e.g., a 10-year-old travel about 35 min and 20 km per day, whereas a 20-year-old travel about 55 min and 38 km per day (Jensen and Hummer, 2002). Danish travel surveys also show that children become less and less dependent on adults with age. Their independence is fully deployed when they reaches 10–12 years of age.

Children below 10 years of age do not have fully developed skills. This affects their safety as pedestrians. The actual risk per walking trip or walked km or hour is higher for young children compared to children aged 10–13 in Denmark (Jensen, 1998a; Jensen and Hummer, 2002). The risk for pedestrians increases again when children are 14 and older. Traffic activity change and become more frequent during nighttime. Fatigue, alcohol and drugs are part of the explanation for increased risk among teenagers on foot.

The risk for child cyclists increases with age and reaches a peak around the age of 20 (Jensen, 1998a; Jensen and Hummer, 2002). The prime reason for this is an increasing trip length with age caused by both longer journey times and higher travel speeds. A longer trip length results in riding along more trafficked roads, which also can be observed in Danish accident statistics. In short, the risk for child cyclists increases with age due to increasing exposure to motorised traffic. Cycling peaks at the age of 13 in Denmark.

Unlicensed moped riders have a higher risk than licensed riders. This is the dominating reason why children below 16 years of age have a higher risk on mopeds than older persons. Danish children can obtain a moped rider license at the age of 16.

The risk in cars also increases with age and reaches its peak at the age of 18, when Danes can obtain a driver license. Older children are more often passengers in cars driven by older siblings and friends who have only recently passed driving tests and have a much higher accident risk than the parents of the younger children. Till the age of 10, the driver is most often the child's parent, which can be deduced because the average driver age increases one year when the age of the killed or injured child increases one year. Somebody other than the parents start to take over at the age of 10, but it is when the age of the driver really starts to drop at the age of 13–14 that the risk starts to increase. Young children use safety belts more often than the older children do. Older children are more often intoxicated than young children.

The risk for children in buses is at the same low level at all ages, but because the older children travel more with bus they experience more accidents in buses. Fig. 1 shows the number of injuries by age and transport mode. Poor cognitive and meta-cognitive skills do not affect the number of injuries to any greater extent due to a low level of travel activity among young children and because skills only affect the pedestrian accident rate. The increasing travel activity, increasing differences in personality that occurs during puberty and youth, and the inexperience with riding and driving motorised vehicles leads to the teenager safety problem. That personality influences child safety is documented by, e.g., West et al. (1998).

2.1. National trends

The police recorded 1841 killed and injured children aged 6–16 in Danish road traffic in the year 1985. This figure dropped by 46% to 1002 in the year 2000. About one quarter of the reduction in injuries is due to a 10% drop in the number of 6–16-year-old children and that the average age in this age group fell from 11.2 years in 1985 to 10.7 in 2000. The health risk (killed and injured per capita) of other Danes dropped by 37% from 1985 to 2000, which is almost the same as for children.

The number of deaths, severe and slight injuries per child has fallen by 58%, 56% and 8%, respectively, during the period 1985–2000 among 6–16 year olds. Corresponding data for the rest of the population are 37%,

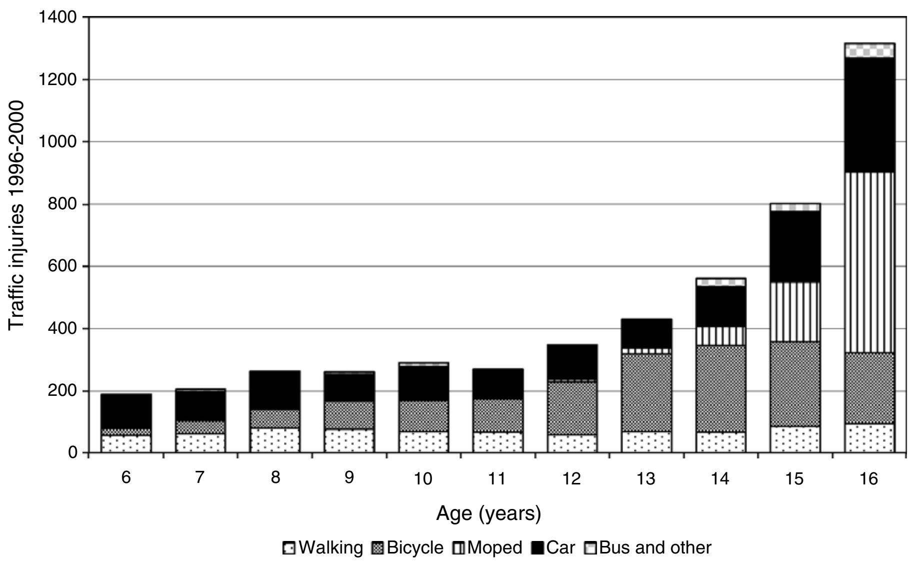

Fig. 1. Traffic injuries among 6–16-year-old children split by transport modes and age levels.

43% and 28%. The health risk has dropped by about 65% and 45% in the period 1985–2000 for, respectively, 6–7 and 8–11 year olds, while the risk has only fallen by about 30% for 12–16 year olds. The variations in accident severity and health risk developments can partly be explained by deviating trends in the use of safety belts and helmets. The share of killed and injured 6–16 year olds that used safety belts and helmets in accidents increased from 14% in 1985 to 30% in 2000. The corresponding figures for 6–7, 8–11 and 12–16 year olds are 3%, 2% and 21% in 1985 and 41%, 33% and 28% in 2000. The reason for the major increases in use of safety devices among young children is predominantly that safety belts on backseats of passenger cars became mandatory to use by 1st October, 1990 in Denmark. The increased use of safety devices can explain about one quarter to one third of the reduction in killed and injured children of 6–16 years of age. The differences in safety belt use trends between 8–11 and 12–16 year olds may fully explain the different health risk trends among these two age groups.

Section 3.1 shows trends in transport mode choice among Danish school children. The huge drop in walking among young children may be a reason to the significant higher drop in health risk among 6–7 year olds compared to 8–11 years olds. Taking into account the trends in demography, use of safety devices and transport mode choices about 40–45% of the drop in killed and injured children in the period 1985–2000 is still unexplained.

2.2. *Effects of local measures*

The Danish Transport Research Institute carried out an enquiry among all Danish municipalities in 2001 (Jensen and Hummer, 2002). Some 181 of the 275 municipalities answered the enquiry and described their efforts to improve child road safety and change their transport mode choice in the period 1995–2000. The answers did not enable the researchers to determine how many children and accidents the individual measures could affect. However, responses enabled identification of which municipalities had made school route studies and other special measures directed towards school children's transport above a certain minimum level. An assessment based on detailed information about several municipalities pinpointed that the responses to the enquiry did not reveal all of the special measures except school route studies.

Some 19% of the municipalities did not carry out measures besides, perhaps, campaigns at the start of the school year and adjustments of school bus routes and school districts. These municipalities were not above the minimum level of measures. Some municipalities in this group did not carry out any changes regarding school children's transport.

Of the municipalities, 41% made school route studies during the period 1995–2000. In school route studies, children and possibly parents answer questions about route choice, road safety, perceived risk and transport mode choice regarding the school journey. Some municipalities carry out questionnaire surveys on all schools and in every class, whereas others select, for examples classes 3, 6 and 9 in one or two schools. Afterwards, the municipality suggests several physical measures based on the answers and analyses of accident data. An action plan to improve the school routes is often set up by the municipal road administration after having consulted the schools and the police. Many school route studies are part of the development of local road safety plans. The overlap of high-risk locations and spots, where children feel unsafe, is significant (Magelund, 1992). School route studies are, therefore, very valuable in the development of local road safety plans, because the number of accidents is often so low that it is impossible to identify black spots from accident data alone. All municipalities that made school route studies also made other special measures.

Some 40% of the municipalities only made other special measures in the period 1995–2000. Several of these municipalities had made school route studies before 1995 or completed questionnaire surveys about perceived risk in traffic among all citizens. These municipalities often analysed accident data and a close co-operation between schools and road administrations took place before the implementation of measures. Other special measures predominantly consisted of

- physical measures to improve child road safety, management of car traffic at schools and an increased level of service for pedestrians and bicyclists;
- reduced school bus fares and
- road safety campaigns and schemes to discourage car travel of children to and from school.

Estimations based on a random test of 107 municipalities indicate that municipalities that made school route studies between 1995 and 2000 had an average road safety budget for the year 2001 of 75 DKK per inhabitant (Marfelt, 2001). The budget among municipalities doing only other special measures was just 25 DKK per inhabitant, but surprisingly 68 DKK per inhabitant in those municipalities that did not carry out measures besides school start campaigns and minor adjustments. These municipalities must have implemented a lot of local road safety measures without focusing on children. However, this random test focused on the year 2001, whereas the enquiry about school children's transport focuses on 1995–2000.

The road safety evaluation of school route studies and other special measures consisted of studies of child and others health risk and children's share of all injuries using time-series analyses and before-and-after meta-analyses. The evaluation used the population and road traffic injuries in the various municipalities as observations. Poisson distributed log-linear regression analyses were used for studies of health risk 1995–2000 and binomial linear logit regression analyses were used for studies of children's share of all injuries based on methodologies by McCullagh and Nelder (1989). Proc GENMOD from the SAS software was used in both cases. The methodology of meta-analysis, also called "logodds method of combining results", has been described by Elvik (2000).

The development in 6–16 year olds health risk was first tested for linearity in the three groups of municipalities; school route studies, other special measures, and below minimum level of measures. The groups of municipalities are assumed to be homogeneous. The test for linearity is accepted ($p = 0.177$, $\chi^2_{(12)} = 16.33$). Then it is tested whether the development is the same in the three groups. This test is also accepted ($p = 0.676$, $\chi^2_{(2)} = 0.78$), meaning that there is no statistical significant difference in the development of child health risk between the three groups. The model behind the tests shows that child health risk has fallen, respectively, 26%, 23% and 16% for the three groups of municipalities; school route studies, other special measures and below minimum level of measures.

The development in health risk among the entire population has been analysed using the same approach as for child health risk. The test for linearity is only just accepted ($p = 0.066$, $\chi^2_{(12)} = 20.05$). The test for uniform development is also just accepted ($p = 0.070$, $\chi^2_{(2)} = 5.31$), i.e., there is a statistical tendency to different developments in health risk. The model behind the tests shows that health risk has fallen, respectively, 13%, 8% and 15% for the three groups of municipalities; school route studies, other special measures and below minimum level of measures. It is not surprising that the group "other special measures" has a poorer development in health risk compared to the two other groups that in 2001 had a much higher budget for road safety measures per capita.

The development in 6–16-year-old children's share of all traffic injuries was also analysed using the approach as for child health risk. The test for linearity is rejected ($p = 0.027$, $\chi^2_{(12)} = 23.14$). No other developments than the linear were analysed due to relatively short time-series. The model behind the test shows that children's share of all traffic injuries has fallen by 10% in two groups of municipalities; school route studies and other special measures, but increased by 4% in the group of municipalities implementing measures below the minimum level. Taking into account the number of 6–16-year-old children and their average age and also the total population, the children's share of all traffic injuries has fallen, respectively, 2.0% and 2.4% per year for the two groups of municipalities; school route studies and other special measures. The corresponding figure for municipalities implementing measures below the minimum level is an increase of 0.7% per year.

The before-and-after meta-analyses are carried out using 1993–1994 as before period and 1999–2000 as after period. The effects of school route studies and other special measures are described using the group of municipalities implementing measures below the minimum level as control group. The meta-analysis includes a test of homogeneity. These tests show that the group of municipalities implementing measures below the minimum level is not homogeneous when the child health risk and health risk for the entire population is analysed, i.e., changes in health risk deviates more between municipalities in this group than random variation can explain. The variation in road safety budgets in this group is also much larger than in the other two groups. However, all groups are homogeneous when analysing children's share of all traffic injuries. The best estimate is that the group of municipalities carrying out school route studies has statistically significant reduced the children's share of all traffic injuries by 18% compared to the group of municipalities implementing measures below the minimum level. The corresponding figure for the group of municipalities carrying out other special measures is an 11% reduction, which is almost statistically significant on a 95% significance level.

2.3. Safe routes to school projects in Odense

Odense is Denmark's third largest city. The Municipality of Odense has 186,000 inhabitants. The study includes 104 safe routes to school projects carried out 1986–1999 in this municipality (Andersson and Jensen, 2002). All projects represent a physical change of roads.

The safety evaluation of the safe routes to school projects is based on a before-and-after accident study with a control group to adjust for the general accident development. The control group consists of accidents occurring in municipalities comparable to the Municipality of Odense when in comes to population density and developments in demography. Six municipalities with a total of 723,000 inhabitants constitute the control group. The yearly number of police recorded accidents and injuries in the control group were, respectively, 2089–3119 and 1229–1935 in the period 1985–2000. It was tested whether the accident developments in the control group was different from the accident developments in Odense. This was done by using accident data from all other roads in the Municipality of Odense than those, which was changed due to the safe routes to school projects. The tests used poisson distributed log-linear regression analysis and showed that the accident and injury developments in the control group was not statistically significant different from the development on all other roads in the Municipality of Odense. The developments were actually very similar, but the number of accidents and injuries on other roads in the Municipality of Odense were considered to be too few in order to be a control group.

For each safe routes to school project is used evenly long before and after periods of 1–3 years. The average length of both before and after periods was 2.9 years. The locations of the 104 safe routes to school projects were entirely made on basis of school children pinpointing spots where they felt unsafe, i.e., accident studies were not used to locate the projects. Therefore an eventual "regression-to-the-mean" effect that typically exists in accident studies of black-spot treatments was not considered in this safety evaluation. There were no accidents recorded in both the before and after periods for 25 of the 104 projects.

A relatively simple method was used to test the homogeneity of safety effects between the safe routes to school projects and to test the safety effects (Jørgensen, 1981). The expected number of accidents for the after period for each safe route to school project is the number of accidents in the before period in the project area multiplied by the change in the control group from before to after. The results in Table 1 make use of the following vocabulary for the test of the safety effect:

- *Significant:* The difference between the observed and the expected number of accidents is statistically significant on the 95% significance level.
- *Tendency:* The difference between the observed and the expected number of accidents is statistically significant on the 90–95% significance level.
- *No change proven:* The difference between the observed and the expected number of accidents is statistically significant below a 90% significance level.

The test of homogeneity was accepted regarding all results shown in Table 1, i.e., the safe routes to school projects may be viewed as one overall project. However, Table 1 shows there are major differences between the safety effects of the various types of safety measures that have been used in the projects.

The number of accidents is significantly reduced by 18% due to the safe routes to school projects. The reduction is almost the same for the various severities of accidents and injuries and also for the two age groups, see Table 1. The safe routes to school projects in Odense do actually not reduce children's share of all traffic injuries due to two things. The safety effects in percent are nearly the same for children and adults. Children's share of injuries are both about 13% on 'safe routes to school'-roads and other roads.

The safety effects are better for pedestrians and motorists compared to bicyclists and moped riders. The reason behind this may be that a major part of the safety effect is due to speed reducing measures, see Table 1. It is well documented in several European studies that speed reductions are less beneficial to bicyclist safety compared to both pedestrian and motorist safety (Jensen, 1998b). Table 1 shows that the overall safety effect

Table 1
Safety effects of safe routes to school projects in the Municipality of Odense

Type of accident, injury and specific safety measure	Observed before	Expected after	Observed after	Statistical test	Change in %
All accidents	335	288.5	237	Significant	−18
Injury accidents	125	108.8	94	No change proven	−14
PDO accidents	210	179.1	143	Significant	−20
Injuries	144	127.4	102	Tendency	−20
Slightly injured	69	65.4	59	No change proven	−10
Killed and severely injured	75	61.4	43	Tendency	−30
Injured pedestrians	23	19.2	8	Significant	−58
Injured cyclist/moped riders	76	66.7	68	No change proven	+2
Injured motorists	45	40.0	26	Tendency	−35
Injured 0–16 year olds	20	15.4	12	No change proven	−22
Injured 17+ year olds	124	112.5	90	Tendency	−20
Environmental road (45 km/h)	51	46.1	29	Significant	−37
Quite road (30 km/h)	12	10.6	7	No change proven	−34
Humps, raised junctions	8	7.3	2	Tendency	−73
Cycle track along road	68	58.6	57	No change proven	−3
Cycle track 'improvements'	13	11.4	11	No change proven	−4
Mid-block median islands	11	10.0	11	No change proven	+10
Signalisation of junction	21	18.0	9	Tendency	−50
Median islands at junctions	19	17.1	16	No change proven	−6

Note: PDO is property damage only, figures for specific safety measures are accidents.

especially stems from systematic applying speed reducing measures on environmental (45 km/h) and quite roads (30 km/h) and solitary humps and raised junctions, and also signalisation of junctions.

3. Children's travel

The dominant transport mode on school journeys in Denmark is the bicycle, see Fig. 2. In pre-school (5–6 year olds) and classes 1 and 2, there is almost an even split between walking, bicycle, car and public transport, whereas the bicycle accounts for around half of the school journeys in classes 5–10 (15–16 year olds). Walking and the use of public transport on school journeys is almost the same for all classes, whereas the use of car decreases and cycling increases until class 7 from where it stays roughly the same.

The car is used up to twice as much on journeys to school compared to journeys from school mainly because parents are unable to drive in the afternoon due to their work. Instead children walk and use public transport more often on journeys from school. Girls cycle a little less than boys especially in classes 8–10. Instead girls walk and use public transport a slightly more than boys, but use the car a lot more again especially in classes 8–10.

Family income and type of family (single or couple) do not affect children's transport mode choice to a significant extent when effects of car ownership are filtered out. An increasing car ownership means less walking and use of public transport in urban areas and less walking and cycling in rural areas in Denmark. Children's travel is particularly influenced by the distance between home and school, see Fig. 3. Use of cars and public transport increases significantly as the journeys to and from school becomes longer. Non-school journeys are influenced in the same manner by the distance between home and school up till this distance reaches 4 km.

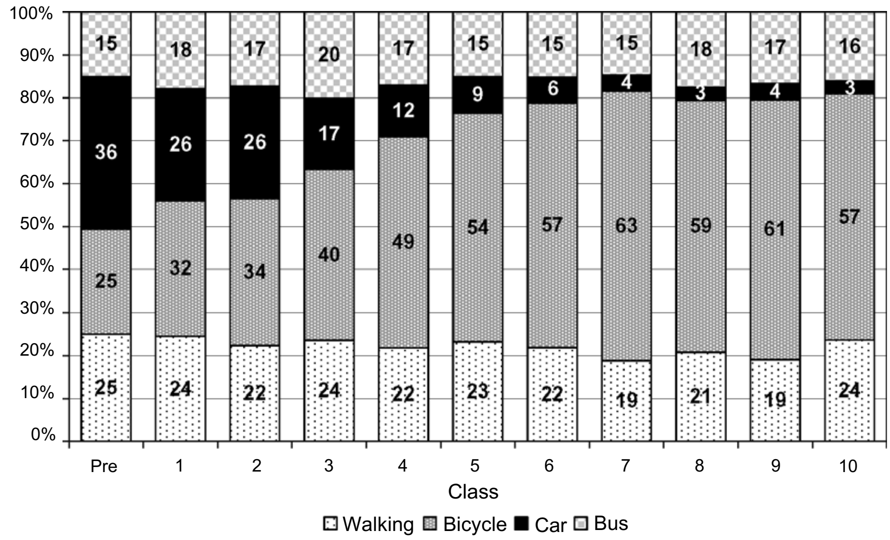

Fig. 2. Modal split on journeys to school for pre-school class to class 10 based on school route studies in 10 Danish municipalities.

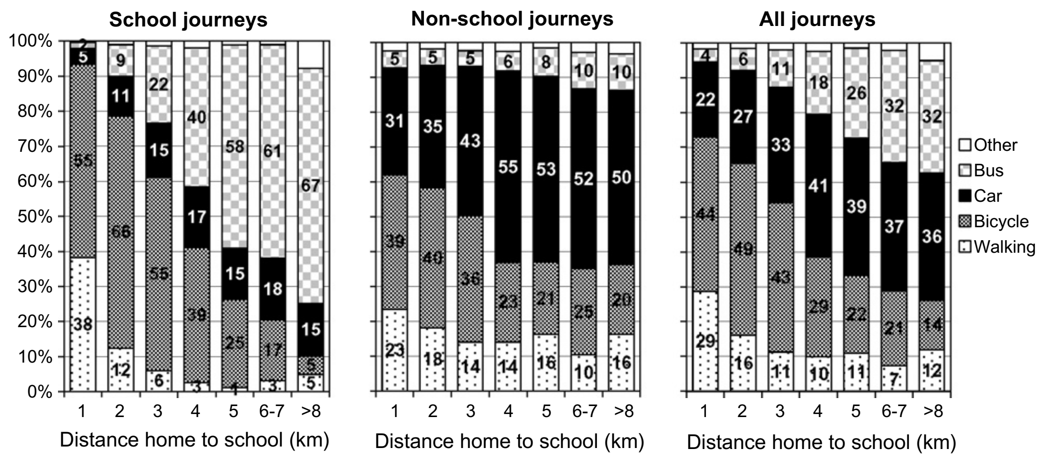

Fig. 3. Modal split on school journeys, non-school journeys and all Journeys among 10–15 year olds with different school journey distance based on telephone interviews 1998–2000.

Public transport is used more on school journeys due to lower ticket prices and higher frequencies of busses. About half of the Danish school children have less than 1.5 km between home and school.

3.1. National trends

Four travel surveys were compared in order to identify trends in children's travel. The methods to collect travel data in the surveys are very different and there must be reservations about the comparability of survey results. The survey from October 1978 was based on home interviews of 1217 representative Danish school children in pre-school class up to class 10. The survey from June and November 1993 was based on home interviews of 1003 children aged 6–15 years from all counties in Denmark. The telephone survey from 1998 to 2000 is representative for Denmark and all months of the year, but covers a much wider age range, 10–84 year olds. Lastly, the school route studies of 1998–2000 from 10 municipalities include trips to school among children in pre-school class up to class 10.

Table 2 shows children's mode choice on, respectively, school and all journeys based on the four travel surveys. The table shows that the levels of cycling are higher and the levels of car and public transport are lower in school route studies compared to telephone survey, both 1998–2000. Comparing the surveys indicate that

Table 2
Children's transport mode choice in Denmark based on four travel surveys

Journeys	Age group	Survey	Walking (%)	Bicycle and moped (%)	Car (%)	Public transport (%)
School	6–10 years	October 1978	39	33	10	18
		June and November 1993	24	42	21	12
		School route studies 1998–2000	23	36	23	17
	11–15 years	October 1978	24	52	3	21
		June and November 1993	15	68	6	12
		School route studies 1998–2000	21	58	5	16
		Telephone survey 1998–2000	22	49	9	20
All	6–10 years	October 1978	36	33	19	12
		June and November 1993	21	41	31	7
	11–15 years	October 1978	27	52	8	13
		June and November 1993	15	62	17	6
		Telephone survey 1998–2000	20	41	26	13

the share of children driven to school in cars has more than doubled possibly tripled between 1978 and 1998–2000. The proportion of younger children walking to school has fallen by approximately 40% since 1978, whereas the level of cycling and use of public transport for school journeys by both young and old children has only diminished slightly. The categories 'Bicycle and moped' and 'Public transport' in Table 2 could be renamed simply to bicycle and bus, because the use of mopeds and trains is very low among children.

The trends for all journeys among children are slightly different from those for school journeys. Both young and old children walk less in 1998–2000 and are driven in cars instead, see Table 2. The trends in 6–10 year olds' mode choice in leisure time resemble the trends of school journeys. The 11–15 year olds have tripled their car trips from 1978 to 1998–2000 and have also lowered their level of cycling by about 30% on journeys in their leisure time. The high level of cycling in 1993 compared to both 1978 and 1998–2000 has also been registered through traffic counts. A cohort effect has been detected in accident data, which indicate that 6 year olds started to shift away from cycling in 1988 onwards; 7 year olds in 1989; ... and 16 year olds from 1998. Cycling was an increasing mode choice five years prior to this. The cohort effect is probably mostly a result of shifting attitudes towards cycling, whereas long-term changes with shifts from walking and cycling to more use of cars probably are due to increasing car traffic and car ownership and also school closures.

3.2. Case study of Odense

The objective of the study was to describe the influence of five themes: travel time, junctions (number, type and motorised traffic), speed (posted and actual of motorised traffic), motorised traffic (total, average and maximum) and infrastructure (type of road and path, sidewalk and bicycle facility) on children's mode choice on the journey to school in the Municipality of Odense (Jensen, 2005). School route studies in classes 3, 6 and 9 provided information about children's sex, class, transport mode choice, accompany by adults on walking and cycling trips, use of cycle helmets, and home and school address. School route studies were made in 2003 and 4269 children were part of the study. Information about children, roads and traffic was analysed in a Geographic Information System in order to characterize the 'fastest' route that each child have respectively walking, cycling, driving in car or bus to school. Data about car ownership, family type, income, occupation, ethnicity and demography was only possible to obtain on a neighbourhood level. Data from 218 neighbourhoods in the municipality were used.

The data was segmented into the three classes 3, 6 and 9. Travel time was the theme of most relative importance to children's transport mode choice on school journeys. Travel time heavily depends on the distance between home and school. Travel time is about five times as important as the other themes junctions, speed, traffic and infrastructure, which were included in the study of relative importance using first principal components.

One nested logit model of hierarchical structure was created for each segment, i.e., classes 3, 6 and 9. The variables with most explanatory value from each theme were used in the models; travel time, junction density, average posted speed limit, average motorised traffic in morning rush hour and share of roads with bicycle path along the route. Accompanying adults were part of the model for class 3 as an endogen variable. Use of cycle helmets was not included, because this did not influence the children's transport mode choice. Sex was part of models in classes 6 and 9, but not in class 3 where the child's sex did not influence mode choice. Car ownership among families with children and share of population of ethnic origin other than Danish was also part of the models. Table 3 shows the nested logit estimates for the three models.

Table 4 shows marginal effects on children's transport mode choice in Odense by using 25% increases in travel time, junction density, posted speed limit, motorised traffic and share of roads with bicycle path. The table also shows effects of traffic calming where the speed limit is reduced by 25%, travel time is increased by, respectively, 10% and 5% for car and bus, and motorised traffic is reduced 5%.

The effects of increasing travel time, i.e., longer journeys to school, are mostly shifts from walking to use of cars. Increasing junction density and more bicycle facilities will not change children's mode choice in Odense significantly. Higher speed limit means more use of cars and public transport and less cycling among children. More car traffic on the roads means that more children uses cars and buses on their journey to school and that they walk and cycle less. Traffic calming reduces use of cars and public transport among children and increase cycling. The effects are different from school to school. On schools with a modest share of journeys in car and bus, the absolute number of children that shift transportation is relatively low, whereas if the share in car and bus is high then relatively many children shift transport mode.

Even major changes of road design, traffic or school structure do not change children's choice of transport mode very much in Odense though larger school districts may result in major increases in car journeys among children. Children's mode choice must therefore predominantly be dependent on culture, socio-economy and other things. The models show that people of other ethnic origin than Danish choose to walk and use the bus much more than Danes in Odense.

Table 3
Nested logit parameter estimates and *t*-values for transport mode choice of children in classes 3, 6 and 9 in the Municipality of Odense

Variable	Specific for	Class 3		Class 6		Class 9	
		Estimate	*t*-Value	Estimate	*t*-Value	Estimate	*t*-Value
Log(travel time)	Walking, bicycle	−7.13	−11.28	−8.94	−13.03	−5.61	−7.99
Log(travel time/distance)	Car, bus	−201.58	−5.09	−339.26	−5.20	−314.22	−2.98
Junction density	AC	2.35	4.55				
Junction density	Walking, bicycle			−0.465	−0.36		
Junction density	Car, bus					−0.0177	−2.02
Speed limit	No AC	−0.122	−6.33				
Speed limit	Walking, bicycle	−0.038	−1.94	−0.083	−2.49	−0.0044	−0.24
Motorised traffic	No AC	−0.00338	−4.80				
Motorised traffic	Walking, bicycle			0.0000216	0.80		
Motorised traffic	Car, bus						
Cycle paths along roads	No AC	−11.17	−3.19				
Cycle paths along roads	Walking, bicycle					−14.29	−3.32
Car ownership	Car	0.00101	3.81	0.00111	2.32	0.00083	1.56
Foreign ethnic	Bicycle	−0.0021	−9.51	−0.0024	−11.07	−0.0023	−8.67
Boys	Bicycle			0.394	2.66	0.340	1.95
Constant	AC walking	9.72	3.90				
Constant	No AC walking	24.83	8.92				
Constant	Walking			39.02	5.58		
Constant	AC bicycle	5.58	2.44				
Constant	No AC bicycle	21.47	8.86				
Constant	Bicycle			32.27	4.80	−4.24	−5.97
Constant	Car	−1.73	−4.97	−2.99	−5.52	−21.02	−6.76
Constant	Bus					−18.47	−6.23
Logsum		0.26	8.89	0.23	7.35	0.44	6.24
R^2 (McFadden's LRI)		0.19		0.47		0.47	

Note: AC is adult accompany.

Table 4
Modal split in current situation and after an increase of 25% of five variables and of traffic calming

	Walking (%)	Bicycle (%)	Car (%)	Bus (%)
Base, current situation	21.6	57.2	10.6	10.6
25% Increase in travel time	18.4	56.4	15.1	10.1
25% Increase in junction density	21.6	57.6	10.4	10.4
25% Increase in posted speed limit	21.8	55.4	11.6	11.2
25% Increase in motorised traffic	21.3	56.5	11.1	11.0
25% Increase in share of roads with cycle path	21.5	56.9	10.8	10.8
Traffic calming	21.4	59.9	9.4	9.3

Children's mode choice is 'reasonable'. The car is a shelter where parents protect their children from high traffic and speed levels. Parents accompany their children on foot and by bicycle especially along roads with much and speedy traffic. The bus is not used as a 'shelter' in Odense, but rather as a second choice on long journeys after the car, and children in class 3 seems to some degree not be allowed to use the bus.

4. Discussion

Developments in child road safety are influenced by both local road safety measures and more general trends like use of safety devices that may occur due to new legislation, police control, mass media campaigns, etc. Section 2.2 about effects of local measures shows how difficult it is to evaluate safety programmes targeted towards special groups of people. It is possible to state that local measures targeted towards school children have improved safety for children by 2–3% per year more than safety for other age groups. However, Section 2.3 shows that safe routes to school projects in Odense improved safety for both children and adults. The targeted safety programmes seem to have beneficial safety effects for other groups than the target group, and it is therefore not possible in this paper to precisely state the safety effect of the local measures targeted towards children. The level of local funds to safety measures seems to be important to the overall accident development.

Traffic calming with emphasis on speed reducing measures has a beneficial safety effect and does make children shift from car and bus on school journeys and instead use the bicycle. The reason for an almost unchanged long-term level of cycling on school journeys in Denmark may be that effects of traffic calming projects have offset effects of, e.g., more car traffic and higher car ownership. However, attitudes and culture seem to be important factors for transport mode choice among children.

The two questions in the introduction are difficult to answer. It seems that the high level of child road safety in Denmark to a great extent has been reached by many local efforts in the municipalities. The legislation forces the municipalities to work with child road safety and this may be an important reason for the many local efforts. The decentralised school structure can possibly explain the high level of walking and cycling among Danish school children, but the studies indicate that attitudes and culture also are important.

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