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ORIGINAL PAPER

Estimated societal costs of a hierarchical measures approach to enhanced school transportation safety at bus stops on roads with high speed limits

Torbjörn Falkmer · Linda Renner · Anna Anund

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Abstract
Purpose Most school bus related injury events in Sweden take place when the child is outside the bus. In order to enhance their safety, the societal costs of four different measures applied on "bus stops" on high speed roads were investigated.
Methods From a door-to-door perspective, a measure hierarchy, comprising the four existing measures, viz.: *Rerouting using the current operating vehicle, New construction, Rerouting using a different operating vehicle, Speed reduction in the vicinity of the "bus stop"* was applied.
Results By allocating 7.7 € per child per school day, almost nine out of ten children's transportation safety may substantially be enhanced, simply by rerouting the current operating vehicle or using alternative operating vehicles.
Conclusions In the investigated municipality it was feasible to enhance school transportation safety for children by implementing cheap and alternative measures.

Keywords Child safety · Cost-benefit analyses · Pilot study · Road safety · School bus

L. Renner · A. Anund
Swedish National Road and Transport Research Institute, VTI, SE-581 85, Linköping, Sweden

T. Falkmer
School of Occupational Therapy and Social Work, Curtin Health Innovation Research Institute, Curtin University of Technology, GPO Box U1987, Perth, WA 6845, Australia

T. Falkmer
Rehabilitation Medicine, IKE, Faculty of Health Sciences, Linköping University, Linköping, Sweden

T. Falkmer
School of Health Sciences, Jönköping University, Jönköping, Sweden

T. Falkmer
School of Occupational Therapy, La Trobe University, Melbourne, VIC, Australia

A. Anund (✉)
VTI,
Olaus Magnus väg 35,
581 95, Linköping, SE, Sweden
e-mail: anna.anund@vti.se

1 Introduction

Sweden, with approximately 9 million inhabitants, has a mixed school transportation system [1, 2]. Two thirds of the children that need transportation are transported by school buses that are provided as such, i.e. contracted school transportation. The remaining third of the children are transported by the regular public transport system [2].Both systems operate on rural and urban roads.

A Swedish contracted school bus is not in itself an icon with any particular exterior, but has a small icon (400× 400 mm) attached to it, with blinking/running lights, as shown in Fig. 1. The lights are manually activated by the bus driver 100 m before the stop and deactivated 100 m after. However, the icon itself does not make oncoming or same direction drivers slow down when they pass a contracted school bus at standstill [3].

Buses running in the public transport system do not have any such icons or lights. The only specific rule that applies to other road users concerning speed and passing these buses is to take precaution [4].

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Fig. 1 The designated school bus icon with black on yellow background with a red frame and blinking lights on top of it, triggered by the driver

Sweden has a school law [2] that states that the local authority has to provide free transportation for the student if:

a, the distance between the child's home and school is more than a specified distance; a typical distance being 2–4 km for primary school children

b, it is required due to the traffic conditions

c, a child's disability (if any), as well as other special circumstances require it.

As a tool for how to decide on whether or not a child has the right to achieve free school transportation, most local authorities have school transport regulations [5]. Local authorities can choose contractors and also prescribe how these services should be operated, e.g., where to pick up and let off a specific child, i.e., where the "bus stops" should be placed. These "bus stops" are sometimes simply being a predefined unmarked spot next to the road, as shown in Fig. 2.

Some children do, in fact, have their designated "bus stop" at roads with up to 110 km/h speed limit, predominantly in rural areas [6]. In the present study, high speed roads are defined as roads with a speed limit equal or above 90 km/h. From a survey of school bus related injury events in Sweden during 1994–2001, data from 361 injured or killed children in 256 school bus related events were analysed and the injury mechanisms identified [6]. In total, 74% of the injury events took place while the child was outside the bus. The predominant reason for being killed or injured when travelling with school transportation was running in front of the bus or behind the bus when crossing the street. Contrary to the general belief that children older than 12 years are competent and reliable road users, the results further revealed, that more than 50% of the fatal and severe injuries affected children aged 13–16. In a follow-up

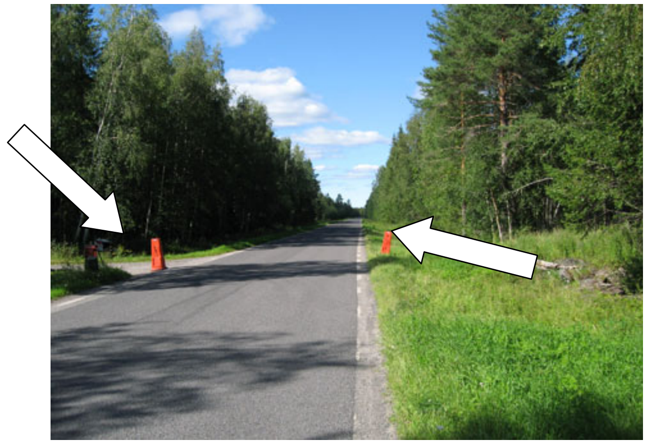

Fig. 2 Commonly used "bus stops" at a high speed road (n=43). The arrows are pointing at the cones representing children at the "bus stop", which in reality is just an unmarked spot next to a high speed road. The "bus stop" to the left has some waiting space for the children

study covering Swedish school transportation injuries from 2003–2006, the above results were confirmed [7]. Hence, the primary focus of safety measures for children of all ages in school transportation should be on road safety around the bus stop. Given these results, Anund et al. [1] made a cost benefit analysis, based on the value of a statistical life being 1.95 million € [8, 9] and a set relation between fatal (1.00), severe (.16) and slight (.01) injuries [9]. Given a financial break even from a societal perspective, they concluded that between 2.6 and 8.7 million € per annum, or 13,000–45,000 € per school day, i.e., 0.06–0.2 € per child per school day in Sweden, could be invested in order to prevent all these injuries.

Extensive monetary costs are, however, most often referred to by local authorities as the reason not to infer measures to enhance school children's safety. Still, both the effects and the "true" societal costs of such measures remain unknown. Based on these facts and in order to enhance road safety for children having their bus stops at high speed roads, the societal costs of relocating their bus stops by suggesting four different measures were investigated in the present study.

2 Materials and methods

A northern Swedish municipality (Luleå kommun) with vast rural areas was selected for the present study. The local authority recounted for a total of 58 children in various ages, 55% of them older than 12, entitled to school transportation from "bus stops" at high speed roads, both in the mornings and in the afternoons. School transportation by contracted operators, as well as public transport was covered.

From a door-to-door perspective [10] for each child, an at-site inventory of the school transportation bus stop location was performed. An existing inventory template used by the local authorities was utilised [11]. Possible measures were identified, discussed, prioritized and finally agreed upon among stakeholders and experts. This procedure took its starting point in each child's situation and individual needs. Secondly, the "bus stop" came in focus. Lastly, the bus traffic lines were considered. The individual relocation situation for each "bus stop" assigned to a child was then exclusively considered from a measure hierarchy, comprising four existing measures, viz.:

1. *Rerouting using the current operating vehicle*

This measure was assigned top priority, since it is cost-effective and relatively simple to carry out. Furthermore, it did not affect the current operating line structure. Since children constitute a large part of the public transport users in many northern Swedish communities, rerouting was considered possible even for public transport buses.

2. *New construction*

This measure was prioritized when su*ch* a large number of children were affected, i.e. >5, that it could be argued to be economically sound. Measure 2 implied that a new bus stop was built on a spot requiring no crossing of a nearby high speed road. In certain cases it could imply that new pedestrian trunk walks were needed. The cost of this measure was averaged over 9 years, i.e. the number of years a child attends compulsory school in Sweden.

3. *Rerouting using a different operating vehicle*

This measure was a much less cost effective, but far safer than the other measures, since the child was picked up at home by a small vehicle, e.g., a taxi. This measure was chosen if the situation only applied to one single or only a few children in locations where it was not possible to operate the bus line with a larger vehicle.

4. *Speed reduction in the vicinity of the "bus stop"*

This measure was considered to be of lowest in rank for two reasons. The first reason was that the traffic flow could actually be negatively affected by this measure. The second reason was that partially reduced speed limits are usually not followed to a large extent by the general public. For the latter reason, if measure 4 was implied, it required speed camera surveillance and a specially designed bus stop [12], which were costs added to the basic cost of changing the speed limit signs of that particular part of the road.

The arguments for the prioritization between different measures were based on the cost for the realization of them and how easy they were to implement for the municipality. Measure 2 (new construction) was only selected if more than five children benefitted from it. The prioritization between measure 2 and 3 was done based on the fact that measure 3 (rerouting using a different operating vehicle) was more expensive than rerouting with the current operating vehicle (measure 2). Measure 4 (reduced speed limit) was not considered as relevant from a municipality perspective, due to increased travel times, and also because of the risk that even with a speed limit reduction there was no guarantee that drivers actually reduce their speed.

The costs for the different measures were, for the utmost possible extent, based on available contracts and projected costs. The actual costs used are shown in Table 1.

For the measures chosen for the children, the net cost was calculated per day and per child per day. A Swedish child attends school 178 days per year, and the net cost calculations used that figure as denominator.

3 Results

As mentioned, 58 children in the municipality boarded and/or alighted buses at high speed roads, i.e. with a speed limit of 90 km/h or higher than; 45% of them were younger than 13 years old. The 58 children used 53 pre-defined "bus stops" at high speed roads for pick-up in the mornings and/or let-off in the afternoons, utilizing 13 different operating lines. In total, 52% of the children used public transport operating lines. Of the 58 children, 48 used the very same "bus stop" each morning and 44 used the same "bus stop" each afternoon. For seven of the children, it was unclear whether the same "bus stop" was used or not. The vast majority of these high speed road "bus stops" (96%) were actually situated on roads with 90 km/h speed limit. Half of them (48% in the mornings and 50% in the afternoons) were one-child "bus stops" and all except one were used by no more than three children.

Of the 53 "bus stops", only ten were bus stops in the traditional sense of the word, meaning that an approaching bus would deviate from the drive lane into a designated bay marked with a bus stop sign. The design of the remaining

Table 1 The relocation costs for the four different measures

	Measure			
	1[a]	2[b]	3	4
Fixed costs (€)	26.7 (–)	466,738	5.0	54,894
Flexible costs (€/km)	1.9 (6.4)	–	1.0	–

The fixed cost is related to each new tour

[a] Presented for contracted school transportation vehicles, public transport buses in brackets

[b] The total cost for the new construction

43 (81%) are illustrated in Fig. 2 by the arrows. The cones of the arrows are pointing towards were only placed there to represent a child/children on the photo. The right hand side arrow indicates a cone placed to mark a "bus stop" with no space for the child to stand and wait, while the left hand side arrow indicates a similar "bus stop" but with some waiting space area for the child. Mainly located on other roads, 31 (72%) of them had waiting space areas.

With no zebra crossings available, 96% of the children had to cross the high speed road either in the morning or in the afternoon to access their "bus stops", while 22% of them twice a day had to walk along it on the shoulder with no side walks available. On average, they walked 57 m on the road each time in the mornings. The corresponding figure was 43 m in the afternoon. The distances from home to the "bus stop" was on average 390 m in the morning and 380 m in the afternoon (range 30–2,100 m). Of the 58 children, 12 (21%) lived next to the high speed road.

In total, 60% of the roads were 6 m wide, but the road width ranged from 5.5 up to 8 m. The range of line sight distance with respect to the 53 "bus stops" is shown in Fig. 3. The median for the line of sight distances were 400 m both for oncoming and same direction traffic.

On six of these 90 km/h high speed roads, the average vehicle speeds were actually measured prior to the study, showing an average speed of 88–92 km/h. The annual average number of vehicles passing the 53 "bus stops" per day was substantial, i.e. 1,419 vehicles (median 560, SD=2.113, skewness 2.46).

The suggested measures are shown in Table 2, divided into: *"going to school"* in the mornings and *"coming home from school"* in the afternoons. They were based on the individual situation for each child and the hierarchy measure previously described.

Based on the suggested measures in Table 2, the net cost was calculated as average costs per day and per child per day:

- For *measure 1* the net cost per day was 173 € and 5.7 € per child per day
- For *measure 2* the net cost per day was 291 € and 36.4 € per child per day
- For *measure 3* the net cost per day was 211 € and 10.5 € per child per day
- If *measure 4* would be used, the net cost per day per "bus stop" would have been 308 €

The total net costs for implementation of the all measures was calculated to be 11.6 € per day per child, or 673 € per day for all 58 children, adding up to a grand total per year of about 119,758 €.

Excluding the costs for measure 2, *new construction*, the net cost for implementation of the other two measures for the remaining 50 children was 7.7 € per day per child, or 385 € per day for all 50 children, adding up to a grand total per year of about 68,530 €.

4 Discussion

With respect to societal costs, the present study suggests that it is feasible to enhance school transportation safety for children by implementing alternative measures for their morning pick-up and afternoon let-off procedures. The societal costs for these measures should, however, be set into context with the cost of a loss of a "statistical life" [8, 9, 13] due to a traffic related fatality.

The Swedish Road Administration (SRA) has adopted the Willingness To Pay (WTP) concept [8, 14] when estimating Society's marginal benefit for every casualty avoided. This valuation consists of several dimensions, material costs representing <0.5% of the total valuation of safety. Currently, the value of a statistical life is set by SRA to 1.95 million €, a value not significantly different than those set by the equivalents of SRA in the U.K. and in the U.S. [15]. Mirrored towards this figure, the investigated measures costing 119,758 € per school year suggests that if only one child's life is saved over a period of 16 years in the target community of the present study, it is, in fact, not only from a humanity aspect but also from a strict economical aspect, a sound implementation strategy. However, the WTP approach may be an oversimplification on a societal level, since the WTP methodology is based upon a theoretically accepted cost of death set by individual judgements. When it comes implementation of the proposed measures, the actual societal WTP remains to be investigated. Nevertheless, the WTP value offers a benchmark for stakeholders to set the costs of the suggested measures into a macro economical context.

One could argue that implementation of measure 2 could be viewed upon as a measure not only supporting school transportation, but also other road users. Hence, the school transportation system should share the costs for *new construction* with others. If excluding measure 2 related costs, the suggested measures required 68 530 € per school year for implementation, suggesting that if only one child's life is saved over a period of 28 years in that municipality, this is a sound implementation strategy.

Based on the Anund et al. [1] cost benefit analyses figure of 0.06–0.2 € per child per school day for a Societal break even, yet another line of reasoning is to say that it will take 58–193 extra days of additional costs of 11.2–11.5 €/school day per child to make the bus stops safe. However, this line of reasoning is based on the assumption that the described measures would prevent *all* school transportation related injuries, which is not the case, since the present study only covered children with "bus stops" at high speed roads.

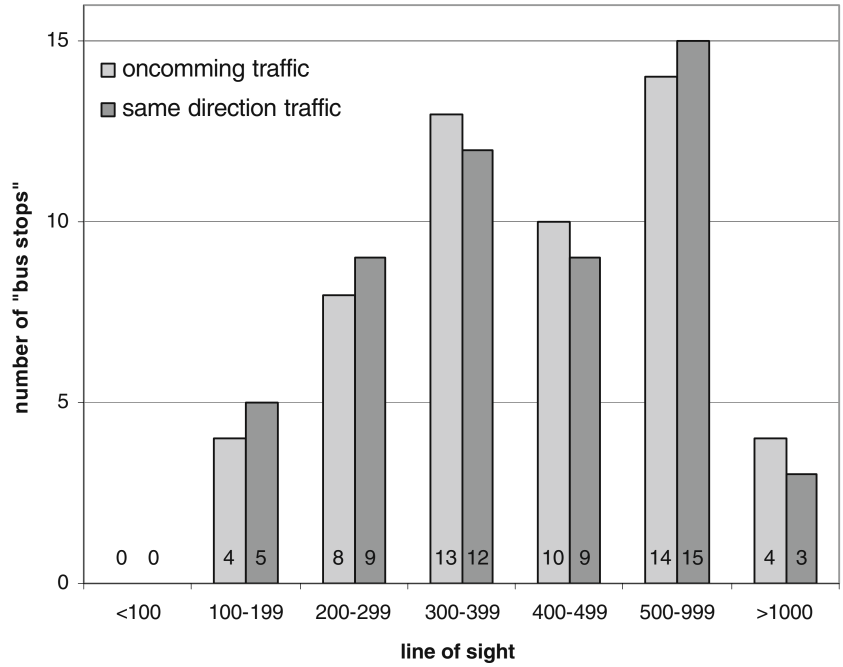

Fig. 3 Line of sight in metres at the 53 bus stops

Since these children use the same buses as children with "bus stops" at other roads within the municipality, it is not possible to use route optimizing to reroute the operating lines. If taking into account the total school transportation system within a municipality, route optimizing most likely would make it possible to relocate "bus stops" from high speed roads at even lower costs. The results related to the cost should thus be regarded as the maximum cost, since the current cost for the children's travel is not deducted from the cost for the proposed measures. Admittedly, this is a limitation of the present study.

Most of the suggested measures are relatively easy to implement, i.e. all but measure 2. The least expensive one, measure 1, is also the one most suitable for the majority of children. Together with measure 3, also being both simple to implement and fairly cheap, these two measures covered the need of 86% of the included children. The present study showed that by allocating a small sum per child per school day, almost nine out of ten children's transportation safety may substantially be enhanced. Relocation of these "bus stops" also opens up for the children to benefit from a future implementation of Swedish law of passing a bus at standstill in no higher speeds than 30 km/h [4, 16]. In fact, planning school transportation is not only an economical issue, but also a matter of creative thinking.

The present study highlights the dangers presented each day to the children within the school transport system. Almost all of the children needed to cross the high speed road at unmarked spots each day and one fifth of the children had to walk along on the shoulder with vehicles passing in speeds about 90 km/h. Equally alarming were the design and location of the "bus stops", shown in Fig. 2, and the fact that one third of them lacked waiting space areas.

This study covered all children at high speed roads known by the local authority in the targeted municipality.

Table 2 Suggested measures 1–4, for the 58 children. The cells contain the number of children recommended for this particular measure, with a total sum of that particular measure in brackets

Type of transportation	Measure			
	1	2	3	4
Going to school				
Contracted	7 (4)	8 (1)	11 (3)	–
Public transport	23 (12)	–	9 (2)	–
Coming home from school				
Contracted	9 (5)	8 (1)	11 (3)	–
Public transport	21 (11)	–	9 (3)	–
Total to/from school	30/30 (16/16)	8/8 (1/1)	20/20 (3/3)	0/0 (0/0)

Such an approach suggests that generalization of the results may be questioned, since we do not compare the results with a random sample of children in school transportation in Sweden. However, for such an investigation, it would be possible to use the same procedures as is used in the present study. The targeted northern municipality was chosen due to its rural nature, rendering a substantial number of children on high speed roads. Southern communities with more urban settings may have fewer "bus stops" on roads with 90 km/h. A shift in proposed measures is in that case also likely to be found. For example, it is highly unlikely that it is possible to suggest rerouting of public transport, due to a significant number of passengers being other types of passengers than the target group of the present study. Instead, measures 2, and 4, would rather be preferred.

The children included in this study is not a sample of children that use bus stops on roads with speed limits of 90 km/h in this area, rather the study includes all children in such an environment. However, a limitation is that it is still a small number of children and in relation to crash statistics it is not possible to evaluate the effects of proposed changes for the 58 children included. This area could be seen as representative for all areas in Sweden, but still such an assumption is risky, due to the limited number of children included and thus the restricted possibility to generalize the results. However, looking into national crash statistics [7] it is clearly shown that children are at highest risk along roads with high speed limits and therefore the results are still of interest, even if the area used and the number of children in this are few.

It is interesting to notice that, despite the fact that one of the reasons behind the child achieving free school transportation is if it is required due to the traffic conditions, children are urged to use this service on high speed roads that they most often also have to cross or walk along. One may argue that this situation hopefully applies to the older children rather than the younger. However, in the present study 45% of the children were younger than 13 years old, indicating that also the younger children are on high speed roads on an every day basis. Now, regardless of whether this holds true or not on a national level, the age of the child does not seem to be the crucial factor. As shown by Anund et al. [6], half of the injured children in school transportation were older than 12. As a matter of fact, the present study supports the idea that no child should be present as pedestrian on or in the vicinity of high speed roads, regardless of age.

The presents study applied a door-to-door "travel chain" perspective [10], meaning that the school transportation starts as the child departures home and ends when the child is inside school (and vice versa in the afternoon). This door-to-door approach includes all events in-between and, hence, "bus stops" and the way to access them becomes part of the school transportation. However, most statistics available do not apply this perspective, which makes comparisons of our results across borders in Europe and elsewhere impossible, unfortunately.

5 Conclusions

With respect to societal costs, it is feasible to enhance school transportation safety for children at high speed roads by implementing alternative measures for their morning pick-up and afternoon let-off procedures. By allocating 7.7 € per child per school day, almost nine out of ten children's transportation safety may substantially be enhanced, simply by rerouting using either the current operating vehicle or using alternative operating vehicles.

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References

1. Anund A, Renner L, Falkmer T, Wara N (2009) Smart Safe School Bus. VTI, Linkoping, Report No.: 649
2. Sörensen G, Anund A, Wretling P, Törnström E, Falkmer T, Matstoms Y (2002) Trafiksäkerhet vid skolskjutsning—Slutrapport. VTI, Linköping, Report No.: 480
3. Anund A, Kronqvist L, Falkmer T (2005) Är kraven på utmärkning av skolskjutsfordon utmärkta? VTI, Linköping, Report No.: 516
4. Kircher K, Thorslund B, Kircher A, Falkmer T, Anund A (2007) Passing a bus with 30 km/h. Assessment of safety effects of a speed limit of 30 km/h when passing a bus—a simulator study. VTI, Linköping, Report No.: 573
5. Wretling P, Sörensen G, Anund A, Yahya M-R, Törnström E (2001) Trafiksäkerhet vid skolskjutsning - enkät till Sveriges kommuner. VTI, Linköping, Report No.:480
6. Anund A, Larsson J, Falkmer T (2003) Skolskjutsbarns inblandning i olyckor 1994-2001. VTI, Linkoping, Notat. No.: 41-2003
7. Larsson J (2008) Skador i trafikolyckor med buss 2003–2006. Sarskilt barns skolresor. VTI rapport. VTI, Linkoping, Report No.: 624
8. Persson U (2004) Valuing reductions in the risk of traffic accidents based on empirical studies in Sweden [PhD Thesis]. Lund University, Lund
9. Persson U, Norinder A, Hjalte K, Gralén K (2001) The value of a statistical life in transport: findings from a new contingent valuation study in Sweden. J Risk Uncert 23(2):121–134
10. Carlsson G (2004) Travelling by urban public transport: exploration of usability problems in a travel chain perspective. Scand J Occup Therap 11(2):78–89
11. Renner L, Anund A (2008) En konsekvensbeskrivning av att inte tillåta på- och avstigning för skolskjutsbarn på 90/110-väg. Vägverket, Borlänge, Report No.: 2008:57

12. Anund A, Falkmer T, Hellsten H (2003) Skyltning av hållplats som används vid skolskjutsning. Pilotförsök. VTI, Linköping, Report No.: 494
13. Persson U, Ödegaard K (1995) External cost estimates of road traffic accidents. J Transp Econ Pol 24(3):291–304
14. Jones-Lee MW (1989) The economics of safety and physical risk. Basil Blackwell, Oxford
15. Bylund P-O, Wretstrand A, Falkmer T, Lövgren A, Petzäll J (2007) Injuries in special transportation services for elderly and disabled—a multi-methodology approach to estimate incidence and societal costs. Traf Inj Prev 8(2):180–188
16. Vägverket (2007) Utvärdering av 30 rekommendationen på Gotland—försök med rekommenderad 30 km/tim vid passage av stillastående skolskjutsskyltad buss. Vägverket, Borlänge