CRITERIA FOR THE EVALUATION OF CHILD DETECTION AIDS AT SCHOOL BUS STOPS

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Paper Number 98-S4-P-22

ABSTRACT

Transport Canada, in cooperation with the SAAQ (Quebec Automobile Insurance Corporation) and Transports Québec (MTQ), and with the support of Groupe Cartier and Les Consultants Génicom, has completed the first phase of a study whose final objective is to develop an evaluation grid for school bus safety aids. Phase I was specifically aimed at identifying and weighting criteria to be used to evaluate child detection aids. The aids considered improve a driver's chance of detecting school children while they are getting on and off the bus and thus increase the children's safety.

After identifying the school bus problem, reviewing the main technologies available, conducting a study of the driver's duties, and analysing the risks of school bus accidents, a number of criteria were selected to evaluate the aids under consideration.

Twenty-one main criteria in five major categories were identified. The categories are the reduction/elimination of the risks of an accident (safety criteria), the impact on the driver's duties and the interface with the children (ergonomic criteria), the cost of the aid and the school bus service (economic criteria), the noise and visual distractions (environmental criteria), and the aid's performance and technical reliability (technical criteria). These criteria have been incorporated into a preliminary evaluation grid. The grid will be validated in Phase II of the project.

INTRODUCTION

Background

In Quebec, approximately 700 000 children use school bus services daily and some 10 000 drivers travel almost 1 million kilometres each day. Considering the scale of this activity, school buses are by far the safest way to travel compared to other modes of transportation.

Nevertheless, each year several children are victims of school bus accidents. Between 1982 and 1991, there were 183 victims, all school-age children; 12 died and 35 were seriously injured. All of these accidents occurred while the children were getting on or off a bus or while the bus was pulling up or moving away from the bus stop.

In Canada, between 1986 and 1995, there were 33 deaths and 520 injuries resulting from children being struck by a school bus at a bus stop.

In light of these circumstances, a number of companies, inventors, and others concerned with school transportation have developed a large number of devices over the years to improve the safety of school children.

The aids considered improve a driver's chance of detecting school children in the driver's blind spots while the children are getting on and off the bus, and thus increase the children's safety.

School Bus Driver Visibility

In 1995, Transport Canada, in cooperation with MTQ, conducted an exhaustive study on drivers' field of view, both direct and reflected, for all bus designs and mirror configurations. The study succeeded in establishing a new requirement for school bus mirrors, and an updated Canada Motor Vehicle Safety Standard (CMVSS) no. 111 (Mirrors) took effect in November 1997 (1). All school buses manufactured in or imported into Canada after that date will have to be fitted with two external mirror systems. The B system (see Figure 1) consists of two cross-view convex mirrors that enable the driver to see a child in front of the vehicle or on the sides as far as a point rearward of the service door. The A system consists of a convex and flat mirror system installed on each side of the vehicle that provides a view rearward of each side of the vehicle extending to the horizon. The improved standard prescribes performance criteria requiring the installation of mirrors that provide the driver not only with a full field of view but also with a clear view of objects located in blind spots.

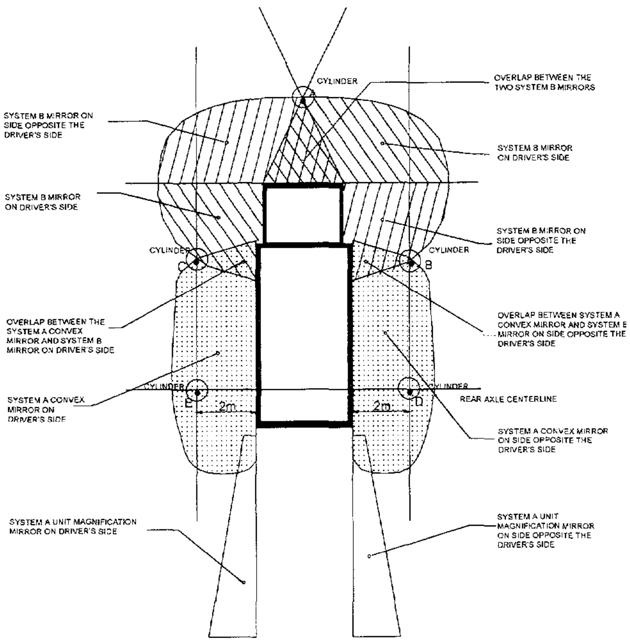

Figure 1. Field of view provided by the new school bus mirrors required by Transport Canada MVSS no. 111

The advent of new mirror systems will greatly improve drivers' visibility, but that alone will not eliminate the problem. Factors such as poor luminosity, poor contrast between the child and its surroundings, or a poor-quality reflective surface will diminish their effectiveness. In addition, drivers will not be able to detect the presence of a child unless they look in their mirrors and look for long enough to make out the image reflected in them. A minimum fixation time is required to make out an object appearing in a mirror. Is there any solution, then? Many advocate mandatory use of flat-nosed buses. Although such vehicles unquestionably offer better direct visibility, the blind-spot problem still remains. Should we, as an adjunct to the new mirror systems, require the addition of auxiliary safety devices, such as retractable barriers, infrared or microwave sensors, camera systems, and alarms? What is the effectiveness, performance, and reliability of these devices? What are their effects on the driver or on the child?

Study Objective

This study is the first phase of a project aimed at developing an evaluation grid for child detection devices (2).

The specific objective of this study was to define and weigh the criteria that are to become an integral part of the evaluation grid for child detection aids at school bus stops.

APPROACH

Conducting this study involved:

- identifying the overall problem of school bus safety in Quebec. Quebec was selected as the reference school transportation system for the study, because it was convenient and because it is representative of a Canadian system;
- reviewing the available devices and those under development that could be applied to improve child detection;
- conducting an investigation of a school bus driver's duties;
- analysing the risks involved when school children get on and off buses;
- determining, defining, and weighting criteria that should be included in the evaluation of safety devices, based on these investigations;
- proposing an approach to make the evaluation criteria operational and formulating recommendations for implementation of the project.

RESULTS

Review of Detection Aids

The purpose of external aids to protect children around school buses is to ensure their safety when the buses arrive at and depart from bus stops, as well as throughout embarkment and disembarkment. The aids include crossing control signal arms, rear-view mirrors, video cameras, external speakers, front and side aprons, and mechanical/ electronic detectors.

They can be classified as active, reactive, or passive. These categories can in turn be subdivided, according to whether the aids are preventive or corrective.

In 1996, in parallel to a major Quebec Coroner's inquest into school bus safety, MTQ mandated researchers at the Université du Québec at Trois-Rivières (UQTR) to evaluate the effectiveness of various safety devices in aiding the detection of children in the danger zones around a school bus (see Figure 2) (3).

This study concluded that a few devices had the potential of reducing the accident risk and recommended that these devices be improved and evaluated in-service for a limited period of time. One element of uncertainty that was not fully explored in the study was the device/driver interface. Our study aims at addressing this issue.

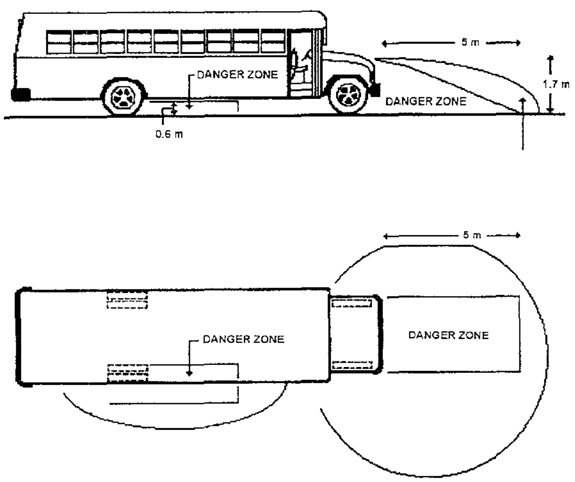

Figure 2. Danger zones around a school bus - UQTR study

Investigation of a Bus Driver's Duties

The main purpose of this investigation was to assess the demands on a driver when he or she approaches a stop, while the children are getting on and off the bus, and when the driver is pulling away, and to determine the variables that could affect these demands. The results are based on a literature review, observations of drivers, and issues raised during three focus group discussion sessions held with drivers and other school transportation stakeholders.

The data gathered showed that driving a school bus is highly demanding and that the number and type of variables involved differ according to the context in which the activity occurs (e.g., several children, high noise level, heavy traffic, etc.). A number of variables related to the school children, roads, type of bus, etc., were also shown to have an impact on the driver's activities. This information was useful in developing the fault tree derived from the risk analysis of school bus accidents.

Risk Analysis

The purpose of the accident risk analysis was to identify and rank in terms of probability the real and possible causes of a specific category of accidents - that is, when a bus hits a child.

The methodology used to gather information consisted of three components: an analysis of accident statistics and reports; driver monitoring and focus group discussions; and creation of incident scenarios via the development of a fault tree.

Analysis of Accident Statistics - The analysis of statistics and accident files provided data on the seriousness of the injuries, the victims' age and sex, the initial and main points of impact, and the causes and circumstances of accidents that occurred while the buses were stopped, loading/unloading, and when they were pulling away. The typical accident scenario is as follows: In late afternoon, a six-year-old girl crosses the street in front of the school bus on her way home; the bus starts up again, hits the girl with the front of the bus, and then crushes her under a back wheel.

The observations of the driver's duties carried out as part of the ergonomic study also helped to identify the risk factors involved in a bus hitting a child.

Development of a Fault Tree - The fault tree analysis showed the dynamics of a "bus hits child" accident in the form of a tree-like structure representing various combinations and sequences of undesirable events that could lead to an accident. From a tip of a branch, an accident scenario can be constructed. As an illustration, Figure 3 presents the final parts of a sequence of events and/or circumstances leading logically to an accident. In the study a total of 114 events/circumstances were inventoried.

Assigning Probability of Occurrence - Using the information from accident statistics combined with that obtained through consultations with bus drivers on their perceptions of the risks, it was possible to estimate the probability of events that could lead to a bus hitting a child (i.e., the top event of the fault tree).

As an illustration, Table 1 presents a partial list of events/circumstances (only those close to the top of the fault tree) with their relative probability of occurrence, based on the driver's perception of the risk, accident statistics, a synthesis of those two probabilities slightly adjusted by the analyst, and finally the calculated top event probability.

The probability of occurrence of the "bus hits child" being caused by event X is determined by the multiplication of the probability of all the events/circumstances between the event X and the top event in the branch. With this information, it was possible to determine the relative importance of various risk factors, to help determine and weight criteria for the evaluation of detection aids.

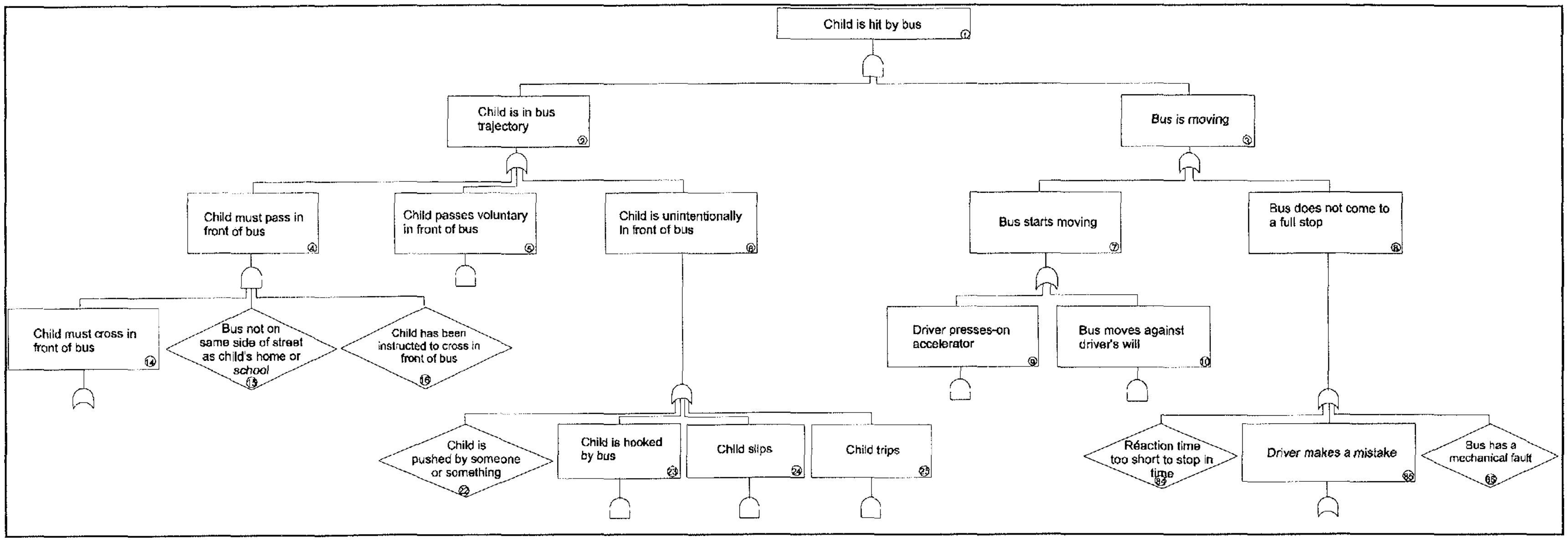

Figure 3. Partial presentation of the fault tree chart depicting the undesirable events/circumstances leading to an accident "bus hits child"

Table 1
Partial Table of Undesirable Events Probability

Event no. (*)	Previous Level Probability(%) Driver's Perception of Risk (std. dev.)	Accident Statistics	Synthesis	Top Event Probability
1	-	-	-	-
2			100	**100**
3			100	**100**
4	21(21.38)	54	50	**50**
5	54(25.15)	13	20	**20**
6	26(21.07)	33	30	**30**
7	51(25.95)	87	80	**80**
8	49(25.90)	13	20	**20**
9	81(24.33)	90	85	**68**
10	19(24.33)	10	15	**12**
14			100	**35**
15			100	**50**
16			100	**50**
22	31(17.81)	20	20	**6**
23	16(19.65)	20	15	**4.5**
24	29(16.39)	50	45	**13.5**
25	23(15.41)	10	20	**6**
84	50(16.23)		50	**10**
85	38(18.48)		40	**8**
86	20(29.31)		10	**2**
...	...	...	...	**...**

(*) Event no. presented in Figure 3

Device Evaluation Criteria

To identify the criteria pertinent to the evaluation of safety devices, the impact of implementing a device was analysed. The analysis identified various aspects where the impact was likely to be felt the most: the elimination of risk (safety), the driver's duties and the interface with the child (ergonomics), the cost of school transportation (economics), noise and visual distractions (environment), and the performance of the device itself (technical). Table 2 presents the main criteria in each of the categories, and their relative weight.

Each of these aspects constitutes a major category of criteria identified as being part of the evaluation of school bus safety devices.

Criteria in the "safety" category were identified and weighted by calculating the probability of undesirable events occurring on the fault tree developed during the risk analysis. This category of criteria evaluates how a device can decrease the risk of an accident occurring.

Table 2
Proposed Weighted Criteria for Evaluation of Detection Aid Safety Devices

CRITERIA CATEGORIES/ Criteria	Weighting
SAFETY	**50%**
Type of action (one of the following)	/100
. Preventing a child's presence	100
. Detecting a child's presence	95
. Helping a driver see the child	70
. Helping a driver see the signals	20
x Danger Zone Coverage	/100
. Location of regions covered	% (*)
. Proportion of regions covered	% (*)
. Time of action	% (*)
ERGONOMICS	**25%**
	/100
. Impact on the driver's duties	70
. Quality of the device/child interface	30
TECHNICAL	**15%**
	/100
. Compliance with standards and regulations	"Go/no go"
. Device performance	60
. Device reliability	30
. Device flexibility	10
ECONOMICS	**8%**
	/100
. Total cost of device	40
. Useful service life of device	40
. Stage of development	20
ENVIRONMENT	**2%**
	/100
. Noise produced	70
. Visual impact	30

(*) Individual weight not yet assigned

The ergonomic criteria were identified and weighted on the basis of information acquired during the ergonomic study and reflect the consultant's experience in this area. These criteria deal essentially with the relationships between the devices and the driver and between the devices and the children.

Technical and economic criteria were identified and weighted using similar studies previously carried out on either school bus safety devices or new technologies. Finally, environmental criteria were defined to ensure that the devices did not have a major impact in terms of visual distraction or noise.

Once the criteria are identified and weighted, it is relatively easy to organize them within an evaluation tool. An initial qualitative grid was thus developed, although it still must be validated.

Proposed Action Plan for Phase II of the Project

The process of validating the evaluation criteria and preliminary evaluation grid will consist of five main activities:

- training a validation committee made up of private and public stakeholders working in the school transportation field;
- holding facilitated sessions using the Delphi technique to get the stakeholders' opinions and agreement on the initial evaluation grid;
- reviewing the evaluation tool;
- using the evaluation grid, analysing the results obtained, and comparing them with those obtained from other evaluations/tests performed on safety devices;
- carrying out a final review of the grid according to the test results.

CONCLUSION

The study activities so far completed have led to the definition and relative weighting of 21 evaluation criteria grouped under five categories. These criteria have been grouped into a preliminary evaluation grid that must be validated in Phase II.

The study has also led to the following conclusions:

- a typical "bus hit child" accident occurs in late afternoon, involves a six-year-old girl crossing in front of a bus after leaving the bus to go home. She is hit by the front of the bus and run over by a back wheel;
- the most critical period is after school on the return trip, when several school children disembark at one stop and take several different directions, walking or running away from the bus;
- January, February, and March are the most accident prone months across Canada, except for Quebec.
- A detection aid device would be more effective if it acts on events/circumstances close to the top of the fault tree.

ACKNOWLEDGEMENTS

The authors would like to thank the members of the study steering committee - representatives from MTQ, SAAQ, the Transportation Coordinator Committee of the Quebec School Board Association, ASTE, ATEQ, APAC and Transport Canada - for their guidance and support. Contributions from the bus drivers and transportation safety officers who participated in the focus group discussions are also acknowledged.

The views expressed in this paper are those of the authors alone and should not be interpreted otherwise.

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