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Evaluation of Two School Bus Advance Signalling Devices: The Eight-Light System and Hazard Lights

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The opinions and views expressed in this report are those of the contractor and do not necessarily reflect those of the Transportation Development Centre.

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16. Abstract

This report analyses two advance signalling devices used on school buses: the eight-light system with alternately flashing amber lights and hazard warning lights. Advance signal lights were tested on the same routes, on rural or near-urban expressways. The data were gathered with two video cameras placed at the front and back of the bus. Illegal passing and changes in drivers' speeds were studied with a relative risk ratio and an efficiency index. The ratios were validated using expected frequencies. The use of advance signalling reduced the number of illegal passes by drivers coming from the opposite direction. Under these conditions, the eight-light system was more effective than hazard warning lights in reducing the speed of drivers and preventing stopping violations.

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16. Résumé

Ce rapport analyse deux dispositifs de pré-signalement d'arrêt utilisés dans le transport scolaire : le système à huit feux avec feux jaunes intermittents par alternance et les feux de détresse. Les pré-signaux sont testés sur les mêmes circuits, sur des voies rapides rurales ou périurbaines. Les données sont recueillies avec deux caméras vidéo placées à l'avant et à l'arrière de l'autobus. Les dépassements illégaux et les changements de vitesse des conducteurs sont étudiés avec un ratio de risque relatif et un indice d'efficacité. Les ratios sont validés à l'aide des fréquences estimées. L'utilisation d'un pré-signal réduit le nombre de dépassements illégaux chez les conducteurs arrivant à contresens de l'autobus. Dans cette condition, le système à huit feux est plus efficace que les feux de détresse à ralentir la vitesse des conducteurs, et à prévenir les infractions à l'arrêt.

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SUMMARY

Goals

The study had three objectives:

1. To assess the relevance of using advance signals on school buses;

2. To measure the effectiveness of two advance signalling devices in the field: the eight-light system and hazard lights;

3. To survey school bus drivers to ascertain their perceptions of the dynamics and effectiveness of these two advance signals.

Methodology

The eight-light system and hazard lights were tested on the same school bus routes, which included rural and near-urban highways. A total of 2,510 drivers were observed using video cameras placed on board the buses. An observer compiled information in the field and noted the drivers' movements. The time-distance-speed triangle was analysed using two indicators: the deceleration rate of motorists on observing the advance signals and the rate of stopping violations. The relative risk ratio evaluated the effectiveness of advance signals in preventing pass-bys when the buses were stopped and in slowing motorists down. The exposure denominator was the number of motorists in a position to pass the bus. The ratios were validated with the sampling deviation between observed and expected frequencies. Bus drivers were also asked to fill out a questionnaire to get their views on the effectiveness of advance signalling methods.

Results

The field observations confirmed that there were two aspects of the problem that had to be examined: oncoming vehicles and vehicles travelling in the same direction. The relative effectiveness of advance signals varied from one system to the other depending on these two situations.

In comparison with the hazard lights, the eight-light system generally made more motorists slow down and was associated with a decrease in stopping violations.

In the case of oncoming vehicles, the eight-light system slowed more motorists down than the hazard lights (60% vs. 27% on two-lane roads and 49% vs. 24% on multi-lane roads). With these data, the relative risk ratio of approximately 2:1 showed that the eight-light system was 54% more effective than hazard lights in getting oncoming motorists to slow down. There were more violations with hazard lights than with the amber lights (eight lights): 3% vs. 1% on two-lane roads and 8% vs. 4% on multi-lane roads. The relative ratio showed that the eight-light

system was 49% more effective than hazard lights in preventing stopping violations by oncoming vehicles.

Behavioural changes in motorists travelling in the same direction as the school bus were less pronounced. The risk of passing was lower, regardless of the advance signalling method used. However, the eight-light system was 22% more effective than the hazard lights in getting motorists from behind to slow down.

These observations were corroborated by school bus drivers' perceptions. The drivers questioned were convinced that flashing amber lights were safer than hazard lights.
A significant majority (73%) advocated standardization of the eight-light system, even those currently using hazard lights.

Conclusion

Practical and theoretical studies have led us to conclude that the use of advance signals is necessary to ensure safety. They significantly reduce the number of illegal pass-bys, particularly by oncoming motorists. The observation of school buses stopping without advance signals had to be discontinued because of the risks involved.

In near-urban areas and for oncoming motorists, the eight-light system was a better choice than the hazard lights. It reduced the number of illegal pass-bys by half and made twice as many motorists decelerate in the advance signalling stage. The impact of a rear advance signalling system could not be quantified.

Suggested Avenues of Research

Since the study looked at a subject that has yet to be extensively documented, a number of avenues of research remain unexplored. In other Canadian provinces, flashing red lights are used as an advance signal. It would be worthwhile to expand the study across the country, comparing this type of advance signal with the eight-light system and the hazard lights. In future research, when experimental conditions will allow vehicle speed to be measured, the added chronological markers could be used to develop a profile of motorists' changes in speed. The light intensity of advance signals is another factor to be considered. Amber lights, red lights and hazard lights probably have an impact on how motorists perceive their message. With regard to weather conditions, measuring the effectiveness of advance signals in winter and in the dark is a fundamental aspect of school bus transportation that has to be considered. According to the questionnaire, 57% of bus drivers felt that at least half of the stopping violations they observed were unintentional. Accordingly, there would be some merit in studying how motorists perceive advance signal lights and stop lights. Moreover, databases would benefit from the inclusion of additional codes to identify accidents involving vehicles passing illegally and school bus stop lights or advance signal lights.

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1 INTRODUCTION

1.1 Background

Advance signals are used on school buses to increase the safety of pupils getting on or off the bus who have to cross the road. In Quebec, school bus drivers use flashing amber lights[1] or hazard lights to alert drivers that a mandatory stop is coming up. As with all measures, advance signals have their advantages and disadvantages. The main shortcoming noted by school transportation stakeholders was the lack of uniformity in advance signalling equipment and techniques across the province. The presence of two different systems means that motorists necessarily receive a variety of messages. Furthermore, we have to recognize that each user interprets hazard lights differently. Another factor is the range of methods with which advance signals are applied by drivers. These discrepancies sometimes make it difficult for motorists to interpret the messages they receive. Given this heterogeneous situation, there is a need to assess and quantify the effectiveness of the two advance signalling methods currently used in Quebec.

1.2 Objectives

The study had three objectives:

1. To assess the relevance of using advance signals on school buses;

2. To conduct a field study to measure the effectiveness of two advance signalling devices: the eight-light system and hazard warning lights;

3. To survey school bus drivers to ascertain how they perceive the interaction and effectiveness of these two advance signals.

1.3 Scope

This analysis is part of the process undertaken by three agencies that are working together to improve school bus safety. The group consists of Transport Canada's Transportation Development Centre, the Quebec department of transport (ministère des Transports du Québec (MTQ)) and the Quebec motor vehicle bureau (Société de l'assurance automobile du Québec (SAAQ)). The safety of schoolchildren is an issue that has prompted much debate and raised a number of questions. Since this research was the first to assess the effects of advance signalling in the field, it was only a preliminary step. It was an exploratory stage with a specific mandate. Although field observations and the school bus drivers' experiences led us to believe that advance signals do significantly reduce the risk of illegal passing and improve safety, we were unable to gather enough observations to demonstrate this conclusion statistically. Most of

[1] Throughout the report, the terms "flashing amber lights," "amber lights" and "eight-light systems" all refer to eight-light alternately flashing amber light signalling systems.

the observations were made in rural and near-urban areas. As a result, our conclusions cannot be generalized and transposed to urban areas, where the problem remains unresolved.

One of the wishes expressed in the educational community was to give organizations concrete courses of action to guide the regulatory thought process. Since the main concern was to ensure pupils' safety, we attempted to determine which advance signalling system was the best or the most effective; cost effectiveness was not a consideration. The goal was to initiate the experimentation process and stimulate research in order to propose avenues for future study.

1.4 Report Organization

The report is divided into five parts: a theoretical and practical framework, a field study, the school bus drivers' questionnaire and, finally, a discussion and conclusion.

Chapter 2 outlines the scope of the problem and defines the school bus advance signalling systems studied. The kinds of advance signals and advance signalling techniques are described, as is the general regulatory context. This is followed by a survey of the literature, which summarizes previous studies. Chapter 3 explains the methodology and results of the field study aboard school buses. This section forms the core of the analysis, which compares the effectiveness of advance signalling methods and the risks involved with each. Chapter 4 contains the findings of a questionnaire distributed to school bus drivers working in the region where the field study was conducted. Chapter 5 reviews the topics discussed to establish associations between the practical (field) and theoretical (questionnaire) studies in relation to the problem. The conclusion summarizes the major findings and recommends some future avenues of research.

2 THEORETICAL AND PRACTICAL FRAMEWORK

2.1 Configuration of Advance Signals and Advance Signalling Methods

Advance signals are used to alert motorists that a school bus is about to stop and that traffic in both directions will have to stop as well. Their function is comparable to that of an amber traffic light, which indicates that a red light is imminent at controlled intersections. However, advance signals on buses present a more complex problem, which is threefold: the type of equipment, how the driver uses it and roadway characteristics.

2.1.1 Eight-Light System (Flashing Amber Lights)

All school buses are equipped with four red lights on the roofline against a black background (Figures 2 and 4). Some buses are equipped with an eight-light system, which includes four flashing amber lights mounted next to the red lights (Figures 1 and 3) at the front and rear of the bus. In this arrangement, the amber lights warn motorists of an upcoming stop while the red lights signal a mandatory stop. The amber and red lights are identical in size and flash in the same manner (i.e., alternating left and right). The amber lights are turned on by the driver when he or she chooses. Opening the door activates the stop arm and red lights and turns off the amber lights at the same time.

2.1.2 Hazard Lights

Drivers operating a vehicle equipped with a four-light system can use the hazard lights as an advance signal. With this method, the four signal (turning) lights flash simultaneously. The size of the hazard lights varies according to the model of the bus and its manufacturer. The configuration differs from the front to the rear of the bus (Figures 1 to 5). Normally, the rear lights indicate the turning direction with a luminous arrow about 20 cm long and are affixed to the body of the bus. The front signal lights on conventional long-nosed buses are small (5 to 10 cm) and square or rectangular in shape (Figure 5). In addition, they are often located on the sides of the nose of the bus rather than the actual front. They are placed in an empty spot on a small metal bracket attached to the outside of the body. On flat-nosed models, the front signal lights are large and attached right on the body (Figure 1).

2.1.3 Combined Use of Advance Signals

The eight-light system is standardized but hazard lights come in a number of forms. As a result, the driver's advance signalling technique is another part of the problem, in addition to the variety of devices used. Drivers sometimes develop their own advance signalling systems. Eight-light systems are occasionally used along with the hazard lights, in which case motorists receive three successive signals: hazard lights, amber lights and red lights. Those who use this technique sometimes combine flashing hazard lights with flashing amber or red lights.

Figure 1 Eight-light system, front view

Figure 2 Four-light system, front view

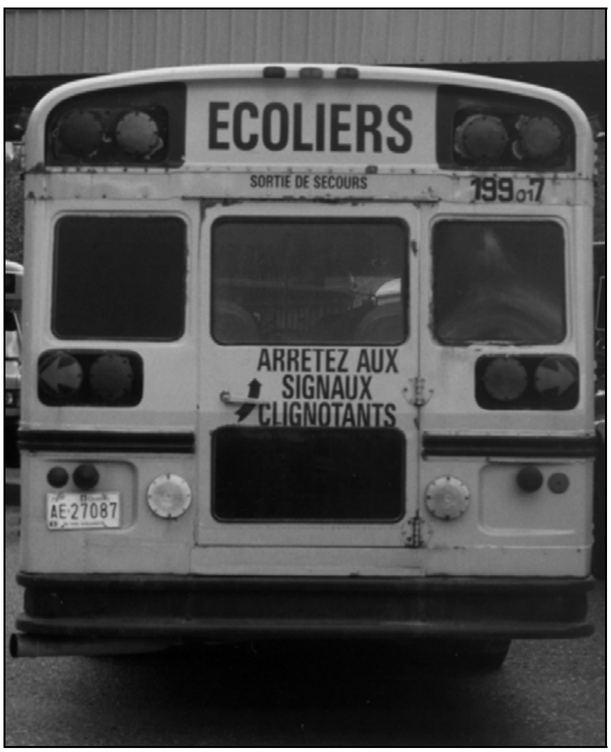

Figure 3 Eight-light system, rear view

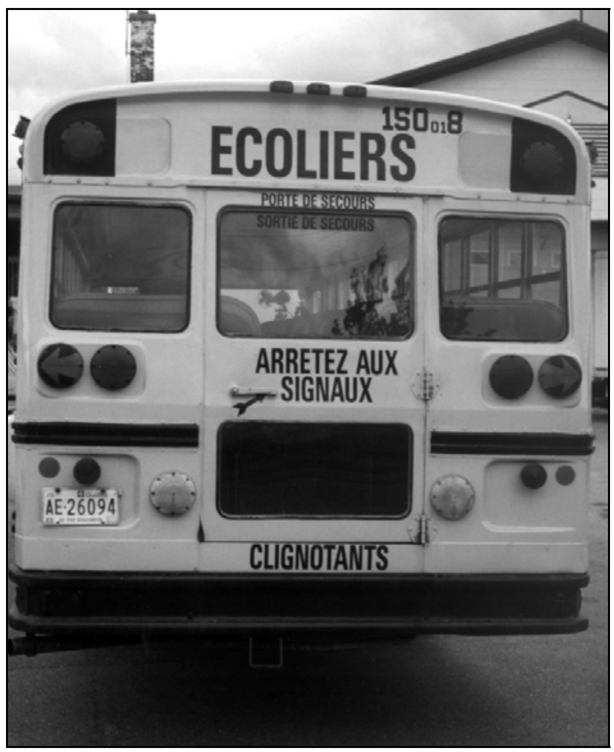

Figure 4 Four-light system, rear view

Figure 5 Long-nosed bus equipped with smaller sized hazard lights

2.1.4 Advance Signals with Red Lights

In some Canadian provinces, flashing red lights are used as an advance signal. Motorists can pass a bus when the red lights are flashing, provided that the bus is still moving. All motorists are required to stop once the bus has come to a stop and the stop signal arm is extended.

2.1.5 Absence of Advance Signalling

If no advance signals are given, two things can happen: the driver can signal his or her intention to stop by turning on the right signal light, or he or she can simply step on the brake without activating any signals. In this case, the rear brake light is the only visual warning that the bus is slowing down. Advance signals are not turned on only in very specific contexts: when there is no traffic, in open country or on a private road or driveway.

2.1.6 Variety and Confusion

Two kinds of advance signalling devices are used in Quebec but there is a wide range of advance messages, which have to be interpreted quickly by people using the road. Considering the disparities in operation and equipment, only vigilant motorists or those accustomed to advance signals can interpret a bus driver's intentions correctly. The best gauge of whether a system is understood is its consistency. Some people might interpret amber lights as the equivalent of red lights, which could provoke a sudden reaction. Hazard lights can also be misinterpreted because they are used by motorists to signal a potentially dangerous situation, a problem at the front of the vehicle that is activating them or a problem related to that vehicle, such as a truck climbing a steep hill. And what about the right signal light, which can indicate a right turn, a lane change or the intention to pull over onto the shoulder? The signs on the back of the bus ("stop at flashing lights" or "stop when signal lights flashing") can also be a source of confusion. A bus has several signals and three types of flashing lights. Which signal is one supposed to obey?

2.1.7 Drivers' Advance Signalling Habits

Another factor to bear in mind is bus drivers' driving habits. Their advance signalling techniques differ in both content and form. A driver activates an advance signal using his or her own frame of reference. He or she analyses the road context while at the same time determining when to begin the advance signal. The following parameters will vary from driver to driver, depending on the type of stop to be made:

- length of advance signal
- distance of advance signal (150 m in New Brunswick)
- bus speed at start of advance signal
- bus visibility at start of advance signal

2.1.8 Distance and Approach Speed

The effectiveness of an advance signal is measured by taking into account how far away vehicles are and their relative speed compared to that of the bus. The bus's speed gives motorists some indication of how close the next stop is. It seems normal that motorists near the bus would be indifferent to a signal if the bus is travelling quickly, but they would pay more attention to a slow-moving bus or one that has come to a full stop. A bus that has stopped or is about to do so is associated with loading or unloading. When a bus is moving, the advance signal produces different reactions, depending on how far away it is and how motorists evaluate the situation. Within a group of motorists who see an advance signal, some will choose to slow down as a preventive measure, a certain number will maintain the same speed while preparing to stop and others will speed up, deciding to take a risk.

2.1.9 Amount of Traffic and Imitation Behaviour

Traffic is another element that influences advance signalling. When vehicles are travelling one behind the other or side by side, we see an "imitation" phenomenon whereby one motorist copies the actions of another. For example, in a traffic jam, if one motorist cuts around traffic by driving on the shoulder, a number of others will follow, even if this action is prohibited. Similarly, a motorist travelling at the speed limit is more inclined to speed if passed by one or more faster-moving vehicles. To counter this group mentality, you need to get one of the motorists to break the imitation chain. In a situation relevant to this study, if no one slows down at the end of an advance signal and the bus driver is ready to stop, there is a problem. He or she has to wait for the best time to do so between two waves of traffic. If the driver extends the stop arm while vehicles are passing, a surprised motorist might brake suddenly. Conversely, if the driver is easygoing and lets everyone pass, the motorists behind the bus will get impatient and may consider passing. An effective advance signal successfully warns all users, not just the first motorist in a line of vehicles. If a motorist's view of an advance signal is blocked, he or she will not necessarily see the dangers that lie ahead. If the advance signal can be seen by everyone, the probability that someone will break the imitation chain is higher, thereby limiting the risk of a violation at the critical moment, that is, when the bus is stopped.

2.1.10 The Dynamics of Advance Signalling

Yet another aspect of the problem is the environment in which the advance signal is activated. Unlike traffic lights, which follow a predictable order at intersections, advance signals are activated in a dynamic context. They can be turned on at any point along a road, not just at intersections. In the front of and behind the bus, the time - distance - speed triangle and the notion of visibility do not have the same impact on a motorist's reaction time. A motorist approaching a bus has less time to react than someone following the bus. We know the distance required to come to a full stop in a static situation. Section D-10 of *La signalisation routière au Québec* specifies the requisite distance in the case of a warning stop signal used to indicate a conventional fixed stop sign (MTQ, 1990). There is another standard for the advance school bus stop sign (section D-260 in the "cahier des charges et devis généraux" in the above-mentioned publication, which specifies the location of a fixed sign near a school bus stop).

The Quebec department of transport (MTQ) has developed a preliminary table of distances required for various posted speeds (Thibault, 1998). For an advance signal along the roofline (amber lights), an advance signalling distance of 150 m for all numbered roads would successfully alert all vehicles travelling towards the bus. This calculation corresponds to the recommended distance in New Brunswick. For hazard lights, which are located at the bottom of the bus, the distance required has to be doubled, i.e. 300 m of advance signalling. Smaller distances are required behind the bus, but since only the largest distance (i.e., the distance in front) counts, the distance in the rear would be identical.

2.1.11 Advance Signals Across Canada

Stop signs and red lights are the only devices mandatory throughout the country. Three kinds of advance signals (amber, red and hazard lights) are permitted in some provinces and territories and prohibited in others. Their use also differs from one jurisdiction to another. An unofficial profile of the situation in each Canadian province and territory appears in Table 1.

The eight-light system is used in eight out of twelve Canadian jurisdictions. Amber lights are used on all school buses in four provinces (Manitoba, Nova Scotia, Prince Edward Island and New Brunswick). This year, Prince Edward Island converted its buses from the four-light system to the eight-light system so equipment will be standardized across the maritime provinces. Significant inter-provincial traffic in that part of the country is an important factor to be considered.

The eight-light system is permitted in four other jurisdictions (British Columbia, Alberta, Quebec and the Northwest Territories). Saskatchewan is also considering changing to the eight-light system (i.e., using flashing amber lights rather than flashing red lights as an advance signalling method).

Red lights are less common as an advance signal than amber lights. Four jurisdictions use this system (Ontario, Saskatchewan, Newfoundland and the Northwest Territories). Quebec is the only place where hazard lights are explicitly tolerated as an advance signal.

Table 1 Use of advance signalling systems across Canada (unofficial)

Province/Territory	Regulations
British Columbia	Four red lights mandatory. Eight-light system permitted.
Alberta	Eight-light system is permitted, but if a bus has such a system, the amber lights have to be used. Amber lights are turned on when the bus begins to slow down. Provincial regulations allow municipalities to prohibit the use of signals in urban areas (red and amber lights) since schoolchildren cannot cross the street in front of the bus. They have to cross at the next crosswalk.
Saskatchewan	The four red lights have to be on before the bus stops. Vehicles coming towards the bus are not required to stop, but those behind the bus are (during the advance signalling stage). The province is considering using the eight-light system. Strobe lights are currently being studied.
Manitoba	Eight-light system has been in use for several years.
Ontario	Four red lights have to be on before the bus stops.
Quebec	Eight-light system and hazard lights* permitted. Red lights are mandatory, but cannot be turned on before the bus comes to a full stop. The effectiveness of the eight-light system is currently being studied.
Nova Scotia	Eight-light system on all buses.
Prince Edward Island	Eight-light system on all buses.
New Brunswick	Eight-light system has been in use for several years. Hazard lights prohibited.
Newfoundland	Four red lights have to be on before the bus comes to a stop.
Yukon	Four red lights have to be on before the bus comes to a stop.
Northwest Territories	Eight-light system permitted, but the four red lights have to be on before the bus stops.

Source: Guérette, C. (1998). Special compilation, Transport Canada, October 23, 1998.
* Section 34, Regulation Respecting Road Vehicles Used for the Transportation of School Children (OC 285-97, March 5, 1997)

2.2 Survey of Literature

Few studies have looked at the effectiveness of school bus advance signals. In the research available, the subject is treated only briefly within one analytical structure that covers all aspects of school bus transportation. No published studies on advance signals have been conducted in the field aboard school buses themselves. Most research concentrates on illegal passing and the measures advocated relate mostly to the effectiveness of stop arms.

2.2.1 Effectiveness of Advance Signalling Systems

Only one study has looked at the effectiveness of the eight-light system, but in connection with the stop arm. According to the United States Department of Transportation (U.S. DOT) of the National Highway Traffic Safety Administration (NHTSA), the stop arm is the only effective safety measure (Hale et al., 1983). There was no significant decrease in passing violations with the amber lights in comparison with the stop arm (see Chapter 5 for a more detailed analysis of the relevance of this study).

Although hazard lights are widely used, no specific study of their effectiveness has been conducted. The same is true for the absence of advance signals and for red lights used as an advance signal.

2.2.2 Understanding Advance and Stop Signals

Two U.S. surveys provided information on how motorists understand advance signal lights and stopping devices (red lights and stop arms). According to a survey conducted by Brackett et al. (1984), 48% of Kansas drivers believed that it was mandatory to stop when a bus with flashing amber lights was coming towards them, while 31% believed that they had to stop when an oncoming bus had its hazard lights on (TRB, 1989). In a study conducted in Florida, 63% of motorists answered that they had to stop for an oncoming bus with flashing amber lights (CUTR, 1997). This high rate of incorrect answers might be explained by respondents' conservative attitudes during a survey (TRB, 1989). However, the data also indicate a misunderstanding of advance signal lights and their configuration.

In Kansas, 95% of motorists believed that they had to stop if a bus travelling in the other direction was stopped when the lanes were separated by a median, which they are not in fact required to do (TRB, 1989). A much lower number (14%) gave the same answer in the Florida study (CUTR, 1997). The improved correct response rate may indicate that motorists gained a greater understanding of their obligations over the 15 years between the two surveys. In addition, a small percentage of the population believed that they were not required to stop if the red lights were on but the stop arm was not displayed (6.2%). This percentage rose to 10% when the hazard lights were used with the red lights (TRB, 1989). The Florida study showed that 14% of motorists did not stop if they saw a stop sign in the opposite direction on a two-lane road (CUTR, 1997). No studies evaluating the understanding of Quebec or Canadian motorists have been published.

2.2.3 Illegal Passing

The frequency of illegal passing (when red lights are on and the stop arm is extended) varies in accordance with a number of parameters that determine the level of risk.

An Ontario study analysed 89 illegal passing incidents using an exposure denominator (MTO, 1987). The length of the advance signal, calculated by surveyors, was not associated with a significant variation in passing. The rate of passing violations was higher among oncoming motorists (8.4%) than among those travelling in the same direction as the bus (2.8%). The reaction time that motorists had seemed to be the origin of this discrepancy. In total, 65% of the pass-bys recorded were made by oncoming motorists (MTO, 1987). Two studies conducted in the United States corroborate this proportion, one by the CUTR (1997) and the other by Hale et al. (1983). The Ontario study found a high rate of violations on four-lane roads (26%), but the denominator was less than 100 occurrences. However, the explanation given is relevant (MTO, 1987): bus signals are difficult to see on a wide road as the angle of view on the signals is not as good, particularly for oncoming motorists. The posted speed was not associated with a greater number of violations, but there was a slight increase in pass-bys by oncoming motorists in urban areas (MTO, 1987). Weather seemed to have an impact on the rate of pass-bys, but the exact causes of these variations were difficult to interpret.

2.2.4 School Bus Accidents

Fortunately, school buses are a safe form of transportation. A study of school bus accidents allows us to estimate the scope of additional future benefits attributed to advance signals. In the context of this study, a typical accident would involve a schoolchild struck by a vehicle other than the bus when crossing the road.

In Canada, according to a sample of accidents involving school buses between 1989 and 1997, one-third of the schoolchildren who were seriously or fatally injured were pedestrians (Gardner and Ste. Marie, 1998). The proportion was 80% in Quebec according to a systematic survey that included minor injuries (Pichette, 1992). Among the pupils injured as pedestrians, several were actually struck by a school bus. In the Canadian study by Gardner and Ste. Marie (1998), only one death involved a motorist other than the bus driver (5%). In Quebec, no deaths of this kind were recorded between 1986 and 1991 (Bureau du coroner, 1992). However, looking at all the injuries, 20% of the schoolchildren hit as pedestrians were struck by a vehicle other than the school bus (Pichette, 1992). In Florida, 33% of the 241 deaths of schoolchildren between 1990 and 1995 involved a motorist illegally passing a stopped school bus (CUTR, 1996). The U.S. Transportation Research Board (1989) demonstrated that 65% of the injuries suffered by pedestrian schoolchildren were caused by a motorist other than the bus driver. This national estimate, which covered the period between 1980 and 1987, was based on the following proportions of cases attributable to a motorist other than the school bus driver: 64% in Michigan, 72% in Texas and 21% in North Carolina.

In this study, we have to assess the risk of a collision between a pupil pedestrian and another vehicle going through a stop based on the vehicle's direction (in the same direction as or approaching the bus). In Quebec, according to provincial motor vehicle bureau records (1982 to 1991), two-thirds of collisions of this kind involved an oncoming vehicle. The Hale et al. study (1983) provided another figure based on a survey of school bus drivers. The drivers reported that, in the accidents they had witnessed, 23% of the motorists who had struck a schoolchild had been coming from the opposite direction.

3 FIELD STUDY

3.1 Methodology

3.1.1 General Approach

In this study, the eight-light system and hazard lights were tested in turn on the same route. The comparison was made with the same population in the same environment with the same stops and in the presence of the same driver to limit bias due to specific road configurations or changes in driving behaviour. The data came from two routes, each studied over a three- to five-week period. Both routes went through mostly rural and near-urban areas, on high-speed roads with two, three or four lanes of traffic. Since few of the buses travelled through urban areas during the course of the study, they were excluded from the analysis. The focus was on highways.

Motorists' behaviour was observed at the front and rear of the bus. These two scenarios were isolated as they involved different situations and parameters. Variables were recorded on board the buses using a data collection form and two video cameras placed at the front and rear of the vehicles. The videotapes were viewed to compile and validate field data. A risk analysis was performed using the relative risk ratio technique, which compared amber lights with hazard lights by relativizing each group over an exposure measurement in relation to the general public. The ratios were validated with a chi-square test of observed and expected frequencies. Only significant results for ratios and any other convincing associations were included.

3.1.2 Routes Inspected

Data were collected aboard vehicles from three transportation companies operating in the outskirts of Sherbrooke (Autobus de l'Estrie, CMTS and the Eastern Townships School Board) over a 31-day period, between April 3 and June 18, 1998. The observations were carried out in accordance with the school calendar and the availability of the buses. Considering the morning and afternoon constituted two separate routes, 21 different routes were inspected out of a total of 72 (Table 2). The complete survey (Appendix A) counted 1,406 stops over a total distance of 1,424 kilometres, giving an average of one stop per kilometre. However, the number of advance signals activated in traffic, whether in front or in the rear, was less than the total number of stops. Roughly 65% of the stops generated at least one observation at the front or the rear.

One of the instructions given to the data collectors was not to compromise the safety of the pupils or motorists by changing motorists' expectations on the routes inspected. Changing the type of advance signal on a route was considered acceptable since this practice was already current owing to bus maintenance and availability. School buses with amber lights were sometimes replaced by buses without these lights.

Table 2 Characteristics of the routes inspected

Route	Time of day	Educational level	Advance signal tested	Total no. of routes	Km	Mean: Stops	Mean: Stops/ km	Mean: Stops with veh.	Mean: % Stops with veh.
117-10	AM	Elementary	1, 2	13	18	23.4	1.3	14.5	62.3
117-40	PM	Elementary	1, 2	13	12	20.9	1.7	13.0	62.8
117-42	PM	High School	1, 2	12	13	11.5	0.9	8.6	74.6
90-10	AM	Elementary	1, 2, 3	6	20	21.6	1.1	18.3	85.5
90-40	PM	Elementary	1, 2, 3	6	15	22.8	1.6	20.3	88.8
27-10	AM	Elementary	1	2	27	25.0	0.9	12.5	50.5
27-11	AM	High School	1	2	23	16.5	0.7	11.0	66.9
27-40	PM	Elementary	1	2	25	25.5	1.0	7.0	27.3
27-42	PM	High School	1	2	23	15.0	0.7	7.5	50.4
95-10	AM	High School	2	2	45	12.0	0.3	11.5	95.8
95-40	PM	High School	2	2	42	10.5	0.3	10.5	100.0
58-10	AM	Elementary	1	1	15	22.0	1.6	12.0	54.5
58-11	AM	High School	1	1	10	13.0	1.3	5.0	38.5
134-10	AM	Elementary	2	1	17	25.0	1.5	7.0	28.0
134-40	PM	Elementary	2	1	18	30.0	1.7	10.0	33.3
41-10	AM	Elementary	2	1	28	27.0	1.0	5.0	18.5
41-11	AM	High School	2	1	16	11.0	0.7	8.0	72.7
45-40	PM	Elementary	1	1	23	27.0	1.2	13.0	48.1
46-11	AM	High School	2	1	35	13.0	0.4	11.0	84.6
R-72	AM	Elem. + HS	1	1	81	23.0	0.3	9.0	39.1
R-46	AM	Elem. + HS	1	1	39	9.0	0.2	6.0	66.7
		Total		72	1,424	1,406	-	915	-
		Mean		-	19.5	19.3	1.0	10.5	65.1

*1 = amber lights, 2 = hazard lights, 3 = no advance signals

Most of the routes in question were on numbered roads with minimal traffic. The exercise required a group of neutral, identical subjects to compare the solutions tested. The breakdown of critical parameters was verified throughout the data collection process in order to maintain constant distributions from one advance signalling method to another. This could have been done on heterogeneous data afterwards with the applicable statistical methods. The method proposed involved creating one reference group, that is, to act on the source in advance. The same route was inspected with amber lights, hazard lights and without any advance signals. The raw frequencies were adjusted as the data were collected.

The school bus transportation safety research group was more interested in high-speed roadways (70 km/h or more). There is a greater need for advance signals on such roads because of the distances required for vehicles to stop safely (Lemay, 1997; Thibault, 1998). The other variable of interest was the number of lanes. The objective was to balance out observations between two-lane and four-lane roads because of interactions with traffic and flow. Two circuits (i.e. a bus and the routes it takes) that met these criteria were retained. They accounted for 86% of the information about oncoming motorists and 82% of rear observations.

Circuit 117 was inspected for 13 days. For part of the distance, the bus travelled on a numbered road (Highway 112) with two, three and four lanes of traffic and no median. Since there was no median, we were able to observe the behaviour of oncoming motorists. The amber lights and hazard lights were tested in turn. This circuit accounted for 67% of the data in front and 60% of the data in the rear.

The other circuit (90) was observed for seven days. It travelled over a straight two-lane road with a posted speed of 90 km/h. Both methods of advance signalling were studied, as was the absence of an advance signal. Nineteen percent of pass-bys from the opposite direction and 22% of pass-bys in the same direction as the school bus were recorded on this road (Highway 220).

The nine remaining circuits accounted for 14% of the observations of oncoming vehicles and 18% of the data from the rear. They were tested over a shortened period. Circuits that yielded few observations were inspected only once, while others were studied over two days to optimize the distribution of the experimental parameters.

3.1.3 Databases

Two databases were built. The first one contained stops and was used to check the homogeneity of bus drivers' actions. Events without advance signals were eliminated from the record, which had 915 stops, so only the amber and hazard lights were compared. Of this number, 856 valid stops were retained. The rejected cases were situations where vehicles were too far away or their actions could not be observed.

In the other database, each motorist constituted an observation. The "motorists" base was divided into two records: front position (opposite direction) and rear position (same direction). From the front, 1,471 motorists were observed on two-lane and multi-lane roads. In the rear, the actions of 903 motorists were observed, 541 of them on multi-lane roads. These two types of roads were isolated because they provided different opportunities for passing the bus.

3.1.4 Parameters Compiled

A total of 72 parameters were derived from the field observations, videotapes and statistical processing. Most of the variables were taken from the tapes (Table 3). The collection was planned so as to distribute the stop locations in accordance with key parameters: posted speed, number of lanes (opposite and same direction) and approach distances. The other variables illustrated the characteristics of the routes, namely the type of stop and the roadway environment (traffic organization and conditions).

The variables in the time - distance - speed triangle were determinant because they defined the motorist's actions.

Chronological markers defined the time and basic indicators. The three main markers were the start of the advance signal (TA), the start of the stop (TC) and the end of the stop (TE). Two secondary markers were also noted: the motorist's action during the advance signalling stage (TB) and in the stopping stage (TD). The time compiled under TB and TD was the amount of time the motorist was stopped or his or her passing time, depending on what occurred. The secondary markers varied according to the motorist observed. By subdividing the data into five markers, it was possible to classify the distances covered and actions performed at key times. Time was measured with the camera's chronometer; the two variables compiled were the length of the advance signal and the amount of time stopped. The time the motorist was exposed to the advance signal was determined using a temporary attribute, namely the time elapsed between the start of the advance signal and the moment when the vehicle appeared.

Three distances were assessed. The advance signalling distance was the distance travelled between the start and end of the advance signal. The visibility distance corresponded to the bus driver's field of vision (maximum 300 metres) at the time when he or she activated the advance signal. Visibility was estimated in light of the site's layout. If a vehicle appeared at the last second (a "hidden" motorist), exposure to the advance signal and the distance at which the vehicle appeared were the two parameters considered. The angle of view on the roofline lights (amber lights) differs from the angle of view on the hazard lights, which are placed lower down. As a result, the observer's angle of view differed from that of the motorist. To avoid introducing bias, the visibility distance was defined as that of the road in general, assuming that it was clear. The other distances corresponded to the distance between the vehicle observed and the bus at times TA to TE.

Distances were estimated by the observer and double-checked on the videotapes. Markers in the field, such as telephone poles (30 metres apart) and lane markings (five to six metres from centre to centre) were helpful in this regard. Because of their three-dimensional aspect, sloped roadways were more useful for relativizing distances than flat roadways, where vehicles appeared fixed on the horizon. The relative size of vehicles compared to their size category was used as a last resort.

To estimate an observer's ability to evaluate distances, a test was carried out on the PMG Technologies test track in Blainville, with an Ultralyte 20-20 laser radar. Under static conditions, distances of 8 to 310 m were estimated with a mean variation of 13 m (9.4% deviation), which gave a correlation coefficient of 0.98 valid 99.9% of the time. In dynamic situations, distances of 44 to 240 m were estimated with an absolute mean variation of 23 m (23.4% deviation), for a correlation coefficient of 0.93 valid 99.9% of the time. Moving subjects made evaluating distances more complicated, but the margin of error remained acceptable. Another consideration was that the estimated values were then redistributed in classes for processing. To compensate for the deviation between the two margins of error (dynamic and static), the distance classes were widened at the start of the advance signal (TA). At that point, vehicles were moving faster and the margin of error was greater. To strengthen the distance evaluation mechanism, observers synchronized themselves with the radar on a regular basis and verified the consistency of their distances.

Table 3 Parameters analysed and breakdown of classes

Source	Parameter	Position	Classes
A	Day of week	Fr-Re	Monday, Tuesday, Wednesday, Thursday, Friday
A	Time of day	Fr-Re	AM (loading), PM (unloading)
A	Type of advance signal	Fr-Re	amber lights, hazard lights, no advance signal
A-V	Weather	Fr-Re	clear, cloudy, rain/drizzle, mist/fog
A-V	Roadway	Fr-Re	dry, wet
A	Location	Fr-Re	rural, near-urban, urban
A	Environment	Fr-Re	residential, commercial, industrial, other
A-V	Posted speed	Fr-Re	50 km/h, 70-80 km/h, 90 km/h
A-V	No. of oncoming lanes of traffic	Fr	1 lane, 2 lanes
A-V	No. of traffic lanes in direction of bus	Re	1 lane, 2 lanes
A-V	Passing permitted	Re	yes, no (for lanes in direction of bus)
A-V	Visibility distance	Fr-Re	0-90 m, 100-175 m, 200 m or +
A	Degree of grade	Fr-Re	flat (0-1%), slight (1-3%), average (4-6%), steep (+7%)
A-V	Bus climbing	Fr-Re	flat, bus climbing, bus descending
A-V	Vehicle climbing	Fr-Re	flat, vehicle climbing, vehicle descending
A	Curve	Fr-Re	straight road, moderate curve, pronounced curve
A	Bus speed at advance signal	Fr-Re	0-25 km/h, 30-55 km/h, 60 km/h or +
A	Driver's action at advance signal	Fr-Re	constant speed, let foot off accelerator, braked
S	Traffic	Fr-Re	light (1-2 vehs), average (3-5 vehs), heavy (6 or + vehs)
A-V	Vehicle distance at adv. signal	Fr	0-45 m, 50-95 m, 100-195 m, 200 m or +
A-V	Vehicle distance at adv. signal	Re	0-19 m, 20-39 m, 40-59 m, 60-79 m, 80 m or +
A-V	Vehicle distance at stop	Fr	0-19 m, 20-39 m, 40-59 m, 60-79 m, 80 m or +
A-V	Vehicle distance at stop	Re	0-4 m, 5-14 m, 15-24 m, 25-54 m, 55 m or +
A-V	Vehicle's relative speed	Re	< bus speed, = bus speed, > bus speed
A-V	Motorist's action at adv. signal	Fr-Re	slowed down, maintained speed, accelerated
A-V	Event at advance signal	Fr-Re	no events, stopped, passed
A-V	Motorist's action at stop	Fr-Re	slowed down, maintained speed, accelerated (in 1 step)
A-V	Event at stop	Fr-Re	no event, stopped, passed
V	Length of advance signal	Fr-Re	0-4 s, 5-9 s, 10-14 s, 15 s or +
S	Time exposed to advance signal	Fr-Re	0-4 s, 5-9 s, 10-14 s, 15 s or +
V	Distance of advance signal	Fr-Re	0-15 m, 16-35 m, 36-55 m, 56-75 m, 76 m or +
A-V	Motorist started up again	Fr-Re	yes, no
A-V	Drove slowly	Fr-Re	yes, no
V	Pupil crossed road	Fr-Re	yes, no
S	Imitation (potential)	Fr-Re	first motorist observed, following motorist
S	Close stop	Fr-Re	isolated stop, stop immediately followed by another
A	Type of vehicle	Fr-Re	automobile, truck, motorcycle

Source: A = audio tape and collection form; V = videotape; S = statistical processing
Position: Fr = front, Re = rear

It was impossible to evaluate the absolute speed of vehicles because laser radar does not work through glass and readings from conventional radar vary significantly so it cannot be used continuously. It was impossible to determine a vehicle's speed at the front of the bus so it was added to the bus's speed. At the rear, a vehicle's relative speed was determined in relation to that of the bus. It was either less than, equal to or greater than the bus's speed. The bus's speed at the start of the advance signal was read from the odometer and was accurate to within ±5 km/h. Depending on what the observer was doing, it was sometimes impossible to get a reading of the bus's speed.

The bus driver's operation of the accelerator and brake pedal was another element observed before the start of the advance signal. Three different commands were identified to evaluate the effect attributable to brake lights at the rear of the bus. The bus driver could have continued to press on the accelerator, let up on the accelerator or braked early. In the latter case, the brake light was a message preceding the advance signal.

Other variables qualified motorists' actions and the events during the advance signalling and stopping stages. The actions were changes in speed (whether motorists slowed down, maintained their speed or accelerated). An advance signal can be long enough for a motorist to react in two stages so two distinct actions were noted (actions 1 and 2). Deceleration (slowing down) was real only when it was perceptible; uncertain cases were excluded. Similarly, acceleration was noted if the increased speed was significant; the indicator used was an observation of the front of the vehicle. Sometimes an advance signal was activated right after the end of a stop, when the bus was starting up again within view of another stop close by. There was a variable to distinguish a close stop from a regular stop. Another parameter covered cases where motorists accelerated to get moving again because acceleration when pulling out is different from acceleration to pass.

The events TB and TD corresponded to the stopping and passing of a vehicle. The absence of an event indicated that the vehicle was still moving close to the bus. Section 460 of the Highway Safety Code stipulates that a vehicle must stop at least five metres from the bus's front or rear bumper. For a pass-by to be deemed illegal in the context of this study, the bus had to be stopped, the red stop lights had to be on and the vehicle had to pass the stop arm (same direction as bus) or the nose of the bus (opposite direction). If a vehicle from behind stopped beside the bus, behind the stop arm, it was not considered an illegal pass. Many people do, in fact, assume that the stop line is next to the stop arm, as is the case for a permanent stop sign. On the routes inspected, the police tolerated this limit and the study followed the same principle. Otherwise, a large number of illegal pass-bys would have been recorded without necessarily identifying the real risk for schoolchildren. The majority of motorists crossed over the five-metre line. That was considered acceptable for vehicles travelling in the same direction, but the corridor in front had to be wide enough for pupils to cross. In such a case, the boundary of the violation zone was the nose of the bus.

A motorist might intentionally or inadvertently imitate the behaviour of a motorist ahead of him or her if he or she was following closely. An imitation of one vehicle by another was deemed "observable" within an arbitrary distance of 40 m. Beyond that distance, it was assumed that a motorist would observe the same traffic conditions as the motorist ahead, even if following that person.

3.1.5 Data Collection Equipment and Operations

Data were collected "live." One video camera was set up at the front of the bus and another at the rear. The real time (hours, minutes, seconds) and date were noted on both videotapes. The observer at the front of the bus sat on the seat beside the door (Figure 6) and recorded the following information on a field collection form (Appendix B):

- bus speed
- the bus driver's control of the brake pedal and accelerator
- characteristics of the road layout

Other variables that could not be written down right away were recorded on an audio tape using a microphone. In the heat of the action, the observer's reaction time was short and he or she was looking straight ahead and not at the form. Time markers (start of the advance signal, start and end of stop) were noted on the audio tape. The bus driver's co-operation was required to determine the exact moment when he or she activated the advance signal. Some buses had cross-view mirrors that reflected the signal lights. Time references were important. Real time was recorded on the front and rear videotapes and references on the rear tape were calculated using the front tape. The clocks on the cameras were synchronized before each data collection session to make sure the time was accurate (to avoid a short-term time lag). To increase accuracy and make it easier to interpret the images, an audio device was attached to the microphone on the rear camera (Figure 7). A voice signal given by the observer was automatically recorded on the rear camera's audio tape. Other data were compiled with the microphone at times TA to TE:

- posted speed (first two inspections of the route)
- direction and grade of slopes (first two inspections of route)
- visibility distance at start of advance signal
- distances between the vehicle and the bus
- the motorist's actions (changes in speed)
- events at times TB or TD
- presence of a close stop or a motorist who starts up again
- pupil crossing road
- driver letting a vehicle pass before turning on stop lights
- presence of police monitoring (unmarked or anonymous) and position relative to the bus

In most cases, the videotapes provided more than enough details, so there was no point in overloading the audio tape. Weather conditions, the number of lanes, ground markings, curves, location and the type and number of vehicles could all be seen on the tape.

Initially, there was one observer at the front and another at the rear of the bus. After the first cassettes were analysed and the situations observed, the rear observer was deemed less useful for collecting data for reasons of discretion. At the back of the bus, the observer had no other choice but to sit very close to the window. Wearing a headset and microphone with his or her head turned toward the traffic, the observer was visible to motorists. In the front, there were three to four metres between the windshield and the camera and observer and the observer was at an angle to oncoming vehicles. He or she was also hidden behind a protective panel.

Figure 6 Front camera and observer's position

Figure 7 Rear camera

In addition to the discretion issue, redundant information from the rear was another reason for retaining only one observer. On two-lane roads, the same vehicle could remain stuck behind a bus for several stops (line of vehicles). In such a case, an observer was unnecessary; the camera was sufficient.

The camera tripods were solidly anchored using a system of elastic cables attached to the seats. The set-up was completely solid to ensure the safety of the schoolchildren and improve picture quality. Installation at the front of the bus was simple because there was little movement and space was adequate. At the rear, there were two constraints. Bumps were magnified by the position of the axle. The tripod head (which connects the camera to the tripod) became unstable despite being solidly anchored. Furthermore, space was reduced. The rotating tripod head, equipped with a control lever, was replaced by a still camera head as the conventional lever was too long and extended over the adjacent seat. The still camera head could be adjusted without a lever. In addition to being solid, the equipment was easy to disassemble and transport, an important factor because transfers were done quickly (change in route or bus).

The videotapes were examined in a logical order since they were used to complete the collection form. The data form contained all the parameters for oncoming vehicles and those travelling in the same direction as the bus (Appendix B). The first task involved transposing information from the field data form to the collection form. The front videotape was viewed first as it contained basic information (specific time markers). When viewing the rear video, only data that changed were recorded on the form (slope, curve, number of lanes, distance and actions, etc.). Several of the parameters were identical in both positions, such as the advance signalling distance and the speed of the bus, as were a number of variables related to the roadway. The motorist’s action and the events that occurred were noted on both forms, as were the corresponding times and distances (TA to TE). The tapes were viewed to compile missing information and validate the data collected.

Four scenes taken from the videotapes (Figures 8 to 11) are presented to give readers an idea of the type of data gathered. A number of phenomena are illustrated:

- line of oncoming vehicles, potential imitation behaviour (Figure 8)
- visibility blocked in opposite direction by heavy trucks (Figure 9)
- motorists caught behind a bus on a single-lane road; no one can pass (Figure 10)
- traffic on a four-lane road; the motorist in the lane next to the bus often crosses the five-metre line stipulated in the Highway Safety Code (Figure 11)

3.1.6 Types of Measurements and Ratio Techniques

The actions and events recorded were used to create two basic indexes. The deceleration rate measured the effectiveness of the advance signal in reducing motorists’ speeds. Deceleration in response to an advance signal was viewed as positive as it indicated a motorist’s willingness to stop at the critical moment. The deceleration rate indicated the number of vehicles that slowed down in relation to the total number of vehicles observed. Deceleration was noted regardless of whether it occurred at the beginning or end of the advance signal, as long as acceleration did not occur afterwards. It was considered valid if a vehicle passed during the advance signal, but was excluded if the motorist passed the bus when its red lights were on, because deceleration occurred too late. The rate of stopping violations measured the effectiveness of advance signals in preventing illegal pass-bys when the bus was stopped. The violation had to involve a vehicle observed during the advance signalling stage.

Figure 8 Line of oncoming vehicles, potential imitation behaviour

Figure 9 Visibility blocked in opposite direction by heavy trucks

Figure 10 Only one lane behind bus: the motorist cannot pass

Figure 11 Five-metre line behind bus crossed

The ratio method was applied to the deceleration and violation rates. A relative risk ratio was calculated to indicate the risk of observing an event in one group in comparison with another group (in this case, the eight-light system compared to the hazard lights). The ratio was established using the following method: relativize a consequence (pass-by, deceleration) over an exposure value (motorists who can pass). The values obtained for one group were always related to the values obtained for the entire population. A basic formula was applied to each group to determine its risk ratio:

(a / A) / (b / B) where: a = total events in the group
b = total observations in the group
A = total events in the population
B = total observations in the population

The relative risk ratio of one group was compared to that of the other group so the complete formula included the ratios of both groups. In the following example, the eight-light system corresponds to group 1 and the hazard lights to group 2. The risk ratio of one group is "R" and the relative risk ratio is "RR":

Risk ratio of eight-light system: $R^1 = (a^1 / a^1 + a^2) / (b^1 / b^1 + b^2)$
Risk ratio of hazard lights: $R^2 = (a^2 / a^1 + a^2) / (b^2 / b^1 + b^2)$
Relative risk ratio: $RR = R^1 / R^2$

Using this formula, the overall risk was set at 1 for the study population. A ratio of less than 1 indicates a smaller risk for a group and a ratio greater than 1 implies an increased risk in that group. However, the risk ratio can be transposed into an effectiveness index if the group with the lowest risk ratio is moved to the numerator position in the relative risk equation. The effectiveness index shows the difference, as a percentage, of the risk in one group compared to another group in relation to the total population:

Effectiveness index: $E (\%) = (1 - RR) * 100$

However, the relative risk ratio varied depending on the parameter considered and the number of cases. Specific risk ratios were calculated to illustrate the variance between classes of the same variable. They supported the overall trend observed. For example, for oncoming vehicles, an overall comparison was made between the amber lights and hazard lights, and then by speed (50 km/h, 70 km/h, 90 km/h), number of lanes (one lane or two or more lanes), and so on for all the parameters analysed. This breakdown by class was used to identify variability in risk and effectiveness in specific circumstances.

Before calculating the ratios, an initial criterion was used to whittle down the basic information. Categories of variables where the numerator was less than ten were eliminated. To validate the margin of error of the relative risk ratio, the frequency of observed events was compared with the frequency of expected events. The chi-square test (observed vs. expected) yielded the probability "p" that the statistical difference was due to chance rather than a phenomenon illustrated by the relative risk ratio. In this study, two groups were compared and together they formed a population. To calculate one group's expected frequency, its exposure was multiplied by the total frequency of events. This result was then related to the total exposure. Here is the calculation for group 1, where "b" represents exposure and "a" refers to events (passing, deceleration):

Expected frequency of group 1: $P^1 = b^1 (a^1 + a^2) / (b^1 + b^2)$

The chi-square test (observed vs. expected) compares the statistical difference between the two groups on the basis of the deviation between the expected and observed frequencies. In the tables, only significant risk ratios were presented.

3.2 Results

The initial results illustrated the characteristics of advance signals and described the overall experimental conditions. This involved verifying whether both advance signals were activated in the same manner to assess the homogeneity of the data collection conditions. The effectiveness indexes using ratios were then presented for the deceleration rate and the stopping violations rate.

3.2.1 Advance Signals versus No Advance Signals

In 1998, the Quebec department of transport (MTQ) conducted a provincial study with 47 primarily rural school boards to determine whether there were areas where advance signals were not used. Eighty of the 2,261 routes evaluated did not use any form of advance signal (3.5%). After adjustments were made with school transportation superintendents, half of this figure proved to be true, i.e. no advance signals were used on 1.7% of the routes. This indicator seemed to be confirmed later on during discussions with school board and bus transportation company officials (e.g., Trois Lacs and Lakeshore). The superintendents and transportation companies contacted recommended that hazard lights be used in the presence of other vehicles and in risk areas.

At the beginning of the project, we had intended to analyse the absence of advance signals on the same basis as both methods of advance signalling. However, this comparison was impossible to make as the frequencies compiled without advance signals were too low. The collection of data for situations without advance signals was interrupted for safety reasons. In the study area (the Eastern Townships), observations without advance signals were permitted by school transportation officials on two-lane roads where no pupils crossed the road, but were prohibited on four-lane roads and locations where pupils crossed. Despite these precautions, collecting data in the absence of advance signals caused three traffic problems among the 79 vehicles observed and the rate of stopping violations climbed to 12.2% in front. Following these brief observations in the field and recommendations from school transportation officials, the experiment was cancelled. Since we were unable to make a comparison including a situation with no advance signals, the emphasis was placed on the comparison between the eight-light system and hazard lights.

3.2.2 Observation Frequencies and Roadway Variables

The distribution of the variables for the information collected is appended: school bus stops (Appendix C), oncoming motorists (Appendix D) and motorists travelling in the same direction (Appendix E). A chi-square test was systematically carried out on each variable observed during the stops to verify the conformity of the sampling parameters (Appendix F). If there was a deviation, the significance of the probability of error was indicated. A valid deviation indicated a heterogeneous distribution between the hazard lights and eight-light system. Ideally, the frequency of the stops and the motorists observed agreed for each advance signalling system. To even out the frequencies of both advance signalling methods, data collection had to be monitored daily. Of course, in the short term, collection could not be distributed to even out the frequency of rain storms or clear days. During a shortened continuous collection period (one to three weeks), an involuntary phenomenon of over- or under-representation might have occurred.

The roadway variables were distributed evenly between the eight-light system and the hazard lights. The posted speed, number of lanes, distance classes and traffic at the start of the advance signal were evenly balanced. Furthermore, the bus drivers who tested both types of advance signals remained constant, changing from one type of advance signal to another. The lack of a deviation in bus speed at the start of the advance signal and the advance signalling distance indicated neutrality.

A few parameters displayed a deviation between the eight-light system and the hazard lights. For these variables, the specific effectiveness indexes had to be studied more closely. The valid "p" for the "location" variable was due to a distinction between rural and near-urban areas. When the two classes were merged, "p" ceased to be significant. The deviation in police monitoring was due to the small number of police interventions during the data collection period for amber lights. The presence of police officers was noted in less than 10% of the cases. The deviation in a driver's use of the brake pedal and accelerator was attributed to rarer cases when the driver braked before activating the advance signal. In these cases, the motorist behind the bus saw the brake lights before the advance signal 5% of the time. At the rear of the bus, the relative speed of vehicles in comparison to the bus's speed was evaluated at the start of the advance signal. Motorists travelling faster than the bus were slightly more frequent with the eight-light system (78%) than with the hazard lights (69%). Finally, the weather and traffic conditions might have had an impact on the effectiveness of advance signals. During the data collection period, hazard lights were used more often during rain showers than the eight-light system (24% vs. 9%). Traffic density and rainfall might have had an impact on the speed of the vehicles observed. The sun could also have made it harder for motorists to see an advance signal, especially if there was glare or a reflection, while cloud cover could have provided a darker background against which advance signal lights were more likely to be noticed.

3.2.3 Types of Advance Signals Used by the Bus Driver

The purpose of categorizing advance signals used by the bus drivers was to test the homogeneity of comparative sampling between the amber lights and hazard lights. The variables of the time-distance-speed triangle are presented in chart form. Five variables were used in this comparison: the length and distance of the advance signal, the visibility and speed of the bus at the start of the advance signal and the stop length (Table 4).

Table 4 Bus driver's actions by the advance signalling method used

	Amber Lights		Hazard Lights		Total	
Variables	**Mean**	**Standard Deviation**	**Mean**	**Standard Deviation**	**Mean**	**Standard Deviation**
Visibility at advance signal	175.8 m	87.9	174.4 m	81.0	175.2 m	84.7
Distance of advance signal	44.0 m	25.9	45.1 m	29.3	44.6 m	27.6
Speed at advance signal	43.7 km/h	18.2	43.9 km/h	20.7	43.9 km/h	19.5
Length of advance signal	11.0 s	3.4	11.2 s	3.6	11.2	4.6
Stop length	8.3 s	4.0	9.0 s	5.4	8.6	4.7

Advance signalling was constant from one method to another and the observation conditions provided a neutral comparison between the eight-light system and the hazard lights. In the advance signalling context observed, the following means were calculated:

- Length of advance signal: 11 s (Figure 12)
- Stop length: 9 s (Figure 13)
- Distance of advance signal: 45 m (Figure 14)
- Estimated speed of bus: 45 km/h (Figure 15)
- Estimated visibility at start of advance signal: 175 m

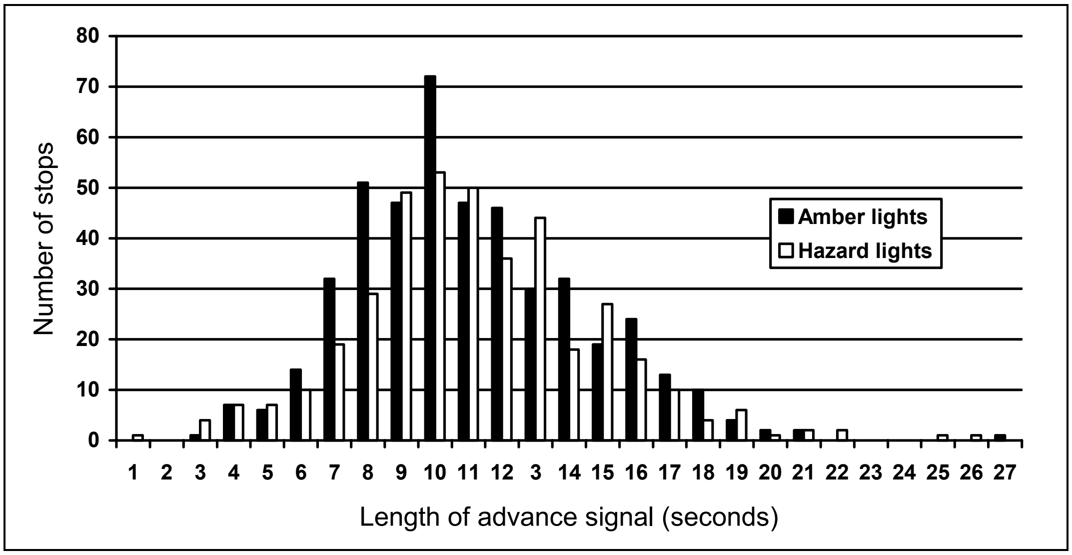

Figure 12 Length of advance signal

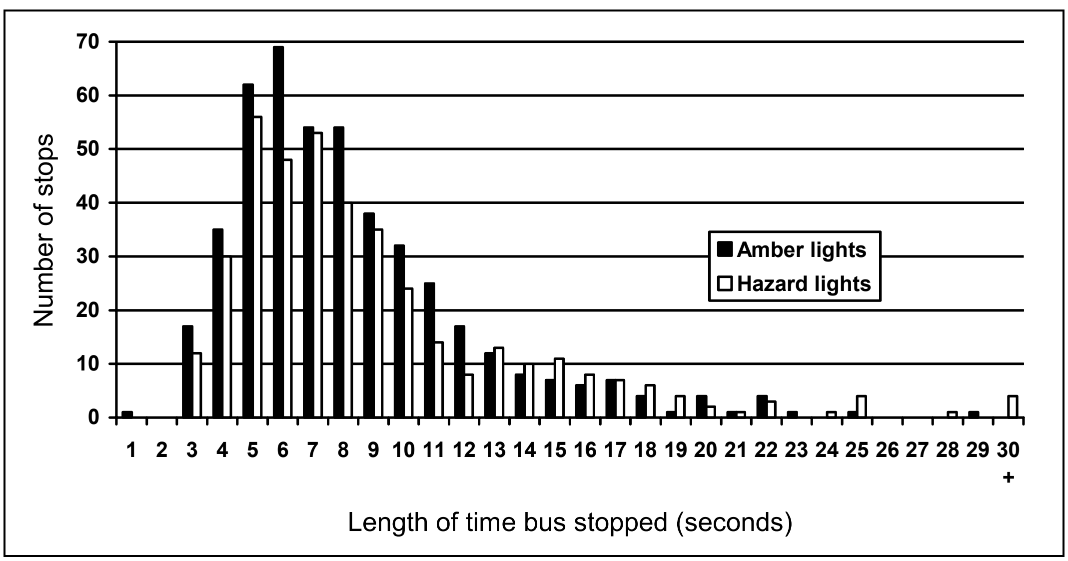

Figure 13 Length of time bus stopped

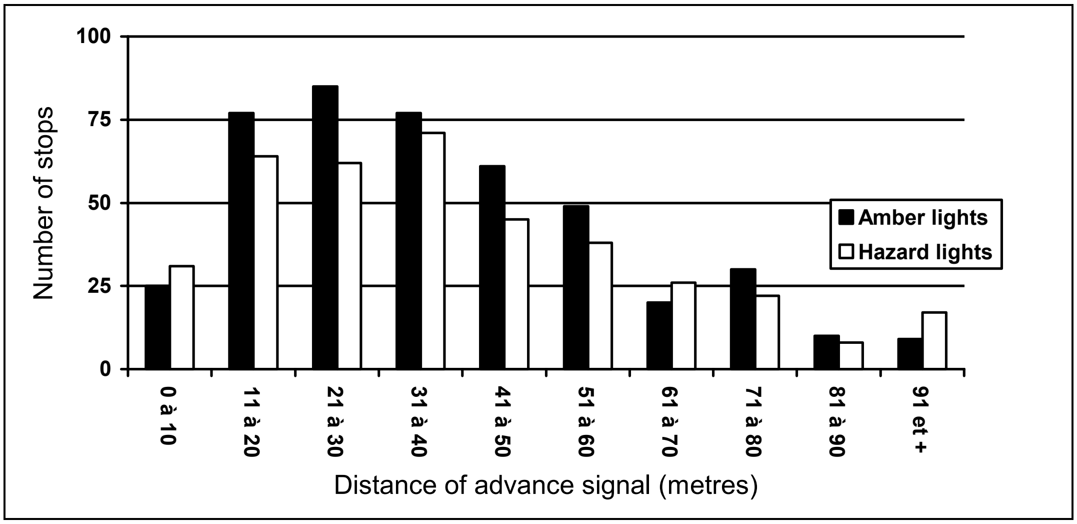

Figure 14 Distance of advance signal

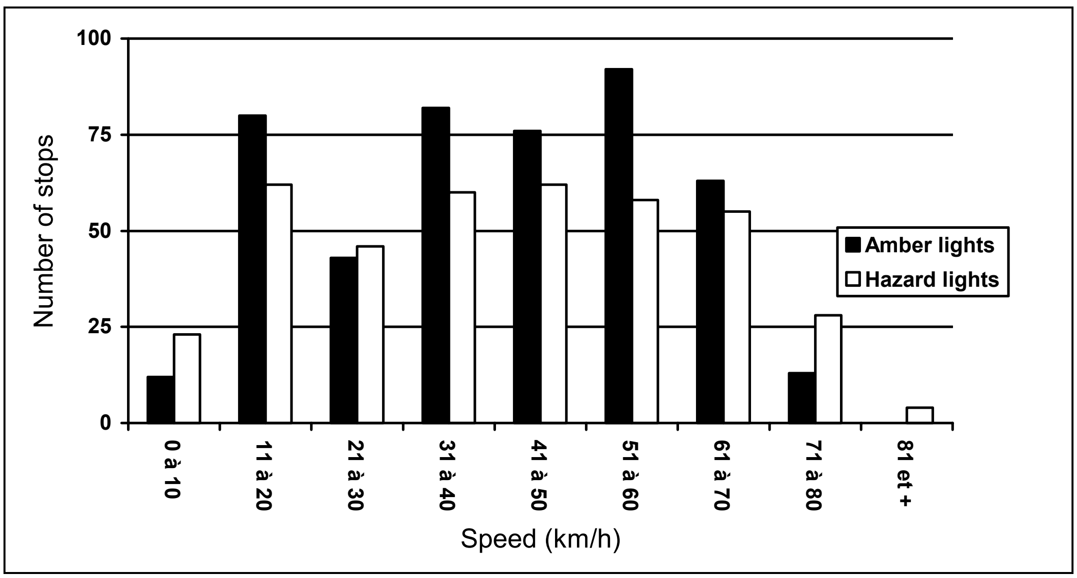

Figure 15 Bus speed at start of advance signal

3.2.4 Rate of Stopping Violations

The rate of stopping violations was an indicator of the risk of an accident for a pupil who would or might have had to cross the road before loading or after unloading. On the routes studied, the eight-light system was associated with lower rates of illegal pass-bys than the hazard lights both in front of and behind the bus (Tables 5 and 6).

On two-lane roads, no motorists passed the bus from behind. The violation rate among oncoming drivers varied slightly, from 1.4% for the eight-light system to 2.9% for the hazard lights. These proportions remained stable in comparison with the 12.2% rate when there was no advance signal.

Table 5 Illegal passing at stop*, two-lane roads

	Opposite Direction			Same Direction			Total		
	pass	no.	%	pass	no.	%	pass	no.	%
No advance signal**	9	74	12.2	0	62	0.0	9	136	6.6
Amber lights	4	279	1.4	0	201	0.0	4	480	0.8
Hazard lights	8	275	2.9	0	161	0.0	8	436	1.8
Total	21	628	3.3	0	424	0.0	21	1,052	2.0
Validity of X^2	p = 0.0001			-			p = 0.0001		

* vehicles present during the advance signalling stage
** braking the bus was equivalent to the start of the advance signal for the "no advance signal" situation

Table 6 Illegal passing at stop*, multi-lane roads

	Opposite Direction			Same Direction			Total		
	pass	no.	%	pass	no.	%	pass	no.	%
No advance signal**	-	-	-	-	-	-	-	-	-
Amber lights	18	413	4.4	1	262	0.4	19	675	2.8
Hazard lights	40	504	7.9	9	279	3.2	49	783	6.3
Total	58	917	6.3	10	541	1.8	68	1,458	4.7
Validity of X^2	p = 0.0001			p = 0.001			p = 0.006		

* vehicles present during the advance signalling stage
** braking the bus was equivalent to the start of the advance signal for the "no advance signal" situation

On three-, four- and five-lane roads, illegal pass-bys were always more frequent with hazard lights than with amber lights, both in the front (8% vs. 4%) and at the rear (3.2% vs. 0.4%). The results also showed that the risk was greater on four-lane roads than on two-lane roads, regardless of the type of advance signal.

If we separate out oncoming drivers, an overall effectiveness index can be calculated for all types of roads. Using the relative risk ratio obtained (0.52:1), the eight-light system was 49% more effective than the hazard lights in preventing illegal pass-bys at a stop (Table 7).

In cases of motorists travelling in the same direction as the bus, the frequency of pass-bys was too low to calculate the relative risk ratio.

3.2.5 Changes in Motorist Speed and Behaviour

We were able to identify two probable causes of stopping violations: risk taking and inattention. A motorist who speeds up to pass a bus before the end of an advance signal is making a decision that could potentially endanger other users. "Distracted" motorists often get a bonus from bus drivers who, in many cases, will let a vehicle pass before extending the stop arm, knowing that the motorist never saw or paid attention to the advance signal.

Table 7 Effectiveness of advance signals in preventing stopping violations by oncoming motorists

Categories	Amber Lights				Hazard Lights				Ratios		
	pass	veh	exp	ratio	pass	veh	exp	ratio			
	(a^1)	(b^1)	(P^1)	(R^1)	(a^2)	(b^2)	(P^2)	(R^2)	RR	E (%)	p
Total	22	692	32.9	0.67	48	779	37.1	1.29	0.52	48.4	.01
Residential	20	625	29.7	0.70	39	671	31.9	1.28	0.55	44.9	.03
70-80 km/h zone	20	490	23.3	0.72	39	548	26.1	1.25	0.57	42.6	.01
Two opposing lanes	18	413	19.7	0.69	40	504	24.0	1.25	0.55	45.1	.001
Visibility 200 m +	11	334	15.9	0.57	32	406	19.3	1.36	0.42	58.2	.002
Slight slope (1-3%)	12	459	21.8	0.50	39	509	24.2	1.45	0.34	65.9	.0003
Straight road	13	473	22.5	0.53	40	558	26.6	1.39	0.38	61.7	.001
Regular stop	11	492	23.4	0.62	28	581	27.6	1.33	0.46	53.6	.01
Close stop	11	200	9.5	0.71	20	198	9.4	1.30	0.54	45.6	.0002
Elementary pupils	21	526	25.0	0.72	36	500	23.8	1.30	0.55	44.6	.005
No police	16	622	29.6	0.56	47	753	35.8	1.36	0.41	58.8	.002
High volume	13	139	6.6	1.37	19	329	15.7	0.84	1.62	-61.9	.002
Automobile	22	645	30.7	0.70	44	712	33.9	1.27	0.55	44.8	.02
Dist. at stop 100-19 m	13	238	11.3	0.77	25	296	14.1	1.19	0.65	35.3	.003
Dist. at stop 0-19 m	11	81	3.9	0.67	14	42	2.0	1.64	0.41	59.3	.0001
First motorist	14	514	24.5	0.67	27	498	23.7	1.34	0.50	49.8	.03
Adv. signal 5-9 s	10	268	12.8	0.59	23	254	12.1	1.43	0.41	58.8	.001

a = observed event; b = exposure; P = expected event; R = risk ratio;
RR = relative risk ratio; E = % effectiveness; p = chi-square threshold (observed vs. expected)

Estimating the acceleration of oncoming motorists was almost impossible. The difference observed between the eight-light system and the hazard lights was recorded for vehicles that maintained the same speed and those that slowed down (Table 8). Oncoming motorists appeared indifferent to the hazard lights, 75% of them maintaining their speed as they approached the bus compared to the 46% who slowed down in reaction to the amber lights.

It was easier to determine the acceleration of vehicles behind the bus (Table 9). In the rear, vehicles sped up more often when they saw the hazard lights (13%) than the eight-light system (6%). This deviation can be attributed to the interpretation of the hazard lights. However, no conclusion could be made in this regard as the frequencies observed were too low.

There were cases where the bus driver let a vehicle pass before extending the stop arm (Table 10). Bus drivers do not normally do this, but sometimes it is necessary. These situations were fairly rare, but there was a significant difference between amber lights and hazard lights in these instances. With the amber lights, 1% of motorists benefited from this kind of permission from a bus driver, while the figure was 3% with the hazard lights.

Table 8 Actions of oncoming motorists

Action	Amber Lights		Hazard Lights		Total	
	No.	%	No.	%	No.	%
Slowed down	371	53.6	193	24.8	564	38.3
Maintained speed*	317	45.8	582	74.7	899	61.1
Accelerated**	4	0.6	4	0.5	8	0.5
Total	692	100.0	779	100.0	1,471	100.0
Validity of X^2	$p = 0.0001$					

* Continued to maintain speed; ** sped up to pass, except when starting up after stopping

Table 9 Actions of motorists behind bus

Action	Amber Lights		Hazard Lights		Total	
	No.	%	No.	%	No.	%
Slowed down	185	70.6	153	54.8	338	62.5
Maintained speed*	62	23.7	89	31.9	151	27.9
Accelerated**	15	5.7	37	13.3	52	9.6
Total	262	100.0	279	100.0	541	100.0
Validity of X^2	$p = 0.0001$					

* Continued to maintain speed; ** sped up to pass, except when starting up after stopping

Table 10 Oncoming motorists allowed to pass by the bus driver

Action	Amber Lights		Hazard Lights		Total	
	No.	%	No.	%	No.	%
Normal stop	685	99.0	754	96.8	1,439	97.8
Let vehicle pass	7	1.0	25	3.2	32	2.2
Total	692	100.0	779	100.0	1,471	100.0
Validity of X^2	$p = 0.004$					

3.2.6 Deceleration Rate

Decelerating (slowing down) during an advance signal can indicate a motorist's intention to come to a full stop. The deceleration rate was calculated from this point of view. It was compiled for two-lane and multi-lane roads (Table 12).

Regardless of the type of advance signal, vehicles slowed down less often on multi-lane roads. This decrease in effectiveness can probably be attributed to the fact that this type of configuration increases passing opportunities.

In Table 11, we can see that amber lights caused more motorists to slow down than hazard lights on two-lane roads (60% vs. 27%) and multi-lane roads (49% vs. 24%).

Behind the bus (Table 12), the eight-light system created a discrepancy for multi-lane roads, causing more motorists to slow down than the hazard lights did (71% vs. 55%). On two-lane roads, the deceleration rate was constant, regardless of whether there was no advance signal or an advance signal with amber lights or hazard lights. In a line of vehicles following a bus, it is very difficult to pass.

Table 11 Deceleration rate* on two-lane roads

	Opposite Direction			Same Direction			Total		
	decel	no.	%	decel	no.	%	decel	no.	%
No advance signal**	11	74	14.8	60	62	96.8	71	136	52.2
Amber lights	168	279	60.2	198	201	98.5	366	480	76.3
Hazard lights	73	275	26.5	154	161	95.7	227	436	52.1
Total	252	628	40.1	412	424	97.2	664	1,052	63.1
Validity of X^2	p = 0.0001			-			p = 0.0001		

* vehicles that slowed down in the advance signalling stage without passing the bus illegally
** braking the bus was equivalent to the start of the advance signal for the "no advance signal" situation

Table 12 Deceleration rate* on multi-lane roads

	Opposite Direction			Same Direction			Total		
	decel	no.	%	decel	no.	%	decel	no.	%
No advance signal**	-	-	-	-	-	-	-	-	-
Amber lights	203	413	49.2	185	262	70.6	388	675	57.5
Hazard lights	120	504	23.8	153	279	54.8	273	783	34.9
Total	323	917	35.2	338	541	62.5	661	1,458	45.3
Validity of X^2	p = 0.0001			p = 0.005			p = 0.0001		

* vehicles that slowed down in the advance signalling stage without passing the bus illegally
** braking the bus was equivalent to the start of the advance signal in the "no advance signal" situation

The eight-light system was 54% more effective than the hazard lights in getting oncoming vehicles to slow down during the advance signalling stage (Table 13). The other effectiveness indexes, those resulting from the ranked categories, were stable and clustered around the mean. The effectiveness of the amber lights was constant, varying between 40% and 70% for most categories of variables.

The effectiveness of the amber lights was maximized when a bus driver turned on the advance signal for a long period. Over an advance-signalling distance of more than 75 m, the eight-light system was 78% more effective than hazard lights in getting motorists to slow down. This percentage rose to 82% for advance signals of 15 seconds or more. The effectiveness index was also high in situations where the observed motorist was following another vehicle. The amber lights were 65% more effective than hazard lights in slowing down motorists following another vehicle less than 40 m behind. In theory, amber lights, which are placed on the roofline of the bus, can be seen by all motorists (unless visibility is reduced by a truck), while hazard lights, placed lower down, can only be seen by the first motorist.

At the rear, the deceleration rate was calculated on all roads with two lanes of traffic in the same direction as the bus. The motorists observed were in the lane next to the bus while those following the bus in the same lane were disregarded, unless one changed lanes to pass the bus. Considering the vehicles that could pass, the amber lights were 22% more effective than hazard lights in slowing motorists down (Table 14). The amber lights were more effective in some circumstances, but otherwise their performance was fairly stable.

Table 13 Effectiveness of advance signalling in slowing down oncoming motorists

Categories	Hazard Lights				Amber Lights				Ratios		
	decel.	veh	exp	ratio	decel.	veh	exp	ratio			
	(a^1)	(b^1)	(P^1)	(R^1)	(a^2)	(b^2)	(P^2)	(R^2)	RR	E (%)	p
Total	193	779	298.7	0.65	371	692	265.3	1.4	0.46	54	.0001
Monday	21	71	27.2	0.68	24	32	12.3	1.72	0.39	61	.0003
Tuesday	28	141	54.1	0.56	90	189	72.5	1.33	0.42	58	.0001
Wednesday	43	169	64.8	0.67	97	201	77.1	1.28	0.53	47	.0005
Thursday	63	252	96.6	0.63	121	215	82.4	1.43	0.44	56	.0001
Friday	38	146	56.0	0.68	39	55	21.1	1.85	0.37	63	.0001
AM	70	327	125.4	0.55	179	315	120.8	1.47	0.38	62	.0001
PM	123	452	173.3	0.72	192	377	144.5	1.34	0.53	47	.0001
Clear	119	481	184.4	0.62	312	594	227.7	1.31	0.47	53	.0001
Cloudy	24	99	38.0	0.73	24	45	17.3	1.6	0.45	55	.005
Rain/mist	50	199	76.3	0.74	35	53	20.3	1.96	0.38	62	.0001
Rural	120	464	177.9	0.66	252	481	184.4	1.33	0.49	51	.0001
Near-urban	71	286	109.7	0.66	107	189	72.5	1.51	0.44	56	.0001
Residential	166	671	257.3	0.65	328	625	239.6	1.38	0.47	53	.0001
Commercial	27	108	41.4	0.59	43	57	21.9	1.78	0.33	67	.0001
50 km/h	20	91	34.9	0.61	33	57	21.9	1.62	0.38	62	.0004
70-80 km/h	136	548	210.1	0.67	248	490	187.9	1.37	0.49	51	.0001
90 km/h	37	140	53.7	0.59	90	145	55.6	1.39	0.43	57	.0001
1 oncoming lane	73	275	105.4	0.61	168	279	107.0	1.38	0.44	56	.0001
2 oncoming lanes	120	504	193.2	0.68	203	413	158.3	1.4	0.48	52	.0001
Visibility 0-90 m	27	91	34.9	0.74	56	115	44.1	1.21	0.61	39	.03
Visibility 100-175 m	63	282	108.1	0.6	133	243	93.2	1.47	0.41	59	.0001
Visibility 200 m +	103	406	155.7	0.66	182	334	128.1	1.41	0.47	53	.0001
Flat roadway	39	162	62.1	0.63	80	148	56.7	1.41	0.45	56	.0001
Slight slope	132	509	195.2	0.65	253	459	176.0	1.39	0.47	53	.0001
Moderate slope	22	108	41.4	0.7	32	77	29.5	1.42	0.49	51	.003
Veh climbing	83	337	129.2	0.64	156	285	109.3	1.42	0.45	55	.0001
Veh descending	71	280	107.4	0.66	135	259	99.3	1.36	0.49	51	.0001
Straight road	145	558	213.9	0.65	267	473	181.4	1.41	0.46	54	.0001
Moderate curve	43	196	75.1	0.68	78	180	69.0	1.35	0.51	49	.0001
Bus 0-25 km/h	46	164	62.9	0.66	88	149	57.1	1.38	0.47	53	.0001

a = events observed; b = exposure; P = expected events; R = risk ratio;
RR = relative risk ratio; E = % effectiveness; p = chi-square threshold (observed vs. expected)

Table 13 (cont'd)

Categories	Hazard Lights				Amber Lights				Ratios		
	decel.	veh	exp	ratio	decel.	veh	exp	ratio			
	(a^1)	(b^1)	(P^1)	(R^1)	(a^2)	(b^2)	(P^2)	(R^2)	RR	E (%)	p
Total	193	779	298.7	0.65	371	692	265.3	1.4	0.46	54	.0001
Bus 30-55 km/h	71	295	113.1	0.6	161	287	110.0	1.41	0.43	57	.0001
Bus 60 km/h	76	320	122.7	0.69	122	256	98.2	1.39	0.5	50	.0001
Adv signal 0-15 m	18	71	27.2	0.62	36	62	23.8	1.43	0.44	56	.001
Adv signal 16-35 m	59	237	90.9	0.63	114	203	77.8	1.43	0.44	56	.0001
Adv signal 36-55 m	58	229	87.8	0.69	99	200	76.7	1.35	0.51	49	.0001
Adv signal 56-75 m	46	145	55.6	0.77	67	130	49.8	1.25	0.62	38	.004
Adv signal 76 m +	12	97	37.2	0.36	54	95	36.4	1.65	0.22	78	.0001
Regular stop	146	581	222.8	0.66	263	492	188.6	1.4	0.47	53	.0001
Close stop	47	198	75.9	0.61	108	200	76.7	1.39	0.44	56	.0001
Elementary pupils	138	500	191.7	0.66	293	526	201.7	1.33	0.5	51	.0001
High school pupils	55	279	107.0	0.69	68	153	58.7	1.56	0.44	56	.0001
No police	186	753	288.7	0.65	335	622	238.5	1.42	0.46	54	.0001
Light traffic	62	180	69.0	0.69	137	216	82.8	1.26	0.54	46	.0001
Moderate traffic	73	270	103.5	0.67	171	337	129.2	1.26	0.53	47	.0001
Heavy traffic	58	329	126.1	0.68	63	139	53.3	1.75	0.39	61	.0001
Initial dist 0-45 m	10	148	56.7	0.55	24	131	50.2	1.5	0.37	63	.0001
Initial dist 50-95 m	44	234	89.7	0.58	113	249	95.5	1.4	0.41	59	.0001
Initial dist 100-195 m	105	296	113.5	0.67	178	238	91.3	1.41	0.47	53	.0001
Init dist 200 m +	33	100	38.3	0.65	54	72	27.6	1.48	0.44	56	.0001
Dist at stop 0-19 m	29	42	16.1	0.82	75	81	31.1	1.1	0.75	25	.0001
Dist at stop 20-39 m	53	70	26.8	0.93	73	84	32.2	1.06	0.87	13	.0001
Dist at stop 40-59 m	27	53	20.3	0.71	61	70	26.8	1.22	0.58	42	.0001
Dist at stop 60-79 m	15	48	18.4	0.51	38	39	15.0	1.6	0.32	68	.0001
Dist at stop 80 m +	10	41	15.7	0.62	26	50	19.2	1.31	0.47	53	.04
First motorist	137	498	190.9	0.66	286	514	197.1	1.33	0.49	51	.0001
Following motorist	56	281	107.7	0.61	85	150	57.5	1.73	0.35	65	.0001
Automobile	171	712	273.0	0.63	349	645	247.3	1.41	0.44	56	.0001
Adv signal 0-4 s	14	35	13.4	0.8	15	23	8.8	1.3	0.61	39	.01
Adv signal 5-9 s	75	254	97.4	0.69	149	268	102.8	1.3	0.53	47	.0001
Adv signal 10-14 s	91	380	145.7	0.68	160	333	127.7	1.36	0.5	50	.0001
Adv signal 15+ s	13	104	39.9	0.37	43	62	23.8	2.06	0.18	82	.0001

a = events observed; b = exposure; P = expected events; R = risk ratio;
RR = relative risk ratio; E = % effectiveness; p = chi-square threshold (observed vs. expected)

Table 14 Effectiveness of advance signals in slowing down motorists from behind on multi-lane roads

Categories	Hazard Lights				Amber Lights						
	decel.	veh	exp	ratio	decel.	veh	exp	ratio	Ratios		
	(a^1)	(b^1)	(P^1)	(R^1)	(a^2)	(b^2)	(P^2)	(R^2)	RR	E (%)	p
Total	153	279	174.3	0.88	185	262	163.7	1.13	0.78	22	.02
Friday	28	62	38.7	0.81	15	15	9.4	1.79	0.45	55	.01
AM	64	126	78.7	0.82	91	125	78.1	1.18	0.69	31	.03
Clear	86	161	100.6	0.84	152	215	134.3	1.12	0.75	25	.04
Rural	102	197	123.1	0.88	127	192	120.0	1.12	0.79	21	.05
Near-urban	51	82	51.2	0.87	58	70	43.7	1.16	0.75	25	.02
Residential	138	255	159.3	0.89	163	238	148.7	1.12	0.79	21	.04
70-80 km/h	133	240	149.9	0.87	167	232	144.9	1.13	0.77	23	.02
Slight slope	126	227	141.8	0.88	155	217	135.6	1.13	0.78	22	.03
Veh descending	50	80	50.0	0.86	64	77	48.1	1.14	0.75	25	.02
Bus 30-55 km/h	41	76	47.5	0.83	49	62	38.7	1.21	0.69	31	.05
Bus 60 km/h	53	93	58.1	0.84	80	102	63.7	1.15	0.73	27	.03
Elementary pupils	115	210	131.2	0.86	159	222	138.7	1.13	0.76	24	.02
Initial dist 60 m +	59	98	61.2	0.82	81	92	57.5	1.19	0.69	31	.001
Dist at stop 25 m +	34	62	38.7	0.79	52	62	38.7	1.21	0.65	35	.02
Veh speed > bus	86	191	119.3	0.79	138	204	127.5	1.19	0.66	34	.001

a = events observed; b = exposure; P = expected events; R = risk ratio;
RR = relative risk ratio; E = % effectiveness; p = chi-square threshold (observed vs. expected)

4 SCHOOL BUS DRIVERS' QUESTIONNAIRE

4.1 Methodology

The questionnaire was developed in co-operation with members of the school bus safety research group and with the approval of school board transportation officials. The questions touched on all aspects of advance signalling. The goal of the exercise was to characterize advance signalling methods and assess bus drivers' perceptions of advance signals.

The objective of the questionnaire method was to obtain a sample comparing amber lights and hazard lights. This objective was achieved: half of the respondents used mainly hazard lights, while the other half used primarily flashing amber lights. Half of the drivers had used both systems at least once.

A total of 450 questionnaires were distributed to school boards in two regions. In the Eastern Townships, the region of the field survey, the response rate was very satisfactory, with 161 out of 250 questionnaires completed and returned. About 20 questionnaires came from the West Island of Montreal. A number of transportation companies (eight) were involved, the Eastern Townships School Board (31%) and Autobus de l'Estrie (22%) being the main respondents.

The frequencies for each question in the 181 questionnaires returned are described below. The percentages shown correspond to the proportion of bus drivers who responded to the question. The percentages that appear in Appendix G include missing data. Variables were cross-tabulated to identify significant associations. The chi-square test was used to estimate the probability of error of the statistical associations.

4.2 Results

4.2.1 Questionnaire Frequencies

The eight-light system was the main advance signalling device used by 48% of school bus drivers, while hazard lights were used regularly by 43%. Both systems were used in equal measure by 6% of the drivers and only 1% did not use any advance signals. Among the drivers who used one or the other advance signal, 84% did so always, regardless of the circumstances. The others did not use advance signals in very specific contexts, such as when no vehicles were on the horizon (9%). This rate remained very conservative in relation to the field observations. Other drivers said they did not bother to activate their advance signals when traffic was light. The lack of advance signals was no more common in urban areas than rural areas. Finally, some drivers did not signal in advance if there was a median in the road.

The advance signalling method varied from one driver to the next. Each one used his or her own frame of reference. The main deciding factor was the range of roadway variables observed. Sixty-three percent of the respondents activated an advance signal depending on location and circumstance. The two parameters mentioned were distance and length of advance signal. The appropriate distance was determined according to the situation by 63% of the bus drivers. One driver in five signalled in advance over a set distance, which ranged from 15 to 200 m. The length of the signal varied with the situation for 28% of the drivers. It was quite rare for an advance signal to be activated for a predetermined time. Other factors explain the reasons behind the type of advance signal chosen. A number of bus drivers wanted to be seen by motorists as early as possible (41%). The presence of heavy vehicles and fast-moving cars was also identified as a potential risk factor to be considered. One driver in four said he or she turned on the advance signal when heavy trucks or fast-moving motorists went by.

When asked whether advance signals encouraged people to pass the bus, the majority of the drivers (74%) said no. The others replied in equal proportions that this was always the case or that advance signals encouraged motorists to pass in specific circumstances.

In terms of motorists' understanding of advance signal lights, the bus drivers tended to be positive. Motorists had an average understanding according to 39% of the drivers, but 46% felt it was good or very good and only 14% believed that advance signals were poorly or very poorly understood.

Furthermore, 74% of the drivers had never observed a dangerous situation directly attributable to advance signals. Of those who said they had witnessed such dangers, half said they occurred an average of five or more times a week. A third of the time, danger was present once or twice a week.

The bus drivers may have had an opinion about an advance signalling method, but it was counted only insofar as they used that advance signal in practice. According to the survey, 45% of the drivers had used both systems at least once. The effectiveness of the two advance signals was compared on this basis. Eight-seven percent of the drivers seemed to prefer the amber lights over the hazard lights. The remaining drivers felt that the two systems were equivalent or that the hazard lights were better.

Another question was aimed at identifying perceived differences in safety between advance signals and their absence. No driver felt that it was safer not to use an advance signal. Almost all of the respondents felt that advance signals were necessary to ensure the safety of schoolchildren at a stop (97%).

The bus drivers were also asked what they thought about standardizing advance signalling devices. Their answer was unequivocal: 96% felt that standardization was necessary. Most of those who were in favour of uniformity opted for amber lights (73%). A smaller number (11%) preferred hazard lights, while 15% wanted a new, more powerful and more effective system. Suggestions in this regard included a combination of hazard and amber lights activated in parallel or one after the other, and other solutions such as strobe lights.

In addition to the advance signals, brake lights alert motorists that a bus is about to stop. Three questions looked at the circumstances surrounding braking and the impact that brake lights have. One-third of the bus drivers said they braked before activating the advance signal while 58% did so occasionally. However, these observations were contradicted by the field observations. Depending on the reason for braking, three out of four drivers tried to warn motorists that the bus was going to stop. They used the brake lights as an additional warning. Eighty-eight percent said that brake lights caused motorists to slow down, while the remainder believed that brake lights made motorists speed up or had another effect.

Using the right turning signal is another possible way to warn motorists, although only 5% of respondents used this technique on a regular basis. Another 14% used it sporadically.

The bus drivers were also asked about their strategy for monitoring pupils who had to get off the bus and cross the road. Although some appear to have misunderstood the question, the majority chose the right answer, which was to keep the door closed as long as all vehicles had not come to a stop. This safety practice was carried out systematically by 95% of the drivers. The remaining respondents said they did so when the situation dictated it.

The last topic addressed in the questionnaire was bus drivers' experience with illegal passing. A number of actual examples of dangerous or tragic pass-bys were provided by respondents. Without going into detail, the goal was to assess the scale of voluntary and involuntary pass-bys to determine to what extent these violations can be countered through preventive information. Intentional passing is difficult to prevent but violations resulting from ignorance can be targeted to improve the situation.

One-quarter of the respondents had never observed a pass-by on their routes, while the remainder had noticed a variable quantity. One-third of the drivers reported an average of less than one violation per day, while another third noted an average of one to three violations daily. Ten percent of the school bus operators surveyed said they witnessed more than three violations each workday. The frequency of pass-bys could be associated with the total number of stops made in traffic. The amount of traffic determines the level of exposure to the risk of passing. The classes of the mean number of stops per driver were normally distributed (10 to 100 stops per day).

With regard to whether the violations were deliberate or not, 20% of the drivers did not respond, which corresponds to the number of drivers who did not witness any violations. Of those who did answer, 59% felt that at least two-thirds of the violations were involuntary. Only 8% of the drivers thought that all pass-bys were intentional. In contrast, 23% said that all pass-bys were unintentional. Overall, 71% of the drivers felt that intentional pass-bys accounted for fewer than half the total number of violations.

In short, passing at stops would appear to be unintentional for the most part and not necessarily deliberate. Emphasis needs to be placed on the occurrence of violations by increasing motorists' awareness of their obligations regarding school buses and mobile signals.

4.2.2 Statistical Associations

The questionnaire parameters were cross-tabulated in pairs and a chi-square test was performed to come up with statistically significant associations.

A series of associations illustrated the differences between users of the eight-light system and those who used hazard lights. There was a marked preference for amber lights: 78% of drivers who used hazard lights believed that they were less effective than amber lights. All users of the eight-light system believed that an advance signal of any kind was safer than no advance signal at all. This proportion fell to 90% among those who used hazard lights. Furthermore, half of the bus drivers who used hazard lights observed more than one violation each work day, compared to 36% of those who used amber lights. Eight-five percent of drivers who used amber lights were in favour of standardizing the eight-light system. The majority of drivers who used hazard lights (57%) also opted for this solution, even though they were accustomed to another system.

The frequency of advance signal use was indicative of two attitudes. Nearly all of the bus drivers who always signalled in advance believed that advance signals were safer than no advance signals (98%). This proportion dropped to 81% among drivers who used advance signals only occasionally. Similarly, there were more respondents who felt that standardization was necessary among drivers who systematically signalled in advance (98%) than among those who did so only sporadically (88%).

The propensity of motorists to pass buses when they observed an advance signal was also looked at: 26% of the drivers noted this phenomenon while 74% did not. Drivers who noted a tendency among motorists to pass were more likely to note dangerous situations resulting from the advance signal (35% vs. 13%). As well, a greater proportion of the drivers who believed in this phenomenon felt that advance signals were somewhat or entirely misunderstood (23% vs. 9%). In contrast, drivers who did not associate advance signals with a tendency to pass were more likely to emphasize the increased safety gained from using some form of advance signalling as opposed to no advance signals (97% vs. 77%).

There were also differences in the perception of danger related to the advance signal. Two categories were identified: bus drivers who observed dangers and those who did not note any. Those who did observe such dangers were less likely to believe that advance signals were well or very well understood (26% vs. 53%). Drivers who had witnessed dangerous situations were less likely to believe that brake lights made motorists slow down (78% vs. 91%). Those who had noted dangerous situations observed more violations when their red lights were on. They were also more likely to observe more than one violation each day (58% vs. 35%). Finally, drivers who did not perceive any dangers related to advance signals were more likely to believe that all violations were unintentional (58% vs. 44%).

With regard to the deliberate or unintentional nature of violations, the better motorists understood advance signals, the fewer the number of intentional violations (Table 15). The median of intentional violations was equivalent to an “average” understanding. The more motorists drivers felt had a good or very good understanding of advance signals, the less likely they were to evaluate the motorists’ violations as intentional.

The deliberate character of violations was also associated with the frequency of pass-bys observed by the drivers (Table 16). The greater the number of violations on a route, the more they were deemed to be intentional. Drivers who observed an average of 1.5 to 3 pass-bys per day felt that at least one-third of the violations were intentional. In contrast, 83% of drivers who did not observe any infractions on their routes felt that all violations were unintentional. This discrepancy suggests that the more a bus driver was accustomed to a high level of pass-bys, the more he or she felt that they were intentional. This would also explain the belief that advance signals are misunderstood or not well understood. The two distributions are related to one another.

Table 15 Voluntary pass-bys by understanding of advance signal (school bus drivers' questionnaire)

% of Voluntary Pass-Bys	Understanding of Advance Signal					Overall Mean*
	very good	good	average	poor	very poor	
0%	39.1%	29.2%	19.2%	6.7%	0.0%	18.8%
1 to 25%	13.0%	22.9%	36.5%	40.0%	66.6%	35.8%
26 to 50%	8.7%	22.9%	17.3%	20.0%	0.0%	13.8%
51 to 75%	8.7%	4.2%	11.5%	13.3%	16.7%	10.9%
76 to 99%	26.1%	10.4%	1.9%	20.0%	0.0%	11.7%
100%	4.3%	10.4%	13.5%	0.0%	16.7%	9.0%
Total	100%	100%	100%	100%	100%	100%

* The overall mean is based on all the percentages in one percentage category.

Table 16 Voluntary pass-bys by pass-by frequency (school bus drivers' questionnaire)

% of Voluntary Pass-Bys	Number of Pass-bys per Day					Overall Mean*
	0	0.01 to 1	1.5 to 2	2.5 to 3	3.5 or +	
0%	82.8%	13.0%	9.1%	0.0%	0.0%	21.0%
1 to 25%	17.2%	32.6%	30.3%	36.4%	23.5%	28.0%
26 to 50%	0.0%	26.1%	18.1%	18.2%	17.6%	16.0%
51 to 75%	0.0%	6.5%	9.1%	9.1%	35.3%	12.0%
76 to 99%	0.0%	8.7%	18.2%	27.2%	11.8%	13.2%
100%	0.0%	13.1%	15.2%	9.1%	11.8%	9.8%
Total	100%	100%	100%	100%	100%	100%

* The overall mean is based on all the percentages in one percentage category.

5 DISCUSSION

In Quebec, it is rare that school buses travelling on the highway system do not signal in advance. There is no validated safety principle that advocates not doing so. Although warning signals are not always necessary in open country or quiet areas, it seems logical to use them in the presence of other vehicles. Vehicles travelling at high speed and reduced visibility are also determining factors requiring advance stop signals. The aim is to avoid abrupt stops.

The distance and length of advance signals are two aspects that can explain the effectiveness of the message sent to motorists. In the study, the average distance of an advance signal was 50 m. The MTQ recommends a distance of 150 m, which is the standard in New Brunswick. However, a constantly long advance signalling distance does not appear to suit some types of stops as well. Bus drivers mentioned that the length and distance of advance signals varied according to the circumstances. The presence of trucks, fast-moving vehicles, heavy traffic and different speed zones all played a role in the distances chosen by the drivers. An advance signal that is too short may not be clearly perceived, while one that is too long can be interpreted as a “green light” that motorists will not take seriously (Lehmann, 1998). A minimum advance signalling distance would require a distance chart in Quebec as two types of signals are used. Amber lights have twice the visibility distance of hazard lights (Thibault, 1998).

Some publications mention that hazard lights have an advantage over amber lights because they are placed at eye level. Although this is true in the rear for a vehicle following closely behind the bus, the data compiled support a theory in favour of the eight-light system for all road situations. A signal light placed higher up is necessarily visible farther away. At the front of the bus, hazard lights are more difficult to see because they are placed lower down, on the nose of the bus. The hypothesis that amber lights are more visible is supported by traffic variables. Motorists who followed closely behind another vehicle were singled out in the databases. In this situation, amber lights were 65% more effective than hazard lights in getting oncoming vehicles to slow down. Amber lights are preferable when a motorist’s view is blocked as the top of the bus almost always remains visible.

The stop arm has a specific role: to stop vehicles. Advance school bus signals, like all forms of road warning signals, also have a purpose, that of preparing motorists to stop by encouraging them to slow down. In road safety, there are very few published examples where speeding up is considered a positive factor. Deceleration in the face of danger is preferable by far and the advance warning of the eight-light system seems to have a greater impact in this regard. It is impossible to know whether motorists interpret amber lights as a message to stop, but the consequence is clear: amber lights cause more motorists to slow down than hazard lights.

Accordingly, amber lights fulfil the role of an advance signal better. Motorists who slow down are better prepared to stop, thereby avoiding sudden and dangerous reactions, which can also affect traffic flow. If the department of transport has to install advance signalling signs on highways for safety reasons, the need to get oncoming motorists to slow down for mobile stops is even more justified. Buses stop anywhere, not only at intersections.

In contrast, the tendency to accelerate after seeing an advance signal is a potential impact that we have to try to avoid. However, according to school bus drivers, impatient pass-bys are not generalized. The cases reported in this compilation do not support a conclusion in this regard. Amber lights are not associated with the acceleration phenomenon, but hazard lights do seem to play a role. This may be the result of the way in which hazard lights are interpreted; they can be associated with a slow-moving vehicle. Bus drivers who believed that advance signals encouraged motorists to pass were more likely to associate them with danger or a poor understanding on the part of motorists. Inversely, 75% of drivers dissociated advance signals from the tendency to accelerate. Of this number, many specified that advance signals were well understood and were not associated with dangerous situations.

The only study that has evaluated the eight-light system concluded that it did not decrease the risk of passing. However, the amber lights were evaluated in the context of the stop arm, which was the focus of the analysis. The stop arm and advance signal have specific, complementary functions and cannot be analysed in the same manner. The United States Department of Transportation (U.S. DOT) study was based on 429 violation reports that looked at three stopping scenarios (Hale et al., 1983):

- red lights only
- advance signal with amber lights, followed by red lights
- advance signal with amber lights, followed by red lights and stop arm

The study concluded that the third scenario (the only one where the stop arm was present) was the only one that demonstrated a decrease in passing violations. But how is it possible to evaluate the effect of amber lights by comparing them with the stop arm? There is no doubt that the stop arm is more effective; it is a measure known by everyone. Assessing the impact of amber lights would have required reversing the systems and keeping the stop arm constant. The advance signal should have been compared with a situation with no advance signal. Under these conditions, a stop arm used alone, without an advance signal or red lights, is associated with a high rate of passing violations. At least, that is what the results from this study suggest.

In this report, two “comparable” methods were tested. The red lights and stop arm were constant variables. There was a numerator and an exposure denominator, and roadway variables were broken down into as many relative risk ratios as there were nominal categories.

To neutralize the effects outside the observed conditions, the advance signalling methods were compared in a homogeneous population in accordance with the following school bus transportation variables:

- bus driver’s behaviour (braking, advance signalling distance and length)
- origin and destination of motorists
- posted and actual speeds
- number of lanes
- amount of traffic and group phenomena
- geometrical characteristics of the roadway (slope, curves)
- loading and unloading times (habituation effect among motorists)

There is no question that the stop arm was more effective. Quite the contrary; the analysis added an important nuance. Advance signals were preferred to no advance signal and the eight-light system appeared more effective than the hazard lights. At the front of the bus, amber lights were twice as effective as hazard lights overall in getting motorists to slow down and in preventing violations.

One of the reasons given to explain the number of illegal pass-bys is motorists' ignorance of the law. The school bus drivers' questionnaire gave us an opportunity to make some distinctions in the perception of advance signals and their effectiveness according to the context and the advance signalling system used by the bus driver. In light of the results derived from the cross-tabulation tables, the opinions proffered can be generalized in the following manner:

The effectiveness indexes give the eight-light system a degree of safety that bus drivers themselves recognize. Quebec bus drivers, who would opt for province-wide standardization, held the same opinion as U.S. drivers. In the United States, bus drivers preferred flashing amber lights after using them for a certain period (Hale et al., 1983).

Bus drivers who felt that there was a danger in using advance signals were more likely to:

- believe that advance signals were poorly or very poorly understood by motorists
- believe that brake lights had no effect on motorists
- believe that pass-bys were intentional and deliberate
- observe more than one stopping violation each school day

In contrast, 75% of drivers did not associate any dangers with advance signals and were more likely to:

- believe that advance signals were well or very well understood by motorists
- believe that brake lights made motorists slow down
- believe that pass-bys were unintentional
- observe less than one violation per day

These figures indicate that the danger level of school routes is an element that affects bus drivers' perceptions of advance signals. A dangerous location is always at risk, regardless of the type of advance signal used.

6 CONCLUSION

The field data, the experience gained while collecting observations and the recommendations of school transportation officials (school board transportation superintendents, transportation companies and school bus drivers) all confirm that advance signals are necessary to ensure the safety of school children and other users of the road.

Practical and theoretical investigations led us to conclude that the eight-light system is more effective than hazard lights. It reduced by half the number of illegal passes by oncoming motorists and made traffic in front of and behind buses slow down more. The amber lights also limited the tendency of vehicles behind buses to accelerate.

Placed on the roofline, amber lights have the advantage of being more visible in the majority of roadway situations. They are more visible at various distances and by more motorists, particularly in traffic. Motorists caught behind a bus, whose view was blocked in a line of vehicles, demonstrated better deceleration rates and were more likely to stop when they saw amber lights. The increased ratios illustrated that amber lights attracted motorists' attention, even in a difficult situation.

The perceptions of school bus drivers corroborated the overall conclusions of these observations. The vast majority of the bus drivers surveyed were persuaded that flashing amber lights were safer than hazard lights. They recognized the need to standardize advance signalling equipment in favour of flashing lights. They also felt that advance signals were fairly well understood by motorists, that they rarely led to passing and that few dangerous situations could be attributed to them. As for illegal pass-bys, potential for decreasing these incidents is significant since a large number of infractions were felt to be unintentional, according to the bus drivers' observations.

7 RECOMMENDATIONS

It would be interesting to extend this analysis across the country, comparing advance signals with red lights, the eight-light system and other systems, to try and determine which is the most effective and least dangerous for use on school buses.

Another possible avenue of study is assessing the impact of advance signals in the dark and in winter. These conditions are a significant part of the transportation experience throughout the school year.

Stopping violations are the main risk for pupils crossing the road. The extent of the phenomenon could be identified through an investigation involving school bus drivers. Stopping violation reports could be used to develop a better profile of violators (driving records and demographic aspects). Since most violations are unintentional, according to bus drivers, we need to try and estimate how much motorists understand and determine how they perceive advance signal lights and stop lights. In this way, concrete solutions (education and publicity) could be used to heighten motorists' awareness, improve understanding of warning and stop messages and instil permanent safe driving habits in reaction to a bus that is about to stop.

Accidents involving young schoolchildren crossing the road appear to be fairly rare, but little is known about rear-end collisions and other types of accidents that occur when vehicles brake suddenly. A risk or effectiveness index could be derived from an estimate of the total number of school bus stops in a given region.

Field studies aboard buses need to have an image recording system that ensures discretion at the rear of the bus. A larger number of very small cameras (10 cm) would be appropriate. The best system would consist of four cameras at strategic locations connected to a quad split device so images could be viewed simultaneously. The important areas to be covered, apart from the front and rear, are the driver's point of view (to observe the bus's speed and the driver's key actions continuously) and the side of the bus, with an angle that covers the advance signal, the red lights and the stop sign. A quad split would increase the amount of space inside the bus and double the cost effectiveness of scanning the videotapes. We also have to remember that it is absolutely necessary to base any estimated measurement on an exposure denominator. In the case of school bus transportation, the number of vehicles in a position to pass the bus is a good denominator.

The only real recommendation to come out of this report is that an advertising campaign is needed to inform motorists. The reasons for advance signals and the forms that they may take, to distinguish them from mandatory stops, have to be explained. However, it goes without saying that such a campaign can be conducted only once advance signalling equipment is standardized.

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APPENDIX A

Summary of Routes Inspected

Table A-1 Details of routes inspected on at least two occasions

Route	Period	Educational Level	Adv Signal Tested*	Km	Stops	Stops/ km	Stops with Vehicle	% Stops with Veh
117-10	AM	Elementary	A	18	23	1.3	13	56.5
117-10	AM	Elementary	A	18	25	1.4	15	60.0
117-10	AM	Elementary	A	18	24	1.3	13	54.2
117-10	AM	Elementary	H	18	25	1.4	15	60.0
117-10	AM	Elementary	H	18	23	1.3	14	60.9
117-10	AM	Elementary	H	18	26	1.4	16	61.5
117-10	AM	Elementary	H	18	23	1.3	16	69.6
117-10	AM	Elementary	H	18	21	1.2	14	66.7
117-10	AM	Elementary	H	18	22	1.2	15	68.2
117-10	AM	Elementary	A	18	23	1.3	15	65.2
117-10	AM	Elementary	A	18	24	1.3	15	62.5
117-10	AM	Elementary	A	18	22	1.2	14	63.6
117-10	AM	Elementary	A	18	23	1.3	14	60.9
			Mean		23.4	1.3	14.5	62.3
117-40	PM	Elementary	A	12	20	1.7	10	50.0
117-40	PM	Elementary	A	12	21	1.8	13	61.9
117-40	PM	Elementary	H	12	20	1.7	14	70.0
117-40	PM	Elementary	H	12	20	1.7	14	70.0
117-40	PM	Elementary	H	12	20	1.7	14	70.0
117-40	PM	Elementary	H	12	23	1.9	13	56.5
117-40	PM	Elementary	H	12	18	1.5	13	72.2
117-40	PM	Elementary	A	12	17	1.4	13	76.5
117-40	PM	Elementary	A	12	22	1.8	13	59.1
117-40	PM	Elementary	A	12	20	1.7	12	60.0
117-40	PM	Elementary	A	12	22	1.8	14	63.6
117-40	PM	Elementary	A	12	21	1.8	12	57.1
117-40	PM	Elementary	A	12	23	1.9	12	52.5
			Mean		20.9	1.7	13.0	62.8

* Advance signals tested: A = amber lights; H = hazard lights; none = no advance signal

(cont'd)

Route	Period	Educational Level	Adv Signal Tested*	Km	Stops	Stops/ km	Stops with Vehicle	% Stops with Veh
117-42	PM	High School	A	13	11	0.8	8	72.7
117-42	PM	High School	A	13	13	1.0	11	84.6
117-42	PM	High School	H	13	13	1.0	8	61.5
117-42	PM	High School	H	13	11	0.8	9	81.8
117-42	PM	High School	H	13	12	0.9	10	83.3
117-42	PM	High School	H	13	12	0.9	9	75.0
117-42	PM	High School	H	13	11	0.8	9	81.8
117-42	PM	High School	A	13	11	0.8	8	72.7
117-42	PM	High School	A	13	11	0.8	8	72.7
117-42	PM	High School	A	13	12	0.9	10	83.3
117-42	PM	High School	H	13	10	0.8	8	80.0
117-42	PM	High School	H	13	11	0.8	5	45.5
			Mean		11.5	0.9	8.6	74.6
90-10	AM	Elementary	H	20	22	1.1	21	95.5
90-10	AM	Elementary	H	20	21	1.1	21	100.0
90-10	AM	Elementary	A	20	21	1.1	19	90.5
90-10	AM	Elementary	A	20	19	1.0	17	89.5
90-10	AM	Elementary	A	20	21	1.1	18	85.7
90-10	AM	Elementary	none	20	23	1.2	21	91.3
90-10	AM	Elementary	none	20	24	1.2	11	45.8
			Mean		21.6	1.1	18.3	85.5
90-40	PM	Elementary	H	14.5	24	1.7	18	75.0
90-40	PM	Elementary	H	14.5	23	1.6	20	87.0
90-40	PM	Elementary	A	14.5	24	1.7	24	100.0
90-40	PM	Elementary	A	14.5	18	1.2	15	83.3
90-40	PM	Elementary	none	14.5	24	1.7	23	95.8
90-40	PM	Elementary	none	14.5	24	1.7	22	91.7
			Mean		22.8	1.6	20.3	88.8

* Advance signals tested: A = amber lights; H = hazard lights; none = no advance signal

(cont'd)

Route	Period	Educational Level	Adv Signal Tested*	Km	Stops	Stops/ km	Stops with Vehicle	% Stops with Veh
27-10	AM	Elementary	A	27	23	0.9	13	56.5
27-10	AM	Elementary	A	27	27	1.0	12	44.4
			Mean		25.0	0.9	12.5	50.5
27-11	AM	High School	A	23	16	0.7	12	75.0
27-11	AM	High School	A	23	17	0.7	10	58.8
			Mean		16.5	0.7	11.0	66.9
27-40	PM	Elementary	A	25	25	1.0	5	20.0
27-40	PM	Elementary	A	25	26	1.0	9	34.6
			Mean		25.5	1.0	7.0	27.3
27-42	PM	High School	A	23	14	0.6	8	57.1
27-42	PM	High School	A	23	16	0.7	7	43.8
			Mean		15.0	0.7	7.5	50.4
95-10	AM	High School	H	45	12	0.3	12	100.0
95-10	AM	High School	H	45	12	0.3	11	91.7
			Mean		12.0	0.3	11.5	95.8
95-40	PM	High School	H	42	11	0.3	11	100.0
95-40	PM	High School	H	42	10	0.2	10	100.0
			Mean		10.5	0.3	10.5	100.0

* Advance signals tested: A = amber lights; H = hazard lights; none = no advance signal

APPENDIX B

Data Collection Forms

Log Book **FRONT Observer** School Board: ______________________________

Bus #/Route:	__________/____________	Aspect of Bus:	__________________
Month/Day/Year:	______/_______/_________	Advance Signal:	__________________
Time of Day:	_______________________	Km/Stops:	_______/___________

Distances: - Advance signal
- Stop
- Vehicle stopped
- End of stop

Actions: - Advance signal
- Stop
- Crossing road

Km departure: _________

Km arrival: ____________

									Roads		Permission		Pass	
#	Speed Zone	Bus Speed	A	O A	Br	Hill	Curve	Visibility	Total	Highway	Yes	No	Stop	Road
1	______	______	o	o	o	______	______	______	______	______	o	o	o	______
2	______	______	o	o	o	______	______	______	______	______	o	o	o	______
3	______	______	o	o	o	______	______	______	______	______	o	o	o	______
4	______	______	o	o	o	______	______	______	______	______	o	o	o	______
5	______	______	o	o	o	______	______	______	______	______	o	o	o	______
6	______	______	o	o	o	______	______	______	______	______	o	o	o	______
7	______	______	o	o	o	______	______	______	______	______	o	o	o	______
8	______	______	o	o	o	______	______	______	______	______	o	o	o	______
9	______	______	o	o	o	______	______	______	______	______	o	o	o	______
10	______	______	o	o	o	______	______	______	______	______	o	o	o	______
11	______	______	o	o	o	______	______	______	______	______	o	o	o	______
12	______	______	o	o	o	______	______	______	______	______	o	o	o	______
13	______	______	o	o	o	______	______	______	______	______	o	o	o	______
14	______	______	o	o	o	______	______	______	______	______	o	o	o	______
15	______	______	o	o	o	______	______	______	______	______	o	o	o	______
16	______	______	o	o	o	______	______	______	______	______	o	o	o	______
17	______	______	o	o	o	______	______	______	______	______	o	o	o	______
18	______	______	o	o	o	______	______	______	______	______	o	o	o	______
19	______	______	o	o	o	______	______	______	______	______	o	o	o	______
20	______	______	o	o	o	______	______	______	______	______	o	o	o	______
21	______	______	o	o	o	______	______	______	______	______	o	o	o	______
22	______	______	o	o	o	______	______	______	______	______	o	o	o	______
23	______	______	o	o	o	______	______	______	______	______	o	o	o	______
24	______	______	o	o	o	______	______	______	______	______	o	o	o	______
25	______	______	o	o	o	______	______	______	______	______	o	o	o	______
26	______	______	o	o	o	______	______	______	______	______	o	o	o	______
27	______	______	o	o	o	______	______	______	______	______	o	o	o	______
28	______	______	o	o	o	______	______	______	______	______	o	o	o	______
29	______	______	o	o	o	______	______	______	______	______	o	o	o	______

Modified 04-30-1998 by J.-F. Bruneau

Unique Sequential Number:	**BEFORE ADVANCE SIGNAL**
Bus #:	Oncoming vehicles: yes o no o
Route #:	Bus: speed (sTA): km/h
Stop #:	Bus: constant speed o let up accel. o braked o
Aspect:	**DISTANCES (m)** 1 2 3 4 5 6 7
Month/Day: /	No. veh. A-S TA | | | | | |
Day of Week: Mo o Tu o We o Th o Fr o	_______ TB | | | | | |
Time of Day: AM o PM o	No. veh. Stop TC | | | | | |
Advance Signal: EL o HL o None o	_______ TD | | | | | |
Weather: clear o cloudy o rain o snow o	**ADVANCE SIGNALS (TA-TB) - ACTIONS**
mist/fog o	Vehicle(s): 1 2 3 4 5 6 7
Road Surface: dry o wet o snowy o icy o	1) Slowed down o o o o o o o
Municipality:	Maintained speed o o o o o o o
Road/Street Name:	Accelerated o o o o o o o
Road #:	2) Slowed down o o o o o o o
Amount of Traffic:	Maintained speed o o o o o o o
Location: rural o near-urban o urban o	Accelerated o o o o o o o
Envir: resid o comm o indust o	Stopped: secs: o o o o o o o
Speed: 50 o 60 o 70 o 80 o 90 o	Passed: secs: o o o o o o o
Total Lanes: 1 o 2 o 3 o 4 o 5 o 6 o	Length of advance signal: sec.
Bus Lanes: 1 o 2 o 3 o	**STOP (TC-TD) - ACTIONS**
Median: yes o no o	Vehicle(s): 1 2 3 4 5 6 7
Visibility distance: _______________ m	Slowed down o o o o o o o
Grade: none o slight o medium o steep o	Maintained speed o o o o o o o
bus climbing o bus descending o	Accelerated o o o o o o o
vehicle climbing o vehicle descending o	Stopped: sec.: o o o o o o o
Curve: no o moderate o pronounced o	Passed: sec.: o o o o o o o
Comments:	Length of stop: sec.
	Pupil(s) crossed road o number _____________
	Distance of advance signal: ___________ m

Modified 04-30-1998 by J.-F. Bruneau

Advance Signal Study **REAR Observer** Time: ______ :______ :______

Unique Sequential Number:	**BEFORE ADVANCE SIGNAL**							
Bus #:	Passing allowed: yes o no o							
Route #:	Vehicle passed o							
Stop #:		1	2	3	4	5	6	7
Aspect:	Speed vehicle < bus	o	o	o	o	o	o	o
Month/Day: /	= bus	o	o	o	o	o	o	o
Day of Week: Mo o Tu o We o Th o Fr o	> bus	o	o	o	o	o	o	o
Time of Day: AM o PM o	**DISTANCES (m)**	1	2	3	4	5	6	7
Advance Signal: EL o HL o None o	No. veh. A-S TA							
Weather: clear o cloudy o rain o snow o	_______ TB							
mist/fog o	No. veh. Stop TC							
Road Surface: dry o wet o snowy o icy o	_______ TD							
Municipality:	**ADVANCE SIGNAL (TA-TB) - ACTIONS**							
Road/Street Name:	Vehicle(s):	1	2	3	4	5	6	7
Road #:	1) Slowed down	o	o	o	o	o	o	o
Amount of Traffic:	Maintained speed	o	o	o	o	o	o	o
Location: Rural o Near-Urban o Urban o	Accelerated	o	o	o	o	o	o	o
Envir: Resid o Comm o Indust o	2) Slowed down	o	o	o	o	o	o	o
Speed: 50 o 60 o 70 o 80 o 90 o	Maintained speed	o	o	o	o	o	o	o
Total lanes: 1 o 2 o 3 o 4 o 5 o 6 o	Accelerated	o	o	o	o	o	o	o
Bus lanes: 1 o 2 o 3 o	Stopped: secs:	o	o	o	o	o	o	o
Median: yes o no o	Passed: secs:	o	o	o	o	o	o	o
Visibility distance: ________________ m	Length of advance signal: sec.							
Grade: none o slight o medium o steep o	**STOP (TC-TD) - ACTIONS**							
bus climbing o bus descending o	Vehicle(s):	1	2	3	4	5	6	7
vehicle climbing o vehicle descending o	Slowed down	o	o	o	o	o	o	o
Curve: no o moderate o pronounced o	Maintained speed	o	o	o	o	o	o	o
Comments:	Accelerated	o	o	o	o	o	o	o
	Stopped: sec.:	o	o	o	o	o	o	o
	Passed: sec.:	o	o	o	o	o	o	o
	Length of stop: sec.							

Modified 04-30-1998 by J.-F. Bruneau

APPENDIX C

Bus Stops by Advance Signal

Table C-1 Stops by day of week of observation

	Amber Lights		Hazard Lights		Total	
	Stops	**%**	**Stops**	**%**	**Stops**	**%**
Monday	31	6.7	44	11.1	75	8.8
Tuesday	123	26.7	78	19.7	201	23.5
Wednesday	89	19.3	102	25.8	191	22.3
Thursday	165	35.8	119	30.1	284	33.2
Friday	53	11.5	52	13.2	105	12.3
Total	461	100.0	395	100.0	856	100.0

Table C-2 Stops by time of day of observation

	Amber Lights		Hazard Lights		Total	
	Stops	**%**	**Stops**	**%**	**Stops**	**%**
AM	243	52.7	187	47.3	430	50.2
PM	218	47.3	208	52.7	426	49.8
Total	461	100.0	395	100.0	856	100.0

Table C-3 Stops by weather conditions

	Amber Lights		Hazard Lights		Total	
	Stops	**%**	**Stops**	**%**	**Stops**	**%**
Clear	387	83.9	264	66.8	651	76.1
Cloudy	32	6.9	35	8.9	67	7.8
Rain/Drizzle	42	9.1	96	24.3	138	16.1
Total	461	100.0	395	100.0	856	100.0

Table C-4 Stops by environment

	Amber Lights		Hazard Lights		Total	
	Stops	**%**	**Stops**	**%**	**Stops**	**%**
Residential	431	93.5	356	90.1	787	91.9
Commercial	30	6.5	39	9.9	69	8.1
Total	461	100.0	395	100.0	856	100.0

Table C-5 Stops by location

	Amber Lights		Hazard Lights		Total	
	Stops	%	Stops	%	Stops	%
Rural	329	71.4	269	68.1	598	69.9
Near-urban	103	22.3	109	27.6	212	24.8
Urban	29	6.3	17	4.3	46	5.4
Total	461	100.0	395	100.0	856	100.0

Table C-6 Stops by posted speed

	Amber Lights		Hazard Lights		Total	
	Stops	%	Stops	%	Stops	%
50 km/h	62	13.4	58	14.7	120	14.0
70 km/h	69	15.0	57	14.4	126	14.7
80 km /h	206	44.7	180	45.6	386	45.1
90 km/h	124	26.9	100	25.3	224	26.2
Total	461	100.0	395	100.0	856	100.0

Table C-7 Stops by number of lanes in same direction as bus

	Amber Lights		Hazard Lights		Total	
	Stops	%	Stops	%	Stops	%
1 lane	258	56.0	190	48.1	448	52.3
2 lanes	190	41.2	193	48.9	383	44.7
3 lanes	13	2.8	12	3.0	25	2.9
Total	461	100.0	395	100.0	856	100.0

Table C-8 Stops by number of lanes approaching bus

	Amber Lights		Hazard Lights		Total	
	Stops	%	Stops	%	Stops	%
1 lane	267	57.9	201	50.9	468	54.7
2 lanes	194	42.1	194	49.1	388	45.3
Total	461	100.0	395	100.0	856	100.0

Table C-9 Stops by grade of roadway

	Amber Lights		Hazard Lights		Total	
	Stops	%	Stops	%	Stops	%
None	110	23.9	105	26.6	215	25.1
Slight (1-3%)	285	61.8	240	60.8	525	61.3
Medium (4-6%)	55	11.9	49	12.4	104	12.1
Steep (7% or more)	11	2.4	1	0.3	12	1.4
Total	461	100.0	395	100.0	856	100.0

Table C-10 Stops by slope approaching bus

	Amber Lights		Hazard Lights		Total	
	Stops	%	Stops	%	Stops	%
Flat	110	23.9	105	26.6	215	25.1
Bus climbing	182	39.5	156	39.5	338	39.5
Bus descending	169	36.7	134	33.9	303	35.4
Total	461	100.0	395	100.0	856	100.0

Table C-11 Stops by geometry of roadway

	Amber Lights		Hazard Lights		Total	
	Stops	%	Stops	%	Stops	%
Straight	327	70.9	296	74.9	623	72.8
Slight curve	97	21.0	89	22.5	186	21.7
Pronounced curve	37	8.0	10	2.5	47	5.5
Total	461	100.0	395	100.0	856	100.0

Table C-12 Stops by number of pupils crossing road

	Amber Lights		Hazard Lights		Total	
	Stops	%	Stops	%	Stops	%
0 pupils	391	84.8	333	84.3	724	84.6
1 pupil	35	7.6	23	5.8	58	6.8
2 pupils	29	6.3	31	7.8	60	7.0
3 pupils	3	0.7	6	1.5	9	1.1
4 or more pupils	3	0.7	2	0.5	5	0.6
Total	461	100.0	395	100.0	856	100.0

APPENDIX D

Oncoming Motorists

Table D-1 Oncoming motorists by day of week of observation

	Amber Lights		Hazard Lights		Total	
	Vehicles	%	Vehicles	%	Vehicles	%
Monday	32	4.6	71	9.1	103	7.0
Tuesday	189	27.3	141	18.1	330	22.4
Wednesday	201	29.0	169	21.7	370	25.2
Thursday	215	31.1	252	32.3	467	31.7
Friday	55	7.9	146	18.7	201	13.7
Total	692	100.0	779	100.0	1,471	100.0

Table D-2 Oncoming motorists by time of day of observation

	Amber Lights		Hazard Lights		Total	
	Vehicles	%	Vehicles	%	Vehicles	%
AM	315	45.5	327	42.0	642	43.6
PM	377	54.5	452	58.0	829	56.4
Total	692	100.0	779	100.0	1,471	100.0

Table D-3 Oncoming motorists by weather conditions

	Amber Lights		Hazard Lights		Total	
	Vehicles	%	Vehicles	%	Vehicles	%
Clear	594	85.8	481	61.7	1,075	73.1
Cloudy	45	6.5	99	12.7	144	9.8
Rain/mist	53	7.7	199	25.5	252	17.1
Total	692	100.0	779	100.0	1,471	100.0

Table D-4 Oncoming motorists by location

	Amber Lights		Hazard Lights		Total	
	Vehicles	%	Vehicles	%	Vehicles	%
Rural	481	69.5	464	59.6	945	64.2
Near-urban	189	27.3	286	36.7	475	32.3
Urban	22	3.2	29	3.7	51	3.5
Total	692	100.0	779	100.0	1,471	100.0

Table D-5 Oncoming motorists by environment

	Amber Lights		Hazard Lights		Total	
	Vehicles	**%**	**Vehicles**	**%**	**Vehicles**	**%**
Residential	625	90.3	671	86.1	1,296	88.1
Commercial	67	9.7	108	13.9	175	11.9
Total	692	100.0	779	100.0	1,471	100.0

Table D-6 Oncoming motorists by posted speed

	Amber Lights		Hazard Lights		Total	
	Vehicles	**%**	**Vehicles**	**%**	**Vehicles**	**%**
50 km/h	57	8.2	91	11.7	148	10.1
70 km/h	81	11.7	117	15.0	198	13.5
80 km /h	409	59.1	431	55.3	840	57.1
90 km/h	145	21.0	140	18.0	285	19.4
Total	692	100.0	779	100.0	1,471	100.0

Table D-7 Oncoming motorists by number of lanes approaching bus

	Amber Lights		Hazard Lights		Total	
	Vehicles	**%**	**Vehicles**	**%**	**Vehicles**	**%**
1 lane	279	40.3	275	35.3	554	37.7
2 lanes	413	59.7	504	64.7	917	62.3
Total	692	100.0	779	100.0	1,471	100.0

Table D-8 Oncoming motorists by visibility at start of advance signal

	Amber Lights		Hazard Lights		Total	
	Vehicles	**%**	**Vehicles**	**%**	**Vehicles**	**%**
0-90 m	115	16.6	91	11.7	206	14.0
100-175 m	243	35.1	282	36.2	525	35.7
200 m or more	334	48.3	406	52.1	740	50.3
Total	692	100.0	779	100.0	1,471	100.0

Table D-9 Oncoming motorists by grade of roadway

	Amber Lights		Hazard Lights		Total	
	Vehicles	%	Vehicles	%	Vehicles	%
None	148	21.4	162	20.8	310	21.1
Slight (1-3%)	459	66.3	509	65.3	968	65.8
Medium (4-6%)	77	11.1	108	13.9	185	12.6
Steep (7% or more)	8	1.2	0	0.0	8	0.5
Total	692	100.0	779	100.0	1,471	100.0

Table D-10 Oncoming motorists by slope of roadway facing vehicle

	Amber Lights		Hazard Lights		Total	
	Vehicles	%	Vehicles	%	Vehicles	%
Flat	148	21.4	162	20.8	310	21.1
Vehicle climbing	285	41.2	337	43.3	622	42.3
Vehicle descending	259	37.4	280	35.9	539	36.6
Total	692	100.0	779	100.0	1,471	100.0

Table D-11 Oncoming motorists by geometry of roadway

	Amber Lights		Hazard Lights		Total	
	Vehicles	%	Vehicles	%	Vehicles	%
Straight	472	68.4	558	71.6	1,031	70.1
Slight curve	180	26.0	196	25.2	376	25.6
Pronounced curve	39	5.6	25	3.2	64	4.4
Total	692	100.0	779	100.0	1,471	100.0

Table D-12 Oncoming motorists by number of vehicles at stopping stage

	Amber Lights		Hazard Lights		Total	
	Vehicles	%	Vehicles	%	Vehicles	%
0 vehicles	82	11.8	92	11.8	174	11.8
1 vehicle	373	53.9	397	51.0	770	52.3
2 vehicles	205	29.6	223	28.6	428	29.1
3 vehicles	24	3.5	39	5.0	63	4.3
4 or more vehicles	8	1.2	28	3.6	36	2.4
Total	692	100.0	779	100.0	1,471	100.0

Table D-13 Oncoming motorists by amount of traffic during advance signal

	Amber Lights		Hazard Lights		Total	
	Vehicles	%	Vehicles	%	Vehicles	%
1 vehicle	139	20.1	106	13.6	245	16.7
2 vehicles	211	30.5	192	24.6	403	27.4
3 vehicles	140	20.2	99	12.7	239	16.2
4 vehicles	78	11.3	104	13.4	182	12.4
5 vehicles	69	10.0	60	7.7	129	8.8
6 vehicles	19	2.7	85	10.9	104	7.1
7 vehicles	21	3.0	49	6.3	70	4.8
8 or more vehicles	15	2.2	83	10.7	98	6.7
Total	692	100.0	779	100.0	1,471	100.0

Table D-14 Oncoming motorists by total traffic

	Amber Lights		Hazard Lights		Total	
	Vehicles	%	Vehicles	%	Vehicles	%
1 vehicle	76	11.0	65	8.3	141	9.6
2 vehicles	140	20.2	115	14.8	255	17.3
3 vehicles	157	22.7	110	14.1	267	18.2
4 vehicles	95	13.7	100	12.8	195	13.3
5 vehicles	85	12.3	60	7.7	145	9.9
6 vehicles	31	4.5	96	12.3	127	8.6
7 vehicles	44	6.4	68	8.7	112	7.6
8 or more vehicles	64	9.2	165	21.2	229	15.6
Total	692	100.0	779	100.0	1,471	100.0

Table D-15 Oncoming motorists by number of pupils crossing road

	Amber Lights		Hazard Lights		Total	
	Vehicles	%	Vehicles	%	Vehicles	%
0 pupils	576	83.2	622	79.8	1 198	81.4
1 pupil	58	8.4	66	8.5	124	8.4
2 pupils	46	6.6	70	9.0	116	7.9
3 pupils	9	1.3	17	2.2	26	1.8
4 or more pupils	3	0.4	4	0.5	7	0.5
Total	692	100.0	779	100.0	1,471	100.0

Table D-16 Oncoming motorists by educational level of pupils

	Amber Lights		Hazard Lights		Total	
	Vehicles	%	Vehicles	%	Vehicles	%
Elementary	526	76.0	500	64.2	1,026	69.7
High school	166	24.0	279	35.8	445	30.3
Total	692	100.0	779	100.0	1,471	100.0

Table D-17 Oncoming motorists by distance between two stops

	Amber Lights		Hazard Lights		Total	
	Vehicles	%	Vehicles	%	Vehicles	%
Normal stop	492	71.1	581	74.6	1,073	72.9
Close stop	200	28.9	198	25.4	398	27.1
Total	692	100.0	779	100.0	1,471	100.0

Table D-18 Oncoming motorists by presence of police monitoring

	Amber Lights		Hazard Lights		Total	
	Vehicles	%	Vehicles	%	Vehicles	%
No monitoring	622	89.9	753	96.7	1,375	93.5
Monitoring	70	10.1	26	3.3	96	6.5
Total	692	100.0	779	100.0	1,471	100.0

Table D-19 Oncoming motorists by vehicle type

	Amber Lights		Hazard Lights		Total	
	Vehicles	%	Vehicles	%	Vehicles	%
Automobile	645	93.2	712	91.4	1,357	92.3
Truck	43	6.2	59	7.6	102	6.9
Motorcycle	4	0.6	8	1.0	12	0.8
Total	692	100.0	779	100.0	1,471	100.0

Table D-20 Oncoming motorists by vehicle position at advance signal

	Amber Lights		Hazard Lights		Total	
	Vehicles	%	Vehicles	%	Vehicles	%
First motorist	514	74.3	498	63.9	1,012	68.8
After first motorist	178	25.7	281	36.1	459	31.2
Total	692	100.0	779	100.0	1,471	100.0

Table D-21 Oncoming motorists by their distance at beginning of advance signal

	Amber Lights		Hazard Lights		Total	
	Vehicles	**%**	**Vehicles**	**%**	**Vehicles**	**%**
0-45 m	131	18.9	148	19.0	279	19.0
50-95 m	249	36.0	234	30.0	483	32.8
100-195 m	238	34.4	296	38.0	534	36.3
200 m or more	74	10.7	101	13.0	175	11.9
Total	692	100.0	779	100.0	1,471	100.0

Table D-22 Oncoming motorists by their distance at beginning of stop

	Amber Lights		Hazard Lights		Total	
	Vehicles	**%**	**Vehicles**	**%**	**Vehicles**	**%**
0-19 m	81	25.0	42	16.5	123	21.3
20-39 m	84	25.9	70	27.6	154	26.6
40-59 m	70	21.6	53	20.9	123	21.3
60-79 m	39	12.0	48	18.9	87	15.1
80 m or more	50	15.4	41	16.1	91	15.7
Total	324	100.0	254	100.0	578	100.0

Table D-23 Oncoming motorists by exposure to advance signal

	Amber Lights		Hazard Lights		Total	
	Vehicles	**%**	**Vehicles**	**%**	**Vehicles**	**%**
0-4 s	23	3.3	35	4.5	58	3.9
5-9 s	268	38.7	256	32.9	524	35.6
10-14 s	333	48.1	380	48.8	713	48.5
15 s or more	67	9.7	104	13.4	171	11.6
Unknown	1	0.1	4	0.5	5	0.3
Total	692	100.0	779	100.0	1,471	100.0

APPENDIX E

Motorists Travelling in the Same Direction
Multi-Lane Roads

Table E-1 Motorists from behind by day of week of observation

	Amber Lights		Hazard Lights		Total	
	Vehicles	**%**	**Vehicles**	**%**	**Vehicles**	**%**
Monday	1	0.4	18	6.5	19	3.5
Tuesday	76	29.0	65	23.3	141	26.1
Wednesday	92	35.1	49	17.6	141	26.1
Thursday	78	29.8	85	30.5	163	30.1
Friday	15	5.7	62	22.2	77	14.2
Total	262	100.0	279	100.0	541	100.0

Table E-2 Motorists from behind by time of day of observation

	Amber Lights		Hazard Lights		Total	
	Vehicles	**%**	**Vehicles**	**%**	**Vehicles**	**%**
AM	125	47.7	126	45.2	251	46.4
PM	137	52.3	153	54.8	290	53.6
Total	262	100.0	279	100.0	541	100.0

Table E-3 Motorists from behind by weather conditions

	Amber Lights		Hazard Lights		Total	
	Vehicles	**%**	**Vehicles**	**%**	**Vehicles**	**%**
Clear	215	82.1	161	57.7	376	69.5
Cloudy	15	5.7	36	12.9	51	9.4
Rain/mist	32	12.2	82	29.4	114	21.1
Total	262	100.0	279	100.0	541	100.0

Table E-4 Motorists from behind by location

	Amber Lights		Hazard Lights		Total	
	Vehicles	**%**	**Vehicles**	**%**	**Vehicles**	**%**
Rural	192	73.3	197	70.6	389	71.9
Near-urban	70	26.7	82	29.4	152	28.1
Total	262	100.0	279	100.0	541	100.0

Table E-5 Motorists from behind by environment

	Amber Lights		Hazard Lights		Total	
	Vehicles	%	Vehicles	%	Vehicles	%
Residential	238	90.8	255	91.4	493	91.1
Commercial	24	9.2	24	8.6	48	8.9
Total	262	100.0	279	100.0	541	100.0

Table E-6 Motorists from behind by posted speed

	Amber Lights		Hazard Lights		Total	
	Vehicles	%	Vehicles	%	Vehicles	%
70-80 km/h	232	88.5	240	86.0	472	87.2
90 km/h	24	9.2	32	11.5	56	10.4
Total	256	100.0	272	100.0	528	100.0

Table E-7 Motorists from behind by visibility at start of advance signal

	Amber Lights		Hazard Lights		Total	
	Vehicles	%	Vehicles	%	Vehicles	%
0-90 m	28	10.7	22	7.9	50	9.2
100-175 m	81	30.9	110	39.4	191	35.3
200 m or more	153	58.4	147	52.7	300	55.5
Total	262	100.0	279	100.0	541	100.0

Table E-8 Motorists from behind by grade of roadway

	Amber Lights		Hazard Lights		Total	
	Vehicles	%	Vehicles	%	Vehicles	%
None	27	10.3	35	12.5	62	11.5
Slight (1-3%)	217	82.8	227	81.4	444	82.1
Average (4-6%)	18	6.9	17	6.1	35	6.5
Total	262	100.0	279	100.0	541	100.0

Table E-9 Motorists from behind by slope facing vehicle

	Amber Lights		Hazard Lights		Total	
	Vehicles	%	Vehicles	%	Vehicles	%
Flat	27	10.3	35	12.5	62	11.5
Vehicle climbing	158	60.3	164	58.8	322	59.5
Vehicle descending	77	29.4	80	28.7	157	29.0
Total	262	100.0	279	100.0	541	100.0

Table E-10 Motorists from behind by geometry of roadway

	Amber Lights		Hazard Lights		Total	
	Vehicles	%	Vehicles	%	Vehicles	%
Straight	196	74.8	199	71.3	395	73.0
Slight curve	47	17.9	61	21.9	108	20.0
Pronounced curve	19	7.3	19	6.8	38	7.0
Total	262	100.0	279	100.0	541	100.0

Table E-11 Motorists from behind by total traffic

	Amber Lights		Hazard Lights		Total	
	Vehicles	%	Vehicles	%	Vehicles	%
1 vehicle	11	4.2	11	3.9	22	4.1
2 vehicles	17	6.5	37	13.3	54	10.0
3 vehicles	39	14.9	66	23.7	105	19.4
4 vehicles	52	19.8	49	17.6	101	18.7
5 vehicles	58	22.1	47	16.8	105	19.4
6 vehicles	16	6.1	24	8.6	40	7.4
7 vehicles	20	7.6	13	4.7	33	6.1
8 or more vehicles	49	18.7	32	11.5	81	15.0
Total	262	100.0	279	100.0	541	100.0

Table E-12 Motorists from behind by bus driver’s deceleration before advance signal

	Amber Lights		Hazard Lights		Total	
	Vehicles	%	Vehicles	%	Vehicles	%
Accelerated	111	42.4	112	40.1	223	41.2
Let up on accelerator	148	56.5	153	54.8	301	55.6
Braked	3	1.1	14	5.0	17	3.1
Total	262	100.0	279	100.0	541	100.0

Table E-13 Motorists from behind by traffic during advance signal

	Amber Lights		Hazard Lights		Total	
	Vehicles	**%**	**Vehicles**	**%**	**Vehicles**	**%**
1 vehicle	112	42.7	104	37.3	216	39.9
2 vehicles	110	42.0	98	35.1	208	38.4
3 vehicles	36	13.7	46	16.5	82	15.2
4 or more vehicles	4	1.5	31	11.1	35	6.5
Total	262	100.0	279	100.0	541	100.0

Table E-14 Motorists from behind by traffic in the stopping stage

	Amber Lights		Hazard Lights		Total	
	Vehicles	**%**	**Vehicles**	**%**	**Vehicles**	**%**
1 vehicle	231	88.2	214	76.7	445	82.3
2 vehicles	31	11.8	59	21.1	90	16.6
3 or more vehicles	0	0.0	6	2.2	6	1.1
Total	262	100.0	279	100.0	541	100.0

Table E-15 Motorists from behind by number of pupils crossing road

	Amber Lights		Hazard Lights		Total	
	Vehicles	**%**	**Vehicles**	**%**	**Vehicles**	**%**
0 pupils	243	92.7	250	89.6	493	91.1
1 pupil	4	1.5	13	4.7	17	3.1
2 pupils	12	4.6	15	5.4	27	5.0
3 or more pupils	3	1.1	1	0.4	4	0.7
Total	262	100.0	279	100.0	541	100.0

Table E-16 Motorists from behind by educational level of pupils

	Amber Lights		Hazard Lights		Total	
	Vehicles	**%**	**Vehicles**	**%**	**Vehicles**	**%**
Elementary	222	84.7	210	75.3	432	79.9
High school	40	15.3	69	24.7	109	20.1
Total	262	100.0	279	100.0	541	100.0

Table E-17 Motorists from behind by distance between two stops

	Amber Lights		Hazard Lights		Total	
	Vehicles	%	Vehicles	%	Vehicles	%
Normal stop	124	47.3	134	48.0	258	47.7
Close stop	138	52.7	145	52.0	283	52.3
Total	262	100.0	279	100.0	541	100.0

Table E-18 Motorists from behind by presence of police monitoring

	Amber Lights		Hazard Lights		Total	
	Vehicles	%	Vehicles	%	Vehicles	%
No monitoring	238	90.8	274	98.2	512	94.6
Monitoring	24	9.2	5	1.8	29	5.4
Total	262	100.0	279	100.0	541	100.0

Table E-19 Motorists from behind by vehicle type

	Amber Lights		Hazard Lights		Total	
	Vehicles	%	Vehicles	%	Vehicles	%
Automobile	228	87.0	254	91.0	482	89.1
Truck	32	12.2	23	8.2	55	10.2
Motorcycle	2	0.8	2	0.7	4	0.7
Total	262	100.0	279	100.0	541	100.0

Table E-20 Motorists from behind by vehicle position at advance signal

	Amber Lights		Hazard Lights		Total	
	Vehicles	%	Vehicles	%	Vehicles	%
First motorist	210	80.2	214	76.7	424	78.4
After first motorist	52	19.8	65	23.3	117	21.6
Total	262	100.0	279	100.0	541	100.0

Table E-21 Motorists from behind by their distance at beginning of advance signal

	Amber Lights		Hazard Lights		Total	
	Vehicles	%	Vehicles	%	Vehicles	%
0-19 m	46	17.6	54	19.4	100	18.5
20-39 m	81	30.9	90	32.3	171	31.6
40-59 m	43	16.4	37	13.3	80	14.8
60 m or more	92	35.1	98	35.1	190	35.1
Total	262	100.0	279	100.0	541	100.0

Table E-22 Motorists from behind by their distance at beginning of stop

	Amber Lights		Hazard Lights		Total	
	Vehicles	%	Vehicles	%	Vehicles	%
0-4 m	37	14.1	43	15.4	80	14.8
5-14 m	49	18.7	44	15.8	93	17.2
15-24 m	40	15.3	36	12.9	76	14.0
25 m or more	62	23.7	62	22.2	124	22.9
Total	188	100.0	185	100.0	373	100.0

Table E-23 Motorists from behind by exposure to advance signal

	Amber Lights		Hazard Lights		Total	
	Vehicles	%	Vehicles	%	Vehicles	%
0-4 s	8	3.1	16	5.7	24	4.4
5-9 s	123	46.9	98	35.1	221	40.9
10-14 s	115	43.9	142	50.9	257	47.5
15 s or more	16	6.1	23	8.2	39	7.2
Total	262	100.0	279	100.0	541	100.0

Table E-24 Motorists from behind by relative vehicle speed

	Amber Lights		Hazard Lights		Total	
	Vehicles	%	Vehicles	%	Vehicles	%
Speed < bus	8	3.1	6	2.2	14	2.6
Speed = bus	50	19.1	82	29.4	132	24.4
Speed > bus	204	77.9	191	68.5	395	73.0
Total	262	100.0	279	100.0	541	100.0

APPENDIX F

Deviations in the Distribution of Sampling Parameters

Table F-1 Deviations in distribution for all sampling parameters*

Parameters	Databases		
	Stops	**Oncoming Motorists**	**Motorists in Same Direction**
Day of week	0.004	0.0001	0.0001
Time of day	-	-	-
Weather	0.0001	0.0001	0.0001
Location	-	0.0001	-
Environment	-	0.01	-
Posted speed	-	-	-
Lanes of traffic	-	-	-
Visibility distance	x	0.02	-
Degree of grade	-	0.01	-
Bus climbing	-	-	-
Vehicle climbing	x	-	-
Curve	0.002	-	-
Bus distance at advance signal	-	-	-
Driver's braking and acceleration at advance signal	-	x	0.03
Total traffic	x	-	0.03
Amount of traffic at advance signal	x	-	-
Amount of traffic at stop	x	-	-
Distance of vehicle at advance signal	x	-	-
Distance of vehicle at stop	x	0.0001	-
Relative speed of vehicle	x	x	0.02
Time exposed to advance signal	x	0.03	0.03
Distance of advance signal	-	-	-
Imitation behaviour (potential)	x	0.0001	-
Close stop	-	-	-
Vehicle type	x	-	-
Presence of police monitoring	0.0001	0.0001	0.001
Pupil crossing road	-	-	-
Educational level of pupils	x	0.0001	0.006

* Significant deviations between amber lights and hazard lights ($p \leq 5\%$) are indicated; an x means that there was no distribution.

APPENDIX G

Vehicle Distance at Stop by Distance from Advance Signal

Oncoming Motorists

Table G-1 Distance at stop – vehicles 15-45 m away at advance signal (oncoming)

Distance at Start of Advance Signal: TA = 15 to 45 m						
Distance	**Amber Lights**		**Hazard Lights**		**Total**	
at Stop (TC)	**No.**	**%**	**No.**	**%**	**No.**	**%**
0 to 19 m	8	33.3	4	40.0	12	35.3
20 to 39 m	3	12.5	1	10.0	4	11.8
40 to 59 m	0	0.0	0	0.0	0	0.0
60 to 79 m	0	0.0	0	0.0	0	0.0
80 m or more	0	0.0	0	0.0	0	0.0
Pass at advance signal	13	54.2	5	50.0	18	52.9
Total	24	100.0	10	100.0	34	100.0
Validity of X^2	-					

Table G-2 Distance at stop – Vehicles 50-95 m away at advance signal (oncoming)

Distance at Start of Advance Signal: TA = 50 to 95 m						
Distance	**Amber Lights**		**Hazard Lights**		**Total**	
at Stop (TC)	**No.**	**%**	**No.**	**%**	**No.**	**%**
0 to 19 m	27	23.9	14	31.8	41	26.1
20 to 39 m	30	26.5	11	25.0	41	26.1
40 to 59 m	7	6.2	3	6.8	10	6.4
60 to 79 m	4	3.5	2	4.5	6	3.8
80 m or more	0	0.0	0	0.0	0	0.0
Pass at advance signal	45	39.8	14	31.8	59	37.6
Total	113	100.0	44	100.0	157	100.0
Validity of X^2	-					

Table G-3 Distance at stop – vehicles 100-195 m away at advance signal (oncoming)

Distance at Start of Advance Signal: TA = 100 to 195 m						
Distance	**Amber Lights**		**Hazard Lights**		**Total**	
at Stop (TC)	**No.**	**%**	**No.**	**%**	**No.**	**%**
0 to 19 m	36	20.2	10	9.5	46	16.3
20 to 39 m	33	18.5	31	29.5	64	22.6
40 to 59 m	41	23.0	20	19.0	61	21.6
60 to 79 m	25	14.0	7	6.7	32	11.3
80 m or more	7	3.9	3	2.9	10	3.5
Pass at advance signal	36	20.2	34	32.4	70	24.7
Total	178	100.0	105	100.0	283	100.0
Validity of X^2	$p = 0.007$					

Table G-4 Distance at stop – vehicles 200 m or + away at advance signal (oncoming)

Distance at Start of Advance Signal: TA = 200 m or more						
Distance	**Amber Lights**		**Hazard Lights**		**Total**	
at Stop (TC)	**No.**	**%**	**No.**	**%**	**No.**	**%**
0 to 19 m	4	7.4	1	3.0	5	5.7
20 to 39 m	7	13.0	10	30.3	17	19.5
40 to 59 m	12	22.2	4	12.1	16	18.4
60 to 79 m	9	16.7	6	18.2	15	17.2
80 m or more	18	33.3	6	18.2	24	27.6
Pass at advance signal	4	7.4	6	18.2	10	11.5
Total	54	100.0	33	100.0	87	100.0
Validity of X^2	-					

Motorists Travelling in the Same Direction

Table G-5 Distance at stop – vehicles 1-19 m away at advance signal (same direction)

Distance at Start of Advance Signal: TA = 1 to 19 m						
Distance	**Amber Lights**		**Hazard Lights**		**Total**	
at Stop (TC)	**No.**	**%**	**No.**	**%**	**No.**	**%**
0 to 4 m	7	15.2	12	22.2	19	19.0
5 to 14 m	5	10.9	5	9.3	10	10.0
15 to 24 m	2	4.3	0	0.0	2	2.0
25 to 54 m	0	0.0	0	0.0	0	0.0
55 m or more	0	0.0	0	0.0	0	0.0
Pass at advance signal	32	69.6	37	68.5	69	69.0
Total	46	100.0	54	100.0	100	100.0
Validity of X^2	-					

Table G-6 Distance at stop – vehicles 20-39 m away at advance signal (same direction)

Distance at Start of Advance Signal: TA = 20 to 39 m						
Distance	**Amber Lights**		**Hazard Lights**		**Total**	
at Stop (TC)	**No.**	**%**	**No.**	**%**	**No.**	**%**
0 to 4 m	21	25.9	21	23.3	42	24.6
5 to 14 m	23	28.4	23	25.6	46	26.9
15 to 24 m	7	8.6	2	2.2	9	5.3
25 to 54 m	0	0.0	3	3.3	3	1.8
55 m or more	0	0.0	0	0.0	0	0.0
Pass at advance signal	30	37.0	41	45.6	71	41.5
Total	81	100.0	90	100.0	171	100.0
Validity of X^2	-					

Table G-7 Distance at stop – vehicles 40-59 m away at advance signal (same direction)

Distance at Start of Advance Signal: TA = 40 to 59 m						
Distance	**Amber Lights**		**Hazard Lights**		**Total**	
at Stop (TC)	**No.**	**%**	**No.**	**%**	**No.**	**%**
0 to 4 m	5	11.6	6	16.2	11	13.8
5 to 14 m	14	32.6	7	18.9	21	26.3
15 to 24 m	15	34.9	14	37.8	29	36.3
25 to 54 m	2	4.7	3	8.1	5	6.3
55 m or more	0	0.0	0	0.0	0	0.0
Pass at advance signal	7	16.3	7	18.9	14	17.5
Total	43	100.0	37	100.0	80	100.0
Validity of X^2	-					

Table G-8 Distance at stop – vehicles 60-79 m away at advance signal (same direction)

Distance at Start of Advance Signal: TA = 60 to 79 m						
Distance	**Amber Lights**		**Hazard Lights**		**Total**	
at Stop (TC)	**No.**	**%**	**No.**	**%**	**No.**	**%**
0 to 4 m	4	11.4	3	7.5	7	9.3
5 to 14 m	3	8.6	7	17.5	10	13.3
15 to 24 m	9	25.7	14	35.0	23	30.7
25 to 54 m	15	42.9	7	17.5	22	29.3
55 m or more	0	0.0	0	0.0	0	0.0
Pass at advance signal	4	11.4	9	22.5	13	17.3
Total	35	100.0	40	100.0	75	100.0
Validity of X^2	-					

Table G-9 Distance at stop – vehicles 80 m or + away at advance signal (same direction)

Distance at Start of Advance Signal: TA = 80 m or more						
Distance	**Amber Lights**		**Hazard Lights**		**Total**	
at Stop (TC)	**No.**	**%**	**No.**	**%**	**No.**	**%**
0 to 4 m	0	0.0	1	1.7	1	0.9
5 to 14 m	4	7.0	2	3.4	6	5.2
15 to 24 m	7	12.3	6	10.3	13	11.3
25 to 54 m	26	45.6	29	50.0	55	47.8
55 m or more	19	33.3	20	34.5	39	33.9
Pass at advance signal	1	1.8	0	0.0	1	0.9
Total	57	100.0	58	100.0	115	100.0
Validity of X^2	-					

APPENDIX H

School Bus Drivers' Questionnaire

School Bus Drivers' Questionnaire

1a Which system of advance signal lights do you use most often?

Class	Frequency	%
- flashing amber lights	87	48.1%
- hazard lights	78	43.1%
- none	2	1.1%
- amber and hazard lights	11	6.1%
- data missing	3	1.7%
Total	181	100.0

1b On average, how many stops a day do you make in the presence of motorists?

Class	Frequency	%
- 1 to 20 stops	49	27.1%
- 21 to 40 stops	51	28.2%
- 41 to 60 stops	38	21.0%
- 61 or more stops	26	14.4%
- data missing	17	9.4%
Total	181	100.0

2a Under what circumstances do you use advance signal lights?

Class	Frequency	%
- always, regardless of location	150	82.9%
- depends on location	27	14.9%
- never	2	1.1%
- data missing	2	1.1%
Total	181	100.0

2b Under what circumstances do you not use them?
(more than one answer permitted)

Class	Frequency	%
- when no vehicles are in sight	17	9.4%
- when there isn't very much traffic	7	3.9%
- when there is a median	8	4.4%
- in urban areas	3	1.7%
- in rural areas	6	3.3%
- other	7	3.9%
Total	48	-

3 **Before a stop, what tells you that it is time to turn on the advance signal lights?** (more than one answer permitted)

Class	Frequency	%
- at a variable distance, depending on the situation	113	62.4%
- at a variable time, depending on the situation	50	27.6%
- at a set distance before the stop	34	18.8%
- at a set time before the stop	5	2.8%
- as soon as possible so vehicles see the flashers	74	40.9%
- when heavy vehicles have gone by	36	19.9%
- when fast-driving automobiles have gone by	15	8.3%
- when all vehicles have gone by	1	0.6%
- other	9	5.0%
Total	337	-

4 **Do you think that amber lights or hazard lights encourage motorists to pass the bus? Why?**

Class	Frequency	%
- yes	131	72.4%
- no	22	12.2%
- it depends	25	13.8%
- data missing	3	1.7%
Total	181	100.0

5 **Have you ever observed dangerous situations related to the advance signal lights?**

Class	Frequency	%
- no	129	71.3%
- yes	45	24.9%
- data missing	7	3.9%
Total	181	100.0

How many times per week on average?

Class	Frequency	%
- 0 times	132	72.9%
- once or twice/week	10	5.5%
- 3 to 4 times/week	8	4.4%
- 4 or more times/week	14	7.7%
- data missing	17	9.4%
Total	181	100.0

6 **Do you think that advance signal lights are well understood by motorists?**

Class	Frequency	%
- very well	29	16.0%
- well	55	30.4%
- average understanding	70	38.7%
- poorly	19	10.5%
- very poorly	7	3.9%
- data missing	1	0.6%
Total	181	100.0

7a **Have you ever used both types of lights (hazard lights and flashing amber lights)?**

Class	Frequency	%
- no, flashing amber lights only	54	29.8%
- no, neither one	4	2.2%
- no, hazard lights only	39	21.5%
- yes, both	79	43.6%
- data missing	5	2.8%
Total	181	100.0

7b **If so, which type of light seems to be most effective?**

Class	Frequency	%
- hazard lights	8	4.4%
- amber lights	83	45.9%
- no difference	10	5.5%
- data missing	80	44.2%
Total	181	100.0

8 **Do you start to brake before activating the advance signal lights?**

Class	Frequency	%
- yes, always	58	32.0%
- no, never	16	8.8%
- it depends on the location and circumstances	101	55.8%
- data missing	6	3.3%
Total	181	100.0

9 **Do you brake to warn motorists that you are going to stop?**

Class	Frequency	%
- yes	136	75.1%
- no	45	24.9%
Total	181	100.0

10 **Do brake lights have an effect on motorists?**

Class	Frequency	%
- no, none	6	3.3%
- yes, they slow down	156	86.2%
- yes, they speed up	7	3.9%
- other effect	8	4.4%
- data missing	4	2.2%
Total	181	100.0

11 **Which is safer, <u>using</u> advance signal lights or <u>not using</u> them?**

Class	Frequency	%
- advance signals are safer	170	93.9%
- equally safe	6	3.3%
- advance signals are not as safe	0	0.0%
- I can't answer; I don't use advance signals	4	2.2%
- data missing	1	0.6%
Total	181	100.0

12 **Do you think that advance signal lights should be standardized across Quebec and be identical on all buses?**

Class	Frequency	%
- no	7	3.9%
- yes, amber lights only	124	68.5%
- yes, hazard lights only	19	10.5%
- other	26	14.4%
- data missing	5	2.8%
Total	181	100.0

13 **Do you signal your intention to stop by turning on the signal light (right flasher)?**

Class	Frequency	%
- no, never	141	77.9%
- yes, always	9	5.0%
- yes, it depends	25	13.8%
- data missing	6	3.3%
Total	181	100.0

14a **How many illegal pass-bys are there on your route each day?**

Class	Frequency	%
- 0 passes	39	21.5%
- 0.001 to 1 pass/day	53	29.3%
- 1.5 to 2 passes/day	37	20.4%
- 2.5 to 3 passes/day	12	6.6%
- 3.5 or more passes/day	18	9.9%
- data missing	22	12.2%
Total	181	100.0

14b **Of the motorists who pass when you are stopped, what proportion do so intentionally?**

Class	Frequency	%
- 0%	34	18.8%
- 1 to 25%	44	24.3%
- 26 to 50%	25	13.8%
- 51 to 75%	13	7.2%
- 76 to 99%	15	8.3%
- 100%	14	7.7%
- data missing	36	19.9%
Total	181	100.0

15 **Do you wait for traffic to stop before letting pupils who have to cross the road get off the bus?**

Class	Frequency	%
- no, never	0	0.0%
- yes, always	170	93.9%
- it depends	9	5.0%
- data missing	2	1.1%
Total	181	100.0