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Comparison of Two Advance Stop Signalling Systems Used on Canadian School Buses: Amber Lights and Red Lights

Prepared for
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by
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Un sommaire français se trouve avant la table des matières.

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16. Abstract

This report compares two advance signalling systems used on school buses to alert motorists that the bus is about to stop: amber lights (eight-light system) and red lights (four-light system). It analyses the relative effectiveness of the two systems in reducing the speed of motorists travelling in the oncoming lane and preventing stopping violations. A variety of routes were studied: high-speed rural and near-urban roads with two and four lanes of traffic. Data from the four-light system (red lights) are from Ontario and Saskatchewan, while eight-light observations (amber lights) are from Quebec. A data collection system was installed on the bus that combined readings from radar and video equipment aimed at traffic in front of the bus. Changes in motorist speed and stopping violations were analysed in relation to selection criteria consisting of distance between the vehicle and the bus, exposure time to the advance signal and vehicle speed. Testing of estimated frequencies and observed frequencies was used to validate the sampling deviation between the two raw performances (amber lights versus red lights).

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16. Résumé

Ce rapport examine deux systèmes de pré-signalement d'arrêt utilisés sur les autobus scolaires servant à avertir les conducteurs d'un arrêt imminent de l'autobus : les feux jaunes (système à huit feux) et les feux rouges (système à quatre feux). L'analyse compare l'efficacité relative des deux systèmes à ralentir la vitesse des conducteurs circulant à contresens et à prévenir les dépassements illégaux à l'arrêt. Les trajets empruntent des zones rurales et périurbaines à haute vitesse, munies de deux ou quatre voies de circulation. Les données sur le système à quatre feux (feux rouges) proviennent de l'Ontario et de la Saskatchewan, tandis que les observations sur le système à huit feux (feux jaunes) du Québec. Un système d'acquisition de données a été installé à bord de l'autobus et il combinait les lectures d'un radar à l'image d'une caméra vidéo dirigée vers les véhicules venant à contresens, soit vers l'avant de l'autobus. Les changements de vitesse et les dépassements illégaux à l'arrêt sont analysés sur la base de critères de sélection faisant intervenir la distance d'éloignement entre le véhicule et l'autobus, le temps d'exposition au pré-signalement, et la vitesse des véhicules. Le test des fréquences estimées et des fréquences observées est employé pour valider l'écart statistique entre les deux performances brutes, celle des feux jaunes et celle des feux rouges.

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EXECUTIVE SUMMARY

Reasons for the study

In North America, advance signalling systems are employed on school buses to warn motorists of a mandatory stop, indicated by red lights and or by the deployment of a stop arm depending on respective provincial or state regulations. Two types of advance signalling systems are used on Canadian school buses. Amber lights, integrated into an eight-light system, consist of four flashing amber warning lights that precede red lights used during the stopping process. With this system, the amber lights are activated before the bus starts to slow down. The eight-light system is mandatory in four out of 12 Canadian jurisdictions. In most others, red flashing lights in the four-light system are required to be used as an advance signal and a stop signal. With the four-light system, the red lights do not necessarily indicate that the bus is stopped and the stop arm is extended. The movement of the bus is an indication whether the red lights mean a stop or an advance signal. Traffic is required to stop only when the bus is fully stopped. With the eight-light system, the change from amber to red flashing lights, indicating the stop signal, is triggered by the opening of the bus door. Considering variations in legislation and the relative sizes of provincial populations, almost equal numbers of motorists throughout the country are confronted with amber or red lights when school buses are preparing to stop.

Previous work analysed the effectiveness of amber lights over hazard warning lights, which are used in Québec as an advance signalling system. The study took place in the Sherbrooke area in spring 1998 using an on-board video recorder set-up in the front and the back of several school buses to assess the relative performance of the two systems[1]. This Transport Canada study found significant reductions in speed along with a strong decrease in stopping violations with the eight-light system. More research was undertaken to validate the 1998 results, and to evaluate the same systems employed in conditions of poor visibility[2] (Bruneau et al., 2001). The results of this new research reinforced the 1998 conclusions on the superior performance of the eight-light system.

The 2001 study produced a large number of amber-light observations using radar to measure reductions in speed. Observations were divided equally among conditions of good and bad visibility. It was possible to use this amber-light database for comparison with the use of red lights as an advance signal, providing that similar routes could be found where the use of red lights was the sole difference and that a similar data collection method be used. From the early stages of the 2001 project, all participating organizations and provinces agreed to a collaborative effort to conduct this four- vs. eight-light study. Road safety research teams were mobilized in three Canadian universities: University of Saskatchewan, University of Western Ontario, and Université de Sherbrooke. The Ministry of Transportation of Ontario (MTO) and Ministère des Transports du Québec (MTQ) each undertook data collection in their respective provinces. Transport Canada supported the current analysis, and the data collection work conducted by the University of Saskatchewan.

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[1] Bruneau, J.-F. (1999a) *Évaluation de deux dispositifs de pré-signalement d'arrêt pour autobus scolaire : le système à huit feux et les feux de détresse.* TP 13346F, Centre de développement des transports, Transports Canada, Montréal, p. 48.
[2] Bruneau, J.-F., Morin, D., et Pouliot, M. (2001a) *Efficacité du pré-signalement d'arrêt des autobus scolaires dans des conditions difficiles de visibilité : rapport final.* Coopératif de recherche en sécurité routière de l'Université de Sherbrooke, Sherbrooke, p. 55.

Goals

The main goal of this project was to assess the relative effectiveness of the two advance signalling systems used on Canadian school buses—amber lights and red lights—in reducing the speed of oncoming traffic and in preventing stopping violations.

The second objective was to survey school bus drivers who use the red lights as an advance warning to ascertain their perception of this system, and to compare their opinions with those of drivers using amber lights, previously surveyed.

Methodology

Analysing the effectiveness of two school bus advance signalling systems required specific tools for on-board measurement of different observable situations. A video–radar system was operated by a trained observer seated in the passenger seat next to the door. The radar was aimed at oncoming traffic to detect the speed of approaching vehicles as well as the speed of the bus. For all vehicles, speeds were evaluated at 1 second intervals until the vehicle stopped or passed the bus. Special markers were displayed on the video image when the warning lights were on and when stop arm was deployed. The observers reviewed all video tapes and evaluated distances along with the occurrence of stopping violations. The stopping violation rate and the speed reduction rate were calculated according to criteria established for this purpose.

The speed reduction rate was the main performance indicator because it revealed the specific effect produced by the two systems. Conversely, speeds and events during the stop signal phase were influenced not only by the advance signal but also by the stop signal and the stop arm. Speed variations taking place during the advance signal were a very good indicator of the specific effect of the warning lights. The impact of flashing lights on a vehicle's speed was measured with valid cases only, which required that the radar display at least two valid readings. The performance ratio numerator is equivalent to the number of vehicles that slowed by at least 10 km/h compared to the denominator, the exposure, which is the number of valid cases. The effectiveness index is the percentage change equivalent to the relative risk ratio between the two groups, the amber light and the red light. For example, a ratio of 2:1 implies that effectiveness reaches 50%, and when the ratio is 3:1, it reaches 67%, and so on. The statistical validity of the index is given by the *p*-level of a Chi-square test applied to "Observed vs. Expected Frequencies."

The stopping violation rate was also used to compare the two systems. It revealed the potential risks for school children crossing the road, although decreases in the stopping violation rate have to be interpreted with care. A statistical test compared the rate of decrease for amber lights and the red lights based on actual results versus expected results, and a Chi-square value for validity beyond the 5% threshold was determined. Unlike the speed reduction rate, which used only valid cases as a denominator, all 2,838 observations are part of the denominator. All the following conditions must have been met to consider the event to be a stopping violation: 1) the vehicle crossed the front bumper of the bus; 2) the red flashing lights were on; 3) the bus was completely stopped; 4) the stop arm was extending or was fully extended.

Two seasons of the school year were analysed to account for a potential difference between different road conditions. End of fall refers to the period following the beginning of the school year, with low ambient light and snow conditions. Spring, at the end of the school year, represents conditions mainly associated with high luminosity and good road conditions. School bus routes were carefully chosen for a best fit between the red and amber lights. Routes were generally located in rural or near-urban areas, and posted speeds varied between 70 km/h and 90 km/h. The number of oncoming lanes of traffic was the key parameter for separating the observations because it produced the greatest impact on stopping violations. With a few exceptions, visibility at the stop site was good and curves or hills were limited. It was possible to find routes in Ontario and to some extent in Saskatchewan similar to those in Québec. Considering the problem of reproducing methodological aspects such as on-board equipment, video reviewing techniques and file management, it was nonetheless possible to generate a comparison of two different systems in three different provinces, and to gather a large number of valid observations.

Results

Two significant results summarize the overall problem of changes in speed and other manoeuvres by motorists during the advance signal. In the majority of cases, the amber lights slowed as many as if not more vehicles thsn the red lights, and allowed a greater number of motorists to pass the bus during the warning phase (51% vs. 30%) suggesting a better traffic fluidity in motorist responses.

The amber lights produced consistent results throughout the study. The trend remained similar regardless of the situation or the number of lanes on the bus route where the data was collected. The only variation in the amber light profile was the level of fluidity observed on four-lane roads (with two oncoming lanes). The red lights produced results that varied according to the number of lanes.

On two-lane roads, the red lights slowed 73% of motorists and kept 87% in front of the bus during the advance signal, whether they stopped or remained in motion. The amber lights tended to let a significant proportion of the traffic pass—44% passed the bus compared to only 13% for the red lights. On the other hand, the speed reduction rate was high for both systems on two-lane roads (an average of 69%), suggesting that reduction in speed is a general phenomenon even though vehicles continued on to pass the bus on an amber lights advance warning.

On four-lane roads, the amber light profile did not change significantly while the red light profile was quite different. When there were two oncoming lanes, the red lights slowed fewer motorists (42%) and kept fewer in front of the bus (59%). The amber lights continued to allow more than half of the traffic to pass (54%) even though a high rate of reduction in speed was recorded (64%).

When taking the database as a whole, the amber lights are more effective at reducing speed, with a significant effectiveness index of 11%. Depending on the prevailing conditions, the amber light system showed higher effectiveness index when specific conditions were present: two oncoming lanes (+34%), high traffic volume (+47%) and proximity to urban areas (+40%). Together with these particular conditions, the amber lights showed a statistically significant better performance on 17 of 82 different combinations of road and observation conditions tested. Effectiveness index also increases for the amber lights as greater reductions in speed are considered, such as 20 km/h, 30 km/h, and so on. Amber lights produced greater reductions in speed than red lights regardless of the exposure time to the advance signal. Average reductions in speed during the advance signal range from 28 km/h to 32 km/h in the presence of amber lights, and they range between 10 km/h and 12 km/h with red lights. When looking at estimated speeds for each second of the advance signal, average speeds with amber lights slowly diminish by an average of 5 km/h per second, to reach an average low speed of 28 km/h after 10 seconds. With red lights, average speed remains at 60 km/h after 10-11 seconds of advance signal and it only drops significantly after 12 seconds.

With regard to stopping violations, the rate of stopping violations was observed to be 3.6% overall, with 4.3% for red lights and 2.8% for amber lights—a raw percentage difference of 1.5%. These percentages are small and comparable to numbers recorded in previous studies. The most important factor affecting stopping violations was the "lane effect." Two oncoming lanes were far more risky than one oncoming lane. Stopping violations reached 5.4% on roads with two oncoming lanes versus 1.6% on one oncoming lane. The high rate of stopping violations on roads with two oncoming lanes could be explained by the space between the bus and the oncoming vehicles—sometimes as much as two empty lanes between vehicles—and by the larger angles at which oncoming motorists observed the bus. Misunderstanding of the stopping rule could also be a factor.

Closely spaced stops, which were defined for purposes of this study as stops made at intervals of less than 50 m away from the preceding stop, were also related to a higher risk of stopping violations. These stops were analysed separately from more distantly-spaced stops because they recorded a rate of stopping violations of 10% on two oncoming lanes of traffic with amber lights, suggesting that this type of situation creates a lot of confusion for oncoming motorists.

Questionnaire

The 1998 study questionnaire was slightly modified and completed by 159 bus drivers who used red lights as an advance signal. The results were merged with the 1998 survey results in which 181 questionnaires were completed by bus drivers who used hazard warning lights or amber lights as an advance signal. More than 90% said that an advance signal is definitely necessary and that it should be standardized throughout Canada. They felt that motorist knowledge of the regulations related to school buses is average and should be improved.

Conclusion

The two systems were almost equivalent in terms of risks for a child crossing the road. Looking at the study database, no major difference was found in regard to preventing stopping violations, although a difference of 1.5% in raw passing rate favouring the amber lights proved statistically significant. The amber lights were 11% more effective than the red lights in reducing the speed of oncoming vehicles by at least 10 km/h, from initial speed at the beginning of advance signal, in all locations and under all road conditions. Regarding the school bus driver questionnaire, tendencies obtained in the first survey were confirmed. School bus drivers want a standard advance signalling system across Canada, and they note confusion and a lack of knowledge about school bus safety laws on the part of the general motoring public.

Recommendations

Advance signalling should be mandatory throughout the country, because it improves safety for school children, especially those walking across the road at school bus stops. Amber lights (the eight-light system) should be mandatory as the standard system as it has proven slightly superior to red lights and would harmonize the Canadian situation with almost 100% of U.S. states. It does not generate adverse effects and likely reduces motorist confusion. The implementation of a standard advance signalling equipment and procedure in Canada should be completed in the shortest period possible and should be accompanied by a nationwide motorist education campaign.

Messages that appear on the back of school buses, such as "Do not pass when lights flashing" should be reformulated to ensure they match the advance signal system in use and do not lead to motorists misunderstanding what they must do when a bus is about to stop. The safety of closely spaced bus stops should be investigated in light of the high rate of stopping violations observed in this study.

SOMMAIRE

Genèse de l'étude

En Amérique du Nord, les autobus scolaires sont munis de systèmes de pré-signalement d'arrêt qui préviennent les automobilistes qu'ils devront bientôt s'immobiliser. Le signal d'arrêt obligatoire est donné par le clignotement de feux rouges ou le déploiement d'un bras d'éloignement, selon la réglementation en vigueur dans la province ou l'État. Au Canada, il existe deux systèmes de pré-signalement d'arrêt. Le premier consiste en quatre feux jaunes clignotants, intégrés à un système à huit feux, qui sont activés avant les feux rouges, lesquels indiquent que l'autobus est immobilisé. Le conducteur de l'autobus active ces feux jaunes avant de commencer à ralentir. Le système à huit feux est obligatoire dans quatre des 12 provinces et territoires du Canada. À peu près partout ailleurs, les feux rouges clignotants du système à quatre feux servent à la fois de pré-signal et de signal d'arrêt. Ainsi, dans le cas du système à quatre feux, le clignotement des feux rouges n'indique pas nécessairement que l'autobus est arrêté et que le bras d'éloignement est déployé. C'est le mouvement de l'autobus qui indique si les feux rouges sont un pré-signal ou un véritable signal d'arrêt. Or, les véhicules ne sont tenus de s'immobiliser que si l'autobus est complètement arrêté. Avec le système à huit feux, le passage des feux jaunes clignotants aux feux rouges clignotants, qui constituent le signal d'arrêt, est déclenché par l'ouverture de la porte de l'autobus. Compte tenu des différentes réglementations en vigueur au Canada et de la taille relative de la population de chaque province et territoire, il y a presque autant d'automobilistes canadiens qui sont prévenus de l'arrêt d'un autobus scolaire par des feux jaunes que par des feux rouges.

Une recherche antérieure a permis de comparer l'efficacité des feux jaunes à celle des feux de détresse, deux systèmes utilisés au Québec pour annoncer un arrêt. L'étude, réalisée dans la région de Sherbrooke au printemps 1998, utilisait des caméras vidéo montées à l'avant et à l'arrière d'autobus scolaires pour évaluer l'efficacité relative des deux systèmes[1]. Cette étude de Transports Canada a révélé que le système à huit feux mène à des ralentissements importants et à une forte diminution des infractions à l'arrêt. Une autre recherche a ensuite été entreprise pour valider les résultats de l'étude de 1998 et pour évaluer les mêmes systèmes dans des conditions de visibilité réduite[2] (Bruneau et coll., 2001). Les résultats de cette deuxième étude ont corroboré les conclusions de l'étude de 1998, à savoir la supériorité du système à huit feux.

L'étude de 2001, qui utilisait un radar pour mesurer les ralentissements, a donné lieu à un grand nombre d'observations sur les feux jaunes, observations qui avaient été faites autant en conditions de bonne visibilité que de visibilité réduite. Cette base de données sur les feux jaunes pouvait servir à comparer l'utilisation de feux rouges et de feux jaunes pour pré-signaler un arrêt, à condition que les parcours effectués et la méthode de collecte des données soient en tous points semblables. Seule la couleur des feux pouvait varier. Dès l'amorce de l'étude de 2001, toutes les organisations et provinces participantes ont uni leurs efforts pour mener à bien cette étude comparative. Des équipes de recherche en sécurité routière ont été réunies dans trois universités canadiennes : l'Université de la Saskatchewan, l'Université de Western Ontario et l'Université de Sherbrooke. Le ministère des Transports

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1 Bruneau, J.-F. (1999a) *Évaluation de deux dispositifs de pré-signalement d'arrêt pour autobus scolaire : le système à huit feux et les feux de détresse.* TP 13346F, Centre de développement des transports, Transports Canada, Montréal, p. 48.

2 Bruneau, J.-F., Morin, D., et Pouliot, M. (2001a) *Efficacité du pré-signalement d'arrêt des autobus scolaires dans des conditions difficiles de visibilité : rapport final.* Coopératif de recherche en sécurité routière de l'Université de Sherbrooke, Sherbrooke, p. 55.

de l’Ontario (MTO) et le ministère des Transports du Québec (MTQ) ont chacun entrepris la collecte de données dans leurs provinces respectives. Transports Canada a financé la présente analyse ainsi que la collecte de données faite par l’Université de la Saskatchewan.

Buts

L’objectif principal de la présente étude était d’évaluer l’efficacité relative de deux systèmes de pré-signalement d’arrêt utilisés sur les autobus scolaires au Canada – feux jaunes et feux rouges – à réduire la vitesse des véhicules venant à contresens et à prévenir les infractions à l’arrêt.

Le deuxième objectif était de demander aux conducteurs d’autobus qui utilisent des feux rouges pour pré-signaler leur arrêt leur opinion sur ce système, et de comparer les opinions ainsi recueillies avec celles, déjà obtenues, des conducteurs utilisant des feux jaunes.

Méthodologie

Pour analyser l’efficacité des deux systèmes, il a fallu installer des équipements spéciaux à bord des autobus pour prendre des mesures des différentes situations observables. Un observateur qualifié, assis dans le siège du passager près de la porte, recueillait des données à l’aide d’un enregistreur vidéo radar. Le radar était dirigé vers les véhicules venant à contresens, pour détecter la vitesse de ces véhicules de même que celle de l’autobus. La vitesse de tous les véhicules était mesurée toutes les secondes jusqu’à ce qu’ils se soient immobilisés ou qu’ils aient passé leur chemin. Des marqueurs spéciaux apparaissaient sur l’image vidéo lorsque les feux de pré-signalement clignotaient et lorsque le bras d’éloignement était déployé. Les observateurs ont revu toutes les bandes vidéo pour évaluer les distances et dénombrer les cas d’infraction à l’arrêt. Le taux d’infraction à l’arrêt et le taux de ralentissement ont été calculés à partir de critères établis à cette fin.

Le taux de ralentissement a été considéré comme le principal indicateur d’efficacité, car il reflétait l’effet spécifique produit par les deux systèmes de pré-signalement. À l’inverse, les vitesses et événements enregistrés pendant la phase du signal d’arrêt étaient influencés non seulement par le pré-signal, mais aussi par le signal d’arrêt et le bras d’éloignement. Les variations de vitesse enregistrées pendant la phase de pré-signalement se sont révélées un très bon indicateur de l’effet spécifique des feux d’annonce d’arrêt. L’influence des feux clignotants sur la vitesse d’un véhicule a été mesurée uniquement pour les cas dits valides, c’est-à-dire les véhicules pour lesquels on disposait d’au moins deux écrans radar valides. Le numérateur du rapport d’efficacité est le nombre de véhicules qui ont ralenti d’au moins 10 km/h et le dénominateur, le nombre de véhicules exposés, ou cas valides. L’indice d’efficacité est l’expression sous forme de pourcentage du rapport de risque relatif d’un système et de l’autre : feux jaunes et feux rouges. Par exemple, un rapport de 2 à 1 indique une efficacité de 50 %, et un rapport de 3 à 1, une efficacité de 67 %, et ainsi de suite. La validité statistique de l’indice est donnée par le niveau p d’un test du Chi^2 appliqué aux «fréquences observées par rapport aux fréquences attendues».

Les deux systèmes ont aussi été comparés sous l’angle des taux d’infraction à l’arrêt. Ces taux sont une indication du risque auquel sont exposés les écoliers qui traversent la rue; il y a lieu, toutefois, d’interpréter avec prudence les baisses du taux d’infraction. Un test statistique a été appliqué pour comparer les taux de diminution des infractions avec les feux jaunes et avec les feux rouges, d’après les résultats observés par rapport aux résultats attendus, et un test du Chi^2 a permis d’établir à plus de 5 % la validité des valeurs obtenues. Contrairement à la méthode adoptée pour le taux de ralentissement, alors que seuls les cas valides étaient inclus dans le dénominateur, toutes les 2 838 observations sont ici incluses dans le dénominateur. Pour considérer un événement comme une infraction à l’arrêt, toutes les conditions suivantes devaient être réunies: 1) le véhicule a croisé le pare-chocs avant de l’autobus; 2) les feux rouges clignotants étaient activés; 3) l’autobus était complètement arrêté; 4) le bras d’éloignement était en cours de déploiement ou complètement déployé.

Les observations ont eu lieu pendant deux saisons différentes de l’année scolaire, de façon à mettre en évidence l’effet éventuel de l’état des routes. Ainsi, la fin de l’automne, soit quelque temps après le début de l’année scolaire, se caractérise par une faible lumière ambiante et des conditions neigeuses. Quant aux conditions printanières, qui coïncident avec la fin de l’année scolaire, elles sont surtout associées à une bonne clarté et à de bonnes conditions routières.

Les trajets d’autobus ont été soigneusement choisis de façon à obtenir la meilleure équivalence entre les données associées aux deux systèmes de pré-signalement. Ces trajets étaient généralement situés dans des zones rurales ou périurbaines, où la vitesse permise variait de 70 km/h à 90 km/h. Le nombre de voies à contresens est le principal paramètre utilisé pour départager les observations, car c’est celui qui a eu l’influence la plus marquante sur les infractions à l’arrêt. Sauf quelques exceptions, la visibilité était bonne au point d’arrêt et il y avait peu de courbes ou de côtes. Il a été possible de trouver en Ontario et, jusqu’à un certain point, en Saskatchewan, des trajets similaires à ceux du Québec. Malgré la difficulté de reproduire parfaitement la méthodologie (équipement embarqué, techniques de revue des bandes vidéo, gestion des fichiers), il a été possible d’arriver à une comparaison valable des deux systèmes dans trois provinces différentes, et de réunir un grand nombre d’observations valides.

Résultats

Deux grands résultats résument toute la question des changements de vitesse et autres manœuvres des automobilistes pendant la phase du pré-signal d’arrêt. Dans la majorité des cas, les feux jaunes ont fait ralentir autant, sinon plus, de véhicules que les feux rouges, et ils ont permis à un plus grand nombre d’automobilistes de dépasser l’autobus pendant la phase d’avertissement (51 % par rapport à 30 %), ce qui permet de penser que la circulation était plus fluide.

Les feux jaunes ont produit des résultats cohérents pendant toute l’étude. Les tendances demeuraient les mêmes dans toutes les situations, peu importe le nombre de voies. La seule irrégularité affichée par le profil «feux jaunes» avait trait au degré de fluidité observé sur les routes à quatre voies (deux voies à contresens). Les feux rouges ont produit des résultats qui variaient en fonction du nombre de voies.

Sur les routes à deux voies, les feux rouges de pré-signalement ont fait ralentir 73 % des automobilistes et 87 % de ceux-ci sont restés en avant de l’autobus, soit immobilisés, soit en mouvement. Les feux jaunes avaient tendance à laisser passer une proportion importante des véhicules – 44 % ont dépassé l’autobus comparativement à seulement 13 % dans le cas des feux rouges. Par contre, l’un et l’autre système se sont montrés très efficaces à faire ralentir les véhicules sur les routes à deux voies (moyenne de 69 %), ce qui donne à penser que le ralentissement est un phénomène généralisé, même si les véhicules continuaient à dépasser l’autobus pendant une phase de pré-signalement avec feux jaunes.

Sur les routes à quatre voies, le profil «feux jaunes» était essentiellement le même, tandis que le profil «feux rouges» était passablement différent. Lorsqu’il y avait deux voies à contresens, les feux rouges faisaient ralentir moins d’automobilistes (42 %) et une proportion moindre de ceux-ci restaient en avant de l’autobus (59 %). Les feux jaunes ont continué de laisser passer une proportion important des véhicules, en fait plus de la moitié (54 %), malgré un taux de ralentissement élevé (64 %).

De l'examen de l'ensemble de la base de données, il ressort que les feux jaunes sont plus efficaces à faire ralentir les véhicules, leur indice d'efficacité s'élevant à 11 % à cet égard. L'indice d'efficacité du système à feux jaunes a été supérieur à celui du système à feux rouges dans les conditions suivantes : deux voies à contresens (+ 34 %), circulation intense (+ 47 %) et proximité de zones urbaines (+ 40 %). Si on ajoute à ces conditions d'autres variables, comme l'état des routes et les conditions d'observation, les feux jaunes se sont révélés significativement plus efficaces, sur le plan statistique, dans 17 des 82 combinaisons différentes de conditions routières et de conditions d'observation analysées. De plus, l'indice d'efficacité des feux jaunes augmente à mesure que le taux de ralentissement considéré augmente (20 km/h, 30 km/h, ainsi de suite). Les feux jaunes ont produit des ralentissements plus importants que les feux rouges, peu importe la durée de l'exposition au pré-signal. Les ralentissements moyens pendant la phase du pré-signal sont de 28 km/h à 32 km/h en présence de feux jaunes, et de 10 km/h à 12 km/h en présence de feux rouges. Lorsqu'on examine l'évolution des vitesses estimatives des véhicules à chaque seconde de la phase de pré-signalement, la vitesse moyenne, avec les feux jaunes, diminue de 5 km/h par seconde en moyenne, pour atteindre un point bas moyen de 28 km/h après 10 secondes. Avec les feux rouges, la vitesse moyenne demeure à 60 km/h après 10 à 11 secondes de pré-signal, et elle ne diminue de façon significative qu'après 12 secondes.

En ce qui a trait aux infractions à l'arrêt, le taux d'infraction global observé a été de 3,6 %, soit 4,3 % dans le cas des feux rouges et 2,8 % dans le cas des feux jaunes – une différence de 1,5 point de pourcentage. Ces pourcentages sont faibles et comparables à ceux enregistrés au cours des études précédentes. Le facteur qui influe le plus sur les infractions à l'arrêt est le nombre de voies. Ainsi, deux voies en contresens représentaient un risque beaucoup plus grand qu'une seule voie en contresens. Les infractions à l'arrêt atteignaient 5,4 % sur les routes à deux voies en contresens, par rapport à 1,6 %, sur les routes à une seule voie en contresens. Le taux élevé d'infractions sur les routes à deux voies en contresens peut s'expliquer par l'espace entre l'autobus et les véhicules venant en sens inverse – il y a parfois jusqu'à deux voies libres entre les véhicules – et par le meilleur angle de vision dont bénéficient les automobilistes venant à contresens. La méconnaissance du règlement peut aussi jouer un rôle.

Les arrêts dit rapprochés, c'est-à-dire espacés de moins de 50 m, selon la définition utilisée aux fins de la présente étude, étaient également associés à un plus grand risque d'infraction. Ces arrêts ont été étudiés séparément des autres (plus espacés), parce qu'ils produisaient un taux d'infraction de 10 % sur les routes à quatre voies (deux voies en contresens), avec les feux jaunes, ce qui laisse penser que ce type de situation crée une grande confusion pour les automobilistes venant à contresens.

Questionnaire

Le questionnaire de l'étude de 1998 a été légèrement modifié et soumis à 159 conducteurs d'autobus qui utilisaient des feux rouges pour annoncer leur arrêt. Leurs réponses ont été fusionnées avec celles du questionnaire de 1998, qui avait été rempli par 181 conducteurs qui utilisaient des feux de détresse ou des feux jaunes en guise de pré-signal d'arrêt. Selon plus de 90 % des répondants, un pré-signal est absolument nécessaire et celui-ci devrait être normalisé à l'échelle du Canada. Ils estiment que les automobilistes ont une connaissance moyenne de la réglementation touchant les autobus scolaires et qu'un effort de sensibilisation s'impose.

Conclusion

Les deux systèmes se sont révélés quasi équivalents en ce qui a trait au risque auquel est exposé un écolier lorsqu'il traverse la chaussée. L'analyse de la base de données n'a révélé aucune différence marquante pour ce qui est de la prévention des infractions à l'arrêt, mais a mis en évidence un écart statistiquement significatif de 1,5 point de pourcentage en faveur des feux jaunes, pour ce qui est du taux de dépassement de l'autobus. Les feux jaunes ont été 11 % plus efficaces que les feux rouges à faire ralentir de 10 km/h et plus les véhicules venant en sens inverse, la vitesse initiale étant celle mesurée au début de la phase de pré-signalement, à tous les endroits et dans toutes les conditions routières. Pour ce qui est du questionnaire rempli par les conducteurs des autobus scolaires, les réponses obtenues ont confirmé celles du premier questionnaire. Les conducteurs d'autobus scolaires sont en faveur d'un système normalisé de pré-signalement à l'échelle du Canada, et ils notent de la confusion et une méconnaissance de la législation concernant la sécurité des autobus scolaires de la part des automobilistes en général.

Recommandations

Le pré-signalement d'arrêt devrait être obligatoire à la grandeur du pays, parce qu'il améliore la sécurité des écoliers, surtout de ceux qui traversent la chaussée aux arrêts d'autobus. On devrait choisir, pour le système normalisé et obligatoire, des feux jaunes (système à huit feux) parce que ceux-ci se sont révélés légèrement supérieurs aux feux rouges et par souci d'harmonisation avec les États-Unis, les feux jaunes étant utilisés dans près de 100 % des États américains. Les feux jaunes ne présentent aucun inconvénient et ils sont de nature à réduire la confusion des automobilistes. Il est urgent de mettre en place un équipement et une procédure normalisés de pré-signalement au Canada et de mener en parallèle une campagne nationale de sensibilisation des automobilistes.

Les messages affichés à l'arrière des autobus scolaires, du type «Interdit de passer quand les feux clignotent» devraient être formulés différemment, pour qu'ils tiennent compte du système de pré-signalement en usage et qu'ils indiquent clairement aux automobilistes ce qu'ils doivent faire lorsque l'autobus est sur le point de s'arrêter. Des recherches s'imposent pour améliorer la sécurité aux arrêts d'autobus rapprochés, compte tenu du taux élevé d'infractions à l'arrêt observées au cours de la présente étude.

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GLOSSARY

Advance signalling	The display of flashing lights activated by a driver of a moving school bus to warn nearby motorists that he is about to stop to pick up or drop off school children, and that he will activate the bus stop lights, imposing a mandatory stop for all traffic. Advance signalling is executed while the bus is moving and preparing to stop. The bus driver activates the red or amber lights or the hazard warning lights, depending on the jurisdiction where the bus is operated. The advance signalling phase ends when the bus comes to a complete stop, the flashing lights switch from amber to red, and the bus stop arm swings-out.
Amber lights	A warning system consisting of four amber lights mounted on the front and back of the bus at each corner just below the roofline that flash alternately. The amber lights are always part of an eight-light system and their only purpose is advance signalling.
Speed reduction rate	A measure of performance that is the number of approaching vehicles slowing by at least 10 km/h from the beginning of advance signal, divided by the number of approaching vehicles with at least two valid speed estimates from radar readings during the advance signal.
Driver	In this report, the term “driver” refers to school bus drivers, in order to differentiate them from motorists encountering the bus.
Eight-light system	A school bus signalling system composed of a pair of amber and red lights mounted on each corner of the front and back of the bus near the roofline that flash alternately left and right. The amber lights flash to indicate an impending stop and the red lights flash when the bus is stopped to indicate a stop. The eight-light system is specified in Canada Motor Vehicle Safety Standard (CMVSS) 108 “Lighting System and Retroreflective Devices” as an alternative to the four-light system that is mandatory equipment on all new school buses manufactured in or imported into Canada.
Four-light system	A warning system consisting of four red lights mounted on the front and back of the bus at each corner just below the roofline that flash alternately. It is used to signal either a mandatory stop or an impending stop, depending on the situation (see “red lights”). One of two school bus warning light systems specified in CMVSS 108 (see “eight-light system”).
Hazard warning lights	A warning signal system installed on all road vehicles for signifying hazard and danger. It is controlled by a switch that causes the left and right turn signal lights to flash simultaneously. CMVSS 108 requires all motor vehicles other than motorcycles to be equipped with hazard warning light systems.
Motorist	Throughout the report, the term “motorist” refers to drivers of vehicles encountering the bus, to differentiate them from school bus drivers.

Red lights	In this report, this refers to the red flashing warning lights used as an advance signal on a moving school bus approaching a bus stop where children will board or disembark. The red lights continue to flash after the bus has stopped. The red flashing warning lights are required equipment on all school buses. When used as an advance signal, the red signal lights are called the four-light system.
Stop arm	A signalling system installed outside on the left side of the bus, near the driver's seat. It consists of a stop sign with two alternately flashing red lights, affixed to a retractable swing arm. It is synchronized with the opening and closing of the door and, where an eight-light system is fitted, with the switch from amber to red flashing lights.
Stopping violation	Failing to stop and illegally passing the school bus when it is stopped with the stop indicators on.

1 INTRODUCTION

1.1 Background

In North America, advance signalling is used on school buses to warn motorists of an imminent mandatory stop, indicated by red flashing lights and/or the deployment of a stop arm, depending on respective provincial or state regulations. Two types of advance signalling systems are most commonly used on Canadian school buses. Amber lights, integrated into an eight-light system, consist of four amber warning lights that precede red lights used during the stopping process. With this system, the amber lights are activated before the bus starts to slow down, to signal the stop in advance. The eight-light system is mandatory in four out of 12 Canadian jurisdictions. In most other provinces, red flashing lights are required to be used as an advance signal, as well as a stop signal. Québec allows but does not require advance signal use. With the four-light system, flashing red lights do not necessarily indicate that the bus is stopped. The movement of the bus serves to indicate whether the red lights mean a stop or an advance signal. Traffic is required to stop only when the bus is fully stopped. With amber advance warning lights, the first flash of red lights indicates the stop. The change from amber to red is triggered by the opening of the bus door. Considering variations in legislation and the relative sizes of provincial populations, almost equal numbers of motorists throughout the country are confronted with amber or red lights when school buses are preparing to stop. These two different approaches to providing the same warning message to Canadian motorists raises the question of why use two systems as well as the relative efficiency of one over the other.

1.2 Objectives

The main goal of this project was to assess the relative effectiveness of two advance signalling systems most commonly used on Canadian school buses—amber and red lights—in reducing the speed of oncoming traffic and in preventing stopping violations. A secondary objective was to survey school bus drivers who use the red lights as an advance warning to ascertain their perception of this system, and to compare driver opinions with responses from drivers who use amber lights, previously surveyed using a similar questionnaire.

1.3 Scope of Research

Previous work analysed the effectiveness of amber lights over hazard warning lights, which are used in Québec as an advance signalling system. The study took place in the Sherbrooke area in spring 1998 using a mobile video set-up in the front and back of various school buses to examine the two systems at a preliminary stage (Bruneau, 1999a). This Transport Canada study found significant reductions in speed, along with a strong decrease in stopping violations, when using the amber lights. New research was undertaken to validate the spring 1998 results and to evaluate systems employed in conditions of poor visibility (Bruneau et al., 2001a). The results of this new research reinforced the 1998 conclusions on the superior performance of the eight-light system.

The 2001 project produced a large amber-light database using radar detection, with equal shares of good and bad visibility conditions. This amber-light database could also be used to conduct a comparison with the use of red lights as an advance signal, providing that similar routes could be found where the use of red lights was the sole difference. The data collection methodology also had to be similar. From the early stages of the 2001 project, all participating organizations and provinces agreed to collaborate to accomplish the goal of conducting this study. Road safety research teams were mobilized in three Canadian universities: University of Saskatchewan, University of Western Ontario, and Université de Sherbrooke. The Ministry of Transportation of Ontario (MTO) and Ministère des Transports du Québec (MTQ) each undertook data collection in their respective provinces. Transport Canada supported the current analysis, and the data collection work conducted by the University of Saskatchewan.

1.4 Report Structure

The report is organized into three different sections: framework, methodology and results. The framework chapter explains the results obtained in previous reports, and presents general considerations for advance signalling systems legislation as well as potential benefits.

The methodology chapter first describes the process for collecting data, including the research teams involved, general procedures, and types of on-board equipment. Parameters are described along with the criteria applied to each category. The database section lists the selection criteria for retaining observations and the statistical treatments applied to the data. Bus driving parameters show the advance signalling technique used by bus drivers, to determine whether both systems were tested under the same conditions. Parameters observed were: speed of the bus at the beginning of advance signal, length and duration of the advance signal, and duration of stop signal. The last methodology section describes potential problems for which specific solutions were applied. Major issues were: the search for suitable routes, radar set-up adjustment, and the difficulty of assessing stopping violations.

In the results section, speed changes and other events are presented for the two phases of the stopping process: the advance signal and the stop signal.

2 FRAMEWORK

2.1 Signalling Equipment Used on School Buses

All buses driving on Canadian roads are required to deploy stop arm and flashing red lights to stop traffic in all directions when loading or unloading school children. There are few exceptions, such as when oncoming motorists are separated by a median road strip/barrier, or other restrictions such as municipal bylaws that may prohibit the use of any school bus stop signal within city limits.

2.1.1 Four-Light System (Red Lights)

The four-light system is the basic stop signalling system used on all school buses. It includes two flashing red lights at the front of the bus, and two identical lights at the back. These four lights indicate that a stop is required for all vehicles, with the few exceptions mentioned above. Drivers of buses equipped with a four-light system sometimes use the red lights as an advance signal. This is a legal requirement in some provinces. The procedure is the following: red lights flash while the bus prepares to stop, and the stop signal becomes "official" when the bus has come to a full stop and/or when the stop arm has deployed, depending on the provincial legislation.

2.1.2 Eight-Light System (Amber Lights)

The eight-light system includes four flashing amber lights that precede the four red stop lights. The amber lights complement the red lights just as they do at traffic lights, although school bus stops are more complex for motorists to interpret because the bus is moving.

2.1.3 Hazard Warning Lights and Other Signalling Techniques

In Alberta and Québec, using the red lights for advance signalling is not allowed. In Québec, pre-stop signalling is not mandatory but is practiced by the majority of bus drivers.

In Québec, the hazard warning lights, or four-way flashers, are used as an advance signal. The practice is perceived by bus drivers as essential, given the prohibition of using red lights as a pre-stop warning, and is tolerated by authorities because hazard warning lights should only be used for emergency or hazardous situations. Some drivers with amber-light equipped buses will use both the hazard warning lights and the amber lights as an advance signalling strategy. While it is true that the rear hazard warning lights are at eye level of the motorist right behind the bus, motorists in vehicles further back may have difficulty seeing them. The combination of different lights flashing at the same time is a possible source of confusion for motorists. Hazard warning lights are also used at railroad crossings or to indicate slower speeds on a hill, for example.

Some drivers may still use the right turn indicator to signal a stop in advance. However, since a right turn signal normally means the bus is turning right, this may lead to undesirable reactions from motorists such as passing on the left, especially if the bus shifts slightly towards the right-hand side of the road. Moreover, motorists do not expect and may not understand an advance warning coming from a right turn signal.

2.2 Advance Signalling Legislation

The eight-light system is currently used nearly everywhere in North America. It is used systematically in the United States, with the exception of Wisconsin (Gauthier, 2001), and for half of Canada (Guérette, 1998). The other half of Canadian legislations permit the use of red flashing lights as a method of signalling a stop in advance. The use of red lights as an advance signal seems to be a method unique to parts of Canada and to Wisconsin. California has recently changed to the eight-light system through a gradual process initiated in the 1990s that required the eight-light system on all new buses. Implementation took place without retrofitting school buses, so the transition time was equivalent to one bus life as the fleet was renewed.

Provincial and Territorial legislation on advance signalling systems is shown in Table 1. Québec and Alberta are the two provinces that do not require the use of an advance signal. All other provinces require mandatory equipment and/or methods for advance signalling. The eight-light system is mandatory in all Maritime provinces: Prince Edward Island, New Brunswick and Nova Scotia. Amber lights are also mandatory in Manitoba. They are "allowed" in Québec, Alberta, British Columbia and Northwest Territories. Provinces and territories that allow or require amber lights account for 8 out of 13 Canadian jurisdictions (62%).

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

Province or Territory	Hazard warning lights	Amber lights	Red lights
Yukon			mandatory
Northwest Territories		allowed	mandatory
British Columbia		allowed	mandatory
Alberta		allowed[2]	
Manitoba		mandatory	
Saskatchewan			mandatory
Ontario			mandatory
Québec[1]	allowed	allowed	
New Brunswick		mandatory	
Prince Edward Island		mandatory	
Nova Scotia		mandatory	
Newfoundland			mandatory
Nunavut	unknown		

[1] Section 34, Regulation Respecting Road Vehicles Used for the Transportation of School Children (OC 285-97, March 5, 1997).
[2] It becomes mandatory if the school bus is equipped with the amber lights. More than 80% of Alberta fleet is equipped with amber lights.

The four-light system and the use of red lights as an advance signal are mandatory in Ontario, Saskatchewan, British Columbia, Newfoundland, and in the two Territories. These jurisdictions represent approximately half of the Canadian population.

2.3 Previous work

2.3.1 School Bus Signalling Equipment

Previous research attempted to determine the relative efficiency of school bus signalling equipment. According to Hale et al. (1983), the stop arm is the only device that significantly reduces the rate of stopping violations. However, the study measured different combinations of equipment. The only set-up in which stop arm was tested included amber lights as a warning and red lights as a stop signal. If the stop arm was tested without flashing lights from the eight-light system, it is possible that the efficiency of the stop-am would drop. The test was conducted without describing the specific contribution of each system separately since the stop arm and warning light systems were used in combination.

2.3.2 Absence of Advance Signal

At the beginning of the first Transport Canada study (Bruneau, 1999a), the absence of advance signals was identified as a potential situation to be observed on Québec's roads. Many attempts were made to find a school board, a bus fleet or a driver who used no form of advance signal. The search was unsuccessful because contrary to what had been assumed, drivers everywhere in the province were using an advance signal, at least when traffic was in sight. This was surprising, given that provincial regulations do not require drivers to perform any type of advance signal. Transportation officials and drivers surveyed explained that the advance signal was used out of necessity to avoid sudden braking or potential collisions between vehicles or involving a crossing pedestrian.

A potential site for the trial was found near Sherbrooke, on a route where children do not cross the road. For purposes of the study, the bus driver was requested not to use hazard warning lights, as he was accustomed, in order to assess the effect on traffic of stopping without displaying a pre-stop warning. Provincial regulations still permit the bus to slow down and stop without using advance signal, and the red flashing lights and stop arm are required only when the bus is completely immobilized. However, this experiment involving the absence of advance signals was cancelled on the second day because there were too many sudden brakings. Out of 79 motorists observed on this rural, 90 km/h road with one oncoming lane, 12.2% passed the bus illegally from the front. This is very high. Using a more restrictive selection criteria for estimating the denominator of vehicles in a position to either slow or pass illegally would see the rate reach higher levels on busy roads with two oncoming lanes, particularly considering that the high rate of stopping violations observed occurred in situations of only one oncoming lane.

In a separate unrelated project, a simulation was also conducted with real subjects driving a vehicle in a computer-assisted laboratory in order to test the effectiveness of using an advance signal against not using one (Bergeron et al., 2000). The scenario was developed by the Centre de recherche sur les transports at Université de Montréal. Motorists were placed in rural and near-urban environments where buses encountered motorists at different preset speeds, representative of situations where speed limits were posted at 70 km/h and 90 km/h. Researchers found that an advance signal increased safety.

2.3.3 Amber Lights vs. Hazard Warning Lights

Three recent studies found hazard warning lights to be an unacceptable solution for advance warning because they are poorly or not seen at all by vehicles in motion (Bruneau, 1999a; Bergeron et al., 2000; Bruneau et al., 2001a). Their low position on the bus, halfway to the roof, probably explains their poor efficiency in slowing and stopping traffic (Bruneau et al., 2002). Indeed, rates of stopping violations dropped with the use of amber lights by a factor of 2:1 (Bruneau, 1999a; 2001a). The greatest risk measured came from traffic in two oncoming lanes, with stopping violation rates of 4.4% using amber lights and 7.9% using the hazard warning lights.

A comparison of amber lights and hazard warning lights was possible using data collected in spring 1998 and spring 2000. The two identical routes were isolated in the databases, and a slight increase in stopping violations was discovered in 2000 for both systems. This change was not significant, however, for one or two oncoming lanes of traffic. The most recent study, using radar, also reveals that speed changes recorded visually in 1998 were accurate despite the lack of radar to evaluate them. With about ten times more information than in 1998, the spring 2000 results were almost identical; no significant difference was measured. The effectiveness index was 76% in favour of amber lights in 2000, compared to 54% in 1998.

2.4 Comparison of Potential Benefits

The most interesting aspect of the eight-light system is that it separates the two phases—the stopping phase from the warning phase. Furthermore, the sequence of amber followed by red is easier to interpret as it mimics the familiar sequence of regular traffic lights. When red lights are used both as a warning and as a stop signal, they remain active whether the bus is stationary or rolling at 80 km/h, making the stopping phase harder to distinguish. On the other hand, amber is appropriate for warning motorists of a potential hazard. Red is used for stopping or for extreme caution. In this sense, an excess of red signals could undermine the primary function: to stop traffic.

One element in favour of red lights as a pre-stop signal is cost. Even though the cost of installing an eight-light system on a new bus is reasonable, retrofitting a fleet—especially on a provincial scale—can become expensive. Nevertheless, the added benefit of standardizing the system for advance signalling needs to be considered given evidence of motorist confusion. Canada's population is more and more mobile, travelling regularly from one province to another as well as to the United States, where almost all states have adopted the amber light system.

Indeed, a decision to impose a standard system has to be assessed with particular attention to existing legislation, especially regulations recently adopted. Today, most regulations in US and Canadian jurisdictions define the eight-light system as a standard. Recent legislative changes across North America favour the amber lights, a move that was initiated by bus drivers and by transportation officials working in the field. After a brief experiment with the amber lights, the eight-light system came to be regarded as more effective and safer by a majority of school bus drivers. Despite the lack of an objective assessment of the system, the laws were changed in deference to the opinions of bus drivers (Hale et al., 1983). The present study, in a relatively new area of research, comes *a posteriori* to regulations that have already been changed, creating the opportunity to confirm the supposed advantage for a distinct pre-stop warning signal. The study was undertaken, not to evaluate simplicity or complication, but rather the changes in any variables relevant to safety of bus passenger loading and unloading.

3 METHODOLOGY

Analysing the effectiveness of two school bus advance signalling systems required specific tools for on-board measuring of various observable situations. The set-up elements are presented in figures 1 and 2, as they appear from outside and inside the bus respectively. A video–radar system was operated by a trained observer seated in the first passenger seat next to the door. The radar was aimed at oncoming traffic to detect the speed of oncoming vehicles along with speed of the bus. For all vehicles, speeds were evaluated at each second until the vehicle stopped or passed the bus. Special markers or "titles" were displayed on the image when the warning lights were on and when the stop arm was deployed. The observers reviewed all video tapes and evaluated distances along with the occurrence of stopping violations. The stopping violation rate and the speed reduction rate were calculated according to criteria designed for that task. A statistical test compared the amber and red lights based on actual results versus expected results using a Chi-square test for relevancy beyond the 5% threshold.

3.1 Data collection

3.1.1 General Procedure

An observer took up position inside the bus in the passenger seat next to the door to operate the data collection system and to note critical actions such as stopping violations. A microphone was used to record specific actions or distances that were not visible on the camera image. For example, a vehicle close to the front bumper of the bus did not appear on the image but needed to be noted for the reviewer of the tapes.

The observer also completed a daily logbook, which listed the road environment parameters for each stop site of the route. Appendix A contains the forms used as logbooks. The logbooks allowed for recording the fixed parameters of the road environment.

The second step of the collection process was to review all video tapes, noting parameters that changed from stop to stop. These contextual parameters applied directly to the approaching vehicles in traffic. A standard data recording sheet was used by the reviewers. Appendix A shows the forms used by the collection teams. Many parameters were established at this stage—time, distance and speed, along with stopping violations—making tape reviewing one of the most important parts of the study. Observations from Ontario and Québec (96% of total) were reviewed by only two observers who both used the same coding list and methodology to fill out the data sheet. The two observers together adjusted their coding methodology for the complete set of parameters using examples from previously collected video tapes. This was essential since there were many situations to account for, especially when using radar, and because tape reviewing was certainly the most difficult and critical part of the technical operations for this study.

Data was not collected for traffic behind the bus because the 1999 study showed clearly that stopping violations from the back are very infrequent and therefore unlikely to give significant results for a statistical analysis (under 1% of occurrence).

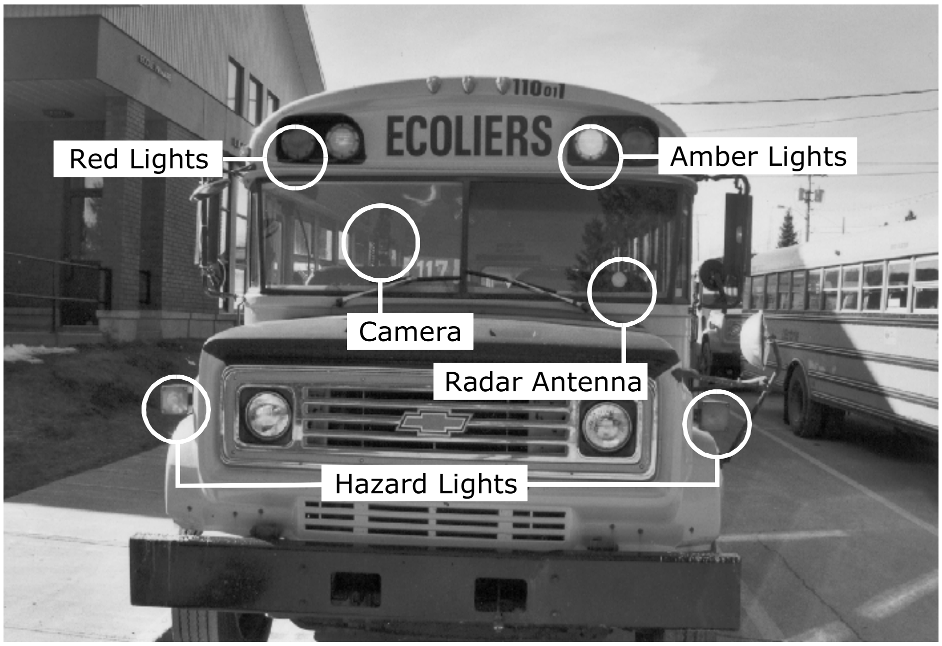

Figure 1 Signal light configuration and set-up as seen from outside

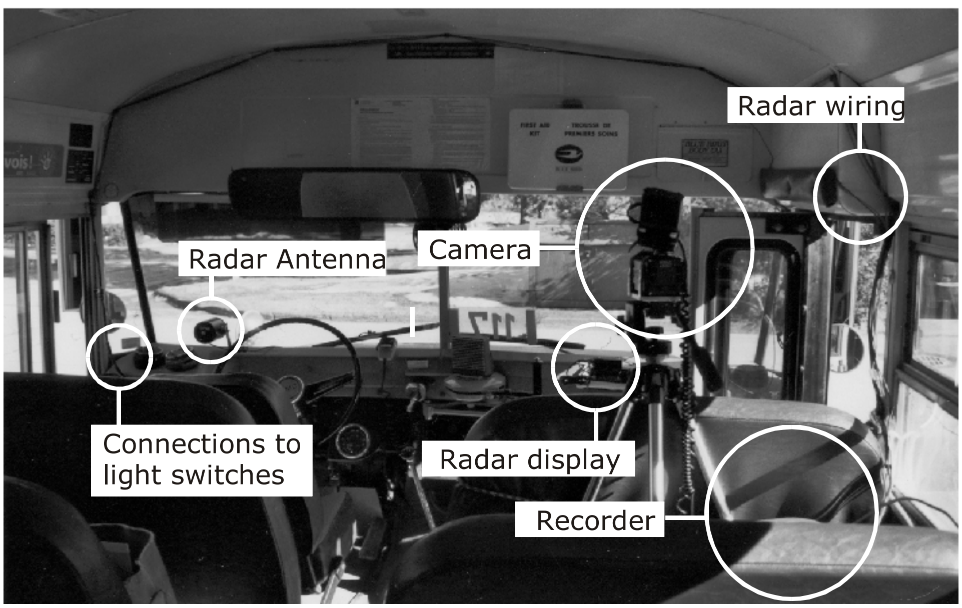

Figure 2 Set-up inside the bus

3.1.2 Collection Teams

Data was gathered by three different teams. The red light data collection was conducted by two teams. The Accident Research Team of the University of Western Ontario conducted the London, Ontario area collection. The University of Saskatchewan Transportation Centre team compiled data on routes around Regina and Saskatoon. Finally, the amber light data collection was sponsored by Transports Québec, as a follow-up to the 1999 Transport Canada study. The Université de Sherbrooke collected the data in rural and near-urban areas around Sherbrooke, Québec. The three collection teams received field training for "live" data collection, video reviewing, and file management and processing.

3.1.3 Data Collection Equipment

The collection equipment consisted of radar and video equipment aimed at oncoming traffic. Two almost identical Mobile Vision® in-car video systems (System 5 and System 7) with a Decatur Electronics® Genesis-1 radar unit were used for the experiment. Speeds detected by radar were superimposed on the video image. The system also allowed automatic insertion of titles on the image to note events such as the activation of the flashing lights. In the case of red lights used as an advance signal, the warning signal was indicated by the red lights title, and when the stop arm was extending, the stop title flashed. For amber lights, the advance signal was indicated by the amber lights title (Figure 3) and the stop signal by the red lights title (Figure 4). Date and time were also displayed on the image, allowing a margin of error of less than one second for estimating the duration of the advance signal and the stop signal phases.

Figure 3 Video image from the data tapes: the amber light title ("jaune")

Figure 4 Video image from the data tapes: the red light title ("rouge")

The radar equipment was used while the bus was moving, which allowed two measurements: the speed of the bus and the speed of oncoming traffic. Speeds were displayed when they exceeded 25km/h. When the bus was rolling at 25 km/h or less, the approaching vehicle's speed was transferred from "vehicle" to "bus" on the display. The range of the antenna was set at "4/5", the best position tested during preliminary trials for detecting a vehicle's speed at a range of 150 m or less. The maximum range of the radar was close to 300 m. The antenna was mounted horizontally on the dash, close to the steering wheel, and parallel to the bus axis (Figure 5). This alignment was important to prevent adverse effects such as under-evaluation of the real speeds. When the antenna is not perfectly horizontal, for example when it drops towards the ground, it is possible to overestimate the speed of the bus or to lose track of the vehicle's speed. The position of the radar on the left hand side of the bus assures that the axis of the antenna is as close as possible to the approaching vehicle's axis and the centre of the road, reducing the risk of misreadings. The "cosine effect," resulting in under-evaluation of real speeds is particularly noticeable on curved roads with several lanes of traffic. The angle formed at the junction of the radar's axis and the axis of the approaching vehicle's trajectory should always remain acute.

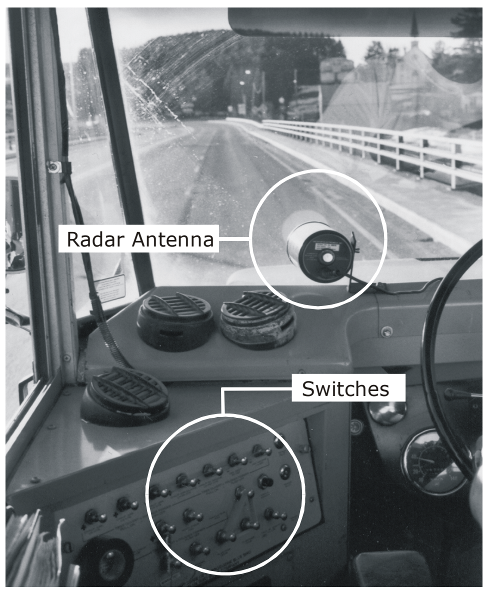

Figure 5 The radar antenna is mounted horizontally on the left side

3.1.4 Time of Year

Two seasons of the school year were analysed to account for a potential difference between different road conditions. End of fall refers to the period following the beginning of the school year, with low ambient light and snow conditions. Spring, at the end of the school year, represents conditions mainly associated with high luminosity and good road conditions. School bus routes were carefully chosen for a best fit between the red and amber lights. Fortunately, the collection process ended up with an equal share of observations for both seasons as well as for both signalling systems. Spring data collection in Québec and Saskatchewan took place between March and June, while in Ontario it was carried out between April and June. The fall collection lasted from October to January in all three provinces.

3.1.5 Routes Surveyed

School bus routes were carefully chosen to enable the best comparison between red lights and amber lights. Routes were generally located in rural or near-urban areas, where posted speeds varied mostly between 70 km/h and 90 km/h. The number of oncoming lanes of traffic was the key parameter for dividing the observations because it produced the greatest impact on stopping violations. With a few exceptions, visibility at the stop sites was good with few curves or hills.

The selection of suitable routes in Saskatchewan and Ontario was the most closely examined aspect of project planning because the routes had to be similar to those surveyed in Québec in 1998 and 2000. The first Sherbrooke route (bus 90) consisted of a 90 km/h, two-lane road with a high volume of traffic, especially in the morning, where isolated stops were sometimes made under conditions of poor visibility as a result of the hilly landscape. Sherbrooke highway 112 was a busy four-lane road with a maximum speed of 80km/h and a very high volume of trucks due to the number of industries located near the stop sites. High school students sometimes had to walk across four lanes. This route was also characterized by stretches where several stops were closely spaced. These had to deleted from the database, as explained in the selection criteria (3.3.1).

Many attempts were made at a preliminary stage to find a suitable route in Ontario, involving two different bus lines. The London route offered two important features that were compatible with the requirements. It had a number of stops on busy 80km/h, four-lane highways and the rest were on 80 km/h to 90 km/h two-lane roads. This fit well with Québec's overall portrait. Traffic volumes were equivalent in both provinces and the routes offered approximately equal numbers of cases with one and two lanes of oncoming traffic.

The London route however appears relatively homogeneous compared to the Sherbrooke routes. This was not unexpected since a single route was being compared to two other routes, and because of certain characteristics related to geography and how school routes are organized. There were no steep hills on the London route and visibility was good almost everywhere, since the roads were also straight. The London route had mainly isolated stops and no close stops such as on Sherbrooke's highway 112.

In Saskatchewan, low traffic volume was the main characteristic of the school bus stops observed, even though relatively busier highways in the area were chosen. In rural areas, few vehicles were encountered and many stops were made directly in the house yard, eliminating the possibility of observing other vehicles. The number of valid observations collected was low but this did not affect comparisons. At some locations on the Regina route, one side of the road was flanked by large fields, while the houses were all located on the other side of the road. This could have led motorists to disregard the stop sign in light of the fact that no children would be crossing the road. Nevertheless, the limited number of observations on this route (17 in total) did not affect the study trends in any particular way.

As a consequence of topography, the Saskatchewan routes did not bear a strong resemblance to the Québec and Ontario routes. Still, the Regina and Saskatoon routes generated data on two-lane roads with posted speeds of 90 km/h, comparable to Québec's Route 90 which also consisted of relatively straight roads. One of the main characteristics of the Saskatchewan routes was excellent visibility created by the road geometry and flat terrain. Many stops in Saskatchewan offered a visibility of one kilometre or more. Almost all observations had a visibility of more than 500 m. Visibility was not as good on the two Sherbrooke routes. Finally, the Saskatchewan routes did not have any stops on four-lane undivided roads.

Table 2 illustrates the main details from the data collection. A total of 148 days, including morning and afternoon outings, were necessary to obtain a total of 3,150 observations that met the selection criteria in the three provinces. The bus drivers stopped 7,068 times, with or without vehicles in sight of the bus, over a total distance of 6,869 kilometres. For each kilometre travelled, one stop was made and between 0.5 and 0.9 observations were obtained on the three main routes of the trial. In Saskatchewan, the data collection generated one observation every 20 kilometres.

Table 2 Data collection facts (2000-2001)

	Amber lights		Red lights		
	Sherbrooke 1*	Sherbrooke 2*	London	Regina	Saskatoon
Spring period	Mar-June	Mar-June	Apr-Jun**	May-Jun	May-Jun
Fall period	Nov-Dec	Nov-Dec	Oct-Dec	Oct-Nov	Oct-Jan
Avg. route length (km)	40	41	50	44	48
Days of collection	22	19	57	10	40
Total route length (km)	880	779	2,850	440	1,920
Total stops	795	911	2,677	484	2,201
Valid observations	577	668	1483	17	93
Stops / km	0.9	1.2	0.9	1.1	1.1
Observations / km	0.7	0.9	0.5	0.04	0.05

* The Sherbrooke area had two different routes: 1=bus 90; 2=bus 117.
** Data gathered during the year 2001; all other data gathered during the year 2000.

3.2 Parameters

Six groups of parameters were used to document road environment against measurements of time, distance and speed. Table 3 present the various categories created to classify the reading of each parameter used in the analysis. Motorist actions were used as numerators in the statistical analysis by categories.

3.2.1 Road Environment

Road environment is in part composed of fixed parameters that remain constant for a specific stop throughout the study, such as posted speed and lanes of traffic. Other environmental parameters change at each bus trip, given the prevailing conditions. The three main parameters for road environment are the number of oncoming lanes (1 or 2), posted speed, and traffic volume at the advance signal and during the two combined signal phases (warning and stop).

The geometry of the road is characterized by its straightness or by the type of curve. Road curvature was assessed visually and not measured. Slope is also defined in relative terms, using three categories, and key percentages are near 1%, 4% and 7%. Direction of the slope, downward or upward, was identified for the vehicle and the bus. Road slope and geometry were assessed by the same observer on both the London route and Sherbrooke routes (96% of the information). This prevented problems of classification that might have varied between observers not using a specialized tool.

Table 3 Parameters by group and categories used in the analysis

Parameters	Categories (status, readings)
Road Environment	
Time of Day	AM, PM
Day of Week	Monday, Tuesday, Wednesday, Thursday, Friday
Posted speed (km/h)	50, 70, 80, 90
Location	Rural, near-urban
Land use	Residential, commercial
Number of lanes	1 oncoming lane, 2 oncoming lanes
Slope (bus and vehicle) (%)	Flat (0-1), slight (1-3), average (4-6), steep (≥7)
Climbing (bus and vehicle)	Flat, climbing hill, descending hill
Geometry of road	Straight, moderate curve, pronounced curved
Road surface	Dry, wet, snowy, icy
Passing permitted	Yes, no
Pupil crossed road	Yes, no
Visibility	
Minimum visibility (m)	0-99, 100-199, 200-299, 300-399, 400-499, ≥500
Luminosity (at bus window) (EV)	≤10, 10.05 to 13.95, ≥14
Season	Fall, spring
Weather	Clear, cloudy, mist, drizzle, rain, snow
Time Markers	
Exposure to advance signal (s)	3-5, 6-10, 11-15, ≥16
Duration of advance signal (s)	1-5, 6-10, 11-15, 16-20, ≥21
Duration of stop signal	1-5, 6-10, 11-15, 16-20, ≥21
Traffic at advance signal (no.)	1, 2, 3, 4, ≥5
Total traffic (no.)	Light (1-2), average (3-5), heavy (≥6)
Distances	
Distance of advance signal (m)	1-19, 20-39, 40-59, 60-79, 80-99, ≥100
Type of stop	Isolated stop, stop ≤50 m from previous
Motorist position	1st motorist, after 1st motorist
Car-bus distance at TA (m)	1-95, 100-199, 200-299, 300-399, ≥400
Car-bus distance at TC (m)	1-19, 20-39, 40-59, 60-79, 80-100, ≥101
Speeds	
Speed at each second (km/h)	From −3s to x, at advance signal and at stop
Min, Max, Δ Min-Max	At advance signal, at stop
Motorist Actions	
Veh. change in speed (>10 km/h)	Slowed, maintained speed, accelerated
Event at advance signal, stop signal	Stayed in front of bus, stopped, passed

Other attributes were used to characterize the road environment. The right for an oncoming motorist to overtake a vehicle in front is indicated by the broken centre line marking. The parameter "location" was used to distinguish rural sites (low density of houses and high posted speed) from near-urban sites (edge of cities, proximity of rural areas and moderate housing density. Land use is the parameter used to separate residential from commercial use.

Time of day was a parameter also included in the road environment category. Morning stops were not made in the same context as afternoon stops. Mornings normally presented a peak period in traffic when most motorists were going to work. Afternoon conditions were different, with different users on the road and different types of driving. The afternoon rush to go home probably explains part of the change in the rate of stopping violations, which required isolating the time of day. The same logic applied to the day of the week. An effort was made to divide trips equally among the days of the week. As was noted in previous research, stopping violations rose significantly at the end of the week. Finally, the last parameter of the environment group identified cases where a pupil crossed the road.

3.2.2 Visibility

The visibility category measures the naturally available ambient light with two parameters recorded on a daily basis: luminosity and weather. Luminosity was measured in exposure value (EV) with a light meter aimed at the sky at the bus window, for evaluating the quantity of total ambient light. The light meter was calibrated at 100 ASA and at a 1/125s shutter speed to give comparable readings in all provinces. The luminosity level was partially determined by weather, but the main determinant was the season of observation.

The visibility was also evaluated between the bus and the oncoming vehicle during the advance signal, to account for potential visual obstruction problems at stop sites. This road condition refers to the shortest line of sight, observed during the advance signal between two points: the bus position anywhere during the advance signal and the oncoming vehicle. The geometrical line of sight was updated daily in the log, but unlike weather and luminosity, only one "final" value was retained at the end of the experiment. This value is important in the characterization of the stop site as very short line of sight can lead to higher stopping violation risk.

3.2.3 Time Markers

Three time markers indicate the beginning and the end of each signal phase (TA, TC and TE). Two other markers, TB and TD, fixed the events in time using the elapsed time from the previous marker. Time of the event was noted when the approaching vehicle stopped or passed in front of the bus. The difference between TA and TC gave the total duration of the advance signal, and the difference between TC and TE indicated the duration of the stop signal:

- **TA : Beginning of advance signal**
- TB : Time elapsed from TA to event
- **TC : Beginning of stop signal**
- TD : Time elapsed from TC to event
- **TE : End of stop**

3.2.4 Exposure Time

The motorist's exposure time was equivalent to the period of time, during the advance signal, during which the motorist was in sight of the bus. When a vehicle passed the bus during this signalling phase, the time remaining for the advance signal was subtracted from duration of the advance signal to calculate the effective exposure time. As seen in Figure 6, motorist exposure time follows a normal curve. Both distributions peak at between 9 and 11 s of advance signalling, but there was a greater concentration of red light observations (60%) than amber light observations (43%). Consequently, the categories of short- and long-term exposure are primarily represented by amber lights.

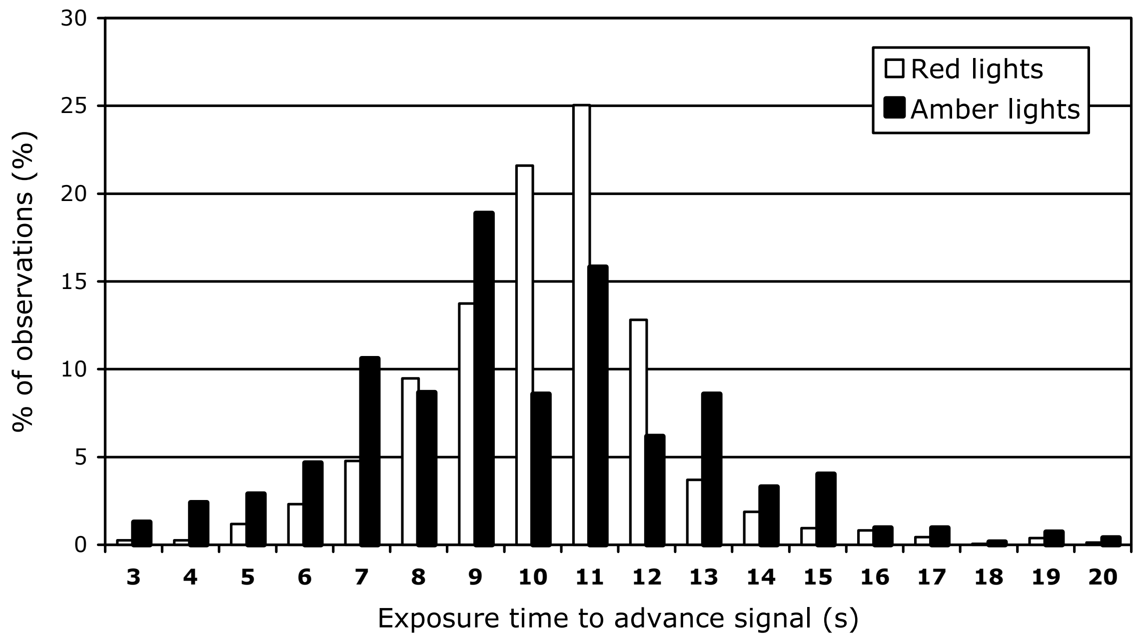

Figure 6 Number of observations by exposure time to advance signal

3.2.5 Distances

Distances to approaching vehicles were not provided by the radar unit and consequently were estimated during review of the videotape. Distances were calculated using landmarks such as the spacing between the broken centre line markings—approximately 8m—or by the average distance between utility poles, which in Québec is 50 m. The angle of observation of the camera also helped estimate distances, because a slight shift to the right of the bus increased the depth of field, creating an effect in which the third dimension helped read distances. First estimations were done inside the school bus and recorded by the microphone, but the final ruling was made while reviewing the video tapes. The use of video tape allowed a particular case to be reviewed several times until a final distance was determined, thus increasing the level of precision. Another benefit from the work in the laboratory was the elimination of potential errors from the observer’s perception and reaction time when observing a vehicle while travelling on the bus.

The distance between the vehicle and the bus was given at the beginning of the advance signal (TA) and at the beginning of the stop signal (TC). The total distances travelled by the bus during the advance signal were categorized by the different ranges of advance signal distances, with intervals of 50 m.

A criterion of fixed distance was used to classify the position of vehicles facing the bus. A vehicle facing the bus without another in between was considered to be the “leading vehicle” or first motorist. A vehicle following the first at less than 50 m was regarded as a following motorist. Following motorists were included in the analysis if the leading vehicle passed the bus during the advance signal. Following motorists that remained behind the leader were not included in the database because they tended to adjust to the leader’s actions.

The type of stop also used distance as a criterion to evaluate each case. A stop preceded by another less than 50 m away was considered a "close stop." Regular stops were isolated ones.

3.2.6 Speeds

Speeds were evaluated with radar readings at each second displayed on the video clock. The speed of the bus was measured starting at three seconds before TA, and continuing until the bus came to a complete stop. Speeds of oncoming vehicles were also recorded from the same starting point, but they were recorded until the stop signal was over because, unlike the bus, vehicles sometimes moved during the stop phase. Speed at the beginning of the advance signal referred to the exact speed measurement at TA, when the advance signal marker began to flash on the screen. Changes in speed during the advance signal were assessed with the difference between the speed at TA, or the closest value to TA, and the minimum or the maximum speed recorded during the advance signal.

Speed reduction rates were also organized into categories, varying in 10 km/h increments from 10 to 100 km/h and over. These categories were used in the reduction in speed graphics to express the absolute change in speed for the two systems. Mean speed reduction rate was also plotted according to the number of radar readings to determine whether the magnitude of the reductions in speed varied with the quantity of available data. All speed changes estimated had valid radar readings. The speed of a vehicle can be estimated based on the reference value of a preceding vehicle, but this is not possible when the two are travelling at a different pace. Speeds were estimated for close vehicles only, when the reference vehicle was less than 50 m away or when the two vehicles were side-by-side.

3.2.7 Motorist Actions

Motorist reductions in speed and stopping violation outcomes were the main parameters recorded under the motorist actions grouping. Changes in speed needed to be at least 10 km/h, whether a reduction in speed or an acceleration, to be accepted as valid data. Changes in speed of 9 km/h or less were placed in the "keeping pace" category. Of course, there were different levels of magnitude for reductions in speed during the advance signal, ranging from 0 to 120 km/h. The magnitude of reduction in speed was assessed to see if a change in relative effectiveness occurred when considering different thresholds of magnitudes of reductions in speed. The most important function of the radar speed data was to give precise indications that speeds displayed were close to actual speeds. This reduced potential problems associated with visual observation of speed changes to marginal levels.

At the same time, radar brought a new complexity sometimes requiring very good interpretation skills, especially on busy roads with two oncoming lanes. Vehicles were often in range for a very short time, decreasing the chances of obtaining valid readings. Reductions in speed were sometimes so sudden that the radar readings could not be refreshed quickly enough to accurately reflect the changes in real time, even though the images leave no doubt about the vehicle's braking action. Although some of these elements cannot be resolved, most of the data was collected in situations that were easy to interpret, when the radar accurately tracked vehicle speed.

Three types of events were noted during the stopping process, and a distinction was made between advance and stop signals. All of these events are legal with the exception of passing during the stop signal:

- The vehicle stops in front of the bus;
- The vehicle keeps moving but remains in front of the bus, without stopping; and
- The vehicle passes the bus.

3.3 Database

3.3.1 Observation Selection Criteria

Six criteria determined whether cases would be included for analysis. Criteria were defined according to time and distance to compare the systems on an identical basis. Regardless of the location or the route, all vehicles observed met the following six criteria:

- Exposed for ≥ 3 seconds to the advance signal
- At ≥100 m or ≤500 m from the bus at the beginning of the advance signal or when the vehicle appears on the video image
- At ≤300 m from the bus at the beginning of stop signal
- At ≤100 m from the bus when stop was over
- First seen at a normal speed (vehicles entering the road were eliminated)
- No police patrolling near the bus
- Isolated stop (stops at <50 m from previous stop were eliminated)

The 312 observations involving a close stop were eliminated from the database because they significantly increased the rate of stopping violations, which is excessive under these conditions (10%). When the bus made a second consecutive stop, motorists who were still a fair distance away may have seen two partial or complete stop processes with different advance and stop signals. The interval between the two stops was marked by an absence of signals for a very short period. This situation is quite complex. It confuses motorists and probably explains the greater number of instances of stopping violations at close stops. Furthermore, it would have been impossible to find similar close stop conditions with a similar frequency in Saskatchewan and Ontario. Eighty per cent of close stops took place on school bus routes where amber lights were used.

3.3.2 Number of Observations

As shown in Table 4, the 2,838 observations that made up the final database were well distributed between amber and red lights, with each system gathering 1,245 and 1,593 valid observations respectively. With regard to season, weather, and number of lanes, a similar number of observations were recorded for both the red and amber light groups. Appendix B gives the detailed number of observations for each category analysed.

Table 4 Number of observations by advance signal

	Red lights	Amber lights	Total
1 oncoming lane	601	718	1,319
2 oncoming lanes	992	527	1,519
Spring	721	689	1,410
Fall	872	556	1,428
Clear or cloudy	1,294	883	2,177
Rain, snow or other	299	362	661
≤ 70 km/h posted	123	296	419
≥ 80 km/h posted	1,470	949	2,419
Total	1,593	1,245	2,838

3.3.3 Reduction in Speed Assessment

Reduction in speed at the advance signal was the main indicator because it revealed the specific effect produced by the two systems. Speeds and events at the stop signal can be partially influenced by both the stop signal lights and the stop arm. On the other hand, speed variations taking place during the advance signal were likely to be influenced largely by the warning lights and the observable reduction in speed of the bus (which is identical with both signal types and thus cancels out of the analysis). The impact of flashing lights on a vehicle's speed was measured with valid cases only. The braking effect induced by each system was calculated with known speeds. To be valid, the radar must have displayed two effective readings, a required minimum to identify a change in speed.

An effectiveness index was applied to valid cases. The numerator is equivalent to the number of vehicles that slowed by at least 10 km/h, compared to the denominator, the exposure, which is the number of valid cases or the number of observations with two valid readings. The effectiveness index begins with a ratio (R) calculated for each group: red lights and amber lights (1):

$$R = (a / A) / (b / B) \qquad (1)$$

Where : a = events in a group; b = observations in a group; A = events in a population; B = observations in a population

The relative ratio, or RR (2), is obtained by dividing the red light ratio (3) by the amber light ratio (4). The effectiveness index E (%), with a maximum value of 100%, expresses the capacity of one system over the other to reduce the speed of oncoming vehicles (5). For example, when RR is 2:1, it indicates that E=50%, and when RR is 3:1, it means E=67%, and so on. The significance of E% is given by the *p*-level of a Chi-square value applied to "Observed vs. Expected Frequencies," with a specific formula for estimation of the expected frequency EF (6).

$$RR = R^1 / R^2 \qquad (2)$$

$$R^1 = (a^1 / a^1 + a^2) / (b^1 / b^1 + b^2) \qquad (3)$$

$$R^2 = (a^2 / a^1 + a^2) / (b^2 / b^1 + b^2) \qquad (4)$$

$$E (\%) = (1 - RR) * 100 \qquad (5)$$

$$EF^1 = b^1 (a^1 + a^2) / (b^1 + b^2) \qquad (6)$$

3.3.4 Stopping Violation Assessment

The stopping violation rate was an important measurement because it revealed the potential risks for school children crossing the road. A statistical difference test was carried out on the rates of stopping violations for each system. The degree of certainty that the stopping violation rates for the two pre-stop systems are significantly different is based on the *p*-level of a Chi-square value applied on Observed vs. Expected Frequencies. Unlike the speed reduction rate, which uses only valid cases as a denominator, all 2,838 observations are part of the denominator for calculating the rate of stopping violations. No unknown action takes place; it is always possible to tell if a violation occurred. In the current analysis, all of the following conditions must apply for an event to be considered a stopping violation:

- The vehicle crosses the front bumper of the bus;
- The red flashing lights are on;
- The bus is completely stopped; and
- The stop arm is extending or is fully extended.

3.4 Bus Driving Parameters

The variation in the four parameters linked to school bus drivers' advance signalling and stopping techniques gave us an opportunity to verify whether amber lights and red lights were tested under similar conditions (Table 5). Both distributions were ranked by category for their entire range. Despite the risks involved in targeting three different routes in two Canadian provinces, the distribution curves are similar in all respects. Overall, although advance signals during trials with red lights were initiated at a slightly higher speed, they were longer in both distance and duration.

The duration of advance signal is one of the most important elements describing the context of the warning and stopping phases. On average, bus drivers using red lights provided an advance signal half a second shorter than the signals provided by drivers using amber lights. As Figure 7 illustrates, three out of four red light observations are concentrated around the average value, from 9 to 12 seconds of advance signalling. On the other hand, the amber light observations have a slightly wider range of distribution, with many shorter and longer advance signals.

With regard to the duration of the stop signal, observations for the red and the amber lights were well distributed, as shown in Figure 8, although red lights stops averaged 3 seconds longer than amber light stops. Many observations for both systems fall into the short stops category, lasting between 5 and 10 seconds. Finally, a large number of categories had a small number of cases in the longer signal ranges. Longer stopping times could increase the risk of stopping violations, but longer stops often involved a line-up of vehicles in front of the bus, protecting the passing zone. As bus drivers noted, it is sometimes hard to stop the first vehicle but it becomes safe afterwards.

The total distance travelled by the bus during the advance signal is very well distributed for the two systems tested, as illustrated in Figure 9, with an identical average value of 90 m for total observations. The red light distribution is concentrated near the average, with 65% of advance signals ranging from 50 m to 150 m. The amber lights were displayed over a wider range of distances, with greater numbers in the shorter and longer distances.

Bus speed at the start of the advance signal proved to be a deciding factor in the choice of selection criteria. When all close stops in the database are included, amber lights account for

20% of cases where bus speed was under 30 km/h at the start of the advance signal. Excluding close stops balances out the comparison of initial bus speeds, as illustrated in Figure 10. Advance signals made on high-speed roads were generally initiated at a speed corresponding to the bus's top speed, recorded just before the driver started to brake.

Table 5 Average values of bus driving parameters by advance signal

	Red lights	Amber lights	Total
Duration of advance signal	10.4 s	11.0 s	10.7 s
Duration of stop signal	13 s	10 s	12 s
Distance travelled during advance signal	89 m	90 m	89 m
Speed of the bus at the beginning of adv. signal	59 km/h	47 km/h	54 km/h

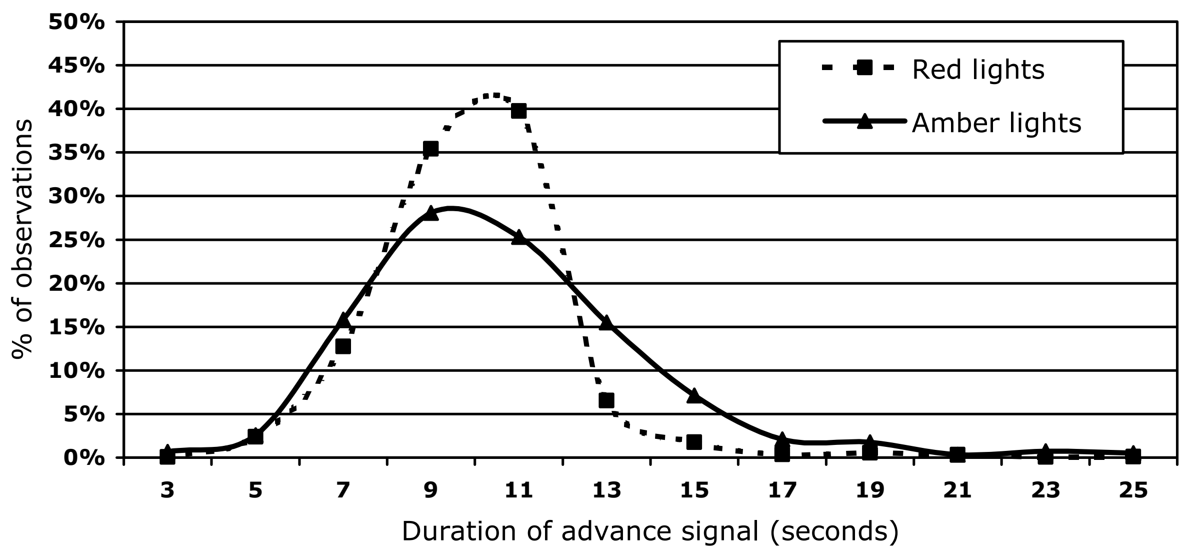

Figure 7 Duration of advance signal

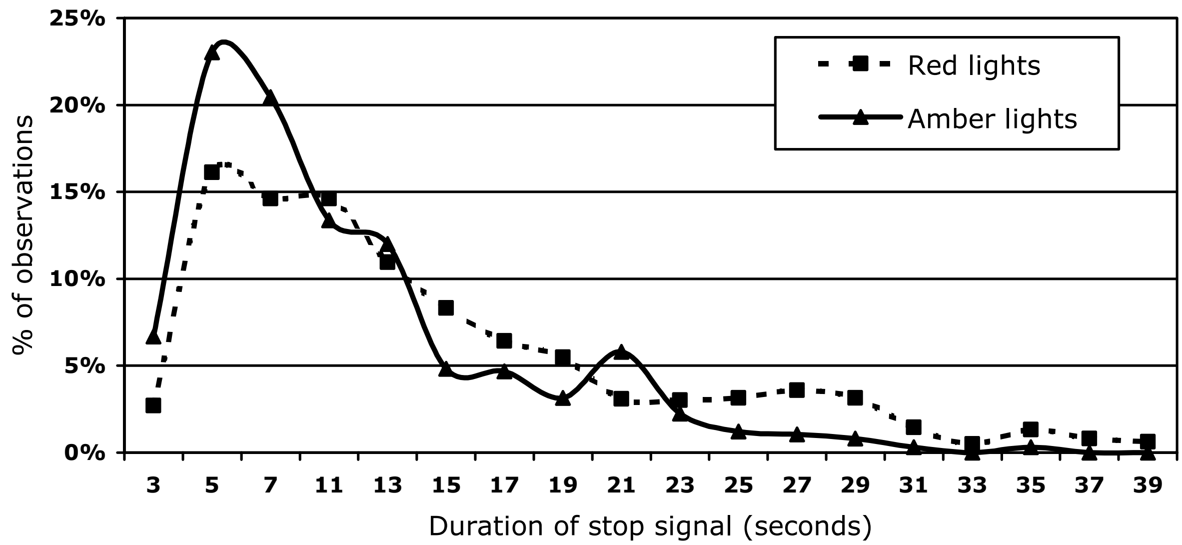

Figure 8 Duration of stop signal

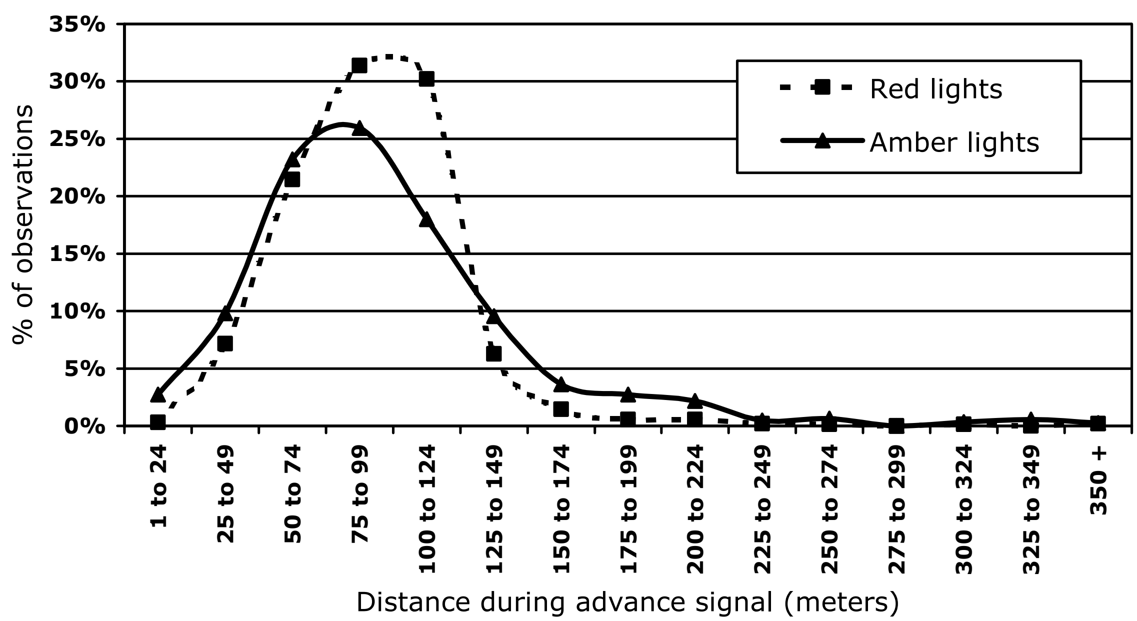

Figure 9 Distance travelled by the bus during the advance signal

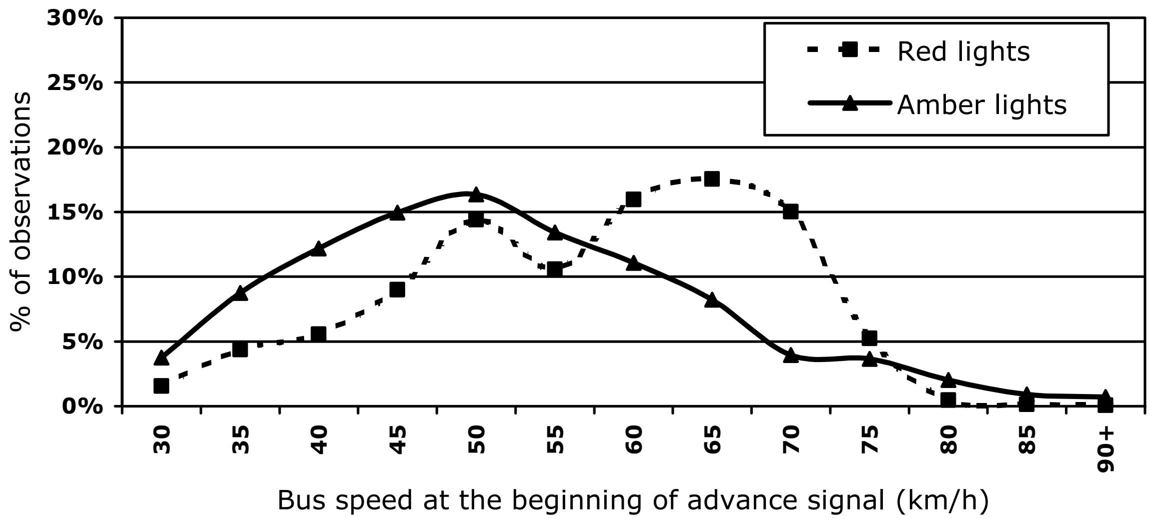

Figure 10 Bus speed at the beginning of advance signal

3.5 Limitations of the Methodology

3.5.1 Comparable Routes

The choice of suitable routes to conduct the study in Saskatchewan and Ontario was raised as a potential deterrent to a comparative analysis. Finding comparable routes was not an easy task, but it was assumed from the earliest stages of the project that identifying identical routes in three different provinces was not feasible, especially when trying to find routes to match those on which data had already been collected. The number and variety of stops could not be exactly the same because the route selection was done within the available routes of the collaborating bus lines. The most challenging problem was to find a bus route that could offer a large set of observations from busy, undivided, four-lane highways with a posted speed limits of 80 km/h.

In order to assure that the route selection was appropriate in Saskatchewan and Ontario, collaborators in these provinces came to Québec to observe the routes tested. This is probably why a good route was found in Ontario. With some reservations, it is possible to consider the Ontario route to be a good fit with the two Québec routes. The London area route reaches the compatibility requirements with comparable traffic volumes and contexts involving two oncoming lanes of traffic. The Québec and Ontario routes were compatible and together they provided 96% of the observations. Even though it was clear that identical routes could not be found, in practical terms the London and Sherbrooke routes still permit a good analysis of the two advance signalling systems.

3.5.2 Impact of Advance Signal on Stopping Violations

Previous work (Bruneau, 1999a) expressed the rate of stopping violations as an effectiveness index calculated for a specific system, as was done for reductions in speed in the current analysis. However, the respect—or disrespect—shown by motorists for the school bus stop signal is likely conditioned by several factors. The stop arm and red lights are probably the most important factors explaining why motorists stop for school buses. But it is impossible to evaluate the specific effect of the stop arm, even with a rough estimate, because the use of the stop arm is always combined with the red stop light. The same can be said for the effect of the advance signal on stopping violations. The objective pursued in this experiment was not to identify the discrete effect of the advance signal but to compare the relative differences in the risk of stopping violations for each advance signal system, keeping all other contextual elements similar.

Because stopping violations are rare occurrence, a simpler method was required. The practical alternative was to compare the raw frequencies of stopping violations for the two systems.

3.5.3 Radar Adjustment

The radar had to be mounted on the left-hand side of the instrument panel near the driver's wheel to minimize the impact of the "cosine effect" and to compensate as much as possible for the presence of multiple lanes at certain stops. Despite this requirement, a portion of the red light data was collected with the radar installed on the right-hand side, and in the upper-right corner of the windshield, creating misreadings or incorrect speed evaluations. This is the most likely explanation for a low number of speed readings available for the red lights, especially for two oncoming lanes. Speeds were unknown in 60% of observations for two oncoming lanes, and 28% for one oncoming lane. This probably explains why the number of red light observations that could be used for calculating the speed reduction rate was just over half of the total (871 out of 1654). The radar worked better during the amber light data collection where speeds were unknown for only 10% to 15% of observations in all situations, resulting in the rejection of only a small portion of total amber light observations.

3.6 Bus Driver Survey Methodology

A survey was administered to school bus drivers who used red lights as an advance signal, to characterize the general use of this system and to learn about driver perceptions of its effectiveness. The 1998 questionnaire, presented in the 1999 report, served as a basis in developing the 2001 questionnaire.

In 1998, the questionnaire was addressed to Québec school bus drivers operating around the Sherbrooke and Montréal areas with the collaboration of a dozen bus companies. The main groups of respondents came from Eastern Townships School Board and Limocar – Autobus de l'Estrie. A total of 181 completed questionnaires were returned, of which half were from respondents who used amber lights. The other half used hazard warning lights for advance signalling.

In spring 2001, a similar questionnaire was distributed to drivers who used red lights as an advance signal. New questions were added but almost all of the previous were retained, to maximize the number of possible comparisons between the two systems. Specific references to amber lights were changed to red lights. Any reference to a specific Québec context was removed. Out of 159 questionnaires completed in 2001, the majority came from respondents who operated school buses in the London area. Murphy Bus Lines participated in the study along with Elgie Bus Lines, who also helped with the field study to collect red light data. One third of the respondents were from Saskatchewan, operating buses in the Regina (Buffalo Plains School Division) and Saskatoon areas (Hertz Northern Bus).

The 2001 questionnaire was merged with the 1999 database, to provide a total of 340 responses from the three provinces. In the 2001 database, all drivers from the red light group were using red lights. In contrast, only 54% of the amber light group is composed of amber light users because the other half was using hazard lights as an advance signalling technique. This particular fact has to be acknowledged since the need for a larger volume of respondents for the amber light group led to the inclusion of the 1998 results as a whole, under the label “amber light users”. Results are shown separately for the two groups of respondents.

4 RESULTS

Results are organized into four sections representing each sequential step in any school bus stopping process: reductions in speed and actions during the advance signal, followed by the same items during the stop signal.

4.1 Speed Variation During the Advance Signal

Unlike stopping violations, whose occurrence is wholly or partly influenced by the stop arm or the bus's immobility, the changes in speed observed during the advance signal are almost always a direct consequence of the effectiveness of advance signal lights. Measuring changes in speed during advance signalling is an appropriate way to assess the effectiveness of the two systems. During advance signalling, the bus is still moving and the stop arm is not in use.

Table 6 shows the proportion of motorists who slowed, maintained their speed or accelerated when exposed to advance signal lights according to the number of oncoming lanes. Amber lights caused the same number of motorists to slow down on roads with one oncoming lane as on roads with two oncoming lanes, with a mean of 65% for all observations. Red lights resulted in different rates of motorists slowing down in these two situations, with a rate of 73% on roads with one opposing lane, but only 42% on roads with two opposing lanes. Looking at the two advance signalling systems together, most vehicles that did not slow down maintained their speed. However, very few vehicles sped up—less than 1% of the 1,935 observations.

Table 6 Speed variation[1] of oncoming traffic during advance signal

		Red lights		Amber lights		Total	
Oncoming lanes	Speed variation	Nb	%	Nb	%	Nb	%
1 lane	Slowed	316	72.5	431	66.3	747	68.8
	Maintained speed	115	26.4	216	33.2	331	30.5
	Accelerated	5	1.1	3	0.5	8	0.7
	Total	436	100.0	650	100.0	1,086	100.0
2 lanes	Slowed	166	42.1	289	63.5	455	53.6
	Maintained speed	221	56.1	166	36.5	387	45.6
	Accelerated	7	1.8	0	0.0	7	0.8
	Total	394	100.0	455	100.0	849	100.0
Total	Slowed	482	58.1	720	65.2	1202	62.1
	Maintained speed	336	40.5	382	34.6	718	37.1
	Accelerated	12	1.4	3	0.3	15	0.8
	Total	830	100.0	1105	100.0	1935	100.0

[1] Known speeds only

4.1.1 Average Speed of Approaching Vehicles

If we look at the radar data available to assess vehicle speed, motorists' average initial speed, for all observations, was just over 80 km/h (Figure 11). The initial average speed is the same for both advance signalling systems. Red and amber lights were thus tested under similar conditions.

The first perceptible effect on vehicle speed occurred after approximately three seconds. However, after this point the two speed curves took on different shapes. The reduction in speed that occurred with amber lights was more constant and more gradual than that with red lights. In the case of amber lights, the average reduction in speed was approximately 5 km/h per second, within 3 to 10 seconds of advance signalling. This was followed by a low-speed plateau, at roughly 25 km/h, which was reached after 10 seconds of advance signalling. In contrast, red lights appeared to be effective only at the end of advance signalling. The average speed was still 60 km/h after 10 or 11 seconds of advance signalling and the average speed did not fall significantly until after about 12 seconds of advance signalling.

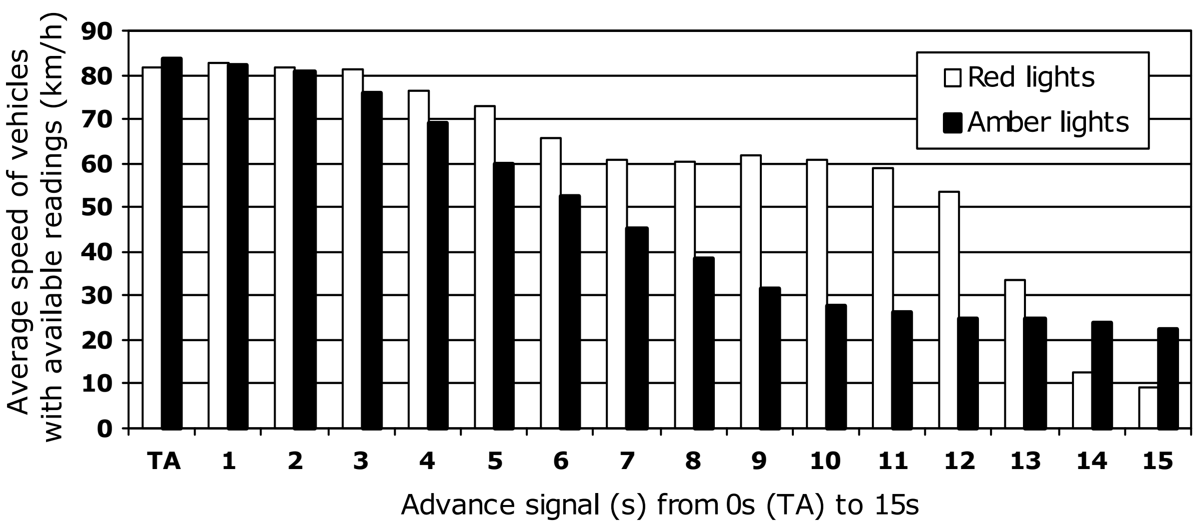

Figure 11 Average speed of motorists during the advance signal phase

4.1.2 Effectiveness in Reducing Speed

In order to assess the effectiveness of advance signalling in reducing motorists' speed, we looked at the number of vehicles that slowed by at least 10 km/h. This group of observations, which constituted the numerator, was correlated with all of the valid observations, i.e., those with a minimum of two valid radar readings. Table 7 shows the road conditions under which one of the two advance signals recorded a higher speed reduction rate and where the difference between the two systems was statistically significant (above .05) (observed frequencies and estimated frequencies). The road conditions presented in the table are those with significant effectiveness indices among the 82 road conditions that were tested out of a set of 24 parameters. The detailed findings, including those that were not significant, can be found in Appendix C.

Table 7 Effectiveness in reducing speed[1] (conditions with .05 p-level or better)

	Red Lights (RL)				Amber Lights (AL)				AL Effectiveness to slow down		
	Slow	Veh.	Exp.	Ratio	Slow	Veh.	Exp.	Ratio			
Condition	(a^1)	(b^1)	(E^1)	(R^1)	(a^2)	(b^2)	(E^2)	(R^2)	RR	p	E(%)
80 km/h	290	575	325	0.9	269	415	234	1.1	0.78	.01	22
Near urban	60	154	92	0.6	421	648	389	1.1	0.60	.01	40
2 oncoming lanes	166	394	211	0.8	289	455	244	1.2	0.66	.01	34
Vehicle descending	107	205	126	0.9	306	468	287	1.1	0.80	.04	20
Straight	457	793	498	0.9	557	821	516	1.1	0.85	.01	15
Passing prohibited	364	672	392	0.9	344	542	316	1.1	0.85	.03	15
Sight ≥500m	349	633	386	0.9	322	467	285	1.1	0.80	.01	20
Spring	212	426	249	0.9	391	607	354	1.1	0.77	.01	23
Advance 11-15s	191	359	213	0.9	338	533	316	1.1	0.84	.05	16
4 veh. at advance	28	81	42	0.7	91	150	77	1.2	0.57	.01	43
≥5 veh. at advance	37	100	50	0.7	118	210	105	1.1	0.66	.03	34
3-5 veh. total	122	252	153	0.8	290	425	259	1.1	0.71	.01	29
≥6 veh. total	24	79	42	0.6	260	450	242	1.1	0.53	.01	47
TA pos. 200-299m	156	246	176	0.9	260	335	240	1.1	0.82	.05	18
TA pos. 300-399m	45	86	61	0.7	118	145	102	1.2	0.64	.01	36
TC pos. 80-100m	37	61	46	0.8	44	47	35	1.2	0.65	.05	35
TC pos. ≥101m	58	123	76	0.8	64	74	46	1.4	0.55	.01	45
All conditions	482	830	516	0.9	720	1,105	686	1.0	0.89	.05	11

[1] Known speeds only, reduction in speed ≥10 km/h

According to the overall effectiveness index, which takes into account all observations, the relative effectiveness of amber lights in reducing vehicle speed by at least 10 km/h was 11%.

The strong indicators for a higher effectiveness index with amber lights are largely related to difficult road conditions, such as near-urban areas (+40%), two oncoming lanes of traffic (+34%), and heavy traffic situations (+47%), with four, five or more oncoming vehicles. Thus, amber lights seem to be more effective if they are used when the vehicle is situated 300–400 m from the bus at the start of advance signalling (+36%). Amber lights also had a greater impact when motorists were exposed to advance signalling for a long period (+16%). In addition, it should be noted that the red lights produced no significant result in their favour.

There are advantages and disadvantages in assessing the effectiveness of advance signals based on a decrease in speed of 10 km/h or more. This criterion meets the objective of recovering as many observations as possible, but in being very inclusive, it fails to take into account the magnitude of reductions in speed. Table 8 shows the effectiveness of advance signals in getting motorists to slow down based on the amplitude of speed decreases. Effectiveness indices are calculated for all observations and the numerators are determined for 10 km/h segments.

Table 8 Effectiveness in reducing speed[1] from 10 km/h to 90 km/h

	Red Lights (RL)				Amber Lights (AL)				AL Effectiveness		
	Slow	Veh.	Exp.	Ratio	Slow	Veh.	Exp.	Ratio	to slow down		
Reduction in speed	(a^1)	(b^1)	(E^1)	(R^1)	(a^2)	(b^2)	(E^2)	(R^2)	RR	p	E(%)
10 km/h	482	830	516	0.9	720	1,105	686	1.0	0.89	.05	11
20 km/h	251	830	330	0.8	518	1,105	439	1.2	0.65	.01	35
30 km/h	170	830	259	0.7	434	1,105	345	1.3	0.52	.01	48
40 km/h	109	830	214	0.5	391	1,105	286	1.4	0.37	.01	63
50 km/h	73	830	180	0.4	347	1,105	240	1.4	0.28	.01	72
60 km/h	57	830	150	0.4	292	1,105	199	1.5	0.26	.01	74
70 km/h	43	830	110	0.4	213	1,105	146	1.5	0.27	.01	73
80 km/h	35	830	70	0.5	129	1,105	94	1.4	0.36	.01	64
90 km/h	13	830	33	0.4	65	1,105	45	1.5	0.27	.01	73

[1] Known speeds only

Table 8 highlights the significant relationship that exists between amber lights and the decrease in speed in response to advance signalling. When a permissive inclusion criterion, such as 10 km/h, is used, the difference between the two advance signal systems is fairly small. However, when reductions in speed of at least 50 km/h in the numerator are targeted, the relative effectiveness of amber lights jumps to 72%, a performance three times that of red lights. Furthermore, regardless of the magnitude of the reduction in speed (10 to 90 km/h), all the indices obtained are significant at the 5% threshold.

4.1.3 Reduction in Speed by Exposure Time to Advance Signal

The average decrease in speed was calculated for all observations based on comparable exposure times, namely 5 to 15 seconds (Figure 12). The raw distribution and trend line for these exposure times indicate the same thing: the magnitude of the reduction in speed is greater with amber lights. The average decrease varies from 28 to 32 km/h for amber lights, and from 10 to 12 km/h for red lights. According to the two regression lines, the decrease in speed is 20 km/h higher on average with amber lights, and this holds true for both short and long exposure times. A small inverse regression can be seen in relation to exposure time, but the reductions in speed are only slightly smaller for the longest exposure times. The duration of exposure to advance signal lights does not, therefore, seem to have a significant impact on the magnitude of the reduction in speed during advance signalling.

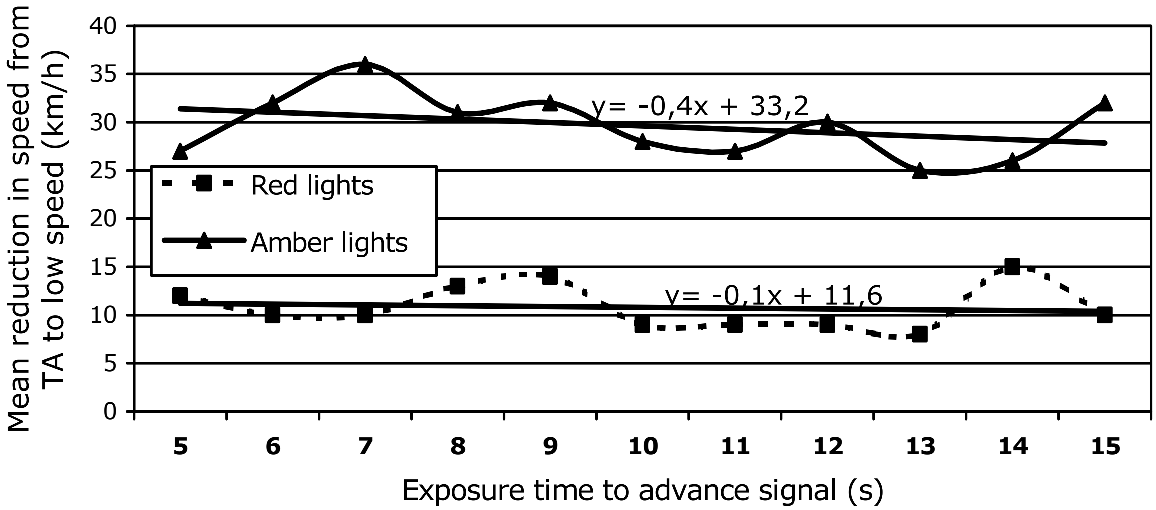

Figure 12 Mean reduction in speed by exposure time to advance signal

4.1.4 Magnitude of Reductions in Speed

Figure 13 presents the distribution of observations for which reductions in speed of at least 10 km/h were observed (between the initial speed and the lowest speed observed). The decreases are by 10-km/h segments, to over 100 km/h.

In the case of red lights, half of the observations were of reductions in speed of 10 to 20 km/h. The distribution for amber lights presents two separate observation groups, giving the line a bimodal aspect. The first group of motorists also showed low reductions in speed, 30% of cases presenting a decrease of 10–20 km/h. The other group presented high decreases in speed: between 60 and 80 km/h. In fact, half of the reductions in speed with amber lights were in the 50 to 90 km/h range, compared to less than 20% of the red light observations.

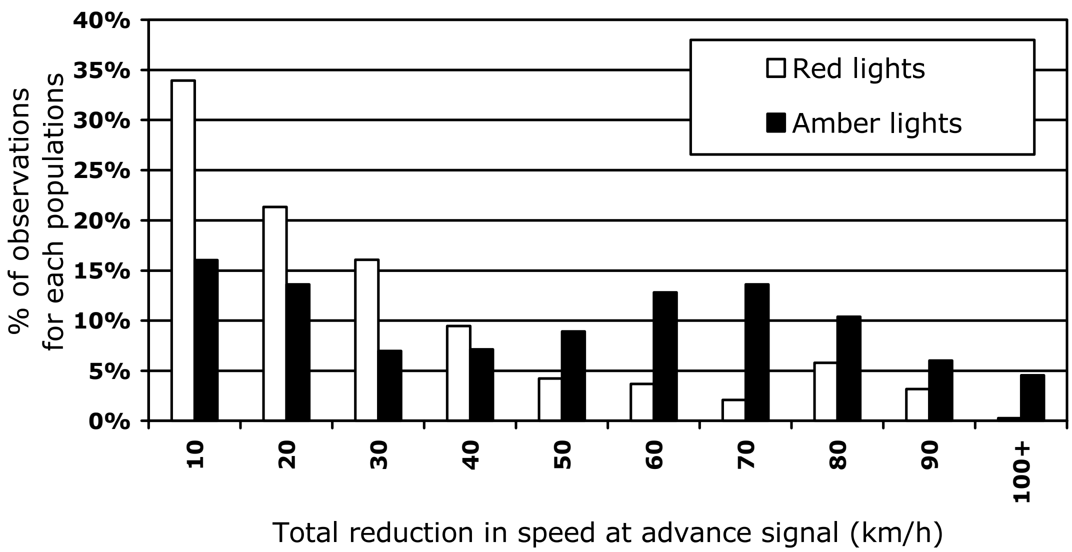

Figure 13 Total reduction in speed during advance signal

4.2 Events During Advance Signal

During the advance signal, more vehicles pass the bus with amber lights, as indicated in Table 9. On roads with one oncoming lane of traffic, nearly half of the motorists facing the amber lights passed the bus before the stop arm swung out (44%). With red lights, nearly all motorists observed stayed in front of the bus, whether they stopped or remained in motion (87%).

Table 9 Motorist actions during advance signal

Oncoming lanes	Motorist action	Red lights No.	Red lights %	Amber lights No.	Amber lights %	Total No.	Total %
1 lane	Passed the bus	75	12.5	353	43.8	428	32.4
	Did not pass the bus: stopped	33	5.5	44	5.5	77	5.8
	Did not pass the bus: kept moving	493	82.0	409	50.7	814	61.7
	Total	601	100.0	718	100.0	1,319	100.0
2 lanes	Passed the bus	403	40.6	283	53.7	686	45.2
	Did not pass the bus: stopped	17	1.7	12	2.3	29	1.9
	Did not pass the bus: kept moving	572	57.7	232	44.0	804	52.9
	Total	992	100.0	527	100.0	1,519	100.0
Total	Passed the bus	478	30.0	636	51.1	1,114	39.3
	Did not pass the bus: stopped	50	3.1	56	4.5	106	3.7
	Did not pass the bus: kept moving	1,065	66.9	553	44.4	1,618	57.0
	Total	1,593	100.0	1,245	100.0	2,838	100.0

The situation changed when there were two oncoming lanes of traffic. The red lights obtained a pattern more similar to the amber lights. Nearly half of the vehicles passed the bus during the advance signal (41%) and the other half, whether they stopped or remained in motion, stayed in front of the bus.

Stopping vehicles during the advance signal phase is not a desirable outcome if it involves sudden braking. This was rare on four-lanes roads, but happened more frequently on roads with one oncoming lane (6%).

A Chi-square test was carried out on frequencies observed and revealed a significant difference between the three types of actions for the two systems in both contexts: one or two oncoming lanes of traffic ($p < .05$). To make sure that these significant relations were not caused by the small sample of vehicles that stopped during the advance signal, the same test was performed excluding the stopped vehicles. In this case, the Chi-square p-level remained significant.

4.3 Reduction in speeds During Stop Signal

Given the large number of vehicles that had already slowed before the stop sign swung out, and because the stop signal was expected, almost all vehicles slowed when the stop signal was active. In fact, those not reducing their speed at the stop or advance signals were the same that passed the bus illegally, a situation discussed in the next section.

4.4 Stopping Violation Rate

With regard to stopping violations, the rate was slightly lower for amber lights, and the difference between the two systems was significant for all observations. As Table 10 shows, there is no difference between the two based on the number of opposing lanes.

Table 10 Stopping violation rate by number of oncoming lanes

	Red lights			Amber lights			Total			
Oncoming lane	Pass	Veh.	%	Pass	Veh.	%	Pass	Veh.	%	*p*
1 lane	13	601	2.2	8	718	1.1	21	1,319	1.6	-
2 lanes	55	992	5.5	27	527	5.1	82	1,519	5.4	-
Total	68	1,593	4.3	35	1,245	2.8	103	2,838	3.6	.04

p: Chi-square p-level for Observed vs. Expected Frequencies

The most important factor contributing to stopping violations is likely the "lane effect." Buses on roads with two oncoming lanes (four-lane roads) are far more likely to be passed than buses on roads with one oncoming lane. Stopping violations reach 5.4% and 1.6% respectively on two- and four-lane highways. On roads with two oncoming lanes, oncoming vehicles located in the far lane, i.e. the lane farthest from the bus driver's viewpoint, were about 15 metres from the bus. This distance, and the wide angle from which motorists were observing the bus, probably explains the higher rate of stopping violations recorded on four-lane roads. In addition, misunderstanding of the stopping rule could also be a factor. The rate of wrong answers noted in motorist surveys has previously suggested this possibility (Hale et al*.*, 1983; TRB, 1989; CUTR, 1997).

4.4.1 Stopping Violation Performance

Table 11 presents decreases in the rate of stopping violations significant above the 5% threshold. Appendix D lists all decreases in the rate of stopping violations obtained for the red and amber lights, non-valid values included. In total, 12 out of the 82 road conditions tested link amber lights with a decrease in stopping violations. There is no clear relationship between red lights and a drop in the rate of stopping violations. Even if all the significant instances of stopping violations favour amber lights, differences in performance between the two systems are not high. It should be mentioned that the exclusion of close stop observations largely determined the current profile of amber lights. Initially, during tests involving all close stops, the stopping violation rate was identical for amber and red lights, which indicates that the chance of observing a stopping violation is higher at close stops because of the confusion caused by this type of stop, particularly when there are two oncoming lanes of traffic. In fact, among the close stops with amber lights that were excluded from the database, many were located on four-lane roads.

Table 11 Effectiveness in reducing stopping violations (road conditions with .05 p-level or better)

Condition	Red lights (RL)				Amber lights (AL)				Rate decrease	
	Pass	Exp.	Veh.	%	Pass	Exp.	Veh.	%	RL-AL	p
AM	25	19	764	3.3	8	14	596	1.3	1.9	.02
90 km/h	13	4	110	11.8	6	15	465	1.3	10.5	.01
Rural	56	47	1,285	4.4	9	18	503	1.8	2.6	.01
Straight	66	57	1,541	4.3	25	34	927	2.7	1.6	.05
No crossing	59	45	1,189	5.0	28	42	1,088	2.6	2.4	.01
Sight ≥500m	57	48	1,199	4.8	12	21	528	2.3	2.5	.02
Low luminosity	11	6	208	5.3	10	15	524	1.9	3.4	.01
Exposure 11-15s	39	26	707	5.5	5	18	472	1.1	4.5	.01
Advance 11-15s	43	30	752	5.7	10	23	579	1.7	4.0	.01
Advance 100-149m	26	19	581	4.5	5	12	343	1.5	3.0	.02
≥6 vehicles	21	12	249	8.4	15	24	503	3.0	5.5	.01
All conditions	68	58	1,593	4.3	35	45	1,245	2.8	1.5	.04

4.5 School Bus Driver Questionnaire

4.5.1 Driver Perceptions of Standardization

When asked about the need for signalling the stop in advance, or standardizing systems for school bus signalling, drivers said that:

- Advance warning is safer than no advance warning (95%);
- A standard advance signal is needed throughout Canada (93%);
- Drivers who use red lights want them as a standard; and
- Drivers who use amber lights want them as a standard.

4.5.2 Advance Signalling Techniques

The vast majority of school bus drivers use the same techniques to signal in advance, whether they use amber lights or red lights as a warning:

- Most drivers always signal in advance, regardless of the location (82%);
- They vary the signalling distance depending on the situation (82%);
- Many drivers turn on the advance lights as soon as possible (38%); and
- Drivers look for heavy vehicles first to let them pass before signalling (24%).

A closer look at advance signalling techniques, especially time and distances of signalling, reveals that these parameters are largely variable depending on the situation. Examining the group of drivers who use red lights, the following average values were derived from the available answers:

- For “variable distance” category: average of 115 m, range of 75 m
- For “variable time” category: average of 15 s, range of 10 s

Unfortunately, in this survey there were only five drivers across Canada who had already used both amber and red lights as an advance signal. It is therefore difficult to make a proper comparison between the two methods of advance signalling.

4.5.3 Driver Perceptions of Advance Signal Effectiveness

According to both red and amber light users, the comprehension of the advance signal by motorists seems to be “average”. This specific category accounted for 39% of all answers. Motorists’ knowledge of the law can still be improved.

When asked if the flashing pre-stop warning lights encourage motorists to pass the bus, the majority of amber light users responded yes (72%). This was not the case among red light users (77%). This relates to an effect of expectancy among motorists—pre-stop warning lights are an invitation to pass the bus. Data collected during this study did not support the theory that pre-stop warning lights incite motorists to speed up before the red lights appear. The two systems together produced only 15 accelerations—12 observed with red lights—out of more than 1900 total observations (Table 6).

4.5.4 Driver Experiences with Stopping Violations

Driver experiences with stopping violations can be summarized as follows:

- 1/3 of drivers notice at least one illegal pass each day;
- 2/3 of all illegal passes are from oncoming traffic; and
- 2/3 of all illegal passes do not appear to be deliberate.

The small share of intentional pass-bys, as estimated by the bus drivers who got a close look at the motorists from the bus window, offers a certain amount of hope. Education, knowledge of the law and improvements in motorist skills can bring supplementary safety benefits because ignorance is still a contributing factor to stopping violations.

4.5.5 Driver Comments

A great number of respondents gave written comments and additional detail to their answers to various questions. A large number of comments were pertinent and merited attention. Bus drivers are especially aware of details that could potentially improve the safety of children on board, but they also know that everyday risk is hard to diminish. They recognize that without a standard system and a publicity campaign, people will remain confused as to what to do when facing lights flashing on a school bus. Here are comments that summarize a modest share of what was said:

> “Yellow means caution, red means stop.”
> “Make all buses the same; then people aren’t confused.”
> “Car motorists don’t know the rules about school bus stops.”
> “Mandatory and consistent training for motorists across Canada.”
> “One stop arm near the back bumper of the bus, one stop arm in front.”
> “Everyone should know what the red flashing lights on a school bus mean.”
> “This driving rule should be standard across Canada.”
> “Less confusing if it is standard.”
> “More people would understand this system.”

5 DISCUSSION OF RESULTS

In light of previous studies and considering the actual findings, it is doubtless that advance signals are a necessity, no matter which system is used by bus drivers. The two driver questionnaires, administered in 1998 and 2001, gave the same results and the opinions confirmed what was observed in the field.

Regarding the field experiment, many elements were initially seen as major difficulties for the study. Two different populations of motorists with potentially different cultures or driving behaviours regarding school bus stop regulations had to be observed. The source of data—attempting to compare identical road environments, stopping contexts and bus routes—was also an issue. At the same time, the elements measured such as obeying the stop may be wholly or partly determined by the influence of the stop arm, flashing red lights or a combination of these devices. The specific contribution of each remains unknown.

The potential impact of these variables on the observations was minimized by choosing comparable routes in Ontario and Québec, by excluding observations with no potential for comparison (closely-spaced stops), and by using a common protocol for data collection and tape reviewing. Even with these precautions, the quality of the observation data may have suffered from the combined effect of these considerations and the added challenge of a collection activity spread over two years. A set of seven different selection criteria was used to exclude unacceptable data, leaving 2,838 cases for analysing stopping violations and 1,935 cases for evaluating changes in motorists' speed with radar readings. The results obtained in 2001 were similar to those from the 1999 report, thus reinforcing the values obtained for the speed reduction rate and the rate of stopping violation.

The fact that there is no marked difference between the two systems is not surprising. The analysis looked at two devices which, at the outset, are both very effective and cause very few accidents. Indeed, the two systems are quite challenging to isolate statistically. An improvement of 11% on a situation that is already safe, such as reduction in speed during the advance signal phase, will not likely generate significant improvements in the risk condition for school children walking across the road. It should be noted that in 2,838 bus stops observed in this study, students crossed the road in front of the bus 20% of the time. As discovered in the driver survey, to improve safety bus drivers open the door only when safe conditions for walking across the road are present. Therefore, the likelihood of a school child crossing the road during a stopping violation is quite remote. Only one vehicle passed the bus while a child was crossing the road.

The difference between the two systems with regard to stopping violations is more difficult to interpret than decreases in speed. Stop signals are wholly or partly responsible for motorists obeying stops, probably more so than advance signals. Other factors influence this measurement, including the school bus route and the type of driving and/or road layout, as well as the interpretation of regulations on flashing lights in the provinces concerned. Despite the difficulties inherent in the methodology used to compare the two systems, the two populations studied were observed under almost identical advance signalling conditions as demonstrated by the comparability of parameters related to the bus drivers' driving behaviour. There is a similarity in the duration of the advance signal, in time and distance, between red and amber lights, as well as in the distance travelled by the bus during advance signalling. The bus's average initial speed at the start of the advance signal was slightly higher for red lights (59 km/h vs. 47 km/h). However, the initial average speed of motorists was similar for amber and red lights—80 km/h during the first 2 to 3 seconds of advance signalling.

The question of a possible analogy between bus stop and traffic lights at controlled intersections has been raised. As expected with traffic lights, red lights should be associated by default with a stop signal. From this point of view, the red lights should be the most effective type for stopping motorists, and by the same token, the most effective for reducing speed of vehicles.

On roads with one oncoming lane of traffic, nearly half the motorists facing the amber lights passed the bus before the stop arm was extended (44%). This suggests that amber is associated with warning, therefore permitting vehicles to pass the bus—which is the message intended to be sent to motorists. With red lights, nearly all motorists observed stayed in front of the bus, whether stopped or in motion (87%). This could mean that red lights are strongly associated with a stop signal rather than a warning. Red lights are normally seen as a traffic stopper and this high rate for red lights on roads with one oncoming lane appears to confirm this assumption. Also, contrary to what is generally believed, neither red nor amber lights produced adverse effects such as inducing motorists to accelerate on the advance signal.

These results are applicable only to rural and near-urban areas and should not be used as indicators of performance in highly congested urban areas. Previous field experiments did not assess the effectiveness of amber pre-stop signals in urban areas. A separate study would be needed to evaluate whether switching from red to amber pre-stop signals would yield similar benefits in urban areas. Similarly, the particular condition of close stops in rural or near-urban areas should be studied as it appears to present a higher stopping violation risk. One can surmise that close stops occur more frequently in urban areas and could be a factor that has lead some municipalities to forbid the use of school bus stop signals within city limits and require that school children be dropped off or picked up at regular crosswalks.

This study measured potential risk of stopping violations for children walking across the road, however collisions between vehicles other than the school bus represent another potential hazard at school bus stop. In one instance during red light data collection, a vehicle rear-ended the vehicle in front after it stopped too suddenly when the red lights and stop arm were activated. Caused by either inattention or too sudden braking , such a case implies that the red signal is not well understood by the motorists. Prince Edward Island recently changed over to the eight-light system following an incident involving a truck and a motorist at a school bus stop. PEI felt that harmonizing the advance signal used in PEI with the practice in the other Maritime provinces (NB, NS) would reduce the risk of motorist confusion. The evidence suggests that an advance signal using amber lights in a context well understood by motorists logically helps them prepare to stop and reduce sudden braking.

In the same manner, the caution message found on the back of the bus and its influence on motorist action at a bus stop must also be reviewed. For example, in certain provinces that use red lights as an advance signal, the following message can be found on the back of the bus: "Do not pass when signals flashing." This is incorrect since red lights also flash during the advance signal phase, when passing the bus is legal.

6 CONCLUSION

The study objectives were achieved. It was possible to compare the relative effectiveness of the two advance signal systems most commonly used in Canada, and to get bus driver opinions about them.

In the conditions observed, that is rural and near-urban areas where traffic speed is between 70 and 90 km/h, the two systems were almost equivalent in terms of risks for a child crossing the road. A statistically valid difference of 1.5% in raw numbers favoured amber lights in the rate of stopping violations, although this difference is too small to conclude that amber lights are a safer alternative on this basis alone. It is not surprising however because this is what motorists naturally expect as a warning signal since it mimics the warning sequence of traffic lights. Amber lights remove uncertainty about where the bus is in the stopping sequence, i.e., the advance or the full stop phase.

The marginally greater effectiveness of the amber lights does not significantly reduce the risk of accidents for children walking across the road since it is already a very safe operation. The overall stopping violation rate observed during this experiment was 4%. Only one vehicle passed the bus while school children were crossing the road.

Nonetheless, amber lights recorded greater reductions in speed during the advance signal than red lights. The amber lights were 11% more effective than the red lights in reducing the speed of oncoming vehicles by at least 10 km/h from the beginning of the advance signal in all locations and under all road conditions. The relative effectiveness reached 34% for two oncoming lanes and remained high in specific contexts such as near-urban areas or zones with high traffic volumes.

Regarding the driver questionnaire, results obtained in the first survey were confirmed. Drivers wanted a standard advance signalling method across Canada. They also noted motorist confusion and lack of knowledge about school bus safety laws.

7 RECOMMENDATIONS

In light of previous studies conducted on school bus advance stop signalling and the results of this study, the following recommendations are made:

1. Advance signalling should be mandatory throughout the country because it improves safety for school children, especially those walking across the road at school bus stops and very likely for motorists confronted with a stopping school bus.

2. Amber lights (eight-light system) should be mandatory as the standard system on all school buses as it has proven slightly superior to red lights, it harmonizes the Canadian situation with almost 100% of U.S. states, and does not generate adverse effects.

3. The implementation of a standard advance signalling equipment and procedure in Canada should be completed in the shortest period possible to reduce the possibility of increased confusion. This should be accompanied by a comprehensive nationwide information campaign to educate motorists.

4. To confirm school bus drivers perceptions of motorist knowledge of the law and to re-inforce the need to move to a standard advance signalling system, a nationwide survey should be conducted to assess motorists' understanding of what to do when encountering a school bus which is about to stop. If there is a standardization to one advance signalling system, the survey should be conducted at the conclusion of the information campaign to measure its success.

5. Messages appearing on the back of school buses, such as "Do not pass when lights flashing", should be reformulated to match the advance signal system in use to avoid motorists misunderstanding what they must do when a bus is about to stop.

6. A further investigation should be conducted into the risk of stopping violations presented by closely spaced bus stops. It appears that these situations should be reduced or eliminated whenever possible in rural and near-urban areas.

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APPENDIX A

Data Collection Forms

Bus / Route #: ______________/_______________	Bus Aspect: Standard ❑ Flat nose ❑	Ev Measurement:
Time of Day: AM ❑ PM ❑	Advance Signal: Flashing Red ❑ None ❑	1: ______/_____
School Level: Kinder ❑ Primary ❑ High School ❑	Total Km / Stops: ___________/___________	2: ______/_____
Day of week: Mon ❑ Tue ❑ Wed ❑ Thu ❑ Fri ❑	DD / MM / YY: ______/_______/_______	Ave: _____/_____

Km Departure:_______________ Km Arrival:_______________ Bus Occupancy:__________/__________passengers

Stop #		Speed Zone	Location			Land Use		Lanes		Sight Distance	% Slope		Curve	Passing		Pupil X-ing	Road Name and/or Adress
Day	All		rur	near	urb	Res	Com	Bus	/ Opposite		Bus	/ Opposite		Yes	/ No		
1			❑	❑	❑	❑	❑							❑	❑		
2			❑	❑	❑	❑	❑							❑	❑		
3			❑	❑	❑	❑	❑							❑	❑		
4			❑	❑	❑	❑	❑							❑	❑		
5			❑	❑	❑	❑	❑							❑	❑		
6			❑	❑	❑	❑	❑							❑	❑		
7			❑	❑	❑	❑	❑							❑	❑		
8			❑	❑	❑	❑	❑							❑	❑		
9			❑	❑	❑	❑	❑							❑	❑		
10			❑	❑	❑	❑	❑							❑	❑		
11			❑	❑	❑	❑	❑							❑	❑		
12			❑	❑	❑	❑	❑							❑	❑		
13			❑	❑	❑	❑	❑							❑	❑		
14			❑	❑	❑	❑	❑							❑	❑		
15			❑	❑	❑	❑	❑							❑	❑		
16			❑	❑	❑	❑	❑							❑	❑		
17			❑	❑	❑	❑	❑							❑	❑		
18			❑	❑	❑	❑	❑							❑	❑		
19			❑	❑	❑	❑	❑							❑	❑		
20			❑	❑	❑	❑	❑							❑	❑		
21			❑	❑	❑	❑	❑							❑	❑		
22			❑	❑	❑	❑	❑							❑	❑		
23			❑	❑	❑	❑	❑							❑	❑		
24			❑	❑	❑	❑	❑							❑	❑		
25			❑	❑	❑	❑	❑							❑	❑		
26			❑	❑	❑	❑	❑							❑	❑		
27			❑	❑	❑	❑	❑							❑	❑		
28			❑	❑	❑	❑	❑							❑	❑		
29			❑	❑	❑	❑	❑							❑	❑		
30			❑	❑	❑	❑	❑							❑	❑		

Modified 02-05-2000 by J.-F. Bruneau

Figure A.1 Logbook (road environment parameters) English form

# Parcours :	_____________/_____________	Aspect :	Nez allongé ❑ Nez plat ❑	Luminosité :	
Période :	AM ❑ PM ❑	Pré-signal :	Feux jaunes ❑ Hazard ❑	1: ______/_____	
Élèves :	Maternelle ❑ Primaire ❑ Secondaire	Total Km / Arrêts :	__________/__________	2: ______/_____	
Journée :	Lun ❑ Mar ❑ Mer ❑ Jeu ❑ Ven ❑	JJ / MM / AA :	______/_______/_____	Moy : ____/____	

Km Départ : ______________ Km Arrivée : ______________ Taux d'occupation : __________/__________ passagers

# Arrêt Auj	Total	Vitesse affichée	Milieu Rur / Urb	Environnement Res / Com	Voies Autobus / Adjacent	Distance visibilité	Pente Autobus / Adjacent	Courbe	Permission Oui / Non	Élèves (Nb)	Nom arrêt ou route
1	___	______	❑ ❑ ❑	❑ ❑	____ ____	______	____ ____	______	❑ ❑	____	________
2	___	______	❑ ❑ ❑	❑ ❑	____ ____	______	____ ____	______	❑ ❑	____	________
3	___	______	❑ ❑ ❑	❑ ❑	____ ____	______	____ ____	______	❑ ❑	____	________
4	___	______	❑ ❑ ❑	❑ ❑	____ ____	______	____ ____	______	❑ ❑	____	________
5	___	______	❑ ❑ ❑	❑ ❑	____ ____	______	____ ____	______	❑ ❑	____	________
6	___	______	❑ ❑ ❑	❑ ❑	____ ____	______	____ ____	______	❑ ❑	____	________
7	___	______	❑ ❑ ❑	❑ ❑	____ ____	______	____ ____	______	❑ ❑	____	________
8	___	______	❑ ❑ ❑	❑ ❑	____ ____	______	____ ____	______	❑ ❑	____	________
9	___	______	❑ ❑ ❑	❑ ❑	____ ____	______	____ ____	______	❑ ❑	____	________
10	___	______	❑ ❑ ❑	❑ ❑	____ ____	______	____ ____	______	❑ ❑	____	________
11	___	______	❑ ❑ ❑	❑ ❑	____ ____	______	____ ____	______	❑ ❑	____	________
12	___	______	❑ ❑ ❑	❑ ❑	____ ____	______	____ ____	______	❑ ❑	____	________
13	___	______	❑ ❑ ❑	❑ ❑	____ ____	______	____ ____	______	❑ ❑	____	________
14	___	______	❑ ❑ ❑	❑ ❑	____ ____	______	____ ____	______	❑ ❑	____	________
15	___	______	❑ ❑ ❑	❑ ❑	____ ____	______	____ ____	______	❑ ❑	____	________
16	___	______	❑ ❑ ❑	❑ ❑	____ ____	______	____ ____	______	❑ ❑	____	________
17	___	______	❑ ❑ ❑	❑ ❑	____ ____	______	____ ____	______	❑ ❑	____	________
18	___	______	❑ ❑ ❑	❑ ❑	____ ____	______	____ ____	______	❑ ❑	____	________
19	___	______	❑ ❑ ❑	❑ ❑	____ ____	______	____ ____	______	❑ ❑	____	________
20	___	______	❑ ❑ ❑	❑ ❑	____ ____	______	____ ____	______	❑ ❑	____	________
21	___	______	❑ ❑ ❑	❑ ❑	____ ____	______	____ ____	______	❑ ❑	____	________
22	___	______	❑ ❑ ❑	❑ ❑	____ ____	______	____ ____	______	❑ ❑	____	________
23	___	______	❑ ❑ ❑	❑ ❑	____ ____	______	____ ____	______	❑ ❑	____	________
24	___	______	❑ ❑ ❑	❑ ❑	____ ____	______	____ ____	______	❑ ❑	____	________
25	___	______	❑ ❑ ❑	❑ ❑	____ ____	______	____ ____	______	❑ ❑	____	________
26	___	______	❑ ❑ ❑	❑ ❑	____ ____	______	____ ____	______	❑ ❑	____	________
27	___	______	❑ ❑ ❑	❑ ❑	____ ____	______	____ ____	______	❑ ❑	____	________
28	___	______	❑ ❑ ❑	❑ ❑	____ ____	______	____ ____	______	❑ ❑	____	________
29	___	______	❑ ❑ ❑	❑ ❑	____ ____	______	____ ____	______	❑ ❑	____	________
30	___	______	❑ ❑ ❑	❑ ❑	____ ____	______	____ ____	______	❑ ❑	____	________

Modifié le 24-03-2000 par J.-F. Bruneau

Figure A.2 Logbook (road environment parameters) French form

School Bus Advance Signalling Study - OBSERVATIONS (Modified 02-05-2000 by J.-F. Bruneau)

Date: ________ / ________ / ________ NOSEQ: __________

Bus # / Route # / Stop # : _________ / _________ / _________

Close Stop ☐ Advance Signal Distance:_______________ m

Vehicle Crossing Bus at Beginning of Advance Signal ☐

Weather: Clear ☐ Cloudy☐ Fog☐ Mist☐ Rain☐ Snow☐

Road Surface: Dry ☐ Wet ☐ Snowy ☐ Icy☐

Video Time : T_A : ________ :________ :_________

T_C : ________ :________ :_________

T_E : ________ :________ :_________

Duration of : Advance Signal / Stop : _______s /_______s

Traffic at : Advance Signal / Stop : ______veh /______veh

Total traffic : ________veh

Circle all the leading cars ➔		Bus	# 1	# 2	# 3	# 4	# 5	# 6
Time of appearance ➔		-						
Dist. TA		-						
Dist. TB		-						
Elapsed Time	Stop		☐ s:	☐ s:	☐ s:	☐ s:	☐ s:	☐ s:
from TA to:	Pass		☐ s:	☐ s:	☐ s:	☐ s:	☐ s:	☐ s:
Dist. TC		-						
Dist. TD		-						
Dist. TE		-						
Elapsed Time	Stop		☐ s:	☐ s:	☐ s:	☐ s:	☐ s:	☐ s:
From TC to :	Pass		☐ s:	☐ s:	☐ s:	☐ s:	☐ s:	☐ s:
Action during Advance	Slowing		☐	☐	☐	☐	☐	☐
	Keeping pace		☐	☐	☐	☐	☐	☐
	Accelerating		☐	☐	☐	☐	☐	☐
Action during Stop	Slowing		☐	☐	☐	☐	☐	☐
	Keeping pace		☐	☐	☐	☐	☐	☐
	Accelerating		☐	☐	☐	☐	☐	☐
-3 s								
-2 s								
-1 s								
0 s								
1 s								
2 s								
3 s								
4 s								
5 s								
6 s								
7 s								
8 s								
9 s								
10 s								

Figure A.3 Observation sheet (English form)

Pré-signalement des autobus scolaires - OBSERVATIONS (Modifié le 25-07-2000 par J.-F. Bruneau)

Date : ________ / ________ / ________ NOSEQ : __________	Repères : T_A : ________ :________ :_________
# Bus / # Route / # Arrêt : _________ / _________ / _________	T_C : ________ :________ :_________
Arrêt rapproché ❑ Distance pré-signal :_______________ m	T_E : ________ :________ :_________
Véhicule en croisement au pré-signal ❑	Temps de : Pré-signal / Arrêt : _______s /_______s
Temps : Beau ❑ Nuage ❑ Brume ❑ Bruine ❑ Pluie ❑ Neige	# véhicules : Pré-signal / Arrêt : ______veh /______veh
Chaussée : Sec ❑ Mouillé ❑ Enneigé ❑ Glacé ❑	Total véhicules : ________veh

Encercler véh. de tête ➔		Bus	# 1	# 2	# 3	# 4	# 5	# 6
Heure d'apparition ➔		-						
Dist. TA		-						
Dist. TB		-						
Temps écoulé de TA à :	Arrête		❑s:	❑s:	❑s:	❑s:	❑s:	❑s:
	Passe		❑s:	❑s:	❑s:	❑s:	❑s:	❑s:
Dist. TC		-						
Dist. TD		-						
Dist. TE		-						
Temps écoulé de TC à :	Arrête		❑s:	❑s:	❑s:	❑s:	❑s:	❑s:
	Passe		❑s:	❑s:	❑s:	❑s:	❑s:	❑s:
Action au pré-signal	Ralentit		❑	❑	❑	❑	❑	❑
	Garde vitesse		❑	❑	❑	❑	❑	❑
	Accélère		❑	❑	❑	❑	❑	❑
Action à l'arrêt	Ralentit		❑	❑	❑	❑	❑	❑
	Garde vitesse		❑	❑	❑	❑	❑	❑
	Accélère		❑	❑	❑	❑	❑	❑

	Bus	# 1	# 2	# 3	# 4	# 5	# 6
-3 s							
-2 s							
-1 s							
0 s							
1 s							
2 s							
3 s							
4 s							
5 s							
6 s							
7 s							
8 s							
9 s							
10 s							

Figure A.4 Observation sheet (French form)

APPENDIX B

Number of Oncoming Motorists (Observations)

Table B.1 Oncoming motorists by time of day

	Red lights		Amber lights		Total	
Time of day	Veh	%	Veh.	%	Veh.	%
AM	764	48.0%	596	47.9%	1360	47.9%
PM	829	52.0%	649	52.1%	1478	52.1%
Total	1,593	100.0%	1,245	100.0%	2,838	100.0%

Table B.2 Oncoming motorists by day of week

	Red lights		Amber lights		Total	
Day of week	Veh	%	Veh.	%	Veh.	%
Monday	297	18.6%	189	15.2%	486	17.1%
Tuesday	408	25.6%	277	22.2%	685	24.1%
Wednesday	313	19.6%	272	21.8%	585	20.6%
Thursday	321	20.2%	281	22.6%	602	21.2%
Friday	254	15.9%	226	18.2%	480	16.9%
Total	1,593	100.0%	1,245	100.0%	2,838	100.0%

Table B.3 Oncoming motorists by posted speed

	Red lights		Amber lights		Total	
Posted speed	Veh	%	Veh.	%	Veh.	%
50 km/h	123	7.7%	121	9.7%	244	8.6%
70 km/h	89	5.6%	175	14.1%	264	9.3%
80 km/h	1271	79.8%	484	38.9%	1,755	61.8%
90 km/h	110	6.9%	465	37.3%	575	20.3%
Total	1,593	100.0%	1,245	100.0%	2,838	100.0%

Table B.4 Oncoming motorists by location

	Red lights		Amber lights		Total	
Location	Veh	%	Veh.	%	Veh.	%
Rural	1,285	80.7%	503	40.4%	1,788	63.0%
Near-urban	308	19.3%	742	59.6%	1,050	37.0%
Total	1,593	100.0%	1,245	100.0%	2,838	100.0%

Table B.5 Oncoming motorists by land use

	Red lights		Amber lights		Total	
Land use	Veh	%	Veh.	%	Veh.	%
Residential	1,447	90.8%	1,157	92.9%	2,604	91.8%
Commercial	146	9.2%	88	7.1%	234	8.2%
Total	1,593	100.0%	1,245	100.0%	2,838	100.0%

Table B.6 Oncoming motorists by number of oncoming lanes

	Red lights		Amber lights		Total	
Number of oncoming lanes	Veh	%	Veh.	%	Veh.	%
1	601	37.7%	718	57.7%	1,319	46.5%
2	992	62.3%	527	42.3%	1,519	53.5%
Total	1,593	100.0%	1,245	100.0%	2,838	100.0%

Table B.7 Oncoming motorists by grade of road

	Red lights		Amber lights		Total	
Grade of road	Veh	%	Veh.	%	Veh.	%
Flat	1,239	77.8%	281	22.6%	1,520	53.6%
Slight (approx. 1-3 %)	295	18.5%	831	66.7%	1,126	39.7%
Medium (approx. 4-6 %)	59	3.7%	107	8.6%	166	5.8%
Steep (approx. ≥7 %)	0	0.0%	26	2.1%	26	0.9%
Total	1,593	100.0%	1,245	100.0%	2,838	100.0%

Table B.8 Oncoming motorists by slope of road facing bus

	Red lights		Amber lights		Total	
Slope of road facing bus	Veh	%	Veh.	%	Veh.	%
Flat	1,239	77.8%	281	22.6%	1,520	53.6%
Bus climbing	312	19.6%	505	40.6%	817	28.8%
Bus descending	42	2.6%	459	36.9%	501	17.7%
Total	1,593	100.0%	1,245	100.0%	2,838	100.0%

Table B.9 Oncoming motorists by slope of road facing vehicle

	Red lights		Amber lights		Total	
Slope of road facing veh.	Veh	%	Veh.	%	Veh.	%
Flat	1,125	70.6%	292	23.5%	1,417	49.9%
Vehicle climbing	75	4.7%	418	33.6%	493	17.4%
Vehicle descending	393	24.7%	535	43.0%	928	32.7%
Total	1,593	100.0%	1,245	100.0%	2,838	100.0%

Table B.10 Oncoming motorists by geometry of road

	Red lights		Amber lights		Total	
Geometry of road	Veh	%	Veh.	%	Veh.	%
Straight	1,541	96.7%	927	74.5%	2,468	87.0%
Slight curve	48	3.0%	205	16.5%	253	8.9%
Pronounced curve	4	0.3%	113	9.1%	117	4.1%
Total	1,593	100.0%	1,245	100.0%	2,838	100.0%

Table B.11 Oncoming motorists by marking of centre line (passing allowed)

	Red lights		Amber lights		Total	
Passing for oncoming veh.	Veh	%	Veh.	%	Veh.	%
Allowed	252	15.8%	625	50.2%	877	30.9%
Not allowed	1,341	84.2%	620	49.8%	1,961	69.1%
Total	1,593	100.0%	1,245	100.0%	2,838	100.0%

Table B.12 Oncoming motorists by pupils crossing the road

	Red lights		Amber lights		Total	
Pupil crossing	Veh	%	Veh.	%	Veh.	%
No	1,189	74.6%	1,088	87.4%	2,277	80.2%
Yes	404	25.4%	157	12.6%	561	19.8%
Total	1,593	100.0%	1,245	100.0%	2,838	100.0%

Table B.13 Oncoming motorists by minimum visibility at the stop site

Minimum visibility	Red lights		Amber lights		Total	
at the stop site	Veh.	%	Veh.	%	Veh.	%
0 to 90 m	0	0.0%	82	6.6%	82	2.9%
100 to 199 m	22	1.4%	171	13.7%	193	6.8%
200 to 299 m	66	4.1%	185	14.9%	251	8.8%
300 to 399 m	45	2.8%	207	16.6%	252	8.9%
400 to 499 m	261	16.4%	72	5.8%	333	11.7%
≥500 m	1,199	75.3%	528	42.4%	1,727	60.9%
Total	1,593	100.0%	1,245	100.0%	2,838	100.0%

Table B.14 Oncoming motorists by luminosity measured at the bus window

	Red lights		Amber lights		Total	
Luminosity at bus window	Veh	%	Veh.	%	Veh.	%
Dark (1.25-4.99)	43	2.7%	136	10.9%	179	6.3%
Low (5.00-9.99)	208	13.1%	524	42.1%	732	25.8%
Moderate (10.00-14.99)	858	53.9%	573	46.0%	1,431	50.4%
High (≥15.00)	484	30.4%	12	1.0%	496	17.5%
Total	1,593	100.0%	1,245	100.0%	2,838	100.0%

Table B.15 Oncoming motorists by season

	Red lights		Amber lights		Total	
Season	Veh	%	Veh.	%	Veh.	%
Fall	872	54.7%	556	44.7%	1,428	50.3%
Spring	721	45.3%	689	55.3%	1,410	49.7%
Total	1,593	100.0%	1,245	100.0%	2,838	100.0%

Table B.16 Oncoming motorists by road surface

	Red lights		Amber lights		Total	
Road surface	Veh	%	Veh.	%	Veh.	%
Dry	946	59.4%	586	47.1%	1,532	54.0%
Wet	481	30.2%	457	36.7%	938	33.1%
Snowy/icy	166	10.4%	202	16.2%	368	13.0%
Total	1,593	100.0%	1,245	100.0%	2,838	100.0%

Table B.17 Oncoming motorists by weather conditions

	Red lights		Amber lights		Total	
Weather condition	Veh	%	Veh.	%	Veh.	%
Clear	453	28.4%	547	43.9%	1,000	35.2%
Cloudy	841	52.8%	337	27.1%	1,178	41.5%
Fog	116	7.3%	11	0.9%	127	4.5%
Rain/mist	91	5.7%	219	17.6%	310	10.9%
Snow	92	5.8%	131	10.5%	223	7.9%
Total	1,593	100.0%	1,245	100.0%	2,838	100.0%

Table B.18 Oncoming motorists by time of exposure to the advance signal

	Red lights		Amber lights		Total	
Exposure time of veh.	Veh	%	Veh.	%	Veh.	%
3 - 5 seconds	27	1.7%	82	6.6%	109	3.8%
6 - 10 seconds	827	51.9%	640	51.4%	1,467	51.7%
11 - 15 seconds	707	44.4%	472	37.9%	1,179	41.5%
≥16 seconds	32	2.0%	51	4.1%	83	2.9%
Total	1,593	100.0%	1,245	100.0%	2,838	100.0%

Table B.19 Oncoming motorists by duration of advance signal

	Red lights		Amber lights		Total	
Duration of advance signal	Veh	%	Veh.	%	Veh.	%
3 to 5 seconds	10	0.6%	22	1.8%	32	1.1%
6 to 10 seconds	796	50.0%	561	45.1%	1,357	47.8%
11 to 15 seconds	752	47.2%	579	46.5%	1,331	46.9%
≥16 seconds	35	2.2%	83	6.7%	118	4.2%
Total	1,593	100.0%	1,245	100.0%	2,838	100.0%

Table B.20 Oncoming motorists by traffic at advance signal

	Red lights		Amber lights		Total	
Veh. seen in advance signal	Veh	%	Veh.	%	Veh.	%
1 vehicle	423	26.6%	316	25.4%	739	26.0%
2 vehicles	350	22.0%	301	24.2%	651	22.9%
3 vehicles	280	17.6%	235	18.9%	515	18.1%
4 vehicles	202	12.7%	160	12.9%	362	12.8%
≥5 vehicles	338	21.2%	233	18.7%	571	20.1%
Total	1,593	100.0%	1,245	100.0%	2,838	100.0%

Table B.21 Oncoming motorists by distance travelled during advance signal

	Red lights		Amber lights		Total	
Length of advance signal	Veh	%	Veh.	%	Veh.	%
1 to 49 m	119	7.5%	156	12.5%	275	9.7%
50 to 99 m	842	52.9%	612	49.2%	1,454	51.2%
100 to 149 m	581	36.5%	343	27.6%	924	32.6%
≥150 m	51	3.2%	134	10.8%	185	6.5%
Total	1,593	100.0%	1,245	100.0%	2,838	100.0%

Table B.22 Oncoming motorists by total traffic (advance and stop combined)

	Red lights		Amber lights		Total	
Total traffic	Veh	%	Veh.	%	Veh.	%
1-2 vehicle(s)	751	47.1%	261	21.0%	1,012	35.7%
3-5 vehicles	593	37.2%	481	38.6%	1,074	37.8%
≥6 vehicles	249	15.6%	503	40.4%	752	26.5%
Total	1,593	100.0%	1,245	100.0%	2,838	100.0%

Table B.23 Distance from bus at the beginning of advance signal (TA)

	Red lights		Amber lights		Total	
Distance from bus at TA	Veh	%	Veh.	%	Veh.	%
100 to 199 m	672	42.2%	567	45.5%	1239	43.7%
200 to 299 m	511	32.1%	369	29.6%	880	31.0%
300 to 399 m	263	16.5%	172	13.8%	435	15.3%
≥400 m	109	6.8%	99	8.0%	208	7.3%
Unknown	38	2.4%	38	3.1%	76	2.7%
Total	1,593	100.0%	1,245	100.0%	2,838	100.0%

Table B.24 Distance from bus when stop signal begins (TC)

	Red lights		Amber lights		Total	
Distance from bus at TC	Veh	%	Veh.	%	Veh.	%
1 to 19 m	82	5.1%	109	8.8%	191	6.7%
20 to 39 m	178	11.2%	105	8.4%	283	10.0%
40 to 59 m	182	11.4%	99	8.0%	281	9.9%
60 to 79 m	174	10.9%	75	6.0%	249	8.8%
80 to 100 m	159	10.0%	60	4.8%	219	7.7%
≥101 m	336	21.1%	135	10.8%	471	16.6%
Passed or unknown	482	30.3%	662	53.2%	1,144	40.3%
Total	1,593	100.0%	1,245	100.0%	2,838	100.0%

APPENDIX C

Effectiveness in Slowing Motorists

Table C.1 Effectiveness in slowing motorists in 82 road conditions

	Red Lights (RL)				Amber Lights (AL)				AL Effectiveness in slowing		
	Slow	Veh.	Exp.	Ratio	Slow	Veh.	Exp.	Ratio			
Condition	(a^1)	(b^1)	(E^1)	(R^1)	(a^2)	(b^2)	(P^2)	(R^2)	RR	p	E(%)
All conditions	482	830	516	0.9	720	1105	686	1.0	0.89	.05	11
AM	259	423	272	1.0	347	518	334	1.0	0.91	-	9
PM	223	407	244	0.9	373	587	352	1.1	0.86	-	14
Monday	86	158	93	0.9	110	174	103	1.1	0.86	-	14
Tuesday	111	199	123	0.9	171	256	159	1.1	0.84	-	16
Wednesday	93	171	104	0.9	161	245	150	1.1	0.83	-	17
Thursday	108	161	110	1.0	173	249	171	1.0	0.97	-	3
Friday	84	141	83	1.0	105	181	106	1.0	1.03	-	-3
≤60 km/h	68	90	66	1.0	77	108	79	1.0	1.06	-	-6
70 km/h	46	56	37	1.2	95	156	104	0.9	1.35	-	-35
80 km/h	290	575	325	0.9	269	415	234	1.1	0.78	.01	22
90 km/h	78	109	73	1.1	279	426	284	1.0	1.09	-	-9
Rural	422	676	430	1.0	299	457	291	1.0	0.95	-	5
Near urban	60	154	92	0.6	421	648	389	1.1	0.60	.01	40
Residential	452	771	479	0.9	665	1026	638	1.0	0.90	-	10
Commercial	30	59	36	0.8	55	79	49	1.1	0.73	-	27
1 oncoming lane	316	436	300	1.1	431	650	447	1.0	1.09	-	-9
2 oncoming lanes	166	394	211	0.8	289	455	244	1.2	0.66	.01	34
Flat road	377	645	386	1.0	161	255	152	1.1	0.93	-	7
Slight slope	86	154	102	0.8	502	734	486	1.0	0.82	-	18
Medium slope	19	31	15	1.2	45	98	49	0.9	1.33	-	-33
Steep slope	0	0	0	-	12	18	12	1.0	-	-	-
Bus climbing	88	158	98	0.9	284	440	274	1.0	0.86	-	14
Bus descending	17	27	18	0.9	275	410	274	1.0	0.94	-	6
Vehicle climbing	25	36	24	1.0	245	372	246	1.0	1.05	-	-5
Vehicle descending	107	205	126	0.9	306	468	287	1.1	0.80	.04	20
Straight	457	793	498	0.9	557	821	516	1.1	0.85	.01	15
Slight curve	23	35	21	1.1	111	187	113	1.0	1.11	-	-11
Pronounced curve	2	2	1	1.8	52	97	53	1.0	1.87	-	-87
Passing allowed	118	158	108	1.1	376	563	386	1.0	1.12	-	-12
Passing prohibited	364	672	392	0.9	344	542	316	1.1	0.85	.03	15
No crossing	350	590	374	0.9	637	965	613	1.0	0.90	-	10
Pupil crossing	132	240	136	1.0	83	140	79	1.0	0.93	-	7

	Red Lights (RL)				Amber Lights (AL)				AL Effectiveness		
	Slow	Veh.	Exp.	Ratio	Slow	Veh.	Exp.	Ratio	in slowing		
Condition	(a^1)	(b^1)	(E^1)	(R^1)	(a^2)	(b^2)	(P^2)	(R^2)	RR	p	E(%)
Sight 0-90 m	0	0	0	-	42	74	42	1.0	-	-	-
Sight 100-199m	7	12	7	1.0	87	148	87	1.0	0.99	-	1
Sight 200-299m	36	47	33	1.1	112	162	115	1.0	1.11	-	-11
Sight 300-399m	23	29	19	1.2	116	188	120	1.0	1.29	-	-29
Sight 400-499m	67	109	67	1.0	41	66	41	1.0	0.99	-	1
Sight ≥500m	349	633	386	0.9	322	467	285	1.1	0.80	.01	20
Dark	37	43	29	1.3	72	120	80	0.9	1.43	-	-43
Low luminosity	86	125	88	1.0	331	467	329	1.0	0.97	-	3
Moderate lum.	235	408	244	1.0	315	511	306	1.0	0.93	-	7
High luminosity	124	254	123	1.0	2	7	3	0.6	1.71	-	-71
Fall	270	404	268	1.0	329	498	331	1.0	1.01	-	-1
Spring	212	426	249	0.9	391	607	354	1.1	0.77	.01	23
Dry	271	502	293	0.9	328	524	306	1.1	0.86	-	14
Wet	140	224	148	0.9	284	416	276	1.0	0.92	-	8
Snowy/icy	71	104	69	1.0	108	165	110	1.0	1.04	-	-4
Clear	128	242	142	0.9	290	470	276	1.1	0.86	-	14
Cloudy	265	448	281	0.9	216	318	200	1.1	0.87	-	13
Fog	37	54	35	1.1	4	9	6	0.7	1.54	-	-54
Rain/mist	27	47	31	0.9	133	194	129	1.0	0.84	-	16
Snow	25	39	26	1.0	77	114	76	1.0	0.95	-	5
Exposure 3-5s	6	13	10	0.6	49	57	45	1.1	0.54	-	46
Exposure 6-10s	276	450	294	0.9	385	563	367	1.0	0.90	-	10
Exposure 11-15s	177	337	191	0.9	261	437	247	1.1	0.88	-	12
Exposure ≥16s	23	30	18	1.2	25	48	30	0.8	1.47	-	-47
Advance 1-5s	3	5	4	0.7	17	18	16	1.1	0.64	-	36
Advance 6-10s	263	433	275	1.0	315	476	303	1.0	0.92	-	8
Advance 11-15s	191	359	213	0.9	338	533	316	1.1	0.84	.05	16
Advance ≥16s	25	33	22	1.1	50	78	53	0.9	1.18	-	-18
1 vehicle	204	290	213	1.0	204	266	195	1.0	0.92	-	8
2 vehicles	144	228	147	1.0	176	267	173	1.0	0.96	-	4
3 vehicles	69	131	76	0.9	131	212	124	1.1	0.85	-	15
4 vehicles	28	81	42	0.7	91	150	77	1.2	0.57	.01	43
≥5 vehicles	37	100	50	0.7	118	210	105	1.1	0.66	.03	34
Advance 1-49m	51	75	58	0.9	110	133	103	1.1	0.82	-	18
Advance 50-99m	254	433	275	0.9	357	530	336	1.1	0.87	-	13
Advance 100-149m	147	282	153	1.0	178	318	172	1.0	0.93	-	7
Advance ≥150 m	30	40	26	1.2	75	124	79	0.9	1.24	-	-24

	Red Lights (RL)				Amber Lights (AL)				AL Effectiveness in slowing		
	Slow	Veh.	Exp.	Ratio	Slow	Veh.	Exp.	Ratio			
Condition	(a^1)	(b^1)	(E^1)	(R^1)	(a^2)	(b^2)	(P^2)	(R^2)	RR	p	E(%)
1-2 vehicle(s)	336	499	346	1.0	170	230	160	1.1	0.91	-	9
3-5 vehicles	122	252	153	0.8	290	425	259	1.1	0.71	.01	29
≥6 vehicles	24	79	42	0.6	260	450	242	1.1	0.53	.01	47
TA pos. 100-199m	231	416	217	1.1	264	534	278	0.9	1.12	-	-12
TA pos. 200-299m	156	246	176	0.9	260	335	240	1.1	0.82	.05	18
TA pos. 300-399m	45	86	61	0.7	118	145	102	1.2	0.64	.01	36
TA pos. ≥400m	33	51	40	0.8	72	82	65	1.1	0.74	-	26
TC pos. 1-19m	51	57	54	0.9	104	106	101	1.0	0.91	-	9
TC pos. 20-39m	86	101	92	0.9	98	100	92	1.1	0.87	-	13
TC pos. 40-59m	89	100	93	1.0	86	88	82	1.0	0.91	-	9
TC pos. 60-79m	74	88	78	0.9	62	65	58	1.1	0.88	-	12
TC pos. 80-100m	37	61	46	0.8	44	47	35	1.2	0.65	.05	35
TC pos. ≥101m	58	123	76	0.8	64	74	46	1.4	0.55	.01	45

E^1: Expected value for the group 1: $E^1 = b^1 (a^1 + a^2) / (b^1 + b^2)$
R^1: Ratio for the group 1: $R^1 = (a^1 / a^1 + a^2) / (b^1 / b^1 + b^2)$
RR: Relative Risk Ratio: $RR = R^1 / R^2$
E(%): Effectiveness index $E(\%) = (1 - RR) * 100$
p: Chi-square p-level for “Observed vs. Expected frequencies”

APPENDIX D

Effectiveness in Reducing Stopping Violations

Table D.1 Effectiveness in reducing stopping violations in 82 road conditions

	Red lights (RL)				Amber lights (AL)				Rate decrease	
Condition	Pass	Exp.	Veh.	%	Pass	Exp.	Veh.	%	RL-AL	p
All conditions	68	58	1593	4.3	35	45	1245	2.8	1.5	.04
AM	25	19	764	3.3	8	14	596	1.3	1.9	.02
PM	43	39	829	5.2	27	31	649	4.2	1.0	-
Monday	18	15	297	6.1	7	10	189	3.7	2.4	-
Tuesday	9	10	408	2.2	8	7	277	2.9	-0.7	-
Wednesday	16	12	313	5.1	7	11	272	2.6	2.5	-
Thursday	13	11	321	4.0	7	9	281	2.5	1.6	-
Friday	12	10	254	4.7	6	8	226	2.7	2.1	-
≤60 km/h	0	1	123	0.0	1	0	121	0.8	-0.8	-
70 km/h	0	1	89	0.0	4	3	175	2.3	-2.3	-
80 km/h	55	57	1271	4.3	24	22	484	5.0	-0.6	-
90 km/h	13	4	110	11.8	6	15	465	1.3	10.5	.01
Rural	56	47	1285	4.4	9	18	503	1.8	2.6	.01
Near urban	12	11	308	3.9	26	27	742	3.5	0.4	-
Residential	61	53	1447	4.2	35	43	1157	3.0	1.2	-
Commercial	7	4	146	4.8	0	3	88	0.0	4.8	.04
1 oncoming lane	13	10	601	2.2	8	11	718	1.1	1.0	-
2 oncoming lanes	55	54	992	5.5	27	28	527	5.1	0.4	-
Flat road	60	56	1239	4.8	9	13	281	3.2	1.6	-
Slight slope	8	8	295	2.7	24	24	831	2.9	-0.2	-
Medium slope	0	1	59	0.0	2	1	107	1.9	-1.9	-
Steep slope	0	0	0	-	0	0	26	0.0	-	-
Bus climbing	8	8	312	2.6	14	14	505	2.8	-0.2	-
Bus descending	0	1	42	0.0	12	11	459	2.6	-2.6	-
Vehicle climbing	0	2	75	0.0	13	11	418	3.1	-3.1	-
Vehicle descending	15	12	393	3.8	14	17	535	2.6	1.2	-
Straight	66	57	1541	4.3	25	34	927	2.7	1.6	.05
Slight curve	2	1	48	4.2	4	5	205	2.0	2.2	-
Pronounced curve	0	0	4	0.0	6	6	113	5.3	-5.3	-
Passing allowed	2	3	252	0.8	8	7	625	1.3	-0.5	-
Passing prohibited	66	64	1341	4.9	27	29	620	4.4	0.6	-
No crossing	59	45	1189	5.0	28	42	1088	2.6	2.4	.01
Pupil crossing	9	12	404	2.2	7	4	157	4.5	-2.2	-

	Red lights (RL)				Amber lights (AL)				Rate decrease	
Condition	Pass	Exp.	Veh.	%	Pass	Exp.	Veh.	%	RL-AL	p
Sight 0-90 m	0	0	0	-	2	2	82	2.4	-	-
Sight 100-199m	1	1	22	4.5	7	7	171	4.1	0.5	-
Sight 200-299m	1	2	66	1.5	7	6	185	3.8	-2.3	-
Sight 300-399m	0	1	45	0.0	5	4	207	2.4	-2.4	-
Sight 400-499m	9	9	261	3.4	2	2	72	2.8	0.7	-
Sight ≥500m	57	48	1199	4.8	12	21	528	2.3	2.5	.02
Dark	2	3	43	4.7	9	8	136	6.6	-2.0	-
Low luminosity	11	6	208	5.3	10	15	524	1.9	3.4	.01
Moderate lum.	38	32	858	4.4	16	22	573	2.8	1.6	-
High luminosity	17	17	484	3.5	0	0	12	0.0	3.5	-
Fall	47	42	872	5.4	21	26	556	3.8	1.6	-
Spring	21	18	721	2.9	14	17	689	2.0	0.9	-
Dry	44	37	946	4.7	16	23	586	2.7	1.9	-
Wet	19	16	481	4.0	12	15	457	2.6	1.3	-
Snowy/icy	5	5	166	3.0	7	7	202	3.5	-0.5	-
Clear	23	18	453	5.1	16	21	547	2.9	2.2	-
Cloudy	32	29	841	3.8	9	12	337	2.7	1.1	-
Fog	7	6	116	6.0	0	1	11	0.0	6.0	-
Rain/mist	2	1	91	2.2	2	3	219	0.9	1.3	-
Snow	4	5	92	4.3	8	7	131	6.1	-1.8	-
Exposure 3-5s	1	1	27	3.7	2	2	82	2.4	1.3	-
Exposure 6-10s	28	32	827	3.4	28	24	640	4.4	-1.0	-
Exposure 11-15s	39	26	707	5.5	5	18	472	1.1	4.5	.01
Exposure ≥16s	0	0	32	0.0	0	0	51	0.0	0.0	-
Advance 1-5s	1	1	10	10.0	1	1	22	4.5	5.5	-
Advance 6-10s	23	27	796	2.9	23	19	561	4.1	-1.2	-
Advance 11-15s	43	30	752	5.7	10	23	579	1.7	4.0	.01
Advance ≥16s	1	1	35	2.9	1	1	83	1.2	1.7	-
1 vehicle	13	11	423	3.1	6	8	316	1.9	1.2	-
2 vehicles	12	12	350	3.4	11	11	301	3.7	-0.2	-
3 vehicles	14	11	280	5.0	7	10	235	3.0	2.0	-
4 vehicles	8	7	202	4.0	4	5	160	2.5	1.5	-
≥5 vehicles	21	17	338	6.2	7	11	233	3.0	3.2	-
Advance 1-49m	4	5	119	3.4	7	6	156	4.5	-1.1	-
Advance 50-99m	35	32	842	4.2	21	24	612	3.4	0.7	-
Advance 100-149m	26	19	581	4.5	5	12	343	1.5	3.0	.02
Advance ≥150 m	3	1	51	5.9	2	4	134	1.5	4.4	-

Condition	Red lights (RL) Pass	Exp.	Veh.	%	Amber lights (AL) Pass	Exp.	Veh.	%	Rate decrease RL-AL	p
1-2 vehicle(s)	22	19	751	2.9	4	7	261	1.5	1.4	-
3-5 vehicles	25	23	593	4.2	16	18	481	3.3	0.9	-
≥6 vehicles	21	12	249	8.4	15	24	503	3.0	5.5	.01
TA pos. 100-199m	11	10	672	1.6	7	8	567	1.2	0.4	-
TA pos. 200-299m	23	23	511	4.5	17	17	369	4.6	-0.1	-
TA pos. 300-399m	19	15	263	7.2	6	10	172	3.5	3.7	-
TA pos. ≥400m	8	6	109	7.3	3	5	99	3.0	4.3	-
TC pos. 1-19m	12	10	82	14.6	11	13	109	10.1	4.5	-
TC pos. 20-39m	16	15	178	9.0	8	9	105	7.6	1.4	-
TC pos. 40-59m	11	10	182	6.0	4	5	99	4.0	2.0	-
TC pos. 60-79m	12	12	174	6.9	5	5	75	6.7	0.2	-
TC pos. 80-100m	8	9	159	5.0	5	4	60	8.3	-3.3	-
TC pos. ≥101m	9	8	336	2.7	2	3	135	1.5	1.2	-

p: Chi-square p-level for “Observed vs. Expected frequencies”

APPENDIX E

Bus Driver Questionnaire and Answer Frequency

Table E.1 What province/territory do you live in?

Answer	Red lights		Amber lights	
	No.	%	No.	%
Ontario	108	67.9	0	0.0
Saskatchewan	51	32.1	0	0.0
Québec	0	0.0	181	100.0
Total	159	100.0	181	100.0

Table E.2 Have you ever lived in another province/territory?

Answer	Red lights		Amber lights	
	No.	%	No.	%
Yes	29	18.2	-	-
No	130	81.8	-	-
Total	159	100.0	-	-

Table E.3 Did you also drive a school bus in that province/territory?

Answer	Red lights		Amber lights	
	No.	%	No.	%
Yes	10	6.3	-	-
No	125	78.6	-	-
Missing data	24	15.1	-	-
Total	159	100.0	-	-

Table E.4 How many stops are located along your bus route?

Answer	Red lights		Amber lights	
	No.	%	No.	%
1 to 10 stops	39	24.5	-	-
11 to 20 stops	74	46.5	-	-
21 to 30 stops	37	23.3	-	-
30 stops or more	7	4.4	-	-
Missing data	2	1.3	-	-
Total	159	100.0	-	-

Table E.5 What is the average distance between stops on your route?

Answer	Red lights		Amber lights	
	No.	%	No.	%
1.0 km or less	42	26.4	-	-
1.1 to 2.0 km	32	20.1	-	-
2.1 to 3.0 km	15	9.4	-	-
3.1 to 4.0 km	10	6.3	-	-
4.1 to 5.0 km	11	6.9	-	-
5.0 km or more	19	11.9	-	-
Missing data	30	18.9	-	-
Total	159	100.0	-	-

Table E.6 Are your routes located in primarily urban, rural or mixed areas?

Answer	Red lights		Amber lights	
	No.	%	No.	%
Primarily urban	25	15.7	-	-
Primarily rural	86	54.1	-	-
Mixed area	47	29.6	-	-
Missing data	1	0.6	-	-
Total	159	100.0	-	-

Table E.7 Which advance signal light do you use as a warning signal?

Answer	Red lights		Amber lights	
	No.	%	No.	%
Flashing red lights	156	98.1	-	-
Flashing amber lights	1	0.6	98	54.2
Hazard warning lights	-	-	78	43.1
Missing data	2	1.3	5	2.7
Total	159	100.0	181	100.0

Table E.8 On average, how many stops a day do you make in the presence of motorists?

Answer	Red lights		Amber lights	
	No.	%	No.	%
20 stops or less	108	67.9	49	27.1
21 to 40 stops	36	22.6	51	28.2
41 to 60 stops	7	4.4	38	21.0
61 or more	-	-	26	14.4
Missing data	8	5.0	17	9.4
Total	159	100.0	181	100.0

Table E.9 Under what circumstances do you use advance signal lights?

Answer	Red lights		Amber lights	
	No.	%	No.	%
Always, regardless of location or circumstances	130	81.8	150	82.9
Depends on the location and circumstances	29	18.2	29	16.0
Missing data	-	-	2	1.1
Total	159	100.0	181	100.0

Table E.10 Under what circumstances do you not use them? (more than one answer possible)

Answer	Red lights		Amber lights	
	No.	%	No.	%
When there are no vehicles in sight	2	1.3	17	9.4
When there isn't much traffic	0	0.0	7	3.9
When there is a median between lanes	2	1.3	8	4.4
In urban areas	9	5.7	3	1.7
In rural areas	1	0.6	6	3.3
Other	34	21.4	7	3.9
Total	N.A.	N.A.	N.A.	N.A.

Table E.11 Before a stop, what tells you that it is time to turn on the advance signal lights?

Answer	Red lights		Amber lights	
	No.	%	No.	%
At a variable distance, depending on the situation	85	53.5	113	62.4
At a variable time, depending on the situation	31	19.5	50	27.6
At a set distance before the stop	31	19.5	34	18.8
At a set time before the stop	12	7.5	5	2.8
As soon as possible	56	35.2	74	40.9
When heavy vehicles have gone by	44	27.7	36	19.9
When fast-driving cars have gone by	28	17.6	15	8.3
When all the vehicles have gone by	5	3.1	1	0.6
Other. Explain	29	18.2	9	5.0
Total	N.A.	N.A.	-	-

Table E.12 Do you think that flashing lights encourage motorists to pass the bus?

Answer	Red lights		Amber lights	
	No.	%	No.	%
No	122	76.7	22	12.2
Yes	8	5.0	131	72.4
It depends	28	17.6	25	13.8
Missing data	1	0.6	3	1.7
Total	159	100.0	181	100.0

Table E.13 Have you ever observed dangerous situations related to advance signal lights?

Answer	Red lights		Amber lights	
	No.	%	No.	%
No	102	64.2	129	71.3
Yes	57	35.8	45	24.9
Missing data	-	-	7	3.9
Total	159	100.0	181	100.0

Table E.14 How well do you think motorists understand advance signal lights?

Answer	Red lights		Amber lights	
	No.	%	No.	%
Very well	15	9.4	29	16.0
Well	34	21.4	55	30.4
Average understanding	64	40.3	70	38.7
Poorly	30	18.9	19	10.5
Very poorly	14	8.8	7	3.9
Missing data	2	1.3	1	0.6
Total	159	100.0	181	100.0

Table E.15 Have you had experience with more than one type of advance signal light?

Answer	Red lights		Amber lights	
	No.	%	No.	%
Ontario	108	67.9	0	0.0
Québec	0	0.0	181	100.0
Total	159	100.0	181	100.0

Table E.16 If so, which type seems most effective?

Answer	Red lights		Amber lights	
	No.	%	No.	%
Red flashing warning lights	8	5.0	-	-
Amber flashing warning lights	1	0.6	-	-
No difference	3	1.9	-	-
Missing data	147	92.5	-	-
Total	159	100.0	-	-

Table E.17 Normally. do you begin to brake before turning on advance signal lights?

Answer	Red lights		Amber lights	
	No.	%	No.	%
Yes. always	45	28.3	58	32.0
No. never	19	11.9	16	8.8
Depends on the location and circumstances	94	59.1	101	55.8
Missing data	1	0.6	6	3.3
Total	159	100.0	181	100.0

Table E.18 Do you think that brake lights have an effect on motorists?

Answer	Red lights		Amber lights	
	No.	%	No.	%
No, none	23	14.5	6	3.3
Yes, they slow down	126	79.2	156	86.2
Yes, they speed up	2	1.3	7	3.9
Other	6	3.8	8	4.4
Missing data	2	1.3	4	2.2
Total	159	100.0	181	100.0

Table E.19 Do you consciously use this early warning strategy before using the advance lights?

Answer	Red lights		Amber lights	
	No.	%	No.	%
Yes, occasionally (a few times a day)	106	66.7	136	75.1
No, never	34	21.4	45	24.9
Missing data	19	11.9	-	-
Total	159	100.0	181	100.0

Table E.20 Do you signal your intention to stop by turning on the right-hand turn signal (right-hand flasher)?

Answer	Red lights		Amber lights	
	No.	%	No.	%
No. never	134	84.3	141	77.9
Yes. always	6	3.8	9	5.0
It depends	19	11.9	25	13.8
Missing data	-	-	6	3.3
Total	159	100.0	181	100.0

Table E.21 In your view, which is safer: using advance signal lights or not using them?

Answer	Red lights		Amber lights	
	No.	%	No.	%
Advance signal lights are safer than not using them	151	95.0	170	93.9
Equally safe	2	1.3	6	3.3
Advance signal lights are less safe	-	-	-	-
I don’t know	6	3.8	4	2.2
Missing data	-	-	1	0.6
Total	159	100.0	181	100.0

Table E.22 In addition to the main advance warning lights, do you use the bus hazard warning lights as an additional warning measure?

Answer	Red lights		Amber lights	
	No.	%	No.	%
Never	121	76.1	-	-
All the time	3	1.9	-	-
Occasionally. When (explain)?	34	21.4	-	-
Missing data	1	0.6	-	-
Total	159	100.0	-	-

Table E.23 Do you wait for traffic to stop before letting pupils who have to cross the road get off the bus?

Answer	Red lights		Amber lights	
	No.	%	No.	%
No. never	4	2.5	0	0.0
Yes. always	143	89.9	170	93.9
It depends	12	7.5	9	5.0
Missing data	-	-	2	1.1
Total	159	100.0	181	100.0

Table E.24 On your route, how many illegal passes occur each day?

Answer	Red lights		Amber lights	
	No.	%	No.	%
0	88	55.3	61	33.7
≤1	32	20.1	53	29.3
>1 and ≤2	21	13.2	37	20.4
>2 and ≤3	9	5.7	12	6.6
>3	9	5.7	18	9.9
Total	159	100.0	181	100.0

Table E.25 Of this number, what proportion would you consider to be deliberate?

Answer	Red lights		Amber lights	
	No.	%	No.	%
0 %	22	13.8	34	18.8
1 to 25 %	18	11.3	44	24.3
26 to 50 %	14	8.8	25	13.8
51 to 75 %	2	1.3	13	7.2
76 to 99 %	12	7.5	15	8.3
100 %	15	9.4	14	7.7
Missing data	76	47.8	36	19.9
Total	159	100.0	181	100.0

Table E.26 What proportion of illegal passes are from oncoming traffic?

Answer	Red lights		Amber lights	
	No.	%	No.	%
0 %	8	5.0	-	-
1 to 25 %	6	3.8	-	-
26 to 50 %	15	9.4	-	-
51 to 75 %	11	6.9	-	-
76 to 99 %	20	12.6	-	-
100 %	17	10.7	-	-
Missing data	82	51.6	-	-
Total	159	100.0	-	-

Table E.27 Should advance signal lights be standardized across Canada so that all buses are equipped identically and motorists can better interpret the signal and their obligations?

Answer	Red lights		Amber lights	
	No.	%	No.	%
No	8	5.0	7	3.9
Yes. red lights only	130	81.8	-	-
Yes. amber lights only	8	5.0	124	68.5
Yes. hazard warning lights only	-	-	19	10.5
Other	10	6.3	26	14.4
Missing data	3	1.9	5	2.8
Total	159	100.0	181	100.0

Table E.28 Range between minimum and maximum distance of advance signalling

Answer	Red lights		Amber lights	
	No.	%	No.	%
≤50	34	21.4	-	-
>50 and ≤100	22	13.8	-	-
>100	9	5.7	-	-
Not applicable	94	59.1	-	-
Total	159	100.0	-	-

Table E.29 Average advance signalling distance

Answer	Red lights		Amber lights	
	No.	%	No.	%
≤50	27	17.0	-	-
>50 and ≤100	16	10.1	-	-
>100 and ≤150	12	7.5	-	-
>150	10	6.3	-	-
Not applicable	94	59.1	-	-
Total	159	100.0		

Table E.30 Range between minimum and maximum time of advance signalling

Answer	Red lights		Amber lights	
	No.	%	No.	%
≤5 seconds	8	5.0	-	-
>5 and ≤10 seconds	9	5.7	-	-
>10 seconds	5	3.1	-	-
Not applicable	137	86.2	-	-
Total	159	100.0		

Table E.31 Average advance signalling time

Answer	Red lights		Amber lights	
	No.	%	No.	%
≤10 seconds	6	3.8	-	-
>10 and ≤20 seconds	12	7.5	-	-
>20 seconds	4	2.5	-	-
Not applicable	137	86.2	-	-
Total	159	100.0		