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EVALUATION OF OCCUPANT PROTECTION IN BUSES

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PREFACE

This report describes the results of a study to review the state of the art in bus occupant protection, with special focus on new intercity buses. The work was conducted for Transport Canada by RONA Kinetics and Associates Ltd. under contract number T8080-01-1214.

We would like to acknowledge the input and assistance of all those contacted during this project. We would also like to extend our thanks the project manager at Transport Canada, Mr. W. (Bill) T. Gardner, Road Safety and Motor Vehicle Regulations (ASFBE) for his valuable direction and help throughout the project, and to his colleagues Janet Boufford and Sandie Ste Marie for their help in the collision data analyses.

The conclusions reached and opinions expressed in this report are solely the responsibility of the authors. Unless otherwise stated, they do not necessarily represent the official policy of Transport Canada.

EXECUTIVE SUMMARY

This report describes the results of a review of bus occupant protection research and regulatory practices in Canada, the United States, Australia and Europe. The focus of the study is on occupant safety in intercity buses and issues for future consideration.

In this context, an intercity bus is categorised as follows:

- seating capacity of 25 or more;
- GVWR of 5,000 kg or more;
- provides intercity, charter or tour services;
- no standing passengers;
- dedicated underfloor storage capacity.

Attempts to extract collision and exposure data for intercity buses were frustrated by the lack of common bus categories. Data were available on severe and fatal collisions which had been investigated in detail. These investigations showed that the majority of fatal and serious bus occupant injuries occur in rollovers and ejections.

In the 1980's, after a series of severe motorcoach collisions and significant public pressure, federal regulations were introduced in Australia to address rollover strength, seat and seat anchorage strength and the fitting of lap/torso seat belts in motorcoaches.

In North America, primary focus to date has been placed on school bus safety. The introduction of Motor Vehicle Safety Standards in the mid-1980's resulted in a passive safety system or "compartmentalisation" in school buses. This passive system, largely dependent on seat spacing and padded seat backs, has worked well in preventing injuries during collisions. Discussion continues, however, on the benefit of seat belts in school buses. It is generally agreed that lap belts are not the solution. The effectiveness of lap/torso seat belts is recognised, however there are concerns regarding installation costs and maintenance issues as well as their proper use.

In Europe, regulations now exist which apply to the strength of the superstructure and the strength of seats and their anchorages. In the United Kingdom, regulations have been introduced which require seat belts to be fitted in all new intercity and minibuses. Fitting of seat belts in other European countries varies from country to country. A three-year research program, Enhanced Coach and Bus Occupant Safety (ECBOS), was initiated in Europe in January 2000. The work is aimed at the reduction of injuries through the development of new bus regulations and standards. Work to date has been focused on an analysis of bus collision data.

In summary, available data confirm that bus travel is one of the safest modes of transport in North America, Australia and Europe. When a bus collision does occur, however, it generally receives considerable media attention and public focus. For this reason, discussions continue on ways to improve bus occupant safety. The key findings of the review are:

- There is no common definition for different types of buses.
- There is little harmony or detail in the classification of bus types in collision data.
- Rollovers and ejections are the major causes of serious and fatal injuries to bus occupants.
- Lap belts are not the preferred manner of restraint.
- Lap/torso seat belts are effective in preventing injuries and ejections.
- Retentive glazing may also reduce the risk of ejections.
- Retrofitting of seat belts is difficult and costly when the floor structure is not strong enough to take the loads.
- Bus seats with integral seat belts are available without weight penalty.
- Regulations in Australia and Europe regarding the strength of the bus superstructure, seat attachments and seat belts generally reflect real world collision data.

1. INTRODUCTION

In Canada, bus travel is one of the safest modes of road transport available. Bus occupants account for only 0.3% of all road fatalities and 0.6% of all reported injuries. When a bus collisions does occur, however, it becomes the focus of media and the general public and the bus safety record is generally overlooked. While the incidence of bus occupant trauma is relatively small, there is continuing public discussion on how best to make buses as safe as possible for their passengers.

In Canada, bus safety is an ongoing responsibility of the Road Safety and Motor Vehicle Regulation Directorate of Transport Canada. In 2002, Transport Canada initiated an investigation into recent and developmental work aimed at improving bus occupant protection in specific locations around the world. The goal of the work was to identify how better to protect Canadians who are travelling by bus, specifically seated passengers in buses travelling between cities or major resorts. This report describes the results of this project.

2. STUDY OBJECTIVES

This study is a review and evaluation of bus occupant protection research and development with particular emphasis on regulatory and manufacturing practices in North America, Australia, and Europe as they apply to seat belts, glazing and structural integrity.

The main objectives of the study were as follows:

- To summarise bus collision data in North America, Australia and Europe and to review collision case studies involving bus occupants in Canada and Australia.

- To identify and review research work in North America, Australia and Europe leading to the development of occupant protection countermeasures in buses. Particular attention to be given to research into seat belts, glazing and structural integrity.

- To determine and review regulatory and manufacturing practices for bus occupant protection in North America, Australia and Europe and to compare them with current practices in Canada.

- To review safety options for improved intercity bus occupant protection.

3. BUS DEFINITIONS AND CLASSIFICATIONS

3.1 Background

There is no universal definition of a bus. The word "bus" applies generally to a motor vehicle with a seating capacity greater than that provided by motor vehicles used for family travel.

In different countries and even within each country and separate reporting authorities, a bus is defined in various ways. In some cases, a bus is simply defined as a motor vehicle designed for carrying more than a specified number of persons. A bus may also be classified into separate categories according to body style, vehicle mass, seating capacity, service provided, or other physical or usage feature. A summary of the different bus definitions used across Canada is given in Appendix A along with definitions used in Federal Motor Vehicle Regulations in the United States and Australia. Bus definitions used in the Economic Commission for Europe (ECE) regulations are also included in Appendix A.

The lack of a common definition of a bus and harmonised bus classification makes it difficult to determine the characteristics of the bus fleet in each country as well as their relative involvement in collisions and the crashworthiness of different types of buses. Varying definitions also confound attempts to compare data for different countries.

Efforts were made to determine a definition for the focus of the present study, so-called intercity buses. Bus definitions in current North American regulations are relevant in this regard.

3.2 Bus Definitions in the Canada Motor Vehicle Safety Standards

In the Canada Motor Vehicle Safety Standards (CMVSS)[1], "bus" means a vehicle having a seating capacity of more than ten, but does not include a trailer. The only type of bus which is further defined in CMVSS is a "school bus", a bus designed or equipped primarily to carry students to and from school. There are no separate classifications or definitions for other types of buses.

3.3 Bus Definitions in Provincial Regulations in Canada

In Canada, all jurisdictions identify school buses, but not all differentiate between other bus types. In the regulations of each province and territory, the definition of a "bus" varies (see Appendix A). For example, the Alberta Highway Traffic Act defines a "bus" as a Type A, Type B, Type C or Type D school bus as described in the CSA Standard D250 "school buses"; the Ontario Highway Traffic Act (R.S.O. 1990, c.H8) defines a "bus" as a motor vehicle designed for carrying ten or more passengers.

[1] Regulations and standards are referenced in Appendix A.

3.4 Bus Definitions in CSA Standards

In the Canadian Standards Association's school bus standard, CSA D250, a school bus is defined as a specially constructed vehicle designed for carrying more than ten persons. School buses are categorised into four types, A to D, reflecting different body type, engine location, and vehicle mass.

CSA D409, Motor Vehicles for Transportation of Persons with Physical Disabilities, categorises "vehicles" as Type A to D as in the school bus standard. CSA D409 includes an additional category, Type E, defined as a multi-purpose vehicle having a GVWR of 4,536 kg (10,000 lb) or less. CSA D409 also includes a definition for "transit bus" and "over-the-road bus (OTRB)", see Appendix A. These definitions are under review for use in two CSA Standards under preparation, viz. D435 (Accessible Transit Buses) and D436 (Accessible Over-the-Road Buses) respectively.

3.5 Bus Definitions in the U.S.

The U.S. Department of Transportation (DOT) does not have standard definitions or classifications for the various bus types (NTSB, 1999b). A bus is either a school bus or other type of bus that is not further defined. The latter includes motorcoaches or intercity buses and transit or urban buses.

The Federal Motor Carrier Safety Regulations administered by the Federal Highway Administration defines a bus in two different ways: any motor vehicle, including taxicabs, designed, constructed, or used for the transportation of passengers (49 CFR 390.5) and; a vehicle designed to carry more than 15 passengers, including the driver (49 CFR 393.5)

3.6 Bus Definitions Used in This Report

In the presentation of collision and exposure data, the term used to describe a bus or different type of bus is that used in the original source. In all other cases, the following terms and definitions are used. The different categories of bus reflect seating capacity, GVWR, service provided, and whether or not there is provision for standing passengers.

Bus	a motor vehicle having a seating capacity of more than ten; this definition would include vans with a seating capacity of 15.
School bus	a bus designed or equipped primarily to carry students to and from school and which complies with all CMVSS pertaining to school buses.

Intercity bus	a motor vehicle • with a seating capacity of 25 or more • with a GVWR of 5,000 kg (11,022 lb) or greater; • that provides intercity, charter or tour services; • that has no provision for standing passengers; • that is equipped with dedicated purpose-built underfloor baggage/storage capacity.
Transit bus	a motor vehicle • with a seating capacity of 25 or more; • with a GVWR of 5,000 kg (11,022 lb) or greater • that provides an urban or suburban transit service; • that may have provision for standing passengers; • that has no provision for underfloor luggage.

The following list gives different terms used by other sources to refer to these types of buses.

Bus	ECE Category M2
School bus	CSA D250 Type A, B, C, D
Intercity Bus	Over-the-road bus (OTRB) Motorcoach Tour bus ECE Category M3, Class III
Transit bus	Regulation route bus Scheduled bus ECE Category M3, Classes I & II

4. WORK PERFORMED

The project team contacted key researchers, agencies and government authorities as well as selected bus manufacturers in Canada, the United States, Australia and Europe.

A world-wide literature search was conducted to identify material in areas related to bus occupant protection. This work was done using in-house library databases and by contacting key safety agencies around the world. The literature search was supplemented with website searches. Information was collected on recent research work related to improved bus occupant protection, including restraint systems and their effectiveness, seats, retentive glazing and structural integrity. At the same time, key bus manufacturers and suppliers in North America, Australia, and Europe were identified.

Through government agencies, information was collected on regulatory practices and performance requirements for buses in Canada, the United States, Australia, England and

other parts of Europe. Individuals were contacted to obtain additional information on the method of collection and interpretation of published statistics.

The two Canadian manufacturers of intercity buses in Canada, MCI and Prévost, were contacted and information sought on the range of their products. The Prévost Car Inc. in Ste-Claire, Quebec as well as the Volvo bus plant in Turku, Finland were visited. A planned visit to MCI in Winnipeg was cancelled as a tour of the manufacturing facilities was not possible. A number of other North American bus manufacturers and suppliers were contacted to define their product range. In Australia, direct contact was made with key intercity bus manufacturers and bus safety equipment suppliers.

Companies producing seat belts or other restraint systems for use in buses in North America and Australia were also contacted. Information was sought on the production and installation of seats, seat belts and glazing in North America. This included local visits in Vancouver to a Cardinal Transportation school bus depot to look at safety features including emergency exits, and integrated child seats installed in local Corbeil school buses; the Greyhound maintenance facility in Vancouver to examine the interior of intercity buses including seating arrangements, method of anchoring seats, emergency exits and installation of a windshield; Western Bus Service, Broco Auto/Glass, and a meeting with the manager of safety and research at the Insurance Corporation of British Columbia regarding glazing installation methods, adhesives and costs.

Test agencies in Canada and Australia with bus or component testing capabilities were contacted and some testing cost estimates obtained. IMMI and CAPE in Indiana, U.S.A. were visited to view their manufacturing and test facilities, including a review of barrier, sled and rollover impact test capabilities and modelling applications.

The key partners in the ECBOS project were contacted. Other agencies and individuals involved in bus safety issues were also contacted. This included the Cranfield Impact Centre and the Transport Research Laboratory in the United Kingdom.

A list of the main contacts is given in Appendix D.

5. STATISTICAL OVERVIEW

5.1 Introduction

This section summarises published data on the Canadian bus fleet and usage as well as bus collision statistics for North America. Collision data for Australia and Europe are given in Sections 9 and 10 along with selected case studies for all countries.

The major shortcoming of the available data is the lack of common classes and definitions for different types of buses. Consideration of this issue has been previously addressed in Section 3. Often the data source fails to differentiate between the various categories of bus and information is only available from all "buses", again variously defined.

The other limit of available data sources on bus transportation and collisions is the manner in which the data are collected. Much of the statistical data available from Statistics Canada depend on response to surveys and accurate reporting by those surveyed. Published collision data are confined to traffic collisions "reportable" to the police. The definition of incidents which are required to be reported varies in the different jurisdictions and it is generally recognised that property damage collisions and slight injury collisions are often not reported.

Accordingly, the bus exposure and collision data are limited by both the method of collection and the bus classification system used.

5.2 Exposure Data

In Canada, the main measurement of road vehicle activity is through the Canadian Vehicle Survey (CVS) started in 1999. The CVS is a voluntary vehicle-based survey conducted by The Transportation Division of Statistics Canada. As the vehicle classification is based on the vehicle registration lists, buses of all types are included in a single category "buses". No data are collected for different types of buses.

Based on the latest published CVS data (Transport Canada et al., 2001) there are 70,507 "buses" registered in Canada. Vehicle model year was provided for 67,611 buses and approximately 17% were model year 1987 or earlier. The estimate of total vehicle kilometres during the third quarter of 2001 for buses in Canada (including van body types) is 247.7 million.

The Transportation Division of Statistics Canada surveys the passenger bus and urban transit in Canada on a quarterly basis. The program covers companies that have annual gross revenues of $200,000 or more. Data are provided for six industry segments of buses according to the North American Industry Classification System (NAICS) which is used by Canada, the United States and Mexico.

Part I	Interurban and Rural Bus Transportation
Part II	Urban Transit System
Part III	School Bus Transportation
Part IV	Charter Bus Industry
Part V	Shuttle Services
Part VI	Scenic and Sightseeing Transportation by Bus

It should be noted that each industry segment also provides bus services outside their primary activity. In the annual report for passenger bus and urban transit statistics (Statistics Canada, 1999), the urban transit industry dominates the passenger bus industry in Canada accounting for 51% of total bus revenues in 1998. Interurban, charter and sightseeing transportation industries combined account for approximately 12% of the total bus revenues. The number of actual intercity carriers is however higher, as the school bus transportation industry which accounts for 36% of the total bus revenues, also owns Greyhound Bus Lines. This is reflected in the data on the number of passengers using scheduled intercity services by industry segment, see Table 1.

Table 1: Passengers Using Scheduled Intercity Services by Industry Segment
(Source: Passenger Bus and Urban Transit Statistics, Statistics Canada, 1998)

	1998 (in thousands)	
	N	%
Interurban Transportation	6,140	44.2
School Bus Transportation	5,496	39.6
Charter Bus Industry	2,148	15.5
Shuttle Services	71	0.5
Sightseeing Transportation	39	0.3
Total	13,894	

After a steady decline in the number of intercity bus passengers during the 70's and 80's, a levelling off began in the mid-nineties. In 1998 almost 14 million passengers travelled by intercity bus services.

In Canada, a Transportation Table has been established to identify ways to reduce greenhouse gas (GHG) from rail and intercity bus operations. In a report for the Transportation Table it was estimated that the economic life of an intercity coach is 15 years (English et al., 2000). The report also notes that Statistics Canada may be under-reporting total commercial bus activity by 10-40%.

According to a survey commissioned by the American Bus Association (Banks, 2000) in 1999, there were about 4,000 companies operating 44,000 intercity buses in Canada and the United States. The motorcoach industry operated intercity buses over 2.6 billion miles in North America carrying an estimated 860 million passengers. In this survey, an intercity bus or motorcoach is defined as a "vehicle designed for long distance transportation of passengers, characterised by integral construction with an elevated passenger deck located over a baggage compartment." It is at least 35 feet in length and carries more than 30 passengers. Based on mileage for about 11,400 motorcoaches, each motorcoach averaged about 50,300 miles (80,480 km). Carriers with an operating fleet of 100 or more motorcoaches reported an average of 95,914 miles (153,462 km) per motorcoach in 1999.

In a recent report on the Canadian Bus Industry Advanced Technology Study (Transport Canada, 2002), data are provided on the public transportation industry in Canada compared to the United States. Table 2 summarises the bus fleet by industry sector. The size of the intercity bus fleet and the number of passengers carried is about ten times greater in the United States compared to Canada.

Table 2: Public Transportation Industry in Canada Compared to the United States (CDN $)
(Source: The Canadian Bus Industry Advanced Technology Study, Transport Canada, 2002)

Service Provided	Country	No. of Service Providers	Fleet Size	Passengers Carried (million)[1]	Kilometres Operated (million)[2]
Urban Transit	Canada	95	13,000	1,440	810
	U.S.	800	92,455	9,170	6,400
Intercity Coach (including charter/tour)	Canada	149	4,000	14	285
	U.S.	3,600	40,000	140	3,750
School Transportation	Canada	649	38,800	3	646
	U.S.	6,600	448,300	24	6,115

5.3 Collision Statistics

5.3.1 Canada

In Canada, Transport Canada in co-operation with the Canadian Council of Motor Transport Administrators (CCMTA) collects vehicle collision data from across the country and stores this information in the Transport Canada TRaffic Accident Information Database (TRAID).

TRAID contains all reportable traffic collisions involving a fatality, injury and/or property damage (exceeding the $1,000 threshold) occurring in the ten provinces and three territories on a public road (Boufford, 2002). The reporting police departments provide the collision reports to the jurisdictions who are responsible for data entry, validation, and reporting for their jurisdiction. They, in turn, send an annual tape to Transport Canada to be included in the national tape. Fatal collisions include all reportable motor vehicle collisions which resulted in at least one fatality, where death occurred within 30 days of the collision, except in Quebec (8 days). Personal-injury collisions include all reportable motor vehicle collisions which resulted in at least one injury but not death within the time frames set out in fatal collisions. Fatalities include all those who died as a result of involvement in a reportable

[1] Numbers have been rounded up for the present report.

traffic collision within 30 days of its occurrence. The exception to this rule is Quebec (8 days). Injuries include all those who suffered any visible injury or complained of pain.

In TRAID, motorcoach does not exist as a distinct vehicle type. The data provided by the provinces and territories reflect the different bus categories used in their collision data recording system which varies across the country. Manitoba, New Brunswick, Newfoundland, Nova Scotia, Ontario and Saskatchewan report collision data separately for transit and intercity buses, however, they also report collisions under "buses unspecified". Alberta began reporting transit and intercity buses separately in 1991, however they also continue to report "buses unspecified". It is not possible to determine the number of intercity buses so classified. Quebec and the Northwest Territories do not report transit and intercity buses separately but report data under "buses unspecified". Data from the rest of Canada similarly fail to distinguish between the different bus types.

Canada's bus occupant safety record is good. The average number of bus fatalities by type of road user is given in Table 3. Bus occupants account for approximately 20% of all fatalities. The remaining casualties are pedestrians or occupants in other involved vehicles.

Table 3: Bus Fatalities in Canada
10-year average: 1990-1999
(Source: Boufford, 2002)

Type of Bus Involved	Type of Road User							
	Bus Occupant		Occupant of Other Vehicle		Pedestrian		Total	
	N	%	N	%	N	%	N	%
School	0.9	5.3	11.6	68.2	4.5	26.5	17.0	100.0
Urban Transit	0.4	4.1	4.9	50.5	4.4	45.4	9.7	100.0
Intercity	1.0	13.5	4.8	64.9	1.6	21.6	7.4	100.0
Unspecified	8.4	41.8	8.3	41.3	3.4	16.9	20.1	100.0
Total	10.7	19.7	29.6	54.6	13.9	25.6	54.2	100.0

Bus occupant fatalities in TRAID for 1984-1999 and categorised as "intercity" or "buses unspecified" are given in Table 4.

Table 4: Intercity and Unspecified Bus Occupant Fatalities in Canada 1984-1999.
(Source: Boufford, 2002)

	Intercity Bus (N=11)		Unspecified Bus (N=102)		
	Driver	Passenger	Driver	Passenger	Unknown
1984			3		
1985				1	
1986			4	5	
1987				1	
1988		1		1	
1989			1	2	
1990		3		4	1
1991	1				
1992				2	
1993			1	19	
1994	1	3		3	
1995			1	5	
1996					
1997	1	1	1	43	
1998				2	1
1999				1	
Total	3	8	11	89	2

The majority of unspecified bus fatalities occurred in the province of Quebec. During 1984 to 1998, there were 83 occupant fatalities in Quebec in buses unspecified, 9 drivers and 74 passengers. Although the Quebec data do not distinguish between transit and intercity buses, knowledge of individual cases indicates that the vast majority of the fatalities occurred on motorcoaches or tour buses, i.e. intercity buses as defined for this report. As the province of Quebec does not report ”ejection from vehicle”, analysis of the number of fatalities who were ejected in Canada is not possible.

Serious bus crashes, particularly those involving school buses and intercity buses are investigated by Transport Canada’s multidisciplinary collision investigation teams. In an attempt to better understand the injury circumstances in bus collisions in Canada, data were extracted by Transport Canada on 21 collisions involving intercity buses which occurred between 1990-2001 and were investigated by the teams. These collisions came to the attention of the teams because of their high level of severity or their high profile in the media. Although this is a biased sample, the data are useful in considering the circumstances of fatal and serious injuries and ways in which they may be prevented. A summary of the known occupancy and injury severity levels is given in Table 5.

Table 5: Occupant Injury Severity in 21 Severe Intercity Bus Collisions in Canada
(Source: Transport Canada, 2002)

		Injury Level (AIS)[1]								Number of known ejections
	Total	0	1	2	3	4	5	6	9	
Rollover										
Driver[2]	7	0	3	0	1	0	0	2	1	1
Passenger	212	26	110	12	5	9	1	50	4	22
Total	219	26	113	12	6	9	1	52	5	23
Non-rollover										
Driver	14	6	2	0	1	1	0	3	1	0
Passenger	332	173	90	30	15	9	1	14	0	11
Total	346	179	92	30	16	10	1	17	1	11

Of the 21 selected collisions there were 7 (33.0%) rollover events which accounted for the majority of severe and fatal injuries (Table 6). There were a total of 64 passenger fatalities and five driver fatalities. Two-thirds of the fatalities occurred in one collision in which the driver and 43 passengers were killed when the bus fell down a ravine (see Case 1, page 32). Of the remaining 25 fatalities, 16 (64.0%) occurred in rollover collisions. There were 31 occupants ejected, 16 (51.6%) of whom were fatally injured. Rollover collisions accounted for 23 (74.2%) of the 31 ejections. A summary of the ejections by collision type is given in Table 6. As the total number of bus occupants in each collision was not always known, percentages are not included.

Table 6: Ejection Status by Collision Type
in 21 Severe Intercity Bus Collisions in Canada
(Source: Transport Canada, 2002)

	Ejected		Not Ejected	
	Fatal	Non-Fatal	Fatal	Non-Fatal
Rollovers	7	16	45	156
Non-rollovers	11	0	6	341
Total	18	16	51	497

[1] Abbreviated Injury Score.
[2] In one rollover, driver's injury status not known.

5.3.2 United States

In the United States, intercity buses are a relatively safe mode of transportation with about 10 bus occupant fatalities per year (9 passengers and 1 driver). Data on fatal collisions are routinely collected as part of the National Highway Traffic Safety Administration (NHTSA)'s Fatal Accident Reporting System (FARS). Data on intercity bus collisions which occurred from 1991-2000 were extracted from the FARS data and supplemented by the NTSB (Federal Register, 2002).

There were a total of 48 collisions, 18 rollovers and 30 non-rollovers, resulting in a total of 101 fatalities. There were 16 drivers and 85 passengers fatally injured. Ejection status was known for all but one passenger, 3 (18.8%) drivers were ejected and 47 (55.3%)[1] passengers were ejected. The number of ejections is given in Tables 7 and 8 for rollover and non-rollover collisions respectively. It was noted that in one single non-rollover collision, 22 passengers were fatally injured.

Table 7: 1990-1999 Motorcoach Occupant Fatalities in Rollover Collisions by Ejection Status
(Source: Federal Register, 2002)

	Ejected		Not Ejected		Total	
	N	%	N	%	N	%
Driver	1	50.0	1	50.0	2	100.0
Passenger	26	74.3	9	25.7	35	100.0
Total	27	73.0	10	27.0	37	100.0

Table 8: 1990-1999 Motorcoach Occupant Fatalities in Non-Rollover Collisions by Ejection Status
(Source: Federal Register, 2002)

	Ejected		Not Ejected		Total	
	N	%	N	%	N	%
Driver	2	16.7	10	83.3	12	100.0
Passenger	21	42.9	28	57.1	49	100.0
Total	23	37.7	38	62.3	61	100.0

[1] Percentages calculated for known values.

For comparison, Tables 9 and 10 show the incidence of fatalities ejected in rollover and non-rollover collisions in the FARS sample and the previously described 21 collisions investigated in-depth in Canada.

Table 9: Intercity Bus Fatalities in Selected Rollover Collisions in Canada[1] and United States[2]

		Ejected		Not Ejected		Total	
		N	%	N	%	N	%
Driver							
	Canada	1	50.0	1	50.0	2	100.0
	U.S.	1	50.0	1	50.0	2	100.0
Passengers							
	Canada	6	12.0	44[3]	88.0	50	100.0
	U.S.	2	16.7	10	83.3	12	100.0
Total							
	Canada	7	13.5	45	86.5	52	100.0
	U.S.	3	21.4	11	78.6	14	100.0

Table 10: Intercity Bus Fatalities in Selected Non-Rollover Collisions in Canada[6] and United States[7]

		Ejected		Not Ejected		Total	
		N	%	N	%	N	%
Driver							
	Canada	0	-	3	100.0	3	100.0
	U.S.	2	16.7	10	83.3	13	100.0
Passengers							
	Canada	11	78.6	3	21.4	14	100.0
	U.S.	21	42.9	28	57.1	49	100.0
Total							
	Canada	11	64.7	6	35.3	17	100.0
	U.S.	23	37.7	38	62.3	61	100.0

[1] Fatalities taken from Transport Canada's sample of 21 severe collisions.
[2] Taken from FARS sample of 48 collisions.
[3] 43 killed in one rollover collision.

6. LITERATURE REVIEW

6.1 Introduction

A summary of the primary findings of selected papers pertaining to bus occupant protection is presented in this section. The papers are presented chronologically. Additional work is summarised within the individual sections for Canada, United States, Australia and Europe.

6.2 Collision Data

Stansifer and Romberg, 1978
This paper describes an assessment of the need and cost-benefit of seat belts in intercity buses. The analysis is based on a review of 66 intercity bus collisions in the U.S. studied in detail from 1972-1976. The authors conclude that seat belts do not demonstrate a positive cost-benefit based on the anticipated voluntary passenger use rates at that time of 11-18%.

Langwieder et al., 1985
This paper describes the results of a study of 97 bus collisions in the Federal Republic of Germany as well as 142 incidences (non-collision) resulting in bus occupant injuries. The study is based on a random sample of bus collision and injuries investigated by the HUK-Verband research team. In the collision sample, 50% of the buses were on scheduled service, 35% were long-distance, and 15% were on school bus service. A total of 40 occupants were fatally injured, 38 (95.0%) in long-distance coaches and 33 of the 38 were involved in 3 single vehicle collisions with rollover. A breakdown of the injury severity by collision type is given in Table 11.

Table 11: Injury Severity by Collision Type for Long-Distance Coaches in HUK-Verband Sample
(Taken from Langwieder et al., 1985)

Collision Type	Injury Severity						Total Occupants Involved
	Slight		Moderate		Fatal		
	N	%[1]	N	%	N	%	N
Bus/Car	19	11.6	3	1.8	-	-	164
Bus/Truck	106	28.9	43	11.7	5	1.4	367
Bus/Bus	42	27.6	6	4.0	-	-	152
Single Vehicle	83	24.5	96	28.1	33	1.0	342
Total	250		148		38		1,025

[1] Percentage of total occupants involved.

The risk of injury for bus occupants in bus/car collisions is relatively low. In the bus/truck collisions, it appears that intrusion resulted in the majority of fatal and serious injuries. The authors note the high risk of injury in rollover collisions and the two main injury mechanisms in rollovers. Either the occupant is ejected out of the bus and crushed by the bus during rollover or the occupant is ejected from their seat and sustain fatal impacts with the bus interior. In most cases the interior space was reduced by roof intrusion. It was observed that in rollovers with roof impact, the roof usually deformed inwards as a result of diagonal loading of the roof posts. The authors conclude that safety measures should be focused on long-distance coaches in which the majority of serious and fatal injuries occur compared with scheduled services. They also note that the use of lap/torso seat belts in conjunction with an appropriate roof construction (to prevent roof intrusion) would provide bus occupants with optimum protection. They recognise the need to consider the cost-benefits and acceptance of seat belts.

Thomas et al., 1985

This study is based on 48 coach collisions which occurred in France between 1978-1984 and resulted in a total of 170 bus occupant fatalities. There were 20 (41.7%) coach frontal collisions, 16 (33.3%) rollovers and "tip-overs", and 12 (25.0%) categorised as "other". In 14 cases the rollovers (180º or more) and "tip-overs" occurred after the coach had left a road bordered by a shallow embankment of at least one metre in depth. The majority of fatally injured bus occupants were ejected during the rollovers, 54% were fully ejected. Ejection occurred through side window tempered glass as well as the windshield and rear window. The 12 remaining collisions resulted in 94 (55.3%) of the fatalities; 48 of whom were killed in one collision in which a fire started at the front of the coach. In this collision, only 16 occupants were able to escape by the rear door within two minutes and before being asphyxiated. Difficulty in finding and reaching the coach exits quickly was related to one-third of all fatalities however, the authors provide no further details. Two countermeasures are proposed, the use of lap/torso seat belts and seat back improvements to reduce occupant rear loading and reduce the severity of lower limb impacts. Retentive glazing for the prevention of ejection is considered in conflict with the need to use windows as potential emergency exits. The need for rapid evacuation, especially in the rare case of fire, is noted.

Botto et al., 1991

This paper describes an analysis of 11 rollovers from a sample of 78 bus collisions. The collisions occurred in France and the study started in 1980. A total of 2,925 occupants were involved. Frontal impacts were most common, accounting for 35 (44.9%) bus collisions and there were 32 (41.0%) rollovers described as either "tip over" (20 cases); "flip over" (6 cases) or "rollover" (6 cases) depending on the extent of the roll. The different types of "tip overs", in collisions in which the coach rolled onto one of its sides, were described by a summary of three collisions.

Case 1
Coach tipped onto its side when almost stopped. Of the 47 occupants, 3 seriously injured (MAIS 3), 27 slightly injured (MAIS 1-2), and 17 uninjured (MAIS 0). The injuries resulted from occupant contacts with the bus interior. The vehicle structure was intact without deformation. Occupants were removed from the coach through the front windshield opening.

Case 2
Coach with 44 occupants left the road at approximately 100 km/h and then rolled onto its side and slid 65 m before coming to a stop. There was no structural deformation, but three side window panels were broken. Three occupants were killed (MAIS 6), 6 seriously injured (MAIS 3), 21 slightly injured (MAIS 1-2), and 14 uninjured (MAIS 0). All the fatalities were ejected. The other occupants were removed from the coach through the front windshield opening.

Case 3
Coach rolled over onto highway central dividing barrier. There was significant intrusion where the coach struck the barrier. Of the 46 occupants, 5 occupants were killed (MAIS 6), 14 seriously injured (MAIS 3 or 4), 11 slightly injured (MAIS 1 or 2), and 16 were uninjured (MAIS 0). The fatally injured occupants were ejected and 3 occupants were seriously injured due to intrusion. The remaining 11 seriously injured occupants were injured during impacts within the coach.

The authors also describe rollover collisions involving double-decker coaches. They conclude that total or partial ejections are responsible for the majority of serious casualties. They also note the benefits of seat belts and retentive glazing.

MacDonald, 1991
In the United Kingdom, the Department of Transport's Vehicle Inspectorate examines approximately 1,800 vehicles following major collisions, the majority of which are trucks and buses. The vehicles are examined to determine whether vehicle conditions contributed to the cause of the collision. There is a report of coach roof hatches detaching during routine travel due to incorrect operation by a passenger and poor glazing security. In one severe coach collision, the majority of seats became detached from their mountings and the seat frames also broke allowing the seat backs to become free of the seats. The seats were tested to 10 g.

Botto et al., 1994
The authors review the potential benefits of two countermeasures; seat belts and retentive glazing. Using data on 47 rollovers studied in detail from the previously reported database (Botto et al., 1991), they conclude that application of both countermeasures would have reduced the injury severity for 55% of the fatally and severely injured occupants.

Rasenack et al., 1996

In an analysis of bus collisions which occurred between 1985-1993 in Germany, 48 were identified as representative of serious bus collisions. Eight of the collisions were rollovers accounting for 109 (50.2%) of all severe injuries and 36 (90.0%) of all fatalities. The source of the non-minor injuries is not clear although the authors conclude that some occupants were partially or fully ejected. Frontal collisions with trucks were the second type of collision resulting in serious and fatal injuries. The potential of lap belts and lap/torso seat belts is examined during computer simulation of frontal and rollover collisions, using MADYMO. The potential benefits of seat belts in reducing injuries is shown. The authors conclude that in rollovers, lap belts provide better protection than lap/torso belts, however, this appears to be largely based on extreme belt slack in the model, which was introduced when the occupant dummy slid out of the torso belt. In the conclusion, the advantages of installing seat belts and making their use mandatory are considered greater than given disadvantages.

Ferrer and Miguel, 2001

This paper is based on an analysis of Spanish in-depth bus investigations of three collisions.

Case 1 - Rollover

The bus was travelling at approximately 106 km/h in the rain, the rear axle started to skid and the bus rotated 180º, then left the road and rolled into a small water course. All 52 of the occupants were ejected from their seats and most were thrown from the bus into the water course. It appears that 29 occupants were fatally injured, most of whom drowned in the water course.

Case 2 - Offset Frontal

In this collision, a truck with a curb weight of 17,000 kg and carrying livestock struck the front left side of the coach. All the passengers sitting on the left side of the coach were fatally injured. A total of 28 occupants sustained fatal injuries. The authors conclude that seat belts would not have helped these occupants. Some occupants sitting on the inside of the seats on the right side sustained fatal injuries as a result of contact with the armrest. In the MADYMO simulation with seat belts introduced, there was no ejection and the armrest had almost no influence on the results.

Case 3 - Full Frontal

In this collision, the front of a coach collided with the underside of a semi-trailer on the road. None of the occupants were using a seat belt. The driver and two front right occupants were fatally injured. The driver's compartment was reduced due to frontal deformation, however the authors conclude that his fatal head injury could have been prevented if he had been wearing the available lap/torso seat belt. The passengers behind the driver were ejected from their seats and sustained serious head injuries from impacting the structure between them and the driver. The right front seat passengers were ejected from their seats, the passenger next to the aisle sustained fatal injuries when he fell on the floor. The window-

side passenger sustained fatal chest injuries when he struck the structure between him and the guide seat. The authors conclude that none of the fatal or serious injuries to the front row passengers would have occurred if they had been using lap/torso seat belts

The three collisions were reconstructed using PC-CRASH and MADYMO to simulate occupant kinematics. The major cause of the fatal and serious injuries in each collision was ejection. MADYMO simulations are made of the occupants during the crash and with lap/torso seat belt systems. To overcome the ejection problems, the authors recommend the use of three-point seat belt systems and improved seat structures and anchorages as the next step in improving passive safety in buses.

Krüger, 2002
In a paper summarising the findings from bus collision analyses, the author concludes that rollovers are the most hazardous type of collision and that the main injury preventative measures are the existence and use of restraint systems and maintenance of occupant compartment space without excessive intrusion. Both these countermeasures are reflected in ECE Regulations 80 and 66, although their effectiveness in real world collisions is not yet known. Krüger notes that at least two main evacuation routes must be provided to enable occupants to self-rescue. He also notes that the risk of a fatal injury is approximately eight times higher for an occupant who is ejected compared to an occupant who remains inside the bus.

6.3 Modelling and Testing

LaBelle, 1963
This early paper describes a frontal barrier impact test at 25 mph (40 km/h) of an intercity bus with 26 adult and child dummies, some restrained by seat belts. Some of the seats detached due to both buckling of the floor and failure of the fasteners. A series of frontal sled tests with 10 g deceleration were also conducted with improved seat attachments. The author concludes that accelerations of 10 g are probably sufficient to test seat systems.

Kecman and Tidbury, 1985
This paper describes the background to the calculation method for certifying bus rollover strength, which was later used for compliance with the ECE 66 Regulation. Three different analysis approaches are outlined: CRASH-D; standard finite element analysis (FEA); and a tubular framework optimisation program WEST. The authors conclude that the calculation method is the most rational and cost effective way of designing bus structures to comply with the new bus structure strength in rollover requirements.

White, 1985
This paper describes the Rollover Accident Simulation Program (RASP) developed to study design factors which affect rollover stability. The main parameters investigated were spring

stiffness, heights of the centre of gravity and roll movement of inertia. The height of the centre of gravity was the most critical factor affecting rollover.

Krüger, 1986

This paper describes the results of sled tests conducted at a speed of 24 km/h to examine the potential of bus seats as restraints. With 50 percentile male and 6-year old child dummies, the tests showed that passenger protection was best with a seat row distance of 800-850 mm. In further tests simulating 10 g deceleration in a frontal impact, original seat anchorages broke loose. The authors note that similar seat anchorage failures were observed in an actual double-decker collision. The tests show the potential of a seat system and energy absorbing seat backs to maintain occupant space and to reduce injury risk.

Dal Nevo et al., 1991

In 1989, New South Wales experienced the two worst coach collisions in Australia's history. First, a coach to truck collision with a closing speed of approximately 200 km/h, in which 19 died. Two months later, a coach to coach collision occurred, again with a closing speed of approximately 200 km/h, in which 35 died. This paper compares the findings from these and three other collisions to a test series on bus seats based on the ECE 80 Regulation conducted at CRASHLAB evaluating the potential gains. It was concluded that ECE 80 did not reproduce the seat damage from the actual collisions, that passive 10 g protection would not offer adequate protection. The collisions confirmed the belief of the authors that a total coach safety package incorporating rollover strength, emergency exits and 3-point seat belt occupant protection was required for collisions of this severity. The results of development testing of a seat incorporating a 3-point seat belt, which offered protection to 20 g, were reported. The authors report that it is possible to manufacture such a seat without incurring significant cost or weight penalty.

Kumagai et al., 1994; Niii and Nakagawa, 1996

The rollover of a bus is simulated using a full FEA program. The results of a full scale dynamic rollover test of a complete bus to ADR 59 or ECE 66 are used to verify the predictions of a model based on the dynamic testing of some critical structural components. The authors conclude that good agreement is shown between the test and the analysis technique.

Appel et al., 1996

The authors review the European legislation in effect at the time including:

- ECE 66 Stability of Bus Structure
- ECE 80 Stability of Seats and their Anchors.

Available German bus collision data (from DEKRA and HUK) were analysed, with the conclusion that bus rollover followed by frontal impact were the critical collision modes leading to fatal and serious injuries to the bus occupants. The most common injuries during the rollover were due to the bus interior, the seats, side windows and roof being the major contributors. These modes of injury causation were studied using a MADYMO model of a

50th percentile Hybrid III dummy. The authors conclude that significant improvements to the safety of bus occupants can be achieved by the installation and mandatory use of seat belts. On the basis of the modelling, the authors conclude that lap belts were sufficient for restraining the occupants in their seats, however the use of padded seats and raised side panels were considered for additional safety.

Dickison and Buckley, 1996

Research work at the Motor Industry Research Association (MIRA) in England was undertaken to develop a method to fit replacement seats with integral seat belts into minibus. The underfloor is reinforced and during validation testing, this system resisted the seat belt anchorage loads without failure. The authors report that the "underfloor" solution prevents loss of headroom and weight penalty observed with overfloor reinforcement.

Kecman and Dutton, 1996

The authors describe the development of a seat to meet both the ECE 80 Regulation (for unbelted occupants) and the ADR 68 (for belted occupants) and which is still commercially feasible in terms of weight and cost. Initial component testing was carried out and this was combined with an analytical study using MADYMO and CRASH-D to optimise the design of a new seat. Prototypes of this design were produced and four rows of the seat sled tested. The test configuration allowing all loading configurations to be checked with dummies. The study concludes that the seat successfully met the regulations, while being the same size as the current European seats, using current materials and manufacturing techniques and weighing 36.3 kg. It should be pointed out that the Australian seats which meet both regulations only weigh about 30 kg.

Kecman and Randell, 1996

This paper reviews the Cranfield Impact Centre experience with the calculation method used for compliance of bus structures with the ECE 66 Regulation. The authors suggest that the best cost and weight efficiencies are found when the safety requirements of ECE 66 are combined with the service load and production requirements during the structural design phase. Both quasi-static and full dynamic analysis of the rollover test can be used for development of the structure. Quasi-static analysis still appears to be more reliable for type approval purposes. The authors conclude that there needs to be specific minimum requirements for the approval by calculation. This process needs to be co-ordinated internationally and may justify changes to the regulation.

Berg and Niewöhner, 1998

Based on the DEKRA database of 371 collisions involving buses which occurred between 1985 and 1997 in Germany, the authors conclude that the rollover collision is the most important in terms of occupant injuries, followed by the frontal impact. Three full scale bus crash tests, one a rollover and two frontal collisions, were performed to demonstrate the causes of injuries to the occupants.

In contrast to the static test carried out in accordance with ECE 66, in the test conducted at DEKRA, the buses were overturned dynamically. The rollover test was done at a velocity of 40 km/h by running the left side wheels up a ramp until the bus tipped on its side. This test used five instrumented 50^{th} percentile Hybrid III dummies as occupants, two restrained by lap belts, three unrestrained. The lap belted dummies had significantly reduced responses when compared to the unbelted dummies. The authors suggest the use of three-point belts in the window seats to reduce the occupants interaction with the side structure and the ground.

The two frontal crash tests each had a mixture of Hybrid III dummies restrained with lap belts and unrestrained. One crash test was at 40 km/h with 70% overlap into the rear of a stationary 16 t truck and the other was at 31 km/h with 30% overlap with a rigid barrier. The decelerations recorded were significantly less than the ECE 80 requirements. The lap belted dummies had reduced loadings, except for the head accelerations in the barrier test.

Matolcsy, 1998

This paper discusses some of the inconsistencies in the current ECE 66 Regulation. The area of the regulation analysed pertains to the discrepancies induced by the test set up. These include:

- Lower energy requirements for high buses.
- Some bus cross sectional shapes reduce loading on the cantrail.
- The ability to absorb test energy in the elastic suspension of vehicle masses such as engine, transmission and suspension.

Some simple modifications are suggested to the test method to overcome many of these problems.

Vincze-Pap, 1998

The author reviews the experience at IKARUS Company, a Hungarian bus manufacturer, in the development of test specifications for coach rollover safety. The paper continues with a comparison of the four different test methods in the ECE 66 regulation accepted for type approval of buses and coaches, i.e. full-scale rollover test on a complete vehicle; rollover test on body segment or segments; pendulum test on body segment or segments; verification of superstructure strength by calculation.

The tests were conducted at AUTÓKUT in Hungary. Problems with the repeatability of the pendulum test are noted as well as differences compared to the complete rollover test. In terms of calculation, it is concluded that a calculation method using simple bending tests and a Hungarian program similar to CRASH-D is the most efficient approach, better than full FEA. Several uncertainties in the type approval tests need to be addressed to ensure reliability and reproducibility of the test method.

Vincze-Pap and Tatai, 1998

In tests conducted at AUTÓKUT, Hungary, correlation between ECE Regulation 80 and ECE Regulation 14 was found to be poor. Some bus passenger seats which had type-approval to ECE Regulation 80 failed ECE Regulation 14. The authors conclude that the regulations should be integrated. A simulation procedure based on PAM-CRASH is suggested as an alternative and inexpensive test method.

de Coo et al., 2001

This paper describes the development of a procedure to assess frontal crashworthiness of coaches. The authors report that in the Netherlands, frontal collisions are the most severe for the bus driver and passengers and that collision speed is usually below 50 km/h. They specified a test approximating a coach impacting the rear of a truck trailer. In a full scale crash test, the truck driver and courier survival space was reduced. Through numerical simulation and testing, the authors showed the potential for increased passive safety for the driver and courier by impact energy dissipation through dedicated and existing structures.

Elias et al., 2001

This paper describes ongoing work by NHTSA to evaluate the potential of safety restraints on large school buses. Two full scale tests were conducted. The first crash test was a frontal impact of a school bus into a rigid barrier at 48.3 km/h (30 mph). A range of Hybrid III dummies were used, including 50th percentile adult male, 5th percentile adult female and 6-year old dummies. In the second crash test, a 11,406 kg cab-over truck was impacted into the side of a stationary school bus at 72.4 km/h (45 mph). Hybrid III dummies were again used including two SID/Hybrid III dummies and a Hybrid II dummy.

Three different restraint strategies were evaluated:

- compartmentalisation;
- lap belts only on reinforced seats;
- lap/torso belts on modified seats.

Loading by unrestrained occupants was also evaluated. All three safety strategies tested provided some level of protection. The compartmentalised seating tests show similar head injury criteria (HIC) response level as the lap belt test. Higher HIC values were recorded for the unrestrained adult dummies when they overrode the seat back and struck the dummy seated in front of them. The high seat back design used with the lap/torso belt systems limited this possibility. Lowest HIC and neck injury (Nij) values were recorded for lap/torso restrained dummies, including the 6-year old and the 5th percentile female dummy. Further work was recommended to evaluate the effects of seat spacing and seat back design in frontal impacts as well as side impact research to evaluate side wall padding and/or redesign of school bus side structures.

Lawrence, 2001

A study of two databases in the United Kingdom was undertaken to determine impact severity associated with serious and fatal injuries. The efficacy of seat belts in the real-world

collisions was examined and compared with sled tests approximating the worst case scenario. The most common type of injury-producing minibus collision involved impacts with other vehicles (75% of all collisions). The probability of fatal or serious injuries was higher if rollover occurred. The author concludes that a test speed of approximately 48 km/h would cover at least 50% of all collisions resulting in fatal or serious minibus occupant injuries. The ECE Regulation 44 crash pulse corridor was used for the sled tests. Factory-made and modified minibuses, fitted with seat belts, were tested. The seats and seat to vehicle attachments failed in most of the standard vehicles. The improved seat/vehicle system was effective in restraining the dummies. Consideration is given to the ECE Regulation 14, seat belt anchorage requirement for M1 vehicles compared to M2 and M3 vehicles (minibuses) as well as the Australian ADR 68.

McCray and Barsan-Anelli, 2001
This paper describes crash simulation conducted by NHTSA to examine compartmentalisation, lap belts, and lap/torso belts. MADYMO was used to simulate occupant kinematics and the results compared with that observed in sled tests. Some limitations of MADYMO are noted. In the sled tests, compartmentalisation worked best for the 6-year old and the 5th percentile female dummies. The dummies tended to override the standard height seat back.

Mitsuishi et al, 2001
In Japan, bus safety efforts have largely focused on passenger protection in frontal collisions. Protective measures recommended for bus drivers and guides are the installation and use of seat belts and the maintenance of the survival space. The authors report that the majority of severely injured drivers sustain their injures due to reduced occupant space and that more than 50% of severely injured bus guides were not seated. The authors report on a sled impact test series simulating frontal impact tests. The tests show the limitations of lap belts in preventing head impacts and the potential of reducing passenger injuries by optimising seat spacing.

6.4 Glazing

NHTSA, 1995
In 1993, NHTSA initiated research into the ejection mitigation potential of improved side window glazing. It is estimated that side window retentive glazing composed of glass and plastic could save up to 1300 lives and prevent a similar number of serious injuries per year in passenger cars. Computer simulation and component testing show that HIC (head injury criteria) values increase with the use of some alternative glazing compared to standard tempered glass.

Clark et al., 2000
This paper describes the different types of glazing and associated ejections as well as risk of laceration. In Europe, laminated side and rear window glazing is being used by some

models of Audi, BMW and Volvo cars. The benefits include ejection reduction. It takes more than three times the kinetic energy of a blunt object to penetrate through a typical laminated glazing than to shatter and penetrate through tempered glass. In previous work, Clark demonstrated the ejection potential of a prototype glass-plastic laminate by impacting it with an 18 kg headform at 33 km/h. The author estimates that the "T-edge" two-ply glass plastic glazing would retain all pre-teen children and almost half of the adults currently ejected. The authors recommend changes to the current Federal glazing standards to measure ejection capability. It is also noted that side airbags can reduce side window ejection.

Willke et al., 1999, 2001
These reports describe NHTSA's study of advanced glazing to reduce occupant ejection. Four types of advanced glazing were evaluated:

- high penetration resistant (HPR) trilaminates similar to windshields in which a plastic film is laminated between two glass layers;
- non HPR trilaminates;
- bilaminates – consisting of glass-plastic laminated construction; and
- polycarbonates.

The prototype window systems included modifications to the front door window frames to provide improved occupant retention. Three types of impact tests were performed. An 18 kg impactor to determine retentive capabilities of the glazing, existing FMVSS 201 free motion headform to evaluate head injury potential and sled tests with a full size dummy to devaluate head and check injury potential.

All but the non-HPR demonstrated good potential for occupant retention. The testing indicated low head injury potential during impacts with both the advanced and tempered glazing. Impacts into advanced glazing resulted in higher neck shear loads and neck moments than impacts into tempered glass. Although the measurements were not repeatable and showed wide variability, NHTSA's concern about the possible increased neck injury risk resulted in focus to other ejection mitigation systems, notably side airbag curtains. The modified frames, used in this study, are not usable in vehicles with frameless side windows.

6.5 Emergency Exits

Rompe and Krüger, 1985
In their paper on improvements for bus safety, the authors consider emergency exits. They note that although emergency exits may be blocked after a collision, there are generally sufficient alternative evacuation possibilities when the bus is upright. In evacuation tests, they found that the doors, especially the rear doors, were the preferred alternative escape routes. The difficulty of operating the emergency exits without prior instructions was noted. The authors conclude there is a need for an effectiveness requirement of bus emergency exit systems based on evacuation time.

Shiosaka and Kuboike, 1996

Evacuation tests using adults and school children as subjects were conducted to investigate the performance of current bus emergency exits in Japan. Improved emergency exit displays were also tested. None of the school children and only half of the so-called "aged persons" could evacuate from the current bus emergency exit. They either did not understand the opening procedure or considered evacuation dangerous from the height of the emergency exit. The improved display increased evaluation success.

6.6 Highlights

- Rollover was the crash mode which caused most of the fatal and serious injury to bus occupants. Frontal impact was the next most frequent mode of serious bus collision.
- The fixes proposed in this set of papers consisted of improving the bus structure to ensure that no infringement of the occupant space occurred.
- These papers present various type approval methods in the ECE 66 Regulation that have been used.
- The method generally favoured appears to be to use the Cranfield CRASH-D program or similar, linked with simple testing of the bus structural components.
- Such models are in agreement with full scale testing of a bus.
- Some deficiencies in the ECE 66 Regulation need to addressed to improve the reproducibility and repeatability of the type approval methods.
- The preferred method for controlling the rates of occupant ejection was to improve seat anchorages (ECE 80) and fit lap/torso belt systems (ADR 66).
- The fitting of lap belts was regarded as problematical and requiring significant improvement in the energy absorption capability of bus interiors.
- Feasible and cost effective seat systems are now available which allow the fitting of lap/torso belts for bus occupants.
- Both full scale and sled tests using instrumented dummies, as well as modelling, have shown that the fitting of lap/torso seat belt systems was highly effective in reducing likely injury to bus occupants.
- Some concerns were expressed about the problem of the shoulder rotating out of the lap/torso belt in a bus side impactor rollover crash and that this may lead to belt slack and allow the occupant to be ejected. Whether or not ejection as a result of loss of upper torso is a feature in real bus collisions is not known, however field data for car crashes indicate otherwise. The position of seat belts on the seat may be a partial solution to the problem observed in tests of the shoulder rotating out of the torso belt.

7. CANADA

7.1 Canadian Bus Industry

The Canadian bus manufacturing industry offers four distinct products serving different markets: intercity buses (motorcoaches); urban transit buses; small and mid-size buses; and school buses. Canadian manufacturers dominate the North American market. Almost all of Canada's intercity buses are provided by Canadian bus producers. Canadian bus production exceeds domestic needs so the industry is export-oriented, mainly to the United States.

Intercity buses consist of an integral body and chassis. The body panels and roof as well as the drive train and axles are then attached. There are two manufacturers of intercity buses in Canada, Prévost Car Incorporated and Motor Coach Industries (MCI). Prévost has only one manufacturing location, which is in Ste-Claire, Quebec where it designs and builds its buses. It has the capacity to build 600 coaches annually. At present MCI has two manufacturing locations in Canada, Winnipeg and Manitoba, and one location in the United States in Pembina, North Dakota. MCI engineers all of its products in Canada but builds only the bus shell in Canada. These are shipped to MCI in Pembina, North Dakota for final assembly and trim. At capacity, the Winnipeg plant can produce over 1,000 shells annually. The capacity of the Manitoba facility is not known. The manufacturing plants are generally low volume assembly operations which are not highly automated.

Industry Canada reports that combined intercity bus production in Canada is around 1,700 units per year which represents approximately 70-80% of all North American sales (Industry Canada, 2002).

7.2 Regulatory Requirements

Every new bus built in or imported to Canada must comply with the applicable Canada Motor Vehicle Safety Standards (CMVSS), see Table 12. There are 18 standards that apply to bus occupant protection, three of which apply specifically to school buses (CMVSS 220, 221 and 222). Of the remaining 15 standards, only seven apply to buses with a GVWR more than 4,536 kg (10,000 lb). In most cases the requirements do not apply to all seating locations. The scope of these standards and their applicability to the different types of buses is given in Appendix E. They are not mandatory for older buses or buses travelling in Canada from elsewhere.

In addition, each province and territory has its own regulations some of which may affect bus occupant safety. Although this study is confined to federal requirements, it is noteworthy that the bus requirements in each province and territory are not always the same. The types and classification of buses so covered vary and the regulations do not necessarily include all buses travelling on provincial roads. There are also other differences in provincial regulations which may affect bus occupant safety, for example emergency exit requirements

Table 12: Canada Motor Vehicle Safety Standards Applicable to Bus Occupant Protection

CMVSS	Title	Buses with GVWR of 4,536 kg (10,000 lb) or less	Other buses
201	Occupant Protection	yes	no
202	Head Restraints	yes	no
203	Driver Impact Protection	yes	no
204	Steering Column Rearward Displacement	yes	no
205	Glazing Materials	yes	no
207	Anchorage of Seats	yes, driver seat only	yes, driver seat only
208	Occupant Restraint Systems in Frontal Impact	applies to forward-facing rear outboard designated seating positions, except for school buses	yes, driver seat only
209	Seat Belt Assemblies	applies to every seat belt assembly with which a vehicle is equipped[1]	
210	Seat Belt Assembly Anchorages	applies to every designated seating position fitted with a seat belt assembly[1]	
212	Windshield Mounting	yes	no
213.4	Built-in Child Restraint Systems and Built-in Booster Cushions	applies to every built-in child restraint system and built-in booster cushion	
214	Side Door Strength	yes	no
216	Roof Intrusion Protection	applies to buses with GVWR of less than 2,722 kg (6,000 lb), except school buses	no
217	Bus Window Retention, Release and Emergency Exits	yes	yes
219	Windshield Zone Intrusion	yes	no
220	Rollover Protection	school buses only	
221	School Bus Body Joint Strength	school buses only	
222	School Bus Passenger Seating and Crash Protection	school buses only	

[1] Seat belt anchorages need not be installed for a passenger seat in a bus.

which may require the after-market installation of additional emergency exits (see Appendix B).

There is no constraint against the use of safety systems which are not regulated and at any time, manufacturers and fleet operators may voluntarily adopt them. For example, seats with integrated seat belts and integrated child seats are installed in some Corbeil school buses and lap or lap/torso seat belts in some Girardin school buses (as required by the customer) and all school buses operated by Laidlaw Transit, Inc. have installed crossing control arms.

In addition to federal and provincial regulations, other standards organisations can produce a standard. The standard may or may not be referenced in regulations. At present the main standard published by a standards organisation applicable to buses is CSA D250, School Buses (Canadian Standards Association, 2000). Although it is not referenced federally, Transport Canada is represented on the CSA technical committee for this standard. CSA D250 is referenced in some provincial regulations. Three other CSA standards (two in preparation) are pertinent to bus transportation of people with special needs.

7.3 Bus Safety Review

Bus safety is an ongoing responsibility of Transport Canada. The Road Safety and Motor Vehicle Regulation Directorate of Transport Canada administers new vehicle construction under the Motor Vehicle Safety Act. The Canada Motor Vehicle Safety Standards (CMVSS) of the Motor Vehicle Safety Act is the primary instrument for bus occupant safety. They may be supplemented by provincial and territorial regulations. Transport Canada also contributes to motor carrier operational safety standards under the Motor Vehicle Transport Act and the National Safety Code for Motor Carriers.

The first bus safety issue dealt with by Transport Canada related to the safe transportation of children to and from school. School buses are the most numerous type of bus. A number of safety standards introduced in 1982 resulted in occupant protection by so-called “compartmentalisation”. The seats are spaced and seat backs are sized to reduce the opportunity for the occupants to contact rigid surfaces in a collision. A barrier is provided in the front row of seats. The seat backs and barrier are required to be energy absorbing. A head impact protection standard defines a head impact area that precludes, for example, overhead luggage racks. School bus window frames must withstand an outward force to help prevent ejection (CMVSS 217). In addition, all Canadian school buses have opening windows with mid-height aluminium bars that also help prevent ejection.

Unlike every other type of passenger motor vehicle, buses are not required to have seat belts. Their introduction has not been favoured for a number of reasons including the relatively low additional safety benefit, the fact that their effectiveness depends on their proper use and concern from past testing that seat belts may introduce new hazards.

In a 1984 test program to evaluate lap belts in school buses it was concluded that "the use of lap seat belts in any of the three sizes of recent model school bus which were tested may result in more severe head and neck injuries for a belted occupant than an unbelted one in a severe frontal collision" (Farr, 1985). In 1986, sled tests were conducted to determine whether or not the potentially adverse side effects of lap belts could be prevented. It was found that lap/torso seat belts or rearward facing seats were effective.

In 1989, a review of 58 school bus collisions that occurred from 1977 to 1988 was undertaken (Burtch et al., 1989). Nine of the school buses were manufactured after the safety standards resulting in passive safety compartments. While the school buses performed relatively well to protect occupants, disembarking children were sometimes at risk.

In a review of 42 severe school bus collisions which occurred from 1989-1997, it was found that passive safety compartments or "compartmentalisation" provides good occupant protection in most cases but the integrity of the compartment must be maintained (Gardner and Ste Marie, 1999). In one case a child was ejected through the rear emergency exit. The safety record for other types of buses is also good.

In Canada, over 25,000 yellow school buses provide one of the nation's safest forms of transportation. In the ten-year period from 1989-1998, there were eight passenger fatalities. There were 3,284 injuries, most of which were minor and this includes children taken to hospital for observation, a routine procedure following a school bus collision. Even so, efforts to improve school bus safety continue.

As part of its ongoing bus safety program, in 1999-2000 Transport Canada held regional consultations on school bus and motorcoach safety in six provinces across Canada (Transport Canada, 2001).

The main outcomes relating to bus occupant safety were:

- seat belts are not a priority issue;
- need to develop a national seating capacity standard to prevent overloading;
- revisit definition of a school bus so alternative means of transportation can be regulated;
- revisit definition of a motor coach to consider other types of vehicles, e.g. shuttle buses.

7.4 Injury Causation

The types and source of injuries sustained by bus occupants in Canada is best determined by a review of collisions which have been investigated in detail. The collisions which have been investigated in depth are usually those which have resulted in fatal and serious injuries. As such, the sample is biased, however it remains a good source of information on injury causation. The cases selected are of special interest to occupant retention.

The location of the occupant is given according to the categories used by the investigation teams. A four digit seating position code is assigned to each occupant to identify the row (1st and 2nd digits), the location in that row (3rd digit) and any unusual seating situations (4th digit). The 4th digit is normally "0". Only MAIS 2 and greater injures are included in the summaries below. Unless otherwise stated the occupants are adults.

Case 1

Bus Type: 1982 intercity bus (capacity 47 passengers)

Description: The bus was approaching a right bend at a speed which the investigator's report described as "too fast". The bus left the road, caught the crash barrier alongside the road and fell down a ravine about 12 metres deep. The front of the bus first contacted the ground and then the rest of the bus rolled onto its left side. There was a small fire at the back of the bus which was quickly extinguished by the first person at the scene.

Occupant Injuries: The unrestrained driver and 43 passengers sustained fatal injuries. The other four passengers were seriously injured.

Comments: The driver was pinned in the bus and sustained fatal chest injuries from the steering wheel. Of the 43 passenger fatalities, 42 died on impact, one died a few weeks later. All fatalities sustained multiple injuries. The main cause of the injuries was the major damage to the bus when it struck the ground after falling down the ravine. The front of the bus collapsed up to the front axle and there was major deformation at the front left corner. The driver's space and first three rows were compressed rearwards. The seats in rows 5 and back were deformed, however most remained anchored to the floor. The seat backs had been loaded by the occupants. The main contributory factor to the collision was the poor mechanical state of the brakes. The air brake system was only at 30% efficiency and the regular brakes were of no use and when the driver attempted to downshift, the transmission went into neutral. In the coroner's report there were 23 recommendations all of which related to collision prevention including road, vehicle and driver factors. There were no recommendations for improved bus occupant protection during a crash.

Figure 1: Case 1 - Left Rear View of Bus Showing Major Deformation

Case 2

Bus Type: 1994 intercity bus (capacity 47 passengers)

Description: The bus was travelling in Canada from the United States. The bus slid on an icy road and the driver lost control. The bus went onto the shoulder, struck a lamp post on the right front side and then rolled into a ditch on its right side. The estimated speed of the bus when it rolled after the lamp post impact was 30 km/h.

Occupant Injuries: Two passengers (positions unknown), MAIS 2
The unbelted driver and the remaining 17 passengers sustained minor or no injuries.

Comments: All occupants came out by their own means although the location of their exit is not known. The front windshield came out of its frame which provided a potential ejection portal. Intrusion in the right front of the bus extended into the front stepwell. During the rollover, the front right corner deformed inwards and the right side of the roof deformed laterally to the left and downwards. The entry door was partly pulled out. All luggage supports on both sides of the bus were cracked and many broken. One of the side laminated windows came out of its frame. This is contrary to the primary purpose of the laminated windows which is to prevent ejection. The investigators noted that adding structural reinforcements would prevent excessive intrusion in a rollover and also reduce deformation resulting in window loss. It is also noted in the collision investigation report that the use of stronger materials for the luggage supports would reduce the risk of them falling onto the passengers.

Case 3

Bus Type: 1996 school bus (capacity 72 passengers)

Description: The bus was impacted on the left front side by a pick-up truck. The bus rotated and went down an embankment onto a field. The bus then rolled two revolutions before coming to rest on its left side.

Occupant Injuries: 0110, lap/torso, MAIS 2
0710, 0940, 1030, 1140, 1210, MAIS 2
1060, fatal closed head injuries

Comments: The passengers were aged 9-14 years and not restrained by seat belts. No-one was ejected. The majority of injuries were sustained when the occupants moved towards the left side of the rolling bus and impacted other occupants and the bus interior. The fatal head injury likely occurred when the occupant's head made contact with the left side interior above the side windows, when the left side of the bus contacted the ground. During the rollover, minimal roof intrusion occurred as a result of impact with a rock pile and fence posts. The laminated windshield and the large window in the rear emergency door came out during the rollover, a possible ejection portal. Two cross braces failed to remain attached to the one side of the window which could have allowed ejection.

Case 4

Bus Type: 1996 intercity bus (capacity 48-passengers)

Description: The right side of the bus was impacted by a tandem tractor unit. The impact tore the front of the bus away.

Occupant Injuries: 0110, lap, fatal
0210, 0310, 0340, 0430, all fatal
0810, MAIS 5
0240, MAIS 4
0230, 0910 and two passengers in unknown seating positions, MAIS 3
0320 (child), 0330 (child), 0420, MAIS 2

Comments: The massive intrusion of the tractor resulted in fatal injuries to the bus driver and the driver of the tractor unit. The structure behind the driver was, however, left reasonably intact.

Most of the fatal and severe injuries were sustained by passengers near the front of the bus. All four fatally injured passengers were ejected. The first six rows of passenger seats on the bus came out as a unit and some seat rows partially detached from the floor and side track. It appears that the seats remaining on the bus restrained the occupants and without significant injury. The investigators conclude that if the front seats had remained secured inside the bus, the occupants would likely have been less severely injured.

Consideration of a standard such as ECE 80 or ADR 68 which address seat securement and occupant loading is recommended.

Figure 2: Case 4 - Example of Seat Detachment

Case 5

Bus Type: 1996 intercity bus

Description: The front right corner of the bus collided with the rear of a truck (heavy vehicle) when the truck suddenly braked.

Occupant Injuries: 0110 lap/torso, MAIS unknown
Three passengers (positions unknown), MAIS 2

Comments: The collision was described as low severity. The maximum intrusion at the front right of the bus almost reached the front row of seats. The relatively minor injuries sustained by the occupants were mainly sustained on impact with the seat back in front. The seats provided reasonable protection and "restraint" in this low severity collision. The unpadded panel separating 0230 and 0240 and the steps were broken and buckled. The bottom structure of 1030 and 1040 were broken and showed repair marks. The laminated windshield separated at the top and side which could have resulted in ejection. The damage to the panel and seats as well as the separated windshield could have resulted in injuries and ejection in a more severe collision. Although none of the luggage compartments were broken, an overhead TV unit was found on seat 0230, highlighting the need to secure add-ons.

Case 6

Bus Type: 1997 intercity bus (capacity 56 passengers)

Description: The bus was starting to overtake a tractor-trailer when it appears the tractor-trailer may have changed gears. The front right of the bus

collided with the rear left corner of the trailer. The trailer penetrated the front right corner into the first row of seats on the right side of the bus. The bus then left the highway and stopped in a ditch.

Occupant Injuries: 0110 not restrained, MAIS 2
0240 not restrained, "apparently" ejected, fatal
One passenger (position unknown), MAIS 3
Two passengers (positions unknown), MAIS 2

Comments: There were a total of nine occupants in the bus, four of whom sustained only minor injuries. The unrestrained bus driver sustained a rib fracture from impact with the steering wheel and a facial laceration from a side window. The driver's seat cushion separated from the seat when the bus went into the ditch. The unrestrained front seat passenger sustained fatal head injuries when he impacted the unpadded separating panel. The padded seat backs appear to have worked well for all other occupants. As noted by the investigators, in place of the unpadded front separating panel, it would be safer to have a false seat back in the first row, as used in school buses. They also report that a more rigid and solid structure would have prevented such a major intrusion. Reinforcement would limit potential intrusion and avoid deformation of the window frame.

Case 7

Bus Type: 1997 intercity bus

Descriptions: The left front two-thirds of the bus collided with the back of a tractor trailer. The bus rolled backwards, entered a ditch and then rolled down a section of fencing.

Occupant Injuries: 0110, lap/torso, MAIS 3

Comments: The driver was trapped in the collision and sustained multiple leg fractures from the intruding instrument panel. The passengers of the bus were not injured. Bumper incompatibility and an inadequate rear under-ride guard on the trailer resulted in the front end bus intrusion.

Case 8

Bus Type: 1997 bus (capacity 58 passengers)

Description: The bus was travelling about 90 km/h on a two-lane road when the driver lost control of the bus on a corner. The rear wheels of the bus went into a ditch and the bus rolled onto its left side. The bus continued to roll until it struck a hydro pole with the rear left corner.

Occupant Injuries: 0110 unrestrained, MAIS 3
0240 (ejected), 0640, both fatal
0230 (ejected), MAIS 5
0340, 0740, 0840 (ejected), MAIS 4

0410, 0630, 0720 (ejected), 1440, MAIS 3
0330, 0510, MAIS 2

Comments: Four passengers were ejected from the bus, one of whom sustained fatal injuries. In all cases, their primary injuries were sustained when they struck the ground after ejection. They were ejected through the front windshield and the side windows. The front windshield and side windows were laminated, and met applicable standards however during the rollover they separated from the frame and allowed ejection of four passengers. It was observed that many of the seat backs were deformed forward due to rear loading. The energy absorption of the seat back reduced the severity of the passengers injuries and also retained many in place. The absence of a seat back in front of the first row of seats contributed to the ejection of two passengers sitting in the front right side. The overhead luggage compartments broke during the rollover and fell onto the heads of the passengers sitting underneath resulting in soft tissue injuries. The armrests partially retained the lateral movement of the passengers, however the investigation report noted that the pivots of the armrests were very rigid and could have caused hip and abdominal injuries. The upper part of the bus was deformed to the right and a section of the rear roof was broken where it impacted the ditch. The rear left corner was deformed inwards due to impact with the hydro pole. The non-ejected occupants sustained their injuries as a result of contacts with the interior of the bus including the side structures, roof, other occupants and seat back loading.

Figure 3: Case 8 - Interior of Bus

Case 9

Bus Type: 1998 intercity bus

Description: The bus collided with the rear of a tow truck which was carrying a damaged vehicle on a flatbed. The tow truck had slowed prior to the collision. The bus skidded safely to a stop.

Occupant Injuries: The driver and 47 passengers sustained no or minor injuries.

Comments: The police report indicated the driver was lap belted but no loading evidence was found. Approximately 50% of the passenger seat backs were deformed forward due to rear loading by occupants. Bus intrusion was confined to the front entrance stairwell. The ΔV for the bus was estimated to be 18 km/h. The impact was of low severity for the bus and occupants due to the large mass of the bus compared to the tow truck.

Case 10

Bus Type: 2000 intercity bus (capacity 57 passengers)

Description: The bus had entered a loop ramp after travelling too fast, the vehicle yawed and went off the road down an embankment. The bus overturned onto its left side. The rearmost window on the left side of the bus was separated from the bus during the collision. There were 49 occupants in the bus. 42 of the passengers were middle school students.

Occupant Injuries: 1510 (ejected), 1611, 1612, and 1623 were partially ejected, all fatal
0810, 1230, 9991, 9992, MAIS 2

Comments: The driver sustained only minor injuries (MAIS 1); it was not known if the driver was using the seat belt. Occupant 1510 was completely ejected through the opening created by the failure of the rear left side emergency window. He sustained fatal head injuries. The source of his injuries are not given in the investigation report. He was reportedly kneeling on the seat facing rearwards at the time of the collision. Occupant 1611 was seated with occupant 1612 on his lap at the time of the collision. They were both partially ejected from the bus through the rear left side window. Occupant 1623 was also partially ejected through the opening created by the failure of the rear left side window. Occupant 1611 sustained fatal head and cervical injuries. Occupant 1612 sustained fatal head injuries. Occupant 1623 sustained fatal chest injuries. These three occupants were reportedly pinned by their upper body between the left side of the overturned bus and the ground. Occupant 9992 was reportedly in the bathroom at the time of the collision and he was ejected across the occupant compartment and came to rest with his left arm pinned between the left exterior of the bus and the ground.

He sustained a fractured left humerus. It appears that neither the driver nor any other passengers were ejected.

Emergency window: The bus was equipped with ten push-out style emergency exit windows, five on each side of the bus. The emergency windows are double-glazed and mounted in metal frames hinged at the top. The lower edge of each emergency window is equipped with a latch mechanism secured by three retaining clips. The rear left side emergency window was found on the ground just rear of the overturned bus. It appears that the emergency window was open when the left side of the bus overturned. There was evidence that the window was not completely latched when it was forced outboard as a result of occupant loading. It was possible that the emergency window had been opened during the trip. It was observed that re-latching an open emergency window could be difficult without instruction. It was also observed that flexion of the bus during the collision could have flexed the window opening allowing separation of the retaining clips. It was concluded that probably none of the rear seated passengers would have sustained serious or fatal injuries if the rear emergency window had stayed in place. The investigation report recommended a review of CMVSS 217 - Bus Window Retention, Release and Emergency Exits.

7.5 Advanced Technology Bus Study

The advanced technology bus study of the Transportation Development Centre (TDC) is focused on bus design changes and product advancement including such issues as low floor buses and accessibility features (Transport Canada, 2002). Croker et al., 2000, describe the results of Phase 1 of the study on the development of design concepts for lighter intercity buses. The weight of intercity buses increased by 20% from 1974 to the mid-1990's. In 1988, a memorandum of understanding specified vehicle size and weight limits for increased uniformity in provincial regulations. The front axle capacity limit was increased in 1997, however of 200 bus observations, 18% exceeded the drive axle weight limit. During the same time, bus manufacturers were looking for ways to reduce bus weight to stay competitive and maintain a bus life of about 3.2 million km or 15 years. It was also recognised that reducing intercity bus weight would reduce pollutant emissions.

Using a finite element model, lightweight design concepts were developed for the major structural components of the bus (roof, floor and side truss). Depending on the method employed, it was estimated that an overall reduction in bus weight of approximately 9 or 20% was possible. The most promising design concepts were selected for prototype manufacturing and testing.

Phase 2 is being undertaken by TDC with Prévost and other partners to design selected prototypes and test lightweight structural concepts for the roof and floor of an intercity bus and to develop a new lightweight seat. Consideration will also be given to the development of an integrated three-point belt. The project is due to be completed by the end of 2002.

7.6 The Future

Transport Canada is reviewing the safety of small children on school buses and will make recommendations regarding limitations on the size or age of children who may be provided protection by the passive compartment. Preliminary indications are that children above the age of four years are well protected but children below that age may require infant or child restraints which meet the requirements for passenger cars (Gardner, 2002). Transport Canada is also reviewing the use of seat belts on school buses and is following research and development by manufacturers of school bus seats to market a new type of seat. These seats will retain the benefits of the passive compartment while being equipped with three-point seat belts.

8. UNITED STATES

8.1 Regulatory Authority

In the United States, the National Highway Traffic Safety Administration (NHTSA) is responsible for establishing federal motor vehicle safety standards including occupant protection requirements.

8.2 School Bus Safety

As a result of the passage of the National Traffic and Motor Vehicle Safety Act of 1966 and the School Bus Safety Amendments of 1974, NHTSA currently has 35 Federal Motor Vehicle Safety Standards (FMVSS) that apply to school buses. The 1974 amendments directed NHTSA to establish or upgrade school bus safety standards in eight areas: emergency exits, interior occupant protection, floor strength, seating systems, crashworthiness of the body and frame, vehicle operating systems, windshields and windows, and fuel systems. During the rulemaking process in the early 1970's, when the school bus safety standards were being established, NHTSA looked carefully at available injury and fatality data, existing research, and public comments submitted to the agency to determine what system of occupant protection should be required in school buses. Research conducted at the University of California, Los Angeles (UCLA) in 1967 and 1972 evaluated existing seats on school buses. That research showed great weaknesses in those seating systems. Those findings led NHTSA to issue a contract to AMF Corporation to design new, protective school bus seating systems that provided uniform levels of protection to seated occupants ranging in size from a six-year old (46 pounds and 48 inches in height) to a 50th percentile male (165 pounds and

70 inches in height). Recognising that school bus vehicles are generally heavier than their impacting partners, impart lower crash forces on their occupants, and distribute crash forces differently than do passenger cars and light trucks in crashes, it was determined that the best way to provide crash protection to children on large school buses was to use a concept called "compartmentalisation." As previously described protection is accomplished through closely spaced seats, energy-absorbing seat structure and padded high seat backs. This requirement (FMVSS 222) became effective for newly manufactured school buses on or after April 1, 1977. Compartmentalisation along with the enhanced safety standards such as joint integrity of the bus body panels and stringent fuel system integrity requirements make school buses the safest vehicles on the road.

Three Federal Motor Vehicle Safety Standards revised or introduced in 1977 apply to school buses only, namely FMVSS 220, School Bus Rollover Protection, FMVSS 221 School Bus Body Joint Strength and FMVSS 222 School Bus Passenger Seating and Crash Protection. In the United States this means the large and small yellow school buses. FMVSS (CFR 571.3) defines a "bus" as a motor vehicle designed to carry more than 10 persons and "school bus" as a bus that carries students to or from school or school-related activities. Collision data show that school buses that meet these 1977 requirements provide good occupant protection. The number of school bus passenger fatalities in the United States averages fewer than ten each year out of approximately 10 billion student trips (NTSB, 1999a). Even so, discussion continues on the potential benefit of seat belts in school buses. FMVSS 222 also requires that small school buses under 10,000 lb are equipped with a lap/torso seat belt at the driver's position and right front passenger position and with lap or lap/torso seat belts at all other designated seating positions. Only six states however, have legislation mandating the use of lap belts on school buses. At present, manufacturers only offer lap belts at passenger seating positions.

In 1985, Thomas Built Buses Inc. performed crash tests on three small school buses and found little difference in head and chest "injuries" between lap-belted and unrestrained dummies. In 1987, the NTSB examined the potential benefits of lap belts in 43 serious school bus collisions (NTSB, 1987). It was concluded that it was unlikely that lap belts would have improved the injury outcome. Intrusion resulted in 11 of the 13 fatalities and caused most of the serious injuries. NTSB further concluded that "compartmentalisation" worked well in protecting school bus occupants.

Since the 1987 NTSB study, there has been increasing debate in the United States regarding the potential for improved school bus occupant protection by the use of seat belts, especially in lateral and rollover collisions. Seat belt advocates largely argue on the potential benefit of even lap belts in a crash and the benefit of providing children with a common message regarding seat belt use. Conversely, it is argued that field data indicate passive safety system offset any potential seat belt benefit and there remains concern that lap belts may result in additional injuries in a collision.

In a recent NHTSA report to Congress on school bus safety, test data are presented which show that lap belts have little if any benefit in reducing serious and fatal injuries in severe frontal crashes (Hinch et al., 2002). In some circumstances lap belts may increase the risk of serious neck and possibly abdominal injury among young passengers. The authors note however, that in small buses, any increased risks associated with the use of lap belts are offset by preventing ejection. NHTSA concludes that the lap/torso belt system could provide some benefit on both large and small buses, although potential misuse could result in serious injuries. With 100% proper use, it is estimated that lap/torso seat belts could save one life a year. It is also noted that lap/torso belts could reduce school bus capacity by up to 17% and add $40-50 (U.S.) per seating position to each new vehicle.

NHTSA is considering requiring that buses under 10,000 lb (4,536 kg) are fitted with lap/torso belts (not just lap belts only) and that seat back height is increased from 20 to 24 inches (51 to 61 cm) to reduce the potential for passenger override during a collision. By September 1, 2002 all small school buses will be required to have a universal child seat attachment system (ISOFIX anchorages) in two seating positions.

8.3 Occupant Protection in Motorcoaches

In a NTSB report on bus crashworthiness issues, it is noted that the occupant protection concerns for motorcoaches are somewhat different than those for school buses (NTSB, 1999). Because motorcoaches are larger in mass and have a lower centre of gravity than school buses they often respond differently during collisions. Motorcoaches are equipped with large panoramic windows and unlike school buses, fatal injuries in motorcoach collisions are often due to occupant ejections. There is no federal regulation requiring motorcoaches to be equipped with active or passive passenger protection systems. In a 1999 report on bus crashworthiness issues, NTSB observe that injuries and fatalities may be significantly reduced by retaining bus passengers in their seats during motorcoach collisions. They further conclude that side window retentive glazing may decrease the number of ejections of unrestrained passengers and decrease the risk of serious injuries to restrained passengers.

9. AUSTRALIA

9.1 Australian Bus Fleet

The Australian Bus and Coach Association (ABCA) represents the interests of the private bus and coach operators. The Bus Industry Confederation (BIC) similarly represents the interests of the businesses involved in the industry. Its membership includes public and private bus operators, chassis suppliers and manufacturers and associated service suppliers. The ABCA fleet totals 16,941 of which there are three main types of buses: route buses; school buses; and coaches for charters, tour and long distance services. Approximately 16% of the fleet are coaches. Seating capacity ranges from about 10 to 75 seats per bus,

however most buses have a passenger seating capacity of approximately 53. Each year, private buses and coaches travel over 640 million kilometres and carry over 800 million passengers. The average age of the entire private bus fleet is 10 years.

Investigation of the Australian bus fleet in regards intercity buses has been hampered by the existing definitions of buses which are based on vehicle weight not by usage, see Appendix A. The consolidated statistics covering such features as the age of the fleet, the kilometres travelled and the relative safety record are not available for the different bus types.

9.2 Bus Manufacturers, Suppliers and Manufacturing Processes

In Australia there is a very diverse bus manufacturing industry with 20 companies supplying or manufacturing buses. In 1998, 848 new buses and coaches were manufactured and supplied in Australia. At that time, the primary manufacturers were Mercedes (31%), Volvo (25%) and Leyland (20%).

The chassis are mainly imported as rolling chassis, the major manufacturers for new buses are European:

- Mercedes with 38% market share, who mainly supply route buses to the larger cities;
- Scania with 19%, mainly route buses;
- Volvo with 17%, mainly coaches; and,
- MAN with 9%, mainly route buses.

The coach builders fit bodies to these imported chassis. The manufacturing technique used for the bus and coach bodies is conventional ring frames on a longitudinal chassis. This type of structure made the implementation of ADR 59 relatively easy as the simple mathematical models were easily adapted. The main constructors of the bus bodies are the following companies:

- APG with 36% market share;
- Custom Coaches with 22%;
- Volgren with 12%; and,
- AB Denning with 6%.

Several specialist seat manufacturers supply the bus manufacturers. The main supplier of seats for use in motor coaches is StyleRide. They make a variety of seat units for use in the different types of buses and coaches. All the seat models are made to comply with the requirements of the appropriate regulations, including Australian Design Rule (ADR) 68, Occupant Protection in Buses. A typical ADR 68 compliant StyleRide coach seat fitted with lap/torso belt systems is shown in Figure 4. The seat system has a single inner leg and is bolted to the bus structure on the outer side. The main supplier of the belt restraint systems fitted to the seats is Autoliv Australia P/L. The belts are now universally lap/torso.

Figure 4: ADR 68 Compliant StyleRide Bus Seat

9.3 Collision Statistics

The most recent source of Australian bus collision data, Australian Transport Safety Bureau (ATSB) show that bus occupants account for a very small portion of reported road fatalities and injuries in Australia (ATSB, 2001). The data are compiled by the ATSB from two separate sources, the coroners records (for the fatalities) and from police and hospital records from the individual states (for the hospitalisations). From 1990 to 1998, there were 17,840 road fatalities, 103 (0.6%) of whom were bus occupant fatalities. Bus occupants also accounted for 988 (0.6%) of the 178,567 road hospitalisations. In the years between 1990 and 1997 there was a significant downward trend in both fatalities and hospitalisations. In 1997, bus travel in Australia was observed to be the safest mode of road transport. There were 0.06 fatalities per 100 million passenger kilometres travelled by bus compared to 0.49 fatalities per 100 million passenger kilometres travelled for passenger cars. The majority of fatal bus collisions (including pedestrians) involved urban buses travelling short distances (58.7%). Approximately 20% of all fatal bus collisions involved coaches (includes long distance, single and double decker buses).

There is limited information on the type of bus, the collision type or the cause of the injuries. In comparison to North American data there appear to be too few collisions categorised as rollovers and ejections are not coded at all. This is due to the lack of detail in the coded data, not the analysis used in the report.

9.4 Regulatory Requirements

All motor vehicles sold in Australia must comply with the Australian Design Rules (ADRs). The ADRs set out design standards for vehicle safety and emissions. They have been developed through a consultative process involving government, industry, employee and

consumer representatives. The ADRs use United Nations vehicle categories and are harmonised to a considerable extent with international standards. A summary of the ADRs that apply to buses is given in Appendix E.

The ADRs are administered by the Department of Transport and Regional Services (DOTRS) Canberra. At this time the policy of the DOTRS is to align with the ECE standards wherever there is no lowering of safety requirements (Seyers, 2002). The DOTRS is currently conduction a review of the current ADRs that will be finished within twelve months.

The regulation and policing of in-service road vehicles is the responsibility of the individual state authorities:

- NSW Roads and Traffic Authority;
- Queensland Transport;
- Transport SA;
- Transport WA;
- Department of Urban Services, ACT;
- Northern Territory Department of Transport and Works;
- Tasmanian Department of Infrastructure, Energy & Resources;
- VicRoads.

The National Road Transport Commission (NRTC) acts as a co-ordinating body for all road transport issues. It was established to ensure that there is a consensus approach taken by the various state authorities and the Federal government on all issues regarding the use of the Australian road system for transport.

9.5 Australian Testing

There are two test agencies in Australia involved in testing related to occupant protection in buses: Crashlab and Autoliv.

Crashlab is operated by the NSW Roads and Traffic Authority. It is the main Australian certification agency for testing the compliance of seat belts and bus seats to the ADRs.

The capabilities of Crashlab for buses include the testing of:

- seats and seat anchorages, seat belts, anchorages for seat belts and child restraints (ADR 3, 4 and 5);
- static testing of bus seat systems (ADR 66);
- sled testing of bus seat systems (ADR 66 and 68); and,
- crash barrier testing (ADR 69).

Autoliv is operated as a general access test facility by Autoliv Australia who is the major manufacturer of restraint systems in Australia.

The capabilities of the Autoliv Laboratory for buses include the testing of:

- seats and seat anchorages, seat belts, anchorages for seat belts and child restraints (ADR 3, 4 and 5);
- sled testing of bus seat systems (ADR 66 and 68); and,
- crash barrier testing (ADR 69).

The testing of the bus structures is confined to pendulum tests of the components of the bus structure to validate the mathematical models allowed in ADR 59. This work is carried out in several university based laboratories including Monash University, Melbourne and the University of Technology, Sydney.

9.6 Actions Taken in Australia

9.6.1 Background

In 1973, Joubert reviewed safety in motor vehicle design in Australia. In his report, he commented on the weaknesses of seat designs fitted in buses at that time. Two of the specific weaknesses that he singled out were the poor design of the seat attachment points and the benefits of higher backrest. The House of Representatives Standing Committee on Road Safety considered Joubert's findings and in their report of 1977 concluded that while bus seats should be padded and bus fixtures not injurious, high-backed seats would only be practical for interurban vehicles. In addition, the Committee reported that the bus collision rate in urban and school buses was too low to warrant installation of seat belts. The Committee did conclude however, that seat belts should be fitted in newly built interurban coaches. There was little done in Australia regarding the safety of bus occupants through to the 1980's.

In the 1980's, gradual changes in the regulations were taking place. By 1988, the installation of seat belts was required in all seating positions, in mini buses (less than 3.5 tonnes and less than 12 seating positions) and the drivers seating position in larger buses. Various construction requirements were made mandatory for all buses as well (ADR 58). These requirements included emergency exits. The introduction of ADR 59 Omnibus Rollover Strength had already been advised for mid-1991.

In the late 1980's to early 1990's, a series of severe collisions involving buses occurred (Dal Nevo et al., 1991). These collisions added significant public pressure to the need for better bus safety. Brief descriptions of these collisions are included here. The findings by the Roads and Traffic Authority of NSW regarding these collisions illustrate the reasons for changes that occurred in bus safety. Further information from other sources is referenced separately.

9.6.2 In-Depth Collision Data

Case 1

Where:	Bass Highway, Anderson, Victoria.
When:	February 1987.
Description:	A coach collided with a small car, subsequently leaving the highway and colliding head-on with a tree. The highway was a single lane and undivided.
Occupant injuries:	5 coach occupants killed including the driver; 15 occupants injured.
Comments:	Inspection of the coach showed that one seat assembly became totally detached from its anchorage points and another 13 seat assemblies had broken or distorted anchorages. Four of the seats had welds broken at the lower mounting plate of the seat leg.

Case 2

Where:	Grafton/Cowper, NSW.
When:	October 1989.
Description:	A fully laden semi-trailer and an interstate coach were travelling towards each other on a single lane highway at approximately 100 km/h. The semi-trailer got out of line and sideswiped the coach. There was massive intrusion into the side of the coach from the leading edge of the trailer. The bus then rolled down a slight embankment on the left side of the roadway. Fence posts penetrated the bus side structure and added to the injuries.
Occupant Injuries:	19 occupants killed; 15 occupants seriously injured.
Comments:	All but two of the 19 coach passenger fatalities were seated on the right (off-side) of the coach (Humphries, 1989). All the seats on this side, and several from the left side, were detached from their anchorages. The detachment of the seats from both the floor and the sidewall structure caused the occupants in the right side seats to be thrown into the crush zone and receive fatal injuries. Two occupants were fatally injured when ejected through the windshield. The opening made when the bus impacted with the trailer made evacuation easy (Humphries, 1989).

Case 3

Where:	Clybucca Flat, Kempsey, NSW.
When:	December 1989.
Description:	Two interstate coaches were travelling towards each other on a single lane highway at approximately 100 km/h and collided head on with an approximate 90 percent overlap.
Occupant Injuries:	35 occupants killed; 40 occupants seriously injured.
Comment:	20 of the 23 seats in one coach and a similar number in the other coach were detached from their anchorages and ended up in the front of the coaches (Waller, 1989). Injuries to the occupants were exacerbated by this and were typically of a crushing nature caused by: 1) the initial impact with the back of the seat in front; and, 2) the impact to the back by the seat behind. Laceration injuries were caused by the sharp edges on the fractured cast aluminium seat anchorages, with numerous complete traumatic leg amputations. The Coroner's Report (Waller, 1989), recommended that, "the NSW and Commonwealth Governments, in conjunction with the long distance coach industry, continue research into bus seats, seat anchorages and seat belts and bring into effect such improvements as are appropriate as expeditiously as possible."

Case 4

Where:	Mt Tamborine, Queensland.
When:	September 1990.
Description:	A coach descending a steep mountain road left the road while attempting to negotiate a turn. The coach, rolling 270 degrees down a two-metre embankment, came to rest against a substantial tree. The speed of the coach before leaving the road was estimated to be 55 km/h (Duignan, 1990).
Occupant Injuries:	11 occupants killed; 38 occupants seriously injured.
Comment:	The injuries resulted from ejection (6 people, including the driver) and contacts with the interior of the coach from the initial deceleration and the rollover (Duignan, 1990). The windows of the coach were toughened glass. Examination of the coach showed that 19 of the 22 seats suffered fractures to the anchorage points. The coach structure also dynamically deformed approximately 30-35 degrees to the side during the rollover, reducing the available occupant survival space.

Figure 5: Front of the Bus in Case 4 Showing Deformation

Case 5

Where:	Talbingo.
When:	May 1991.
Description:	The coach was descending on a single lane highway with gradients reaching 4 percent. The driver lost control of the coach. It left the road and rotated through 540 degrees coming to rest on its roof at the bottom of a five-metre embankment.
Occupant Injuries:	26 children injured.
Comment:	The coach roof was completely torn from the vehicle structure at waist level (i.e. from bottom of the windows up). All the occupants were ejected.

The authors of the study (Dal Nevo et al., 1991), discuss the findings of the collision investigations summarised above.

9.6.3 Structural Improvements Required

In the five cases reported, four different collision modes occurred: full frontal (Case 1); side-swipe (Case 2); offset (Case 3); and, rollover (Cases 4 and 5).

A common element in each collision was the inability of the seat anchorages to withstand the impact. Three of these collisions involved a substantial forward component in the deceleration. This deceleration brought the occupants into contact with the seat in front, adding to the inertial loading already being applied to the seat anchorage points and seat legs. The most common failure mode was fracturing of the lower mounting plates of the seat legs and bolts.

In the frontal impacts (Cases 1 and 2) the coach structures performed adequately considering the severity of the impact. The estimated average deceleration in the Kempsey collision (Case 3) was 16 g and the coach structure was undeformed except in the very front.

In both rollover collisions (Cases 4 and 5) the coach structure was considered by the authors to have performed poorly. In the Mt Tamborine collision (Case 4) the dynamic deflection of the structure above floor level was estimated to be approximately 35 degrees. This was compared to the (then) new Australian Design Rule ADR 59 requirements by the authors, where the structure is not to deform more than approximately 11 degrees. This requirement is shown in Figure 6. In the Talbingo collision (Case 5) the entire roof structure was torn off to the level of the base of the windows leaving the interior of the coach exposed and offering no protection to the occupants.

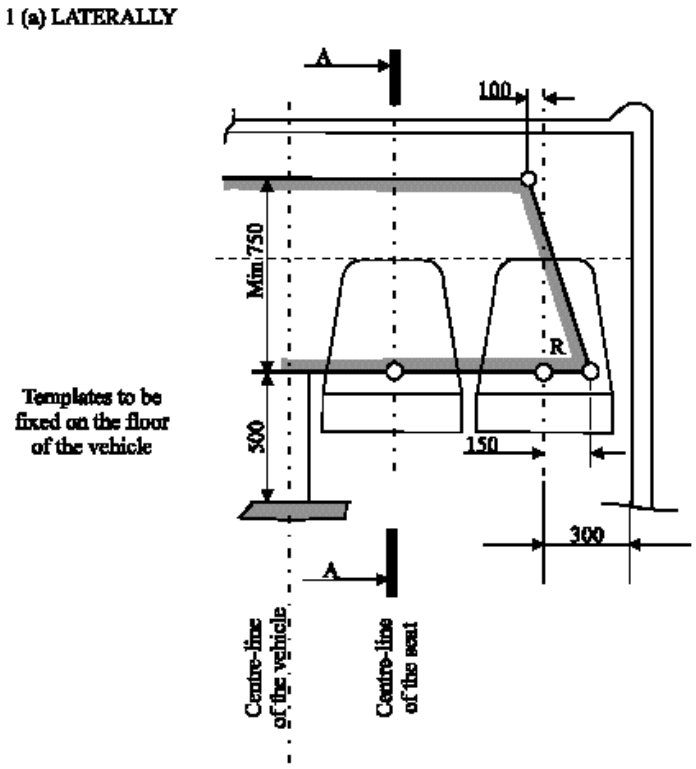

Figure 6: Dynamic Deflection Requirement of ADR 59 for a Coach Structure in Rollover.

In all five collisions there was extensive intrusion into the occupant survival space by either the external bus structure or interior components, which became dislodged as a result of the impact.

In conclusion, the authors recommended that the bus structure in rollover needed to be strengthened and they supported the introduction of ADR 59. As a secondary effect of this rollover strength improvement it was felt that an improvement to the general strength of the bus structure and fittings of the coaches would occur as well.

9.6.4 Occupant Injury Causation

Dal Nevo et al. report that in most cases the inability of the seat anchorages to withstand the impact loading during the collision contributed to the severity of the injuries. Injuries were sustained when contacting the seat in front as well as due to impact by the seat immediately behind. In the case of the Mt Tamborine collision (Case 4) the lack of occupant restraints allowed some occupants to be ejected from the coach and others to contact the luggage racks or roof structure. The major injuries suffered in this collision were to the thorax. They found that the severity of the injuries in this collision increased as the age of the passengers increased. The passengers were all over 55 years old. The authors conclude that this collision demonstrated that it was not sufficient to use the seat in front as a passive restraint system.

The authors found that the Talbingo collision (Case 5) highlighted the problem of fitting seat belts alone. The fitting and use of seat belts alone would have led to an increased injury severity. They went further and suggested there was a need for a total safety package, which included not only the incorporation of three-point (lap/torso) seat-belts, but improved rollover strength. The belt systems and seats had to meet a 20g impact strength requirement to be effective in these major collisions.

9.6.5 Emergency Exit Design

The final area that the authors felt could be improved were aspects of the emergency exit design. During the post collision rescue operations, particularly the two night collisions, Grafton (Case 2) and Kempsey (Case 3), confusion existed over the location of the emergency exits. Those bus occupants who were still partially mobile could not find the emergency exits. At least one occupant received serious lacerations smashing through a window. Another occupant who managed to find a roof exit, broke a leg while exiting. The rescuers also could not find the emergency exits and even if they had, the exits were not suitable for stretcher access. The authors recommended that the exits need to be:

- identifiable in the dark, both by occupants and rescuers;
- towards the middle of the coach on both sides;
- large enough to allow stretcher access; and,
- accessible from the ground.

9.6.6 ADR 66 Testing

The authors also compared the seat failures to the results of testing to ADR 66 (i.e. ECE 80). They found poor correlation between the static and dynamic parts of ECE 80. The static test produced modes of failure that did not represent those found in the real life collisions. The dynamic requirements were not severe enough to reproduce the actual collision failures. The use of ECE 80 as a design tool was found to be likely to lead to poorly designed seats.

The authors of the report (Dal Nevo et al., 1991), concluded that:

- it was not sufficient to use the seat back as a passive restraint system;
- seats were available with lap/torso belts able to withstand 20 g collisions;
- a significantly strengthened bus structure was required.

9.6.7 Other ADR Developments

Later that year (1991) Keith Seyers, the Chief Engineer of Vehicle Standards at the Federal Office of Road Safety, reported on the coming developments in the ADR system resulting from these collisions (Seyers, 1991). These developments were to be as follows:

- ADR 8/00 Glazing was to be extended to make laminated glazing mandatory for the windshields of coaches (July 1994);
- ADR 58/00 Requirements For Omnibuses Designed For Hire And Reward was modified with the aim of improving the access to the exits, increasing their size and standardising their position and number (July 1988, amended 1992);
- ADR 59/00 Omnibus Rollover Strength was extended to all omnibuses with more than 12 passengers (July 1992);
- ADR 66/00 was introduced based on the existing ECE Regulation 80, consisting of static or dynamic seat strength;
- The formulation of a more advanced ADR was initiated to address the need for fitting full three-point restraints to coaches. This later became ADR 68/00.

Following a workshop which reviewed the progress being made in improving the safety for bus occupants, in 1993 FORS funded the development of a voluntary code of practice for improving occupant protection in existing buses (NRTC, 1995). The modifications outlined in this Code of Practice became the subject of a cost-benefit analysis aimed at the long distance or touring type coach (Andreassen and Cusack, 1996). This cost-benefit analysis was based on the standard approach used by the Australian Road Research Board and used 1992 injury and usage figures. It was found that the amount of bus collision data was limited as there was no way to isolate coach collisions. In addition, it was found that there had been a drop in the number of new coaches entering the fleet from 200 per year to 50 per year. The authors conclude that there was insufficient benefit to install lap/torso belts and new seats to coaches.

Since 1991, the ADR system has addressed many of the issues raised in the paper by Seyers, 1991 and 2002.

- laminated glazing became mandatory for the windshields of coaches; further extension of the use of laminated glazing was opposed due to the implications for emergency escape;
- increased emergency exit size and standardised position and number;
- rollover strength requirements were extended to all omnibuses with more than 12 passengers;

- an equivalent to ECE Regulation 80, consisting of a static or dynamic seat strength testing, was introduced;
- a more severe 20 g dynamic requirement was introduced for all coaches.

9.6.8 Occupant Protection Issues

Internal working documents from the Federal Office of Road Safety summarise the same group of crashes involving long distance coaches (Smith 1995, 1998). The aim of that work was to identify occupant protection issues in casualty crashes involving long distance coaches, and a summary of the crash statistics is presented in Table 13. A summary of the crashes reviewed is presented in Table 14.

Table 13: Summary Statistics of Fatal and Serious Injury Coach Crashes, Australia 1988-1993
(Source: Smith, 1998)

Crash Type	Number	Fatalities	Injuries	All Casualties
Coach and car	4	1	>44[1]	>45
Coach only (single vehicle)	8	17	167	184
Coach and other heavy vehicle	10	74	>229[11]	>303
Other (coach/car then tree)	1	5	17	22
Total	23	97	>457	>554

[1] The exact number of injuries is not known for a small number of crashes.

Table 14: Summary of Fatal and Serious Injury
Coach Crashes, Australia 1988-1993
(Source: Smith, 1998)

Crash			Casualties		Ejections	
Date	Location	Type	Fatality	Injured	Partial	Complete
24/10/94	Bracken Ridge	Coach Only	12	39	Several	3
02/11/93	Wangaratta	Side Impact	10	35	0	0
10/10/93	Molong	Head On	0	16	0	0
24/09/93	Sarina	Head On	1	34	0	0
20/09/93	Myrtleford	Coach Only	0	12	0	0
18/09/93	Coober Pedy	Coach Only	1	16	7	0
26/07/93	Slacks Creek	Coach Only	0	11	0	0
14/10/92	Linden	Head On	1	40	0	2
04/06/92	Gin Gin	Right Angle	1	17	0	2
03/06/92	Cloncurry	Coach Only	0	6	0	0
04/01/92	Gunnedah	Coach Only	5	19	0	0
11/07/91	Toowoomba	Front Impact	1	10	0	0
19/05/91	Talbingo	Coach Only	0	25	0	All
25/09/90	Gold Coast	Coach Only	11	38	0	2-5
28/05/90	Berowra	Head On	1	18	0	0
22/12/89	Kempsey	Head On	35	39	0	0
20/10/89	Grafton	Head On	20	15	0	Some
23/12/88	Breadalbane	Head On	4	31	0	0
16/02/87	Anderson	Front Impact	5	17	0	0

The aim of the first report, Smith 1995, was to supply the crash data to decide as to whether there was a case to require the retrofit of some safety features to vehicles already in service. The retrofit packages are listed in Table 15.

The second report, Smith 1998, combines the crash summaries from the previous report with a cost-benefit study, Andreassen and Cusack, 1996, which only found a positive benefit/cost ratio for only one of five upgrading measures, see paper summary in this report and Table 15.

Table 15: Summary of Recommended Packages and Cost for Improving Occupant Protection in Existing Buses
(Sources: Bleakly, 1995, and Andreassen et al., 1996)

Package	Description	Estimated Cost (AUD 1996)
Level 1	Improved emergency exit signing and function.	n/a
Level 2	Strengthened seat mounting structure, including replacement of aluminium legs.	$6,855
Level 2a	Level 2 with the addition of padding to seat back.	$9,455
Level 3	Strengthened seat mounting structure and replacement of seats with ADR 66 conforming seats.	$23,775
Level 4	Lap belts in existing seats, with replaced seat leg systems with seat belt anchorages, and strengthened seat mounting structure.	$12,880
Level 4a	Level 4 with addition of padding to seat back.	$15,480
Level 5	Strengthened seat mounting structure and ADR 68/00 conforming seats and lap/torso seat belts	$30,675

A significant number of the crashes, many involving relatively large numbers of injuries, involved the coach turning over and restraining or containing occupants would reduce these injuries. Rollover protection becomes a significant injury mitigation measure by preventing intrusion of objects into the coach cabin, and roof crush. Several crashes (examples are Gunnedah and Linden) were found to also involve numbers of injuries remote from the point of impact. Restraining or containing occupants in the seats will reduce or eliminate injuries in these crashes.

The coach industry in Australia has shown a slowdown in the rate of introduction of new coaches. This has been due to the increased competition from the airlines with significantly lower fares now available for intercity travel. RTA of NSW has become concerned about the age and number of coaches in service not fitted with seat belts. To address this issue coach owners are being encouraged to retrofit older buses in a continuation of the earlier program (RTA, 2002). This has become allied with concerns regarding the quality of the retrofitted seat and belt systems (McGuire, 2002). A project is under way to investigate ways to improve the quality of these retrofitted systems. This has three parts, an audit of the consulting engineers doing this work, a review of the mass data, and a revised series of dynamic tests on the seat and belt systems available on the market.

The RTA of NSW sees as its most significant problem the encouragement of bus occupants to wear the belt systems when installed. It is tackling this by having a compulsory certification requirement for bus operators and drivers. This certification requirement is met by taking a course run by the Institute of Transport Studies, the University of Sydney, which includes a component on bus safety. Legally the driver is liable for the wearing of a seat belt by the bus occupants. Public pressure is forcing the fitment of complying seat belt systems anyway.

A review of the Motor Vehicle Standards Act, 1989 is now under way (DOTRS, 1999). The Act provides the legislative basis for the Australian Design Rules that set standards in the areas of vehicle safety, emissions and anti-theft performance. The terms of reference require the review to:

- assess the appropriateness, effectiveness and efficiency of the Act;
- identify and assess the costs and benefits to the industry of alternative arrangements for ensuring compliance with appropriate vehicle standards and of harmonising Australian standards with international regulation; the aim is to move to the ECE Regulations, unless there is some loss of safety; and
- report on the preferred approach for meeting future vehicle standards requirements.

As part of the review, the effectiveness of the current ADRs is being assessed (Seyers, 2002). The results will be available by mid-2003. The section of the review of those ADRs concerning bus occupant safety has already gone to the industry for comment. The industry response (Bath, 2002), was to suggest simplifying the system by removing ADR 66, which is basically the ECE Regulation 80, and depending on ADR 68, the more severe Australian seat requirements and to have seat belts on all coaches. The industry takes the view that market forces are making it necessary to fit seat belts to all motor coaches. The technology is readily available and proven from ten years of use.

A significant loophole in ECE 80 needs to be dealt with regarding the height of the seat back which does not require a seat belt system to be fitted (Seyers, 2002).

The case notes for a recent coach collision (Glynn, 1997) are of interest with respect to the number of bus occupants wearing seat belts.

Case 6 (Glynn, 1997)

Where:	Tenterfield
When:	1996
Description:	The fully occupied 52 seat coach (built in 1996) was travelling at 85 km/h (from the tachograph), when it impacted a culvert causing significant damage to the lower front of the coach. Approximately one metre of crush occurred to the lower front, equivalent to a 6g deceleration, the vehicle coming to rest with its rear just past the culvert.

Occupant Injuries 2 fatally injured;
some minor injuries.

Comments: Inspection of the vehicle indicated that only 5 seating positions were not using the lap/torso seat belts at the time of the collision. One of these was a relief driver asleep on a berth at the back of the bus, he was fatally injured after being thrown out of the berth and hitting his head on a seat pedestal. The second was a 12-year old who was in the aisle at the time of the impact. The other three had left signs of impact on the seats in front.

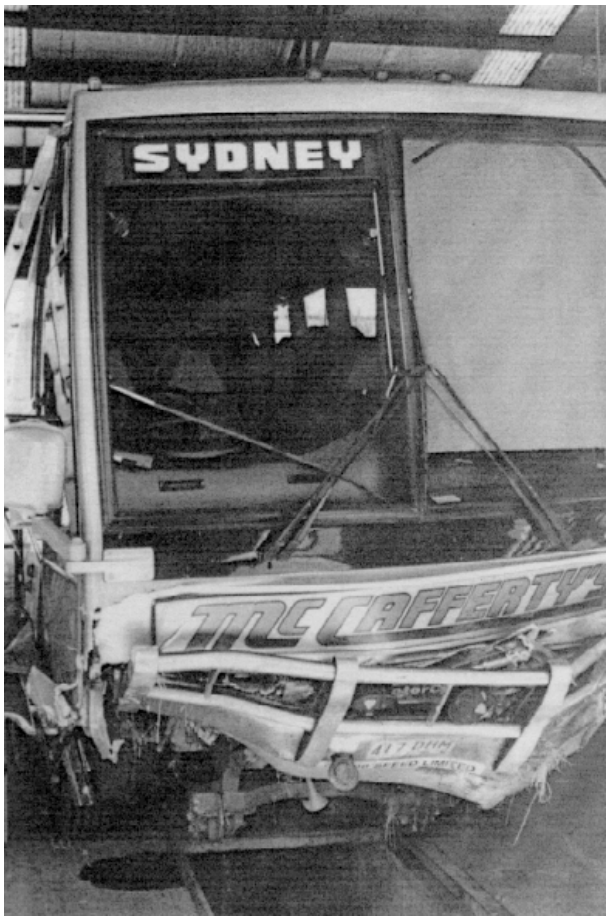

Figure 7: Front of the Bus in Case 6 Showing Deformation - Front View

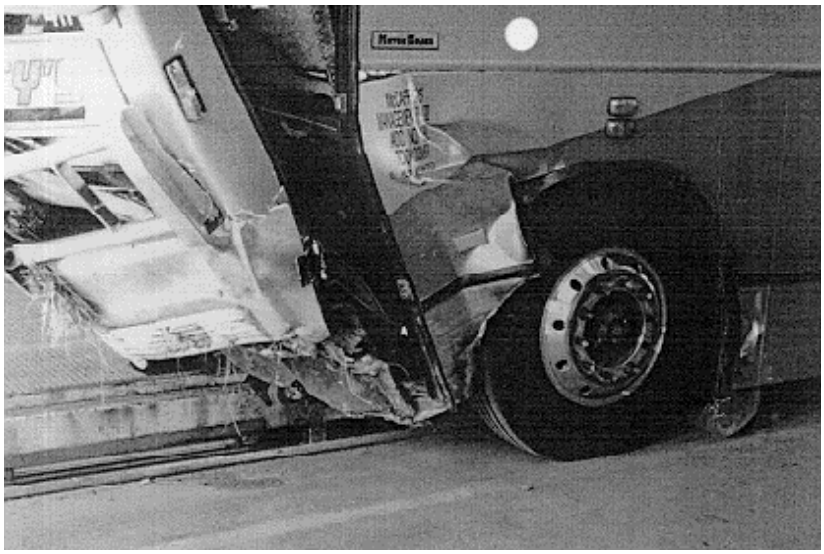

Figure 8: Front of the Bus in Case 6 Showing Deformation - Side View

Hildebrand and Rose (2001) investigated the safety record of the Australian bus industry. Bus safety was benchmarked against other transport modes and countries to identify areas of concern. This benchmarking was based on Australian, Canadian and U.S. data. There was a great deal of difficulty in obtaining data which were directly comparable, and the results need to be treated with some caution. The following conclusion was made. Although the proportion of road fatalities involving buses was much higher in Australia compared to North America, when the rates were adjusted for exposure by including fleet size and distance travelled then the Australian rates were lower.

9.6.9 Conclusions Regarding Testing

From the review, several features stand out which need to be considered when formulating a limited test series. The approach taken in Australia was to incorporate structural improvements to the seats and seat anchorages (ADR 66), incorporate three-point belt systems on the seats (ADR 66), incorporate improved three-point belt systems (ADR 68) and ensure that the bus structure itself was sufficient to protect the integrity of the occupants survival space (ADR 59). The authors concluded that the use of ECE 80 as a design tool was most likely to lead to poorly designed seats.

Seat design programs in Europe at Cranfield (Kecman and Dutton, 1996), and by several manufacturers in Australia (Dabelstein, 2002), have shown that it is feasible to construct seats able to pass the stricter Australian requirements in ADR 68 without a significant weight penalty.

Glazing was at no time in Australia considered a viable alternative to improvements in occupant restraint. The design of emergency exits was considered an important factor post

crash and the inclusion of laminated glass has been thought to increase the problems associated with this.

Restricted testing might prove beneficial using a three-fold program:

1) investigating the current bus interiors with regard to seat and anchorage strength and the aggressiveness of the interior fittings, including seat backs and grab rails as well as overhead shelves and air conditioning fittings, etc.;
2) check the feasibility of including passive safety compartments for adult occupants applying some of the available components such as strengthened and padded seats;
3) examine the effectiveness of having full three-point belts attached to strengthened seats with appropriate floor structure.

9.7 Future Directions in Australia

The DOTRS is currently reviewing the ADR system (Seyers, 2002). The long term aim is to move to the ECE Regulations unless there is some loss of safety.

The NSW RTA has several objectives for improving the safety of coach occupants in the next ten years and is currently working to achieve them (McGuire, 2002):

- Re-invigorate the voluntary seat belt retrofit program for buses (RTA, 2001).
- Improve belt wearing rates by training the drivers.
- Extend rollover strength requirements to small buses.
- Improve emergency exits.

10. EUROPE

10.1 Collision Statistics in Europe

In the Economic Commission for Europe (ECE) each year approximately 20,000 (4%) buses and coaches of more than 5,000 kg are involved in collisions. More than 35,000 people are injured due to these collisions and over 250 occupants suffer fatal injuries. In terms of exposure, it is estimated that bus and coach travel in the European Union is at least ten times safer than other modes of road transport, see Table 16.

As part of the study of Enhanced Coach and Bus Occupant Safety (ECBOS) described later in section 10.4, collision statistics were collected from eight European countries, i.e. Austria, France, Germany, Great Britain, Italy, Netherlands, Spain and Sweden (ECBOS, 2001). The sampling and injury definitions for each country are summarised for comparative purposes in Table 17.

Table 16: Passenger Casualty Rates by Mode of Transport
(Source: ETSC, 2001)

	EU Deaths per:	
	100 million person km	**100 million hours**
Motorcycle/moped	16	500
Foot	7.5	30
Cycle	6.3	90
Road (total)	1.1	33
Car	0.8	30
Ferry	0.3	10.5
Air (public transport)	0.08	36.5
Bus and Coach	0.08	2
Rail	0.04	2

The ECBOS data were collected primarily from police records and it was noted that there may be inaccuracies in the injury information and that under-reporting may also occur. Even so, it provides the best available source of bus collision data for Europe. The data analysed are for a five-year period, 1994-1998 with the exception of Italy where 3 or 4 years of data are used. The data from Italy were multiplied during the ECBOS study to reflect 5 years.

All countries in the ECBOS study have significantly lower numbers of bus and coach casualties than other road users. Bus and coach casualties account for less than 2.0% of all casualties.

The types of collisions, in terms of the number and type of vehicles involved, were only reported for four countries. These were countries in which it was possible to confirm that the casualties were occupants in the bus. This data are summarised in Table 18.

Table 17: Overview of Bus Collision Data Collected by ECBOS

(Source: ECBOS, 2001)

Table 1	Austria	France	Germany	Great Britain	Italy	Netherlands	Spain	Sweden
Sampling	All injured bus or coach occupants.	All injured bus or coach occupants.	BASt: only injured bus or coach occupants. StBA: all injured people involved in bus collision.	All injured bus or coach occupants.	All injured bus or coach occupants.	100% Fatalities, 60% of those hospitalised.	At least one bus and one injured road user involved.	For SNRA injury assessed by police officer at scene.
Fatal (Time after collision in which a death is recorded as a fatality)	30 days.	Less than 6 days (weighting factor to 30 days, 1.057).	30 days.	30 days.	Less than 7 days (weighting factor to 30 days, 1.08).	30 days.	24 hours after collision (no weighting factor available).	30 days.
Serious	More than 3 days in hospital or a discontinuation of normal business for more than 24 days.	More than 6 days in hospital.	All persons who were immediately taken to hospital for in-patient treatment (of at least 24 hours).	Hospital in-patient.	All non-fatal injuries are grouped together.	Admitted to hospital as an in-patient.	More than 24 hours in hospital.	Any injury that requires the person to be admitted to hospital.
Slight	Less than three days hospitalised.	Less than 6 days in hospital.	All other injured persons.	Receive or appear to need medical treatment.		Injured but not transferred to the hospital as an in-patient.	Less than 24 hours in hospital.	Minor or slight injury should not require admission of the patient to hospital.
Unknown Injury	Yes	No	No	No	No	Yes	Yes	No
Vehicles	M2 and M3.	Buses and coaches.	M2 and M3 vehicles with 9 or more seats.	M2 and M3 (but all over 16 passenger seats).	Buses and Coaches over 8 seats.	M2 and M3.	Not known	Vehicles registered to carry more than eight passengers.
Area Covered	All of Austria.	All of France.	Federal Republic of Germany.	Great Britain (not Northern Ireland)	All of Italy.	All of the Netherlands.	All of Spain.	All of Sweden.

Table 18: Bus Collision Type in Four European Countries
(Source: ECBOS, 2001)

Collision Type	France	Great Britain	Netherlands	Spain
		Percentages		
Single Vehicle	10.1	63.8	29.7	43.7
Bus - car	41.9	22.7	29.3	24.3
Bus - truck	14.6	6.8	17.2	13.4
Bus - bus	2.1	5.4	7.7	3.9
Bus - other	10.7	1.3	16.1	2.8
More than two	10.6	-	-	11.9

The most common type of bus collision was a single vehicle collision in which no other vehicle was involved. It is noted in the ECBOS report that more detailed information on the circumstances of the collision was difficult to collate due to differences in reporting format and definitions. From the available data, they conclude that the main area of damage and the principal direction of force are to the bus or coach. Accurate data on the incidence of rollover are not available. In Austria, Germany, the Netherlands and Sweden, there is no "rollover" or "overturning" data fields. No Italian data were available for collision type. In the three countries, France, Great Britain and Spain, which have "rollover" or "overturning" data fields, it was found that rollovers were under-reported. It appeared that the first impact event may supersede a subsequent rollover. The limited data indicate a higher incidence of casualties and more severe injuries during bus rollovers compared to other bus collisions. In Spain, 93.6% of rollover casualties and all rollover fatalities occurred on intercity roads.

There are no data available on the countermeasures, although Spain and Austria reported data on seat belt use which show low seat belt use (Tables 19 and 20).

Table 19: Seat Belt Use in Bus Collisions in Spain
(Source: ECBOS)

Year	Using Seat Belt		Not Using Seat Belt		Use Not Known		Total
1994	63	2.2%	2426	82.9%	438	15.0%	2927
1995	71	2.3%	2518	81.3%	507	16.4%	3096
1996	89	2.8%	2390	76.1%	663	21.1%	3142
1997	83	2.4%	2472	72.1%	875	25.5%	3430
1998	144	3.7%	3027	77.1%	756	19.3%	3927
Total	450	2.7%	12833	77.7%	3239	19.6%	16522

Table 20: Seat Belt Use in Bus Collisions in Austria
(Source: ECBOS)

Year	Using Seat Belt		Not Using Seat Belt		Total
1994	9	2.0%	449	98.0%	458
1995	7	1.5%	448	98.5%	455
1996	9	2.2%	409	97.8%	418
1997	4	1.0%	411	99.0%	415
1998	9	2.0%	444	98.0%	453
Total	38	1.7%	2161	98.3%	2199

10.2 ECE Regulations

The regulatory requirements within Europe largely reflect the directives of the European Union (EU) and the Economic Commission for Europe (ECE) regulations. The members of the European Union must adopt the EU directives or regulations and these take precedence over the ECE regulations. On some occasions, the ECE will adopt an EU directive word for word.

The ECE regulations for motor vehicle equipment and parts are developed by Groups of Rapporteurs (GR) reporting to the World Forum for Harmonization of Vehicle Regulations Working Party 24. A major GR for bus regulations is the Working Party on Passive Safety (GRSP). Canada sits on several GR's including GRSP WP 24 with full voting rights. Signatories of the 1958 Agreement may adopt ECE requirements into their national system but this is not mandatory. With the adoption of the 1998 Global Agreement to which Canada was the first signatory, world harmonization of vehicle regulations becomes possible.

Signatories agree to align their national requirements with those of the adopted regulations. The manufacturer must have the vehicle certified by an approved test laboratory. There is no formal compliance authority or system of recall in Europe. Recall is voluntary unless a national system exists.

Two ECE regulations apply to the passive safety of coaches, ECE Regulation 66 (Strength of Superstructure) and ECE Regulation 80 (Strength of Seats and their Anchorages). Although these regulations are not yet compulsory in Europe, they are taken into account by bus manufacturers in the development and approval/testing of new buses.

ECE Regulation 66 applies to a rollover test. After the bus has been overturned onto the edge of its roof, a defined survival space must be intact (see Figure 9).

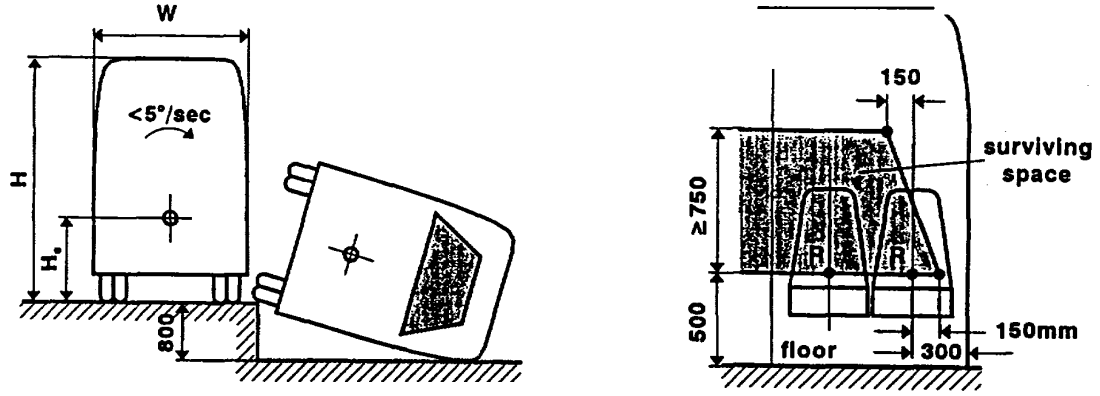

Figure 9: Superstructure Strength Regulation

ECE Regulation 80 tests the seat strength and anchorages when impacted by an unrestrained dummy. Specifications include both deformation and energy absorbing criteria (see Figure 10).

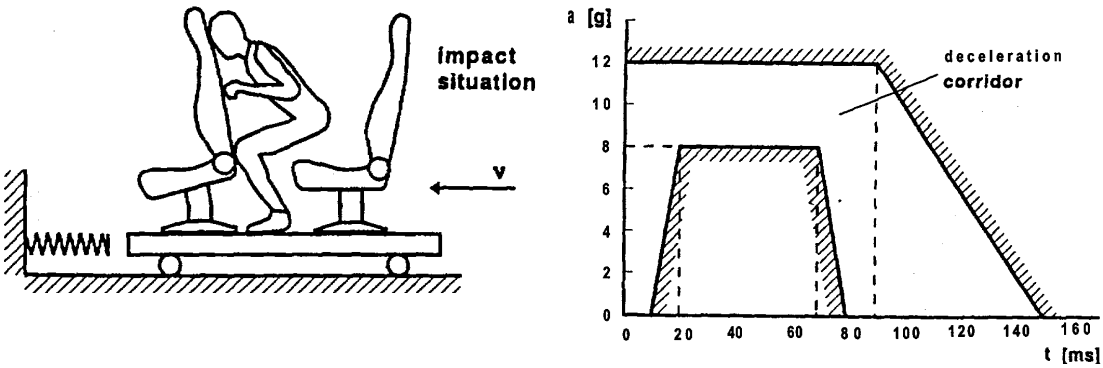

Figure10: Seat and Anchorage Strength Regulation

According to the latest version of the EU guideline, seat belts are to be installed in buses only in “those seats with no passenger ahead”. The EU Commission in Brussels require the installation and use of two-point belts on all seats in touring buses over 5t. For buses 3.5-5t, manufacturers can choose between two-point and three-point belts and in mini buses (up to 3.5t) three-point belts are required.

Regulation 66 Test Methods

- A rollover test on a complete vehicle.

  The vehicle is placed on a horizontal platform and then tilted (without rocking and without dynamic effects) until it rolls over. The angular velocity shall not exceed 5 degrees per second (0.087 round/sec).

- A rollover test on a body section or section.
  Test procedure same as described above.

- A pendulum test on a body section or section.
  Multiple pendulum tests on a body section to satisfy specified requirements. The pendulum impact velocity is between 3 and 8m/s.

- A verification of strength of superstructure by calculation as specified.

Regulation 80 Test Methods

To determine if:

1) Seat occupant is correctly retained by the seat in front of them.

2) Occupant is not seriously injured.
   Head Acceptability Criterion (HAC) (calculated from resultant triaxial accelerator for prescribed time intervals)
   < 500
   Thorax Acceptability Criterion (ThAC)
   < 30 g
   Femur Acceptability Criterion (FAC)
   < 10 kN

3) The seat and seat anchorages are strong enough:
   - no part of seat or anchorages is completely detached
   - seat remains firmly held even if anchorage(s) is partly detached
   - no sharp edges likely to cause injury

Dynamic Test
Seat (with manikin) installed on test platform behind seat being tested.
Impact velocity 30-32 km/h, average deceleration 6.5 g - 8.5 g.

Static Test
Prescribe force applied to rear part of seats and anchorages.

10.3 Seat Belt Regulations

In the United Kingdom, regulations have recently been introduced which require seat belts to be fitted to all new buses (except for urban buses designed for standing passengers), coaches and mini buses (passenger vehicles with more than 8 passenger seats) registered on or after 1st October 2001 (Statutory Instrument, 2001). This includes all vehicles in the European M2 and M3 categories, including van conversion as well as purpose built vehicles.

The seat belts must meet either the British Standard BS3254 Part 1 or ECE regulation 16.04. The seat belt anchorages must meet the requirements of ECE regulation 14.04 or 14.05 or EU Directive 76/115/EEC which is generally equivalent to ECE Regulation 14. In buses with a gross weight exceeding 3,500 kg (including minibuses and coaches) inertia reel three-point seat belts or retractable lap belts are required in all forward and rearward facing seats. Lap belts however may only be fitted in forward-facing non-exposed seats where an appropriate energy absorbing seat or surface is present in front. In buses with a gross weight not exceeding 3,500 kg (including minibuses), the required restraints are inertia reel three-point seat belts in forward facing seats and inertia reel three-point seat belts or retractable lap belts in rearward facing seats. There are no plans at present to mandate or monitor seat belt use in the UK.

The decision to allow lap belts is linked with the European Directive (Knowles, 2002). In the early 1990's when modifications to the European seat belt and anchorage Directives were being discussed to allow Member States to require seat belts on buses and coaches, there was disagreement on whether three-point belts were necessary, given that most coach collisions were of the rollover variety rather than primarily frontal impact. Eventually a compromise was reached whereby lap belts would be allowed as an alternative to three-point belts (on vehicles over 3.5 tonnes), provided an energy-absorbing seat or surface was provided in front of every lap belt-equipped seat. Since this is now enshrined into the Directive, Member States have to accept vehicles complying with this Directive and cannot demand anything over and above the Directive (otherwise this would be seen as a barrier to trade).

In other European countries, the fitting of seat belts in coaches varies from country to country (Table 21). Although all Member States have to accept vehicles that meet the seat belt Directive, it is up to each member whether they require vehicles to meet the seat belt Directive. This may change in the future as the Commission is trying to make compliance with the seat belt Directive (for new vehicles) mandatory in all countries.

Table 21: Fitting of Seat Belts in Coaches[1]
(Source: Knowles, 2002)

Category of vehicle		Member States												
		AUT	**BEL**	**DAN**	**GER**	**GRE**	**FIN**	**FRA**	**IRL**	**IT**	**LUX**	**NED**	**SWE**	**UK**
M2 (1)		**X (01/10/01) (01/10/99)**	**X (During 2002)**	**X**	**X (01/10/01) (01/10/99)**	(2)	**X (01/10/01) (01/10/99)**	**X (01/10/01) (01/10/99)**	**X (01/01/92)**	**X (01/10/01) (01/10/00)**	–	**X (01/10/01) (01/10/99)**	–	**X (01/10/01)**
M3	**Class A**	**X (01/10/01) (01/10/99)**	**X (During 2002)**	**X**	**X (01/10/01) (01/10/99)**	(2)	**X (01/10/01) (01/10/99)**	**X (01/10/01) (01/10/99)**	**X (01/01/92)**	**X (01/10/01) (01/10/00)**	–	**X (01/10/01) (01/10/99)**	–	–
	Class B	**X (01/10/01) (01/10/99)**	**X (During 2002)**	**X**	**X (01/10/01) (01/10/99)**	(2)	**X (01/10/01) (01/10/99)**	**X (01/10/01) (01/10/99)**	**X (01/01/92)**	**X (01/10/01) (01/10/00)**	–	**X (01/10/01) (01/10/99)**	–	**X (01/10/01)**
	Class I	**X (01/10/01) (01/10/99)**	**X (During 2002)**	**X**	**X (01/10/01) (01/10/99)**	(2)	**X (01/10/01) (01/10/99)**	**X (01/10/01) (01/10/99)**	**X (01/01/92)**	**X (01/10/01) (01/10/00)**	–	**X (01/10/01) (01/10/99)**	–	–
	Class II	**X (01/10/01) (01/10/99)**	**X (During 2002)**	**X**	**X (01/10/01) (01/10/99)**	(2)	**X (01/10/01) (01/10/99)**	**X (01/10/01) (01/10/99)**	**X (01/01/92)**	**X (01/10/01) (01/10/00)**	–	**X (01/10/01) (01/10/99)**	–	–
	Class III	**X (01/10/01) (01/10/99)**	**X (During 2002)**	**X**	**X (01/10/01) (01/10/99)**	(2)	**X (01/10/01) (01/10/99)**	**X (01/10/01) (01/10/99)**	**X (01/01/92)**	**X (01/10/01) (01/10/00)**	–	**X (01/10/01) (01/10/99)**	–	**X (01/10/01)**

–: Optional
X : Mandatory (Date of enforcement)
(1) Dates depend on the maximum mass of the vehicle (<3,5 t or above)
(2) Since 1980, for school buses for children up to 12 years old
(3) X except buses that can be considered as having, special area for standing passengers
(4) X is classified interurban as regard the Italian legislation

[1] Compiled by the European Commission, no data for Spain and Portugal.

10.4 ECBOS Study

On 1st January 2000, a new three-year research program, Enhanced Coach and Bus Occupant Safety (ECBOS), was funded by the European Commission. It was initiated to look into the safety of buses, coaches and city buses across Europe. The seven ECBOS partners are: Technical University of Graz (Austria); GDV (Gesamtverband der Deutschen Versicherungswirtschaft e.V.) (Germany); Politecnico di Torino (Italy); University of Madrid, UPM - INSIA (Spain); TNO Automotive Crash Safety Centre (The Netherlands); Cranfield Impact Centre, and Loughborough University (Great Britain). The main objective of the project was to reduce the incidence and cost of injuries caused by bus and coach collisions through the development of new bus regulations and standards.

The aims of the work are:

- to analyse real world bus collision data;
- to determine injury mechanism through component tests, full scale and numerical simulation;
- to develop test methods with special test procedures for city buses;
- to summarise suggestions for new regulations and standards and to develop a numerical demonstration of improved interior design.

The first task of the project, the analysis of available statistics on bus and coach collisions in eight European countries has been completed (ECBOS, 2001).

11. SAFETY OPTIONS IN INTERCITY BUSES

11.1 Seat Belts

Seat belts are highly effective in reducing the risk of injury in motor vehicle collisions. Their use is mandated across Canada and in many other parts of the world. Canada Motor Vehicle Safety Regulations require that seat belts be installed in each designated seating position in all passenger vehicles except buses.

The issue of seat belts in buses is regularly raised because of their importance in protecting occupants of other types of vehicles. Arguably, the safety of school bus travel for many reasons, including safety requirements for school buses and the resulting effectiveness of passive safety compartments in preventing injuries, does not clearly indicate a need for seat belts. The potential benefits of fitting seat belts in school buses are often countered by the difficulty of enforcing and ensuring proper seat belt use, maintenance and vandalism issues and increased costs and reduced seating capacity.

In other buses without compartmentalised areas, the benefits of fitting seat belts may be greater, although the majority of stakeholders at the Transport Canada bus safety

consultations were of the opinion that the safety record of motorcoaches did not indicate a need for seat belts to be fitted.

Safety considerations in the installation of seat belts in buses are:

Benefits

- Lap/torso seat belts are highly effective in preventing injuries, especially in frontal collisions and rollovers, the two most common types of bus collisions.
- Properly used lap/torso seat belts prevent ejection. They also prevent the occupant being thrown from their seating position and reduce the risk of injurious impacts with the bus interior.
- Experience in Australia indicates that the installation of seat belts can be achieved without an increase in seat mass.
- The carrying capacity of intercity buses with the installation of lap/torso belts would probably remain the same.

Negatives

- Lap-only belts may cause injuries.
- The protective benefits of a lap/torso seat belt can only be realised if the seat belt is worn and used properly.
- Improperly used lap/torso seat belts, for example torso belt under the occupant's arm or behind their back, can cause serious and fatal injuries.

11.2 Retrofitting Seat Belts

In the United Kingdom, retrofitting is allowed but not required. Part of the reason it is not required is the difficulty in assessing whether a retrofitted installation meets adequate standards. Another reason is that retrofitting older vehicles (perhaps with only a few months remaining service life) would never be cost-effective (Knowles, 2002).

In a document providing advice on retrofitting seat belts to minibuses and coaches (DOT, 1996), the following points are noted:

- Seat belt anchorages must withstand high loads in collision.
- Significant reinforcement may be needed to the floor structure.
- Extra strengthening of the seat may be required.
- Lap belts will keep occupants in their seats and prevent ejection.
- Lap/torso seat belts offer greater protection but the extent and cost to retrofit them on existing seats (in older vehicles) may not be justifiable.
- Manual seat belts are less expensive and easier to install than retractable seat belts.
- Retractable seat belts automatically adjust to fit the occupant and stow neatly removing the risk of passengers tripping on discarded seat belts.

- Seat belt anchorages must be positioned to ensure correct belt geometry.
- Component testing may be the only viable option to best retrofit seat belt anchorages in older vehicles, however component tests will not provide the reassurance of a full scale test.
- If the increased weight from the installed seat belts exceeds the vehicle's maximum permitted weight, it may be necessary to reduce seating capacity.

Attaching seat belts to an existing seat is usually not possible because the seat and its anchorages were not designed to withstand the loads of a belted occupant in a collision. In Australia, in bus collisions involving retrofitted seat belts, the seat detached from the floor or collapsed onto the occupant . Specially designed structural seats with integral lap/torso seat belts provide good occupant protection when the seat belts are used properly. The use of these seats, however generally requires significant strengthening to handle the seat belt loads. The costs associated with this modification is usually high.

In 1993, consultants Price Waterhouse prepared a report on the cost of retrofitting New Zealand's school bus fleet with seat belts. They estimated the average cost of installing seat belts in a typical school bus is $10,000 (NZ), 70% of which relates to providing stronger anchorage points for the seats. With approximately 2,200 dedicated school buses in New Zealand, the Land Transport Safety Authority (LTSA) proposed that any requirement to fit seat belts should only apply to new-registered vehicles.

The Motor Industry Research Association in the United Kingdom developed a system to deal with the problem of installing replacement seats with integral seat belts into minibuses (Dickison and Buckley, 1996). The concept was based on the addition of low cost under-floor structural members. Finite element modelling and preliminary tests indicated the design concept was feasible, although further development work was indicated.

11.3 Retentive Glazing

An extensive glazing study by NHTSA confirmed the effectiveness of laminated windows in preventing ejections from passenger cars. During impact testing, however, higher neck shear loads and neck moments were recorded for tri-laminates compared to tempered glass. Although the biofidelity of the neck of the Hybrid III dummy used is generally considered poor, these impact test results were treated cautiously and the focus shifted to the development of performance based test procedures which would allow other technology.

In contrast to school buses and even transit buses, intercity buses are characterised by large side windows through which occupants have been ejected in bus collisions.

Properly secured laminated windows would likely reduce the possibility of ejection.

Benefits

- Prevention of ejection of non-belted occupants.
- Relatively low fabrication and installation costs.
- Retentive glazing already installed in some intercity coaches.

Negatives

- Unresolved issue of high neck loads during NHTSA impact testing.
- Retention can be offset by inadequate window latches.
- Potential loss of glazing when bus structure deforms.
- No test data.

11.4 Emergency Exits

The window latch and hinge mechanism system which failed in the Canadian bus collision (Case 10) is commonly used in intercity buses sold in North America. In Europe, bus windows are bonded to the bus structure. Exit through a tempered glazing emergency window is achieved by using a striker located near the window.

In the European system and in those cases where the laminated window is bonded directly to the bus, the rigidity of the bus wall may be improved. The potential of laminated glass bonded directly to the bus structure as a system to prevent ejection has been largely unexplored. There are no known test data which examine its retention during occupant loading, the retention of laminated side windows when the bus structure deforms has also not been quantified.

12. ISSUES FOR DISCUSSION

12.1 Introduction

While the incidence of bus occupant injury is small, in severe bus collisions particularly those involving rollovers, intercity buses may not be as safe as possible for their passengers. Further countermeasures and improvements in collision protection may reduce the incidence and severity of injuries. Future issues for consideration for improved occupant protection in intercity buses are given below.

12.2 Classifications and Definitions

There is little harmony in the manner in which bus collision data are recorded and analysed. Available collision and bus usage data are not routinely available for the different bus types, including intercity buses. There are no standard definitions and classifications of buses in Canada or any of the other countries studied. The lack of common terminology hinders comparative evaluation of countermeasures aimed at reduced occupant injuries.

12.3 Primary Injury Circumstances

Rollover collisions result in the majority of fatal and serious injuries to bus occupants. During dynamic rollover, total or partial ejection is the major cause of injury. In-depth rollover collision investigation reports often conclude that the ejected occupant would have been less severely injured if he or she had remained in the bus and been retained in their seat.

Frontal collisions are the second most common cause of fatal and serious injuries. The injuries result from ejections and impacts with the interior as well as deformation of the front of the bus. The driver's seating compartment offers little protection in frontal impacts and is often significantly compromised. If the guide is not restrained, he or she is also exposed to a high risk of severe injuries in frontal collisions. In bus collisions, impacts with unpadded interior features are a source of injury. Occupants in the front row of seats often sustain severe impacts with the unpadded separating panel in front of them. Interior roof fixtures in intercity buses often fall during collisions and can cause injuries to occupants.

Intrusion, often as a result of impacts with rigid fixed objects can cause unavoidable serious and fatal injuries.

In all types of collisions, the inability of the seat anchorages to withstand the loading conditions contribute to the severity of the injuries.

12.4 Injury Prevention

Preventing ejections would reduce the risk of serious and fatal injuries in otherwise survivable and even non-injurious collisions. Ejections can be prevented by seat belts. Australian data indicate that the preferred method for controlling the rates of occupant ejection occurring in bus collisions was to improve seat anchorages (ECE 80) and fit three-point belt systems (ADR 66).

Retentive glazing may also reduce the risk of ejection. If laminated windows are used, they need to be used in conjunction with a positive locking window release mechanism and a warning system for the driver.

While compartmentalisation works well in school buses, it depends on some specific features which are not easily introduced into intercity buses. Intercity buses are also characterised by large side windows which can break loose during a collision and deformation of the bus structure, resulting in ejection.

The replacement of the separating panel at the front of the bus with padded seat backs would probably reduce front row passenger injuries.

The need to maintain the security of overhead fixtures during a collision is indicated. There are no standards regarding the security of their attachments or the risk of injury from impacts with these or other add-on fixtures within the bus.

Test work indicates that strengthening of the bus structure would reduce the degree of deformation and intrusion.

12.5 Seat Belts

Full scale and sled tests using instrumented dummies as well as modelling have shown that lap/torso seat belts are highly effective in reducing the likely injuries to bus occupants. Feasible seat systems are now available which allow the fitting of lap/torso seat belts for bus occupants without weight penalty. Through the installation of seat belts in buses, there is also an opportunity for a consistent approach to safety systems for motor vehicle occupants.

The fitting of lap belts is less beneficial and requires significant improvement in the energy-absorption capability of bus interiors. Research indicates that lap belts may increase the risk of head injuries.

Seat belt retrofit experience in Australia and Britain was hampered by poor control and the overall problems suggest it is inadvisable. If retrofit seat belts are used, available floor structure must be strong enough or capable of taking loading.

There are concerns regarding the difficulties of enforcing the use and proper use of seat belts. There are no known seat belt use data.

12.6 Seat and Seat Anchorage Strength

Failure of seats and seat anchorages have been observed in many collisions and indicate the need for a dynamic strength test. There is evidence that the ECE 10 g test requirements are not adequate and it is argued that the 20 g Australian requirement may be too rigorous.

12.7 Rollover Strength

The Australian and ECE rollover strength requirements appear to approximate the mechanism of roof deformation in a 90 degree rollover. Data indicate, however, that many real world rollover collisions are more severe. Further consideration should be given to whether or not current rollover regulations do adequately check the structural integrity of buses. Some deficiencies in ECE Regulation 66 need to be addressed to improve reproducibility and repeatability.

12.8 Emergency Exits

Collision data suggest that the need to retain the occupant in the vehicle supercedes the need for emergency exits. Emergency exits which are not secured against unauthorised use may become a portal for ejection. Testing with subjects indicates that the doors of the bus are most commonly selected as emergency exits and the researchers concluded that emergency exits need to be designed for ease of identification and use.

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APPENDIX A

DEFINITIONS RELATING TO BUSES

DEFINITIONS RELATING TO BUSES

CANADA – FEDERAL

CANADA –TRANSPORT CANADA		
bus	A vehicle having a designated seating capacity of more than 10, but does not include a trailer.	Transport Canada Motor Vehicle Safety Act Motor Vehicle Safety Regulations, Section 2(1)
multipurpose passenger vehicle	A vehicle having a designated seating capacity of 10 or less that is constructed either on a truck-chassis or with special features for occasional off-road operation, but does not include an air cushion vehicle, all-terrain vehicle, golf-cart, passenger car or truck.	Transport Canada Motor Vehicle Safety Act Motor Vehicle Safety Regulations, Section 2(1)
school bus	A bus designed or equipped primarily to carry students to and from school.	Transport Canada Motor Vehicle Safety Act Motor Vehicle Safety Regulations, Section 2(1)
school bus passenger seat	A seat in a school bus, other than the driver's seat or a seat that is installed to accommodate a handicapped or convalescent passenger and is oriented in a direction that is more than 45 degrees to the left or right of the longitudinal centre-line of the vehicle.	Transport Canada Motor Vehicle Safety Act Canada Motor Vehicle Safety Regulations (CMVSR) Standard 222

CANADA – National Safety Code		
commercial vehicle	A truck, tractor, or trailer, or combination thereof exceeding a registered gross vehicle weight of 4,500 kg or a bus designed, constructed and used for the transportation of passengers with a designated seating capacity of more than 10, including the driver, but excluding the operation for personal use.	Canadian Council of Motor Transport Administrators (CCMTA) National Safety Code Standard 14

CANADA - STATISTICS CANADA		
interurban and rural bus transportation	This industry comprises companies primarily engaged in providing passenger transportation principally outside a single municipality and its suburban areas. These companies operate over fixed routes and schedules, and charge a per-trip fee	Statistics Canada - Catalogue no. 53-215 (NAICS 485210; SIC 4572) North American Industry Classification System (NAICS) Standard Industrial Classification 1980 (SIC)
urban transit systems	This industry comprises companies primarily engaged in operating local and suburban mass passenger transit systems. Such transportation may involve the use of one or more modes of transport including light rail, subways and streetcars, as well as buses. These companies operate over fixed routes and schedules, and allow passengers to pay on a per-trip basis, including monthly passes.	Statistics Canada - Catalogue no. 53-215 (NAICS 485110; SIC 4571)

CANADA - STATISTICS CANADA - Cont'd.		
school bus transportation	This industry comprises companies primarily engaged in operating buses and other motor vehicles to transport pupils to and from school. These companies operate over fixed routes and schedules, but do not charge a per-trip fee. Bus services supplied by school boards with their own fleet of vehicles are excluded.	Statistics Canada - Catalogue no. 53-215 (part of NAICS 485410; SIC 4573)
charter bus industry	This industry comprises companies primarily engaged in providing charter bus services. The charter bus companies normally do not operate over fixed routes and schedules, and rent the entire vehicle, with driver.	Statistics Canada - Catalogue no. 53-215 (NAICS 485510; part of SIC 4574)
shuttle services	This industry comprises companies primarily engaged in furnishing passenger transportation by automobile or bus to or from hotels and airports or rail terminals.	Statistics Canada - Catalogue no. 53-215 (part of NAICS 485990; part of SIC 4575)
scenic and sightseeing transportation by bus	This industry comprises companies engaged primarily in providing recreational transportation such as scenic and sightseeing bus transportation. The sightseeing bus companies operate over fixed routes and schedules, and sell individual seats.	Statistics Canada - Catalogue no. 53-215 (part of NAICS 487110; part of SIC 4574)
private carriers	Carriers, for whom transportation is an incidental part of their operations, who use their own or leased vehicles to transport passengers, but do not offer services to the public for compensation.	Statistics Canada - Catalogue no. 53-215

CANADA – CANADIAN STANDARDS ASSOCIATION		
school bus	A specially constructed vehicle that is designed for carrying more than 10 persons. School buses are categorised as follows:	CSA D250-00 School Buses
Type A	A conversion or body constructed upon a cutaway front section vehicle with an original equipment-manufacturer chassis, supplied with a left-side driver's door, designed for carrying more than 10 persons. The service door is behind the front wheels; This definition includes two classifications: (a) Type A1 - a vehicle with a GVWR over 4,536 kg (10,000 lb); and (b) Type A2 - a vehicle with a GVWR 4,536 kg (10,000 lb) or less.	
Type B	A conversion or body constructed and installed upon a van, a front section vehicle chassis, or a stripped vehicle chassis, having a GVWR of more than 4,536 kg (10,000 lb), and designed for carrying more than 10 persons. Most of the engine is beneath and/or behind the windshield and beside the driver's seat. The entrance door is behind the front wheels.	

CANADA – CANADIAN STANDARDS ASSOCIATION - Cont'd.		
Type C	A body installed upon a flat-back cowl chassis, having a GVWR of more than 4,536 kg (10,000 lb), and designed for carrying more than 10 persons. The entire engine is in front of the windshield and the entrance door is behind the front wheels.	CSA D250-00 School Buses
Type D	A body installed upon a chassis with the engine mounted in the front, midship, or rear, having a GVWR of more than 4,536 kg (10,000 lb), and designed for carrying more than 10 persons. The engine may be (a) behind the windshield and beside the driver's seat; (b) at the back of the bus behind the rear wheels; or (c) midship between the front and rear axles. The entrance door is ahead of the front axle.	
over-the-road bus (OTRB)	A vehicle, having a GVWR of 7,000 kg (15,400 lb) or greater, that is designed and manufactured to provide intercity, suburban, commuter, or charter service, and that is primarily equipped with forward or rearward facing seating and dedicated purpose-built baggage/storage capacity.	CSA D-409-02 Motor Vehicles for the Transportation of Persons with Physical Disabilities
transit bus	A vehicle, having a GVWR of 7,000 kg (15,400 lb) or greater, that is designed and manufactured to provide an urban or a suburban transit service, for the primary use of ambulatory passengers and that uses a fare collection system and has no provision for under floor luggage.	
Type E	A multi-purpose passenger vehicle having a GVWR of 4,536 kg (10,000 lb) or less.	

CANADA – PROVINCIAL

CANADA – ALBERTA		
bus	A Type A, Type B, Type C or Type D school bus as described in the CSA standard.	Alberta Regulation 235/82 Highway Traffic Act Bus Safety Regulation
bus	A bus other than a bus used exclusively for personal transportation.	Alberta Regulation 235/82 Highway Traffic Act Bus Safety Regulation Part 3 Compliance with Safety Standards
CSA Std	CSA Standard D250-98 "School Buses" as amended or replaced from time to time and issued by the Canadian Standards Association.	Alberta Regulation 235/82 Highway Traffic Act Bus Safety Regulation

CANADA – BRITISH COLUMBIA		
bus	A motor vehicle of a weight, when unloaded, of more than 2,800 kg, and which is designed, constructed and used for the transportation of more than 9 passengers.	BC Reg. 26/58 Motor Vehicle Act Regulations - Division 6
scheduled bus	A motor vehicle that (a) is available for use by the public, and (b) is operated at any time on a highway over a regular route or between fixed terminating points and on a regular time schedule by, for or on behalf of any person who charges or collects compensation for the transportation of passengers in or on the motor vehicle.	RSBC 1996 Motor Carrier Act Chapter 15
intercity bus	A bus that (a) conforms to the safety standards under the *Motor Vehicle Safety Act* (Canada) that are applicable to "buses" or "school buses" on the date of manufacture, (b) has a gross vehicle weight rating of not less than 9,100 kg, and (c) is operated as either a limited passenger vehicle or a public passenger vehicle under the authority of a licence issued by the Motor Carrier Commission.	BC Reg. 26/58 Motor Vehicle Act Regulations - Division 11
transit bus	A bus operated some or all of the time to provide a regular scheduled public passenger transportation service as specified in an operating agreement made pursuant to the British Columbia Transit Act.	BC Reg. 26/58 Motor Vehicle Act Regulations - Division 11
yellow and black school bus	A bus that on the date of its manufacture conformed to the safety standards under the *Motor Vehicle Safety Act* (Canada) that were applicable to school buses on that date and that meets the requirements of the Minimum Standards for Construction of School Buses Regulation as amended from time to time and the Small School Bus Standards Regulation, B.C. Reg. 542/78, as amended from time to time.	BC Reg. 26/58 Motor Vehicle Act Regulations - Division 11

CANADA – MANITOBA		
bus	A motor vehicle designed for carrying 11 or more persons including the driver, other than a motor vehicle in a public transportation system owned by, or operated on behalf of the City of Winnipeg of the City of Brandon.	Manitoba Regulation 76/94 The Highway Traffic Act C.C.S.M.c.H60
school bus	A vehicle that is designed and classified by the manufacturer as a school bus and used for the purpose of transporting pupils and other authorised persons to or from school or to or from approved school related activities.	The Highway Traffic Act Chapter H60

CANADA – NEW BRUNSWICK		
bus	Any motor vehicle designed for carrying ten or more passengers and used for the transportation of persons.	Motor Vehicle Act Chapter M-17

CANADA – NEWFOUNDLAND		
bus	A vehicle capable of seating 7 or more passengers in addition to the driver.	Motor Carrier Act Chapter M-19 1996 cR-10.1 s50
school bus	A bus as defined in the *Highway Traffic Act* and operated for the transportation of children to or from school or school related activities.	Motor Carrier Act Chapter M-19 1996 cR-10.1 s50
school purpose vehicle	A vehicle owned or operated or contracted to a school board or agent of a school board for the occasional transportation of children to and from extra curricular school related activities but does not include a motor vehicle designed to carry less than 7 passengers in addition to the driver.	Consolidated Newfoundland Regulations 1000/96 Bus Regulations under the Highway Traffic Act O.C. 96-210
bus	A vehicle adapted to carry more than 6 adult passengers in addition to the driver.	City of St. John's Act RSNL 1990 Chapter C-17
bus	A motor vehicle, designed or used for the transportation of passengers with a seating capacity of 10 or more in addition to the driver, but excluding those motor vehicles when used for personal transportation by the owner or with the owner's permission.	Highway Traffic Act RSN 1900 Chapter H-3
commercial motor vehicle	A vehicle designated to carry goods, and includes a bus, a school bus, a truck, a truck tractor and other motor vehicles designed for commercial use but does not include camper type vehicles designed or adapted exclusively for recreational purposes.	Highway Traffic Act RSN 1900 Chapter H-3
school bus	A motor vehicle (i) designed or used to carry 8 or more passengers in addition to the driver, (ii) owned, operated by or contracted to a school board or an agent of a school board, and (iii) used to transport children to or from school or to and from places other than school for the purpose of school related activities.	Highway Traffic Act RSN 1900 Chapter H-3

CANADA – NORTHWEST TERRITORIES		
bus	A motor vehicle with a maximum seating capacity set by the manufacturer of more than 10 persons, including the driver's seat.	Consolidation of Motor Vehicles Act R.S.N.W.T. 1988,c.M-16
NSC vehicle	A commercial vehicle or a public service vehicle that is (a) a truck, etc. (b) a bus, other than a bus operated by the owner exclusively for his or her personal use.	Consolidation of Motor Vehicles Act R.S.N.W.T. 1988,c.M-16
school bus	A motor vehicle used to convey students to or from school or any other place approved by the authority in charge of the school that the students attend where (a) the vehicle is owned or operated by the authority in charge of the school, or (b) the vehicle is operated pursuant to a contract with the authority in charge of the school.	Consolidation of Motor Vehicles Act R.S.N.W.T. 1988,c.M-16
"school bus"	A vehicle operated for conveying students to or from school by or under a contract with the authority in charge of the school or the Department of Education.	Consolidation of School Bus Regulations R.R.N.W.T. 1990,c.M34

CANADA – NOVA SCOTIA		
bus	A motor vehicle operated by or on behalf of a person carrying on upon a highway the business of a public carrier of passengers for compensation and includes any motor vehicle when used for such purpose that the Department shall determine.	Motor Vehicle Act Chapter 293 of the Revised Statutes, 1989
bus	A bus designed, constructed and used for the transportation of passengers with a designated seating capacity of more than ten, including the driver, but does not include a bus when being operated for personal use.	Nova Scotia Reg. 296/90 Commercial Vehicle Maintenance Standards made under Sections 303 and 304 of the Motor Vehicle Act R.S.N.S. 1989, c.293
large school bus	Define "large school bus" in clauses (b) and (c) of subsection (1) hereof as meaning a vehicle designed to transport school children and intended to seat twenty-four or more passengers.	Nova Scotia Reg. 65/74 Equipment Approval Regulations made under Section 200 of the Motor Vehicle Act R.S.N.S. 1989, c.293

CANADA – NUNAVUT		
bus	A motor vehicle with a maximum seating capacity set by the manufacturer of more than 10 persons; including the driver's seat.	Consolidation of Motor Vehicles Act R.S.N.W.T. 1988,c.M-16
NSC vehicle	A commercial vehicle or a public service vehicle that is (a) a truck, etc. (b) a bus, other than a bus operated by the owner exclusively for his or her personal use.	Consolidation of Motor Vehicles Act R.S.N.W.T. 1988,c.M-16

CANADA – NUNAVUT - Cont'd.		
school bus	A motor vehicle used to convey students to or from school or any other place approved by the authority in charge of the school that the students attend where (a) the vehicle is owned or operated by the authority in charge of the school, or (b) the vehicle is operated pursuant to a contract with the authority in charge of the school.	Consolidation of Motor Vehicles Act R.S.N.W.T. 1988,c.M-16
school bus	A vehicle operated for conveying students to or from school by or under a contract with the authority in charge of the school or the Department of Education.	Motor Vehicles Act School Bus Regulations

CANADA – ONTARIO		
bus	A motor vehicle designed for carrying ten or more passengers and used for the transportation of persons.	Highway Traffic Act R.S.O. 1990, c. H-8
school purposes vehicles	A school purposes vehicle is prescribed as a type or class of vehicle to which section 85 of the Act applies while it is being used for the transportation of, (a) six or more adults with a developmental handicap; (b) six or more children; or (c) six or more persons referred to in clause (a) or (b).	Revised Regulations of Ontario Regulation 611 O. Reg. 762/91, s. 1

CANADA – PRINCE EDWARD ISLAND		
bus	Any motor vehicle designed for carrying more than seven passengers and used for the transportation of persons, and any motor vehicle, other than a taxicab, designed and used for the transportation of persons for compensation.	Highway Traffic Act Chapter H-5
school bus	A bus bearing the signs referred to in subsection 202(2) indicating that it is a school bus.	Highway Traffic Act Chapter H-5
commercial vehicle	A commercial vehicle as defined in clause 1(b.2) that has a gross mass exceeding 4,500 kg and includes a bus that has a seating capacity of more than ten passengers.	Highway Traffic Act Chapter H-5

CANADA – QUEBEC		
school bus	A bus or minibus used to carry school children;	Quebec c. C-24.2, r.1.03 Regulation respecting safety standards for road vehicles Highway Safety Code
bus	A road vehicle designed for the transportation of more than 9 occupants at a time and used mainly for that purpose.	Quebec c. C-24.2, r.0.1.2.1 Regulation respecting an agreement between the Gouvernement du Québec and the Government of the State of New York respecting the mechanical inspection of buses Highway Safety Code

CANADA – SASKATCHEWAN		
bus	A vehicle that is designed and used primarily for the movement of people and their personal belongings on a highway and that is over 2060 millimetres in width.	The Vehicle Equipment Regulations, 1987 Chapter V-2.1 Reg 10
school bus	A bus or van operated primarily for the purpose of transporting people to school and registered as Class PS under the Act.	The Vehicle Equipment Regulations, 1987 Chapter V-2.1 Reg 10

CANADA – YUKON		
bus	Having a seating capacity of not more than 24 passengers, excluding the driver.	Motor Vehicle Act C.O. 1978/120

UNITED STATES - Federal

UNITED STATES - FEDERAL MOTOR CARRIER SAFETY ADMINISTRATION		
bus	Any motor vehicle designed, constructed, and or used for the transportation of passengers, including taxicabs.	Code of Federal Regulations Title 49, Volume 4 49CFR390.5
school bus	A passenger motor vehicle which is designed or used to carry more than 10 passengers in addition to the driver, and which the Secretary determines is likely to be significantly used for the purpose of transporting preprimary, primary, or secondary school students to such schools from home or from such schools to home.	Code of Federal Regulations Title 49, Volume 4 49CFR390.5
bus	A vehicle designed to carry more than 15 passengers, including the driver.	Code of Federal Regulations Title 49, Volume 4 49CFR393.5

UNITED STATES – ANSI		
bus	A motor vehicle with motive power (except a trailer) designed to carry more than ten persons.	American National Standard for Safety Glazing Materials for Glazing Motor Vehicles and Motor Vehicle Equipment Operating on Land Highways ANSI/SAE Z26.1-1996
multipurpose passenger vehicle	A motor vehicle with motive power, except a trailer, designed to carry ten persons or less which is constructed either on a truck chassis or with special features for occasional off-road operation	

AUSTRALIA - FEDERAL

AUSTRALIA – ADR		
omnibus	A passenger vehicle having more than 9 seating positions, including that of the driver. An omnibus comprising 2 or more non-separable but articulated units shall be considered as a single vehicle.	Australian Design Rules
light omnibus (MD)	An omnibus with a *Gross Vehicle Mass* not exceeding 5.0 tonnes. Sub-categories:	Australian Design Rules
MD1	up to 3.5 tonnes GVM, up to 12 seats	
MD2	up to 3.5 tonnes GVM, over 12 seats	
MD3	over 3.5 tonnes, up to 4.5 tonnes GVM	
MD4	over 4.5 tonnes, up to 5 tonnes GVM	
MD5	up to 2.7 tonnes GVM	
MD6	over 2.7 tonnes GVM	
heavy omnibus (ME)	An omnibus with a *Gross Vehicle Mass* exceeding 5.0 tonnes.	Australian Design Rules
small omnibus	An omnibus having an occupant capacity of up to 25 persons, including the driver.	ADR 58/00
large omnibus	An omnibus having an occupant capacity of over 25 persons, including the driver.	ADR 58/00
national heavy vehicle dimensions, mass limits & registration charges	Heavy vehicles operating in Victoria, Queensland, South Australia, Northern Territories, Tasmania and the Federal Interstate Registration Scheme (FIRS) are now able to operate at higher mass limits if they have road-friendly suspensions, travel only on approved routes and meet other requirements.	National Road Transport Commission
two axle bus	maximum lass limit: 16 tonnes* annual charge: up to 10t $310 up to 16t $156 width = 2.5m height = 4.3 m length = 12.5 m *the mass of two axle buses complying with particular standards is 16t, (including up to 6.5t on the front axle), otherwise it is 15t.	National Road Transport Commission
three axle bus	maximum lass limit: 22.5 tonnes* annual charge: $1,291 width = 2.5m height = 4.3 m length = 12.5 m *if eight-tyred tandem drive. *if six-tyred tandem drive, maximum mass is 20t for buses complying with particular standards. *note: always check with local road authorities for variation in any of these national standards.	National Road Transport Commission

AUSTRALIA – VICTORIA		
regulation route buses	Route buses, licensed as a public commercial passenger bus providing scheduled services over designated routes, may operate at the mass limits of: front axle: 6t rear axle: 10t gross mass: 16t	Motor Traffic Act of Victoria
buses with added safety features	Buses complying with ADR's 44, 59 & 68 having seat belts rollover protection and emergency exits, and fitted with air suspension on all axles, may operate under a VicRoads' permit at the mass limits of: front axle: 6.5t rear axle: 10t gross mass: 16t six-tyred tandem drive front axle: 6.5t rear axle: 14t gross mass: 20t eight-tyred tandem drive front axle: 6.5t rear axle: 16.5t gross mass: 22.5t	Motor Traffic Act of Victoria

UNITED KINGDOM		
bus	A motor vehicle which is constructed or adapted to carry more than eight seated passengers in addition to the driver.	Road Vehicles Construction and Use Regulations, 1986 SI 1986-1078
minibus	A motor vehicle which is constructed or adapted to carry more than eight but not more than 16 seated passengers in addition to the driver.	Road Vehicles Construction and Use Regulations, 1986 SI 1986-1078
large bus	A vehicle constructed or adapted to carry more than 16 passengers in addition to the driver.	Road Vehicles Construction and Use Regulations, 1986 SI 1987-1133
coach	A large bus with a maximum gross weight of more than 7.5 tonnes and with a maximum speed exceeding 60 mph.	Road Vehicles Construction and Use Regulations, 1986 SI 1987-1133

EUROPE

ECONOMIC COMMISSION FOR EUROPE (ECE)		
Vehicle	A vehicle designed and equipped for the public transport of more than sixteen passengers. There are three Classes of vehicles:	ECE Regulation 36 Large passenger vehicles with regards to their general construction
Class I (see also below)	City buses, a vehicle of this Class has seats and spaces for standing passengers;	
Class II (see also below)	Interurban buses or coaches; a vehicle of this Class may have provision for standing passengers but only in the gangway.	
Class III (see also below)	Touring coaches; a vehicle of this Class has no provision for standing passengers.	
Articulated bus or coach (see also below)	A vehicle which consists of two or more rigid sections which articulate relative to one another; the passenger compartments of each section intercommunicate so that passengers can move freely between them.	ECE Regulation 36 Large passenger vehicles with regards to their general construction
Category M1	Vehicles used for the carriage of passengers and comprising not more than eight seats in addition to the driver's seat.	Working Party on the Construction of Vehicles Annex 7/Rev.2 Classification and definition of power-driven vehicles and trailers
Category M2	Vehicles used for the carriage of passengers, comprising more than eight seats in addition to the driver's seat, and having a maximum mass not exceeding 5 tonnes.	Working Party on the Construction of Vehicles Annex 7/Rev.2 Classification and definition of power-driven vehicles and trailers
Category M3	Vehicles used for the carriage of passengers, comprising more than eight seats in addition to the driver's seat, and having a maximum mass exceeding 5 tonnes.	Working Party on the Construction of Vehicles Annex 7/Rev.2 Classification and definition of power-driven vehicles and trailers
Vehicles of category M2 and M3 belong to:	(i) One or more of the three classes (Class I, Class II, Class III) in accordance with Regulations Nos. 36 and 107. (ii) One of the two classes (Class A, Class B) in accordance with Regulation No. 52.	Working Party on the Construction of Vehicles Annex 7/Rev.2 Classification and definition of power-driven vehicles and trailers
Class I	Vehicles constructed with areas for standing passengers, to allow frequent passenger movement.	
Class II	Vehicles constructed principally for the carriage of seated passengers, and designed to allow the carriage of standing passengers in the gangway and/or in an area which does not exceed the space provided for two double seats.	
Class III	Vehicles constructed exclusively for the carriage of seated passengers.	

ECONOMIC COMMISSION FOR EUROPE (ECE) - Cont'd.		
Class A	Vehicles designed to carry standing passengers; a vehicle of this class has seats and may have provisions for standing passengers.	
Class B	Vehicles not designed to carry standing passengers; a vehicle of this class has no provision for standing passengers.	
Articulated bus or coach	A vehicle which consists of two or more rigid sections which articulate relative to one another; the passengers compartments of each section intercommunicate so that passengers can move freely between them.	Working Party on the Construction of Vehicles Annex 7/Rev.2 Classification and definition of power-driven vehicles and trailers
special purpose vehicle	A vehicle of category M, N or O for conveying passengers or goods and for performing a special function for which special body arrangements and/or equipment are necessary.	Working Party on the Construction of Vehicles Annex 7/Rev.2 Classification and definition of power-driven vehicles and trailers

APPENDIX B

EMERGENCY EXIT REQUIREMENTS IN CANADIAN PROVINCIAL REGULATIONS

EMERGENCY EXIT REQUIREMENTS IN CANADIAN PROVINCIAL REGULATIONS

CANADA - ALBERTA	Alberta Regulation 235/82 Highway Traffic Act Bus Safety Regulation

Schedule 4

1. A bus as defined in section 12.1 of this Regulation must meet the following standards and specifications:
   (a) the main and emergency exits must operate easily and must close securely;
   (b) the emergency door must be unobstructed, and must be easily opened from inside and outside the vehicle;

Schedule 5

12. If an emergency exit is provided in the roof of a handi bus, it must comply with CMVSS 217.

CANADA - BRITISH COLUMBIA	BC Reg. 26/58 Motor Vehicle Act Regulations - Division 6 en. B.C. Reg. 448/87, s.2.

Emergency door

10.10

(1) Subject to section 10.11, every passenger vehicle having a seating capacity including the driver of more than 12 occupants shall be equipped with an emergency exit door,
   (a) located on the left side near the rear of the vehicle, or on the rear of the vehicle,
   (b) and in the case of an emergency door located on the left side of the vehicle, be hinged on its forward vertical edge,
   (c) affording a minimum horizontal clearance of 60 cm, and
   (d) affording the maximum vertical clearance permitted by the body construction of the vehicle.

(2) The emergency door of a passenger vehicle shall be equipped with an opening and fastening device that affords instant and easy release from both inside and outside the vehicle, is safeguarded against accidental release and cannot be operated from the driver's seat.

(3) The emergency door of a passenger vehicle shall be identified by an interior and exterior sign reading "EMERGENCY DOOR" in letters not less than 38 mm in height.

(4) Subsections (1) (a) and (b) do not apply to a special sightseeing bus.

Emergency windows

10.11

(1) The number of emergency exit windows determined in accordance with subsection (2) may be provided in a passenger vehicle in lieu of an emergency exit door if the windows are
   (a) of a push-out type,
   (b) able to be unlatched, opened or removed by the application of manual force from inside the vehicle by a person of average size,
   (c) adequate in size to facilitate the speedy exit of all passengers, and
   (d) identified by an interior sign reading "EMERGENCY EXIT", together with directions as to use in an emergency.

(2) The number of emergency exit windows referred to in subsection (1) shall be determined according to the seating capacity including the driver, as follows:
   (a) seating capacity under 24 - at least one emergency exit window on each side;
   (b) seating capacity 24 to 47 inclusive - at least 2 emergency exit windows on each side;
   (c) seating capacity 48 and over - at least 3 emergency exit windows on each side.

(3) Notwithstanding subsection (2), a special sightseeing bus only requires one emergency exit window on each side on each level.

CANADA - BRITISH COLUMBIA - Cont'd.	BC Reg. 292/89 Motor Vehicle Act Minimum Standards for Construction of School Buses Regulation

Doors - emergency door and window exits

14.

(a) The emergency door shall be located either
  (i) on the left side toward the rear; or
  (ii) in the centre of the rear, provided the bus is equipped with emergency push-out side-window exits in compliance with clause (e). The emergency door shall be hinged so as to open outward. emergency doors shall be equipped with an audible electrical device capable of actuating a horn, bell, or buzzer to warn the driver whenever the locking device is unfastened. A warning light shall be used in conjunction with the audible device, and shall be installed on a panel in front of the driver.

(b) Shall provide an unobstructed opening of not less than 24 inches horizontal clearance and 48 inches vertical clearance; provided that vehicles of panel-delivery type when converted for school bus purposes may be equipped with an emergency door at the rear. This door shall be the door as supplied by the manufacturer of the body, and must be hinged on its vertical edge.

(c) Shall be provided with a latch control approved by the Mechanical Inspector. This control to be of such type as to allow opening of door from inside, or outside, and equipped with fastening device which may be quickly released by so designed as to offer protection against accidental release.

(d) Control from driver's seat shall not be permitted. Provision for opening from outside shall consist of a non detachable device of such design as to prevent "hitching" but permit opening when necessary, and such device must not project beyond the body side.

(e) A school bus equipped with an emergency door located at the rear shall be equipped with emergency push-out side window exits according to the following seating capacities:
  (i) up to 35 passengers one window on each side.
  (ii) 36 to 57 passengers two windows on each side, equally spaced.
  (iii) 58 to 73 passengers three windows on each side, equally spaced.

(f) All emergency push-out side-window exits shall be equipped with a latch control and a warning device capable of warning the driver if the push-out window exit becomes unfastened.

(g) A school bus with a seating capacity in excess of 73 passengers shall be equipped with three emergency push-out side window exits on each side of the bus, equally spaced.

Windows

45.

(a) Shall lower not more than 12 inches from the top only, with exception of emergency door window and window immediately to left of driver.

(d) All windows shall be of laminated safety glass

CANADA - MANITOBA	Highway Traffic Act Chapter H60
no reference to emergency exits	

CANADA - NEW BRUNSWICK	Motor Vehicle Act Chapter M-17
no reference to emergency exits	

CANADA - NEWFOUNDLAND	Highway Traffic Act Bus Regulations
no reference to emergency exits	

CANADA - NORTHWEST TERRITORIES	Northwest Territories Consolidation of School Bus Regulations R.R.N.W.T. 1990, c.M-34

Emergency Exits

8.

(1) Every school bus having a passenger seating capacity exceeding 12 must have an emergency door located in the centre rear or the rear left side of the body.

(2) The emergency door referred to in subsection (1) must be equipped with

  (a) a fastening device to enable it to be opened from inside and outside the body and a safety device to prevent the accidental opening of the door; and

  (b) a buzzer or other audible device that unmistakably warns the driver when the emergency door is not safely closed.

CANADA - NOVA SCOTIA	Nova Scotia Reg. 296/90 Commercial Vehicle Maintenance Standards made under Sections 303 and 304 of the Motor Vehicle Act R.S.N.S. 1989, c.293 Appendix "A" Commercial Vehicle Component Performance Standards

General

1. **Body, sheet metal and equipment**

(n) In the case of a bus other than [a] a passenger vehicle for the physically disabled or [a] bus used for the purpose of transporting prisoners or other persons held in custody, an emergency exit

  (i) that is a door shall have a clear passageway thereto and be located at the rear of the vehicle and the release mechanism when actuated shall function from inside the vehicle as well as from outside the vehicle where fitted with outside release and the door shall open freely and close securely and the emergency door's audible or visible warning device, if originally fitted, shall function properly,

  (ii) that is a hinged pushout window shall be visually inspected to ensure that it opens outward when the release mechanism is actuated and adequate direction for the emergency use thereof shall be displayed on or adjacent to the pushout window and the emergency warning device, if originally fitted, shall function properly, or

  (iii) that is a roof hatch shall open outward when the release mechanism is actuated and a reasonable amount of manual force is applied and adequate direction for the emergency use thereof shall be displayed on or adjacent to the roof hatch.

CANADA - NUNAVUT	Nunavut Consolidation of School Bus Regulations R.R.N.W.T. 1990, c.M-34

Emergency Exits

8.

(1) Every school bus having a passenger seating capacity exceeding 12 must have an emergency door located in the centre rear or the rear left side of the body.

(2) The emergency door referred to in subsection (1) must be equipped with

  (a) a fastening device to enable it to be opened from inside and outside the body and a safety device to prevent the accidental opening of the door; and

  (b) a buzzer or other audible device that unmistakably warns the driver when the emergency door is not safely closed.

CANADA - ONTARIO	Revised Regulations of Ontario Highway Traffic Act Regulation 612 Amended to O. Reg. 307/00

School Buses

3.

(1) No bus shall be operated by or under contract with a school board or other authority in charge of a school to transport adults with a developmental handicap or children and no bus shall be operated unless,

(*i*) it is equipped with at least one door or exit and,

(i) a door or exit for emergency use situated at the rear of the vehicle or near the rear on the left side of the vehicle and which has a door lock equipped with an interior handle which releases the lock when lifted up, or

(ii) subject to subsection (2), at least three pushout windows on each side of the passenger compartment of the vehicle each of which,

(A) has a minimum height of 500 millimetres and a minimum width of 760 millimetres,

(B) is designed, constructed and maintained to open outwards when a reasonable amount of manual force is applied to the inside of the window, and

(C) displays on or adjacent to the window adequate directions for its emergency use.

(2) A motor vehicle that is equipped in accordance with subclause (1) (i) (ii) shall be equipped with an additional pushout window located in the rear of the vehicle.

CANADA - ONTARIO - Cont'd.	Revised Regulations of Ontario Highway Traffic Act Regulation 611 Amended to O. Reg. 330/01 Safety Inspections

Schedule 1 - Inspection Requirements and Performance Standards for Commercial Vehicles and Motor Vehicles, Except Motorcycles - Body Work.

1.

(1) The body, sheet metal and equipment shall be inspected and tested for conditions hazardous to occupants, pedestrians or vehicles and,

(n) in the case of a bus, other than a physically-disabled-passenger vehicle or a bus used for the purpose of transporting prisoners or other persons held in custody, an emergency exit,

(i) if a door, shall have a clear passageway thereto and be located at the rear of the vehicle or near the rear on the left side of the vehicle, and the release mechanism when actuated shall function from inside the vehicle, as well as from outside the vehicle where fitted with outside release, and the door shall open freely and close securely, and the emergency door audible or visible warning device, if originally fitted, shall function,

(ii) if a hinged pushout window, shall be visually inspected to ensure that it should open outwards when the release mechanism is actuated and adequate directions for the emergency use thereof shall be displayed on or adjacent to the pushout window, and the emergency warning device, if originally fitted, shall function,

(iii) if a non-hinged pushout window, shall have adequate directions for the emergency use thereof displayed on or adjacent to the pushout window, and

(iv) if a roof hatch, shall open outwards when the release mechanism is actuated and a reasonable amount of manual force is applied, and adequate directions for the emergency use thereof shall be displayed on or adjacent to the roof hatch.

CANADA - PRINCE EDWARD ISLAND	Highway Traffic Act Chapter H-5
no reference to emergency exits	

CANADA - QUEBEC	Règlement du Québec c. C-24.2, r.1.03 Regulation respecting safety standards for road vehicles Highway Safety Code

Chapter 1, General

54.

Every bus or minibus, excluding those used as police wagons, shall comply with the following standards:

(1) the passageway to the emergency exits shall be free of any encumbrance and, in the case of a vehicle equipped with wheelchair locking devices, allow wheelchairs to move about;

(2) the emergency window shall be securely mounted on its hinges;

(3) he emergency window exit release shall allow the window to be easily opened and closed from inside and, if so designed, from the outside, and the warning light or buzzer shall be adequate;

(4) the hatch of the roof emergency exit shall open outwards easily and adequately; and

(5) the signs provided by the manufacturer with respect to emergency exits shall be present and legible.

CANADA - SASKATCHEWAN	The Vehicle Equipment Regulations, 1987 Chapter V-2.1 Reg 10

Part III - Type A Vehicles

Exits

54.

(1) The vehicle shall have at least two passenger compartment exits, located one on each side of the vehicle.

(2) One passenger exit may be a window with an opening of not less than 400 millimetres by 400 millimetres.

CANADA - YUKON	Motor Vehicles Act Motor Vehicle Regulations
no reference to emergency exits	

APPENDIX C

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BIBLIOGRAPHY

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APPENDIX D

LIST OF PRIMARY CONTACTS

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Tel: (613) 238-1800
Tel: 1-800-600-6824
www.buscanada.ca

Canadian Council of Motor Transport Administrators (CCMTA)
2323 St. Laurent Blvd.
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Tel: (613) 736-1003
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Canadian Standards Association (CSA)
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Canadian Statutes and Regulations
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Fernand Roy
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www.girardin.com

Greyhound Bus Lines
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16th Street S.W.
Calgary, Alberta T3C 3V7
Tel: (403) 260-0611
www.greyound.ca

Industry Canada
Tel: 1-800-328-6189
strategis.ic.gc.ca

Insurance Corporation of British Columbia
John Gane, Manager
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Insurance Corporation of British Columbia
1575 Hartley Ave.
Coquitlam, B.C. V3K 6Z7
Tel: (604) 661-2800
Tel: 1-800-663-3051
www.icbc.com

Motor Coach Industry (MCI)
Paul Murphy
Regulatory Complaints
1475 Clarence Avenue
Winnipeg, Manitoba
Tel: (204) 284-5360
www.mcicoach.com

Multina Inc.
214, 19e Avenue
Drummondville, Quebec J2B 3V5
Tel: (819) 474-6930
www.multina.com

Ontario Motor Coach Association
441 Yonge Street
Toronto, Ontario M2P 2A8
Tel: (416) 229-6622
www.omca.com

Pacific Coach Lines
Ken Weeks
Operations Manager
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Vancouver, B.C. V6A 4C7
Tel: (604) 662-7575
www.pacificcoach.com

Prévost Car
35 Gagnon Boulevard
Ste-Claire, Quebec G0R 2V0
Tel: (418) 883-3391
www.prevostcar.com

Quebec Bus Owners Association
Jacques Guay, Executive VP
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Quebec City, Quebec G1K 3G9
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www.apaq.qc.ca

Standards Council of Canada (SCC)
270 Albert Street, Suite 200
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Tel: (613) 238-3222
www.scc.ca/standards

Statistics Canada
Robert Laroque
Transportation Division
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www.statcan.ca

Transportation Development Centre (TDC)
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Traffic Injury Research Foundation of Canada (TIRF)
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Parts & Warranty
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Center for Advanced Product Evaluation (CAPE) A Division of IMMI
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IMMI Child Restraints
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Australian Bureau of Statistics (ABS)
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www.trl.co.uk/vehicle.htm

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APPENDIX E

SUMMARY OF REGULATIONS APPLICABLE TO BUS OCCUPANT PROTECTION

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CMVSS 201 - Occupant Protection

Purpose: To minimise the severity of head and other contacts which might be made by vehicle occupants with the interior of the vehicle.

Applicability: Buses with GVWR of 4,536 kg (10,000 lb) or less.

CMVSS 202 - Head Restraints

Purpose: To reduce the frequency and severity of the hyper-extension type of neck injuries suffered in rear-end collisions.

Applicability: Buses with GVWR of 4,536 kg (10,000 lb) or less.

CMVSS 203 - Driver Impact Protection

Purpose: To reduce the frequency and severity of chest injuries sustained by drivers who strike the steering system in frontal collisions.

Applicability: Buses with a GVWR of 4,536 kg (10,000 lb) or less. Does not apply to vehicles that meet the frontal crash requirements of CMVSS 208 by means other than seat belt assemblies.

CMVSS 204 - Steering Column Rearward Displacement

Purpose: To reduce the incidence and severity of injuries caused by the steering column in frontal collisions.

Applicability: Buses having a GVWR of 4,536 kg (10,000 lb) or less.

CMVSS 205 - Glazing Materials

Purpose: To reduce the incidence and severity of injuries sustained by occupants who come in contact with glazed interior surfaces during a collision.

Applicability: Multipurpose passenger vehicles

CMVSS 207 - Anchorages of Seats

Purpose: To reduce the frequency and severity of injuries caused by seat anchorage failures.

Applicability: Driver seat only (excludes bus passenger seats).

CMVSS 208 – Occupant Restraint Systems in Frontal Impact

Purpose: To reduce injuries sustained in frontal collisions through the installation of restraint systems meeting the dynamic criteria.

Applicability: Every bus that has a GVWR of 4,536 kg (10,000 lb) or less, other than a school bus, shall be equipped at each forward-facing rear outboard designated seating position with a Type 2 seat belt assembly.

A bus that has a GVWR greater than 4,536 kg (10,000 lb) shall be equipped at the driver's seating position with a Type 1 or Type 2 seat belt assembly.

CMVSS 209 - Seat Belt Assemblies

Purpose: To minimise the possibility of seat belt failure during a collision.

Applicability: Every seat belt assembly with which a vehicle is equipped.

CMVSS 210 - Seat Belt Assembly Anchorages

Purpose: To minimise the possibility of a seat belt anchorage failing during a collision and to specify the anchorage locations.

Applicability: Every designated seating position fitted with a seat belt assembly, seat belt anchorages need not be installed for a passenger seat in a bus.

CMVSS 212 - Windshield Mounting

Purpose: To minimise the possibility of ejection through the windshield area.

Applicability: Buses with GVWR of 4,536 kg (10,000 lb) or less.

CMVSS 213.4 - Built-in Child Restraint Systems and Built-in Booster Cushions

Purpose: To provide protection to children weighing over 9 kg (20 lb) involved in motor vehicle collisions.

Applicability: Every built-in child restraint system and built-in booster cushion.

CMVSS 214 - Side Door Strength

Purpose: To provide protection to the occupants of a vehicle when it is struck in the side.

Applicability: Buses with a GVWR 4,536 kg (10,000 lb) or less

CMVSS 216 - Roof Intrusion Protection

Purpose: To protect vehicle occupants in collisions involving rollover by specifying roof strength requirements.

Applicability: Buses with a GVWR 2,722 kg (6,000 lb) or less, except school buses.

CMVSS 217 - Bus Window Retention, Release and Emergency Exits

Purpose: To minimise the possibility of ejection through bus windows and to specify emergency exit requirements.

Applicability: Buses

CMVSS 219 - Windshield Zone Intrusion

Purpose: To minimise the intrusion of the vehicle's hood into the windshield area during a frontal impact and hence reduce the possibility of injuries to the front seat occupants.

Applicability: Buses with a GVWR of 4,536 kg (10,000 lb) or less.

CMVSS 220 - Rollover Protection

Purpose: To protect school bus occupants in rollovers by establishing a roof strength requirement.

Applicability: School buses

CMVSS 221 - School Bus Body Joint Strength

Purpose: To minimise the potential for injury caused by riveted joints on the interior surface of school bus separating and exposing sharp edges in a collision.

Applicability: School buses

CMVSS 222 - School Bus Passenger Seating & Crash Protection

Purpose: To protect the occupants of a school bus involved in a collision by containing them between the seats or between the seat and a barrier ahead of the seat.

Applicability: School buses

FMVSS

with respect to buses they are essentially the same as CMVSS, except for:

every bus manufactured on or after 1 July 1971 must also conform to requirements of FMVSS 208 (571.208, relating to installation of seat belt assemblies) and FMVSS 210 (571.210, relating to installation of seat belt assembly anchorages);

every bus manufactured on or after 1 January 1972 must conform to the requirements of FMVSS 207 (571.207, relating to seating systems).

ADR 3 - Seats and Seat Anchorages

Purpose: To specify requirements for seats, their attachment assemblies and their installation to minimise the possibility of occupant injury due to forces acting on the seat as a result of vehicle impact.

Applicability: Light omnibus up to 3.5 t GVM.

ADR 4 - Seat Belts

Purpose: To specify requirements for seat belts to restrain vehicle occupants under impact conditions, facilitate fastening and correct adjustment, assist the driver to remain in his seat in an emergency situation and thus maintain control of the vehicle, and protect against ejection in a collision situation.

Applicability: Light omnibus (MD) manufactured on or after 1 January 2000.
Heavy omnibus (ME) manufactured on or after 1 January 2000.
Only the driver's seat belt, for omnibuses complying with ADR 68, is required to comply with the detailed requirements for vehicle categories MD3, MD4 and ME, corrosion conditioning procedure and adjustment requirements for vehicle categories MD3, MD4 and ME.

ADR 5 - Anchorages for Seatbelts and Child Restraints

Purpose: To specify requirements for anchorages for both seatbelt assemblies and child restraints so that they may be adequately secured to the vehicle structure or seat and will meet comfort requirements in use.

Applicability: Only the driver's seat, for omnibuses complying with ADR 68, is required to comply with the seat belt anchorage requirements.

ADR 8 - Safety Glazing Material

Purpose: To specify the performance requirements of material used for external or internal glazing in motor vehicles which will ensure adequate visibility under normal operating conditions, will minimise obscuration when shattered, and will minimise the likelihood of serious injury if a person comes in contact with the broken glazing material.

Applicability: Light omnibus (MD), manufactured on or after 1 July 1994.
Heavy omnibus (ME), manufactured on or after 1 July 1994.

ADR 44 - Specific Purpose Vehicle Requirements

Purpose: To specify requirements for construction of emergency exits for omnibus, MD3, MD4 and ME vehicles designed for more than 16 passengers in addition to the driver and crew.

Applicability: Light omnibus (MD), manufactured on or after 1 July 1993
- up to 3.5 tonnes 'GVM', up to 12 seats (MD1)
- up to 3.5 tonnes 'GVM', over 12 seats (MD2)
- over 3.5 tonnes, up to 4.5 tonnes 'GVM' (MD3)
- over 4.5 tonnes, up to 5 tonnes 'GVM' (MD4).

Heavy Omnibus (ME), manufactured on or after 1 July 1993.

ADR 58 - Requirements for Omnibuses Designed for Hire and Reward

Purpose: To specify requirements for the construction of omnibuses designed for, and intended for licensing for hire and reward.

Applicability: Light Omnibus (MD), manufactured on or after 1 July 1988
- (MD1) $\leq$ 3.5t 'GVM', $\leq$ 12 seats
- (MD2) $\leq$ 3.5t 'GVM', > 12 seats
- (MD3) > 3.5t $\leq$ 4.5t 'GVM'
- (MD4) > 4.5t, $\leq$ 5t 'GVM'.

Heavy Omnibus (ME), on or after 1 July 1988.

ADR 59 - Omnibus Rollover Strength

Purpose: To specify the strength of an omnibus superstructure to withstand forces encountered in rollover crashes.

Applicability: Light Omnibus (MD)
- up to 3.5 tonnes 'GVM', up to 12 seats (MD1)
- up to 3.5 tonnes 'GVM', over 12 seats (MD2), manufactured on or after 1 July 1993
- over 3.5 tonnes, up to 4.5 tonnes 'GVM' (MD3), manufactured on or after 1 July 1993
- over 4.5 tonnes, up to 5 tonnes 'GVM' (MD4), manufactured on or after 1 July 1993.

Heavy Omnibus (ME), manufactured on or after 1 July 1992.
ME category vehicle "Route Service Omnibuses" need not comply with this rule until 1 July 1993.

Omnibuses are not required to comply if given percentage of the area of the upper surface of the floor measured between its "Axles" is not more than 550 mm above the ground.

ADR 66 - Seat Strength, Seat Anchorage Strength and Padding in Omnibuses

Purpose: To specify requirements for the strength of seats, seat anchorages and seat belt anchorages of certain omnibuses and for protecting occupants from accessories on the seats and the armrests. The rule includes requirements for both the seats themselves and for vehicles fitted with seats.

Applicability:
Light Omnibus (MD)
- up to 3.5 tonnes 'GVM', up to 12 seats (MD1)
- up to 3.5 tonnes 'GVM', over 12 seats (MD2)
- over 3.5 tonnes, up to 4.5 tonnes 'GVM' (MD3), manufactured on or after 1 Jan. 1993
- over 4.5 tonnes, up to 5 tonnes 'GVM' (MD4), manufactured on or after 1 Jan. 1993.

Heavy Omnibus (ME), manufactured on or after 1 July 1992.
Does not apply to "Route Service Omnibuses" or omnibuses with less than 17 seats including the driver and crew, or vehicles in which all passenger seats have a reference height of less than 1.0 metre.
Omnibuses complying with ADR 68 need not comply with this rule.

ADR 68 - Occupant Protection in Buses

Purpose: To specify, for certain omnibuses, requirements for seat belts, the strength of seats, seat anchorages, seat belt anchorages and child restraint anchorages, and provisions for protecting occupants from impact with seat backs and accessories on seats and armrests.

Applicability:
Light Omnibus (MD)
- up to 3.5 tonnes 'GVM', up to 12 seats (MD1)
- up to 3.5 tonnes 'GVM', over 12 seats (MD2)
- over 3.5 tonnes, up to 4.5 tonnes 'GVM' (MD3), manufactured on or after 1 July 1995
- over 4.5 tonnes, up to 5 tonnes 'GVM' (MD4), manufactured on or after 1 July 1995.

Heavy Omnibus (ME), on or after 1 July 1994.
Does not apply to "Route Service Omnibuses" or omnibuses with less than 17 seats including the driver and crew, or vehicles in which all passenger seats have a reference height of less than 1.0 metre.

ECE Regulation 14 – Uniform Provisions Concerning the Approval of Vehicles With Regard to Safety Belt Anchorages

Purpose: To specify, in particular, the strength requirements for seat belt anchorages.

Applicability: Anchorages for safety-belts for adult occupants of forward-facing seats in vehicles of category M.

ECE Regulation 16 – Uniform Provisions Concerning the Approval of Safety-Belts and Restraint Systems for Occupants of Power-Driven Vehicles and Vehicles Equipped with Safety-Belts

Purpose: To assure the satisfactory operation of the belt or restraint system (when correctly installed and properly used) and that it reduces the risk of bodily injury in the event of a collision.

Applicability: Safety-belts and restraint systems in power-driven vehicles with three or more wheels.

ECE Regulation 36 – Uniform Provisions Concerning the Approval of Large Passenger Vehicles With Regard to their General Construction

Purpose: To specify requirements for general construction including some relating to bus occupant safety notably protection against fire risks, exits and interior arrangements (access to emergency exits).

Applicability: Single-deck rigid or articulated vehicles designed and constructed for the carriage of persons and having the capacity in excess of 16 passengers, whether seated or standing, in addition to the driver, and having an overall width exceeding 2.30 metres.

ECE Regulation 66 – Uniform Provisions Concerning the Approval of Large Passenger Vehicles With Regard to Strength of Superstructure

Purpose: To determine that the superstructure of the vehicle shall be of sufficient strength such that when subjected to one of the prescribed tests or calculations, no displaced part of the vehicle intrudes into the defined “residual space” of the passenger compartment and no part of the residual space shall project outside the deformed structure.

Applicability: Single-decked vehicles constructed for the carriage of more than sixteen passengers, whether seated or standing, in addition to the driver and crew.

ECE Regulation 80 – Uniform Provisions Concerning the Approval of Seats of Large Passenger Vehicles and of these Vehicles With Regard to Strength of Seats and their Anchorages

Purpose: To specify that the seat occupants are correctly retained by the seats in front of them and not seriously injured. To specify the strength of the seat and seat mountings.

Applicability: Vehicles constructed for carriage of more than sixteen passengers, in addition to the driver and crew.