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Safe Integration of Electric Low Speed Vehicles on Ontario's Roads in Mixed Traffic

Prepared for:

Ontario Ministry of Transportation (MTO)
Building "A", Room 212
1201 Wilson Avenue
Downsview, Ontario M3M 1J8

Prepared by:

C.V. Tabra, P. Eng.

Project 54-F3808

Technical Report | Rapport technique

November 24, 2008 | CSTT-HVC-CTR-074

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Any mention of specific vehicle make, model or brand in this document is done so as a means to present factual information that was obtained from publicly available sources. Neither vehicle testing nor model-to-model comparisons were conducted by NRC-CSTT as part of this study. As such, no comment is made on the suitability of any particular vehicle for any particular application, use or task.

ABSTRACT

An eight-week study was conducted by NRC-CSTT to identify the risks associated with the introduction of Low Speed Vehicles (LSVs) on Ontario's public roads in mixed traffic. Based on the survey of U.S. and Canadian jurisdictions, information gathered from publicly available sources, reports from subject matter experts and data analysis, NRC-CSTT identified risks and recommended mitigating strategies as they relate to safely integrating LSVs into mixed traffic on Ontario's public roads. Mitigating strategies for risks associated with LSV safety features, additional road infrastructure enhancements and initiatives to increase public awareness of LSV features have also been proposed.

EXECUTIVE SUMMARY

The Ontario Ministry of Transportation has retained the National Research Council of Canada (NRC), as represented by the Centre for Surface Transportation Technology (CSTT) to undertake an independent, third-party investigation into how Low Speed Vehicles (LSVs) can be safely integrated into mixed traffic on Ontario's public roads.

LSVs are currently allowed on public roads in many states in the United States of America, and in British Columbia, and Québec, either relatively freely or in pilot projects under various sets of rules. The Ontario Ministry of Transportation is considering allowing LSVs on public roads, and has asked NRC-CSTT to identify the risks, and to provide strategies for mitigating risks associated with:

- safely integrating LSVs for operation in mixed traffic on public roads in Ontario; and
- continued safe operation of LSVs in mixed traffic following their introduction onto public roads in Ontario.

In this eight-week study, NRC-CSTT performed a background investigation and data collection effort on LSV usage in North America, and to a lesser extent, Europe. The background investigation involved a thorough web-based search and review of publicly available information. Representatives from Canadian and U.S. LSV manufacturers, government and non-governmental organizations, insurance companies and other parties of interest such as police officers and bus drivers were also interviewed. Finally, additional subject matter experts were retained to provide further insight into issues surrounding human factors, traffic flow and traffic safety.

Risks have been identified in seven areas related to traffic flow, human factors, traffic safety, LSV equipment, road infrastructure, licensing and operating restrictions.

Risks related to traffic flow

- as the density of LSVs on public roads increases, the 40 km/h maximum speed capability of the vehicles may impede traffic flow.

Risks related to human factors

- drivers of other vehicles may expect LSVs to perform like typical passenger cars on public roads, which may increase the potential for collisions when they do not;
- it may be difficult for drivers of other vehicles to detect large closing speed differences with LSVs, which may increase the potential for rear-end collisions;
- drivers of other vehicles may exhibit aggressive driving behaviour due to slower moving traffic caused by LSVs; and
- the lack of noise generated by LSVs may result in increased collisions with both pedestrians (in particular, the visually impaired) and cyclists.

Risks related to traffic safety

- there may be a substantially higher driver injury and fatality rate amongst LSV operators due to the relatively low mass of LSVs compared to other vehicles on public roads;

- LSVs may be unable to clear a red or yellow light in the signal times typically allocated for clearance on public roads; and
- there may be an increased occurrence of collisions between 40 km/h LSVs and other vehicles travelling at higher speeds on public roads due to large differentials in speed.

Risks related to LSV equipment

- LSVs may not comply with some of Ontario's motor vehicle equipment standards and therefore may not have adequate braking, lighting, etc.;
- the crashworthiness of LSVs is unknown, and may be very low;
- the LSVs identified in this study do not have airbags and may cause serious injury to occupants;
- the performance of the seat belt assembly anchorage in LSVs is unknown. The seat belt assembly anchorage may fail in accidents;
- LSV operators or first responders may be injured while handling lead-acid batteries that have been damaged in a crash;
- the LSVs identified in this study do not have daytime running lights and thus it may be difficult for other drivers to see them;
- an LSV operator may try to install a child seat in an LSV when there is no provision for such seats. This could result in seat failure and serious injury or death to the child in a severe crash;
- on some LSV models, it is possible to conduct vehicle modifications to achieve speeds greater than 40 km/h, resulting in a greater severity of collision should a collision occur;
- some LSVs identified in this study do not have back-up warning systems;
- the EMC at the vehicle level of the LSVs identified in this study is unknown, and may cause erratic behaviour of electronic systems in other automobiles; and
- towing a trailer using an LSV may be unsafe.

Risks related to road infrastructure

- the existing road connectivity may limit LSV drivers to operating in a confined area. This could result in LSV operators eventually taking unsafe risks and driving on higher speed roads; and
- dedicated LSV lanes could be blocked or partially blocked by snow during the winter, and by debris or inoperable vehicles at any time, forcing LSV operators to drive in the higher-speed lanes.

Risks related to licensing and disclosure documents

- if LSVs are licensed as passenger cars, it may be difficult to collect collision data for statistical purposes;
- LSVs may be operated by drivers who possess a lower-class driver's license. These drivers tend to have less experience and may not be aware of the safety risks to which they expose themselves; and
- if a "Notice of Limitations" document is not presented to prospective clients during the sale process, they may not be aware of the performance limitations and reduced safety features of the vehicle.

Risks related to operating restrictions

- LSVs' operating performance in winter conditions is not well understood. The increased need for use of ventilation, heating and defrosting systems and the low ambient temperatures may significantly affect the operating range (distance) of the vehicle. Thus, LSV operators may become stranded with little or no warning, depending on the LSV's power management system performance. The major risk though is that LSV owners may start trading safety features such as heating and defrosting for operating range;
- LSVs may be difficult to see in the dark by other motorists and pedestrians/cyclists, as the lighting system may not provide adequate conspicuity;
- LSVs may be tightly restricted due to a lack of road connectivity and the existence of linear barriers. LSV owners may venture onto roads with higher speed limits, or other roads where LSVs are not allowed to operate; and
- if the density of LSVs on public roads is high, traffic congestion may become a concern in larger cities with dense transit networks.

Mitigating strategies have been identified for risks in four areas: safely integrating LSVs into mixed traffic on Ontario's public roads; additional LSV safety features; additional road infrastructure enhancements; and initiatives to increase public awareness of LSV features.

Safe integration of LSVs into mixed traffic on Ontario's public roads

To minimize the safety risks associated with integrating LSVs into mixed traffic on Ontario's public roads, the following recommendations are put forth:

- LSVs should be equipped, at minimum, with the same features as those that are required by the 2008 MTQ pilot project;
- LSVs should demonstrate compliance with the applicable sections of the Ontario motor vehicle equipment standard, such as Section 62, Lamps, Section 64, Brakes, Section 69, Tires and Wheels and Section 72, Safety Glass (Highway Traffic Act, R.S.O. 1990, Chapter H.8, Part VI).;
- LSVs should be licensed as passenger cars;
- MTO should initially allow only G class or higher-class licensed drivers to operate LSVs on public roads;
- MTO should require that LSV buyers sign a "Notice of Limitations" document at the time of sale that explains what are the LSVs' performance and safety limitations;
- LSVs should only be operated on a public road when the posted or un-posted speed limit of that road is not greater then 50 km/h, except when municipalities impose prohibitions on those roads;
- LSVs should only be driven across a road with a posted or un-posted speed limit greater than 50 km/h at an intersection where there is a traffic light, or all-direction stop signs are present;
- MTO may grant the municipalities the authority to impose further restrictions on LSVs use, such as permitting LSVs only where the projected future average daily traffic is less than a predetermined threshold;
- where key road sections in a desired road network would preclude LSV use because of anticipated congestion concerns, municipalities should consider filling those gaps by use of a separate right-of-way or separated, adjacent LSV/bicycle lanes;
- where LSVs are permitted to operate on four-lane roads, the LSV driver must drive in the right lane, except if making a left turn;

- MTO and municipalities should reject all requests to allow LSVs to travel in mixed traffic on roads with a speed limit greater than 50 km/h;
- Ontario provincial legislation should be updated to include a regulatory provision prohibiting modification or tampering with the maximum speed control or limiter of LSVs; and
- the transportation of infants and children in an LSV on public roads should not be allowed if the infants or children would be required to use infant or child seats in a regular passenger vehicle.

Additional LSV Safety Features

It is recommended that, as a minimum, MTO consider requiring additional LSV safety features such as seat belt anchors compliant with CMVSS 210. In addition, LSVs should meet the applicable crashworthiness occupant protection standards defined by CMVSS in the 200 series, such as CMVSS 201 “Occupant Protection”, CMVSS 206 “Door Locks and Door Retention Components”, CMVSS 214 “Side Door Strength” and CMVSS 216 “Roof Intrusion Protection”.

To enhance LSV conspicuity, it is recommended that:

- LSVs be equipped with daylight running lights compliant to CMVSS 108;
- the slow-moving vehicle emblem, already required by federal regulations, be added to the sides of the vehicle;
- the maximum speed of 40 km/h be marked on the back of the LSV, similar to the marking used for the 2008 Québec pilot project; and
- LSVs be fitted with equipment capable of emitting an audible signal for pedestrians.

Additionally, it is recommended that LSVs meet appropriate electromagnetic compatibility standards.

Additional Road Infrastructure Enhancements

It is recommended that:

- road infrastructure improvements be addressed by municipalities as part of their transportation planning process. To be cost effective, such initiatives should be supported by the density of LSVs and complementary infrastructure upgrades, such as dedicated parking spaces and charging stations;
- LSVs routes should be developed prior to allowing LSVs on public roads. The routes may consist of existing roads and newly created road infrastructure, such as dedicated LSV lanes;
- changes in traffic signal phasing be considered to accommodate these slower vehicles, should the density of LSVs in a given area become significant;
- route planning address limitations to LSV use imposed by linear barriers;
- adjacent municipalities coordinate LSV routes to allow LSVs to travel across their common boundaries;
- provincial standards for LSV-related signs and pavement markings be developed for use throughout the province; and
- large municipalities with dense bus networks and frequent bus service consider carefully whether it would be appropriate to allow LSVs on bus routes.

Initiatives to increase public awareness of LSV features

To increase public awareness of LSV features, it is recommended that:

- the public be informed of their crashworthiness and operating limitations through public information campaigns;
- public information campaigns explain the meaning of the SMV emblem on LSVs;
- MTO consider conducting awareness campaigns aimed at firefighters, paramedics and other collision response personnel, to inform them about the particular features of LSVs and the potential risks posed by battery electrolyte spillage;
- MTO consider organizing, in collaboration with LSV manufacturers, test driving campaigns on closed courses, under various weather conditions, to allow potential LSV owners to better understand the performance and limitations of such vehicles; and
- LSVs have a clear warning sign affixed inside the vehicle in a highly visible location to alert the potential buyers of significant risk exposure due to lack of safety features.

In addition to the risk mitigating strategies outlined above, it is strongly recommended that further analysis be performed on CMVSS standards to determine their applicability to the safe operation of LSVs in mixed traffic on public roads.

It is recommended that MTO undertake a pilot project with a wider scope than that currently being run in Ontario. The Québec pilot project, which allows the operation of what will likely be a larger sample size of LSVs, and on carefully selected public roads, appears to be a good model to follow, but still would require tailoring to Ontario's unique requirements.

It is recommended that the pilot project be developed by city professionals, including experts in traffic signals, safety, planning, emergency services and driver and public education, in conjunction with experts in test program development to ensure complete and relevant data are collected and analyzed. This pilot project would be expected to lead to a better understanding of the safety issues associated with operating on public roads in mixed traffic and would help to develop LSV policies that are appropriate for Ontario, such as: operation in the slow lane only, marked lanes and times of operation in the urban network (during day and night and specific months of the year). It would also lead to consideration of traffic signalization and warrants for special timing and phasing for LSV needs.

MTO may also want to consider, either during a pilot project and/or during an eventual full integration of LSVs on public roads, harmonization of LSV policy, operating restrictions and safety requirements with neighboring jurisdictions, in particular Québec, New York state and Michigan.

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ACKNOWLEDGEMENTS

The author wishes to thank the following organizations, who provided information for the study:

- Ontario Ministry of Transportation (MTO)
- Ministère des Transports du Québec (MTQ)
- Transport Canada Safety Programs Branch
- Canadian Council of Motor Transport Administrators (CCMTA)
- Transportation Association of Canada (TAC)
- Insurance Bureau of Canada (IBC)
- Insurance Corporation of British Columbia (ICBC)
- Société de l'Assurance Automobile du Québec (SAAQ)
- Electric Mobility Canada (EMC)
- Manitoba Public Insurance (MPI)
- Canadian Automobile Association (CAA) – Québec
- Ontario Provincial Police (OPP)
- City of Ottawa (OC Transpo)
- City of Ottawa (Police Service)

- District of Oak Bay, British Columbia
- City of Lincoln, California
- Borough of Belmar, New Jersey
- City of Brillion, Wisconsin
- City of Chicago Water District, Illinois

- ZENN Motor Company Limited
- NEMO Vehicles Inc
- Dynasty Electric Car Corporation
- Miles Electric Vehicles
- Autoco Motorsports

1 INTRODUCTION

1.1 Background

Golf carts, modified golf carts, and a range of other vehicles have become widely used in temperate areas of the United States as a means of local transportation for residents of gated communities such as country clubs and retirement homes. Some municipalities provide these vehicles access to shopping and other services outside their communities. Pressure within the U.S. to improve these vehicles so that they could use public roads led the National Highway Traffic Safety Administration (NHTSA) to define the class of Low Speed Vehicle (LSV) in June 1998, and to set a Federal Motor Vehicle Safety Standard (FMVSS) for it [1].

The situation in Canada is different, as gated communities are neither so large nor so popular as in the U.S., and golf carts are not compatible with Canadian winters. Nevertheless, an electric LSV manufacturing industry has developed in Canada, and Transport Canada created a definition and standard for low speed vehicles in July 2000 [2]. A low-speed vehicle (LSV) in Canada is defined [3] as a vehicle that:

- is designed for use primarily on streets and roads where access and the use of other classes of vehicles are controlled by law or agreement;
- travels on four wheels;
- is powered by an electric power train;
- has a maximum speed of 40 km/h;
- does not use fuel as an on-board source of energy; and
- has a Gross Vehicle Weight Rating (GVWR) less than 1,361 kg.

Although the LSV vehicle class has existed since July 2000, most Canadian provinces have not implemented legislation that would allow LSVs to operate on public roads, though pilot or demonstration projects have been authorized, and a number have been undertaken.

Ontario has an ongoing pilot project operating LSVs in provincial and municipal parks and conservation areas, but does not allow them on public roads because these vehicles do not meet federal safety standards for passenger cars. The Ontario government is committed to improving air quality, and has launched a program to help innovative companies create well-paying sustainable jobs, including those that reduce energy consumption and carbon emissions. Transportation Minister Jim Bradley recently announced: "We want low-speed electric vehicles on our roads, and we are looking at how it can be done safely. Additional safety features may be necessary, and …. I look forward to getting these vehicles on the road."[4]

1.2 Purpose

The Ontario Ministry of Transportation (MTO) has retained the National Research Council of Canada (NRC), as represented by the Centre for Surface Transportation Technology (CSTT), hereafter known as NRC-CSTT, to undertake an independent, third-party investigation into how LSVs can be safely integrated into mixed traffic on public roads. In particular, MTO would like to identify the safety risks associated with the use of LSVs on public roads, as well as recommended strategies for mitigating these risks.

This study is not intended to investigate whether LSVs should be integrated onto Ontario roads in mixed traffic, but rather to help MTO make key decisions surrounding the introduction of these environmentally friendly, zero emission vehicles while at the same time maximizing operator safety and the safety of other road users.

1.3 Objective

The objective of this study is to identify, and to provide strategies for, mitigating the risks associated with:

- safely integrating LSVs for operation in mixed traffic on public roads in Ontario; and
- continued safe operation of LSVs in mixed traffic following their introduction onto public roads in Ontario.

1.4 Limitations

Risks and proposed mitigating strategies are based on previous relevant work, currently available information with respect to LSV technology, and existing Canadian federal and provincial legislation.

Content from subject matter expert reports commissioned by NRC-CSTT has been used throughout this report, and when so used, expresses the opinion of the NRC-CSTT author. The complete reports received from the subject matter experts are included as appendices and represent solely the opinions of the respective experts.

This report does not address any need for changes to law or regulations to allow use of LSVs on public roads. It is presumed that the Ministry of Transportation will determine the legal steps necessary once it has decided what it will do.

2 METHODOLOGY

NRC-CSTT performed a background investigation and data collection effort on LSV use in North America. LSV use in Europe was also investigated, but with a more limited scope.

A multi-faceted approach was used, employing a thorough web-based search and review of publicly available information, while also conducting interviews and consulting with subject matter experts. The interviews were carried out by e-mail or telephone, as required. The interviewees included representatives from Canadian and U.S. LSV manufacturers, government and non-governmental organizations, insurance companies and other parties of interest such as police officers and bus drivers. Subject matter experts were retained to provide reports in their respective fields of expertise, as applicable to this study.

The background investigation and data collection exercise was conducted with two specific goals:

- to produce a synopsis of present LSV regulation and use in order to identify any safety-related issues; and

- to determine how LSV use is evolving in order to produce a forward-looking image of the future of LSV use in Ontario.

During the data collection exercise, emphasis was placed on a number of factors, which included:

- human factors, particularly involving how drivers of LSVs and drivers of other vehicles might react to each other when in mixed traffic;

- crash data/statistics for LSVs or other similar vehicle categories;

- technical characteristics of LSVs that might affect traffic safety and traffic flow, such as acceleration and braking performance, handling, vehicle conspicuity, passenger restraint and crash protection, and crash avoidance systems; and

- other safety issues, such as transportation of children, as well as the potential safety threat to pedestrians, cyclists and other drivers.

2.1 Interviews

Telephone interviews were conducted with representatives of the following organizations:

1. Jurisdictions that have implemented LSV Integration Projects

    - Ontario Ministry of Transportation (MTO)
    - Ministère des Transports du Québec (MTQ)
    - District of Oak Bay, British Columbia
    - City of Lincoln, California
    - Borough of Belmar, New Jersey
    - City of Brillion, Wisconsin
    - City of Chicago Water District, Illinois

2. LSV Manufacturers

    - ZENN Motor Company Limited
    - NEMO Vehicles Inc
    - Dynasty Electric Car Corporation
    - Miles Electric Vehicles
    - Autoco Motorsports

3. Federal, Provincial and Municipal Government Departments and Agencies

    - Transport Canada Safety Programs Branch
    - Ontario Ministry of Transportation
    - Ontario Provincial Police (OPP)
    - City of Ottawa (OC Transpo)
    - City of Ottawa (Police Service)

4. National Non-Government Organizations and Subject Matter Experts

    - Canadian Council of Motor Transport Administrators (CCMTA)
    - Transportation Association of Canada (TAC)
    - Insurance Bureau of Canada (IBC)
    - Insurance Corporation of British Columbia (ICBC)
    - Société de l’Assurance Automobile du Québec (SAAQ)
    - Electric Mobility Canada (EMC)
    - Manitoba Public Insurance (MPI)
    - Canadian Automobile Association (CAA) – Québec

2.2 Subject Matter Experts

Three subject matter experts were retained in the areas of human factors, traffic safety and traffic levels of service, as presented in the following sections.

2.2.1 Human Factors

Dr. Alison Smiley, PhD, CCPE, President of Human Factors North, is Adjunct Professor at the Department of Mechanical and Industrial Engineering, University of Toronto, and Adjunct Professor in the Department of Civil Engineering, Ryerson University. Dr. Smiley has over 35 years experience in human factors research and application. She has conducted numerous field experiments using various test batteries, driving simulators and instrumented vehicles to study the effects of shiftwork, medical conditions, experience, fatigue, lighting, alcohol and drugs on driver performance. She has conducted large scale experimental studies involving assessment of legibility, comprehension and information load of highway signs.

She has taught approximately 40 courses on human factors and traffic safety to traffic engineers, highway designers and police accident re-constructionists across Canada and the U.S. and has acted as an expert witness in over 300 legal cases involving car, truck, boat and train accidents.

Dr. Smiley's report is contained in the Human factors section of the "Low Speed Electrical Vehicles and Human Factors and Road Safety Impacts Study" in Appendix A.

2.2.2 Traffic Safety

Ms. Geni Bahar, P.Eng., of NAVIGATS Inc., is a civil engineer, specializing in highway safety with 30 years of professional experience. Ms. Bahar is known for her expertise in the multi-disciplinary aspects of road safety, and her experience in policy development and public communications. The Transportation Association of Canada awarded Ms. Bahar the 2007 Transportation Person of the Year award, in recognition of her leadership, excellence, and achievements. Most recently, she led the preparations of the Fundamentals and Knowledge chapters for the Transportation Research Board (TRB) Highway Safety Manual (to be published by American Association of State Highway and Transportation Officials - AASHTO in 2009) and the Federal Highway Administration / Institute of Transportation Engineers (FHWA/ITE) Crash Modification/Reduction Factors Desktop Reference containing hundreds of safety measures accompanied by their expected crash reduction/modification and reliability.

Ms. Bahar's report is contained in the Traffic Safety section of the "Low Speed Electrical Vehicles and Human Factors and Road Safety Impacts Study" in Appendix A.

2.2.3 Traffic Levels of Service

Mr. Milt Harmelink, P. Eng., of Harmelink Consulting Inc. worked for the Ontario Ministry of Transportation for 32 years, in planning, design, traffic, transit, communications, R&D and technology. He was Manager of the Traffic Management and Engineering Office for several years, which included development of freeway traffic management systems on Highway 401 and the Burlington Bay Skyway, and responsibility for the Ontario Manual of Uniform Traffic Control Devices. He also participated in the development of the Canadian and U.S. Manuals of Uniform Traffic Control Devices. Later he was Director of Transportation Technology and Energy at MTO for 7 years. He led MTO's Intelligent Transportation Systems (ITS) program for several years, including urban and freeway traffic management, advanced road and transit traveler information, the Highway 401 AVION Commercial Vehicles Operation (CVO) project with I-75, the Canada/US border crossing project, and the all-electronic tolling system for Highway 407 near Toronto. With colleagues, he developed and championed the Highway 407 tolling concept, which led to implementation of the first fully-accessible all-electronic toll highway in the world.

After leaving MTO, Milton worked as an ITS consultant on the Highway 407 tolling system for both the government and the private operator, and for various clients on other traffic, ITS and toll systems. He has also worked on development of the Ontario Traffic Manual, including Book 7 (Temporary Conditions) on work zones. Since the completion of Book 7 in 2001, he has delivered extensive training on Book 7 work zone safety and traffic control through Arges Training & Consulting. He is working on a variety of other ITS and traffic projects. He also works as an expert witness for collisions related to traffic control and work zones.

He is a registered professional engineer in Ontario, is a member of the Institute of Transportation Engineers, and served for seven years on the Board of Directors of ITS Canada.

Mr Harmelink’s report, entitled “Effect of Low Speed Vehicles on Mixed Traffic Flow”, is presented in Appendix B.

3 PREVIOUS WORK

The National Highway Traffic Safety Administration (NHTSA) introduced LSVs as a new vehicle class in the U.S. in June 1998 [1]. Transport Canada adopted a similar regulation in July 2000. Since then, numerous demonstration and testing programs, pilot projects and studies have been conducted across North America with the purpose of better understanding the operating performance and specific requirements of LSVs.

The U.S. Department of Energy has provided funding for many LSV projects. The state of California has participated extensively in these projects in various capacities, and commissioned its own study through the California Energy Commission. Several representative U.S. studies are:

- Field Operations Program, Neighborhood Electric Vehicle (NEV) Fleet Use, July 2001 [5] - report prepared for the United States Department of Energy by the Idaho National Engineering and Environmental Laboratory.

  A total of 348 NEVs were operated in a variety of missions by 15 fleets to understand how NEVs were being used. The fleets included military, commercial, municipal, rental, and transportation organizations. The fleets varied in size, with a minimum of two and a maximum of 82 NEVs. Of the total NEVs used, 56% were used on private roads, 32% were used on public roads and 12% were used on both public and private roads.

- Demonstration of Neighborhood Electric Vehicles, July 2002 [6] - study commissioned by the California Energy Commission (CEC).

  In total, 40 NEVs were demonstrated at four host sites: 10 NEVs at the Anaheim Transportation Network (ATN), Anaheim, two NEVs at Salas O'Brien Engineering (SOBE), San Jose; seven NEVs in the City of Sebastopol; and 21 NEVs in the City of Palm Springs (CPS). The NEVs were operated in various capacities, ranging from airport maintenance activities to transporting community members on local errands. The authors of the report analyzed qualitative and quantitative data generated by the host sites with a view to understanding issues that may enhance or impede the commercialization of NEVs.

- Guidelines for the Establishment of a Model Neighborhood Electric Vehicle Fleet, June 2006 [7] - report prepared for the United States Department of Energy by the Idaho National Laboratory.

  Previous testing activities executed on closed tracks and in fleet environments have shown that NEVs represent a viable alternative to conventionally powered vehicles, based on operating cost. The report outlines the necessity for a dedicated charging infrastructure and unique maintenance requirements, especially for those NEVs using flooded lead acid batteries for their energy storage system. Guidelines for fleet managers are also provided so that the introduction and operation of NEVs in fleet operations are successful.

- NEV America: Neighborhood Electric Vehicle Technical Specification, September 2007.

  The NEV America Program was put in place by the U.S. Department of Energy Office of Transportation Technology to allow independent assessment of NEVs. Only NEVs powered by an electric drive train and meeting the requirements of 49 CFR 571.500 qualify for this testing program. The NEVs must meet a clearly defined set of requirements in order to be accepted for testing [8]. The NEVs are evaluated against a comprehensive set of qualitative and quantitative metrics so that the published results allow potential users to compare NEVs against each other and against consistent standards. The U.S. Department of Energy provides funding for programs involving NEVs only if the vehicles were tested under the NEV America Program.

Ontario and Québec are the only two provinces in Canada that have been involved in LSV pilot projects:

- Assessment of Low-Speed Electric Vehicles in Urban Communities, Pilot Project, April 2002 [9] - prepared for Transportation Development Centre (TDC), Transport Canada (TC) by Centre for Electric Vehicle Experimentation in Québec (CEVEQ).

  The pilot project was carried out over a 12 week period (from August 10 to November 2, 2001), in the city of St. Jérôme, Québec, which had a population of 60,764 and covers an area of 89.3 km^2. Seven LSVs provided by four manufacturers were driven a total of 6,067 km by 53 participants from various backgrounds. The study used evaluation questionnaires to gather the operators' opinions regarding the risks related to using LSVs in normal city traffic and their technical characteristics. In addition, other members of the community, including police officers and taxi drivers had the opportunity to express their opinions vis-à-vis how well the LSVs integrated into city traffic.

- In Ontario, the Province has begun an LSV pilot project to determine appropriate operator qualifications, the roads they should be allowed to travel on, and the safety equipment they should have. For the duration of the pilot project, LSVs can be operated by park employees on roads in provincial parks, municipal parks and conservation areas. The pilot project started in September 2006 and is expected to end in September 2011 as defined in Ontario Regulation 449/06 under the Highway Traffic Act [10].

- État de la situation mondiale des véhicules à basse vitesse (Current world status of low speed vehicles), March 2008 [11] - Institut du Transport Avancé du Québec (ITAQ)

  The report presented the most up to date information concerning LSVs in North America, the European Union, Japan and Australia. The report covered important areas such as legislation, traffic regulations, efforts to integrate LSVs in mixed traffic, market trends and accident statistics. More than 200 government agencies, associations, municipalities and individuals were interviewed and their opinions were presented throughout the report.

4 LSV LEGISLATIVE BACKGROUND

4.1 U.S. LSV Legislation

The National Highway Traffic Safety Administration (NHTSA) is an agency of the U.S. Government, part of the Department of Transportation. It is responsible for setting and enforcing standards for motor vehicles in the United States of America.

4.1.1 U.S. Federal Legislation

Conventional golf carts are manufactured with a maximum speed less than 15 mi/h (24 km/h). However, other golf cart-type vehicles, capable of speeds up to 25 mi/h (40 km/h), found their way onto the roads in many states. This precipitated the creation of state legislation that not only re-defined the “golf cart” class to include these higher speed vehicles, but specified additional safety equipment for them. In addition, some states established a new class of vehicles, often called “neighbourhood electric vehicles”, also defined as being capable of attaining a speed of 25 mi/h.

Conventional golf carts, as originally designed, were built to not exceed 20 mi/h. The safety equipment for vehicles not designed to exceed 20 mi/h was regulated by state and local regulations. However, a vehicle designed to attain 25 mi/h was considered a motor vehicle under Federal law, was classified as a passenger vehicle, and was therefore required to comply with all safety standards for that type of vehicle.

Safety issues surrounding the increased volume of LSVs on public roads led NHTSA to develop a new standard to address the conflict between federal, state and local laws on one hand, and issues arising from higher speed crashes of these golf cart-type vehicles on the other.

In June 1998, NHTSA created a new Federal Motor Vehicle Safety Standard (FMVSS) No. 500, “Low speed vehicles” that defined a new class of motor vehicle, the low-speed vehicle, and set standards for it [12]. The initiative for a new class of motor vehicles responded to a request made by a manufacturer of low-cost, electric-powered vehicles. At the same time, the agency acknowledged the growing public interest in using golf carts and similar 4-wheeled vehicles for other purposes, such as social and recreational activities, primarily within planned, self-contained communities.

FMVSS 500 initially excluded trucks from the LSV class, and did not include a weight restriction. FMVSS 500 was amended twice, as follows:

- October 2005 – the definition of an LSV was amended to eliminate the restriction against trucks, and by imposing a maximum Gross Vehicle Weight Rating (GVWR) of 1,134 kg (2,500 lb). [13]

- June 2006 – the GVWR was increased to 1,361 kg (3,000 lb) in response to a petition from two LSV manufacturers; this change was made to “level the playing field” between electric and gasoline-powered LSVs, by allowing for additional weight of the batteries of electrically powered LSVs. [14]

The current FMVSS 500 [15] defines a low speed vehicle as a motor vehicle:

- that is 4-wheeled;
- whose attainable speed in 1.6 km (1 mi) is more than 32 km/h (20 mi/h) and not more than 40 km/h (25 mi/h) on a paved level surface; and
- whose GVWR is less than 1,361 kg (3,000 lb).

An LSV as defined above must be equipped with:

- headlamps;
- front and rear turn signal lamps;
- tail lamps;
- stop lamps;
- reflex reflectors: one red on each side as far to the rear as practicable, and one red on the rear;
- an exterior mirror mounted on the driver's side of the vehicle and either an exterior mirror mounted on the passenger's side of the vehicle or an interior mirror;
- a parking brake;
- a windshield that conforms to the Federal Motor Vehicle Safety Standard on glazing materials (49 CFR 571.205);
- a VIN that conforms to the requirements of part 565, Vehicle Identification Number (49 CFR 571.565); and
- a Type 1 or Type 2 seat belt assembly conforming to FMVSS No. 209, Seat belt assemblies, installed at each designated seating position (49 CFR 571.209).

NHTSA's rulemaking noted that "at the heart of the rulemaking regarding LSVs is that they were too small to meet the requirements of passenger cars, and would only be used in controlled, low-speed environments, where the risk of collision would be small"[16].

More recently, NHTSA denied two requests for change to FMVSS 500:

- an increase of GVWR for electric-powered LSVs, from 3,000 lb to 4,000 lb, and the addition of regulations regarding braking performance and tire specifications; and
- creation of a new vehicle class, to be known as medium speed vehicles, which would be capable of attaining a maximum speed of 35 mi/h and which would be subjected to a greater number of FMVSS compared to LSVs, but substantially less than those imposed on other light vehicles such as passenger cars.

The reasons for denying the petitioners' requests are outlined later in section 10.5 and explained in detail in the Federal Register [16], [17].

4.1.2 U.S. State Legislation

While the Federal standards for LSVs define the vehicle class and establish mandatory equipment requirements, the states are responsible for regulating the licensing of LSVs and their use on roads. The states may impose safety requirements in addition to those specified by the Federal standards, and may define other operating restrictions. Many states allow their departments of transportation or local jurisdictions to further restrict the use of LSVs on their roads. Although “LSV” is the only term used in the Federal legislation to define Low Speed Vehicles, some states use the term “Neighborhood Electric Vehicle” (NEV) in their legislation.

Several studies presented information regarding the states that allow LSVs to be registered and operated on public roads. These studies include a Canadian study [11] and a more recent U.S. report [18].

The U.S. report identified 40 states that have granted statutory authority for LSVs to operate on certain types of road. According to the report, although some similarities exist, LSV legislation is not harmonized across the states. For example, every state that authorizes operation of LSVs requires them to be registered. On the other hand, although most of the states limit the operation of low speed vehicles to roads for which the speed limit is not more than 35 mi/h, the specific speed limits vary from state to state:

- *Idaho, West Virginia, and Rhode Island limit LSVs to roads with a speed limit of 25 mi/h or less;*
- *New Jersey authorizes LSVs for roads up to 25 mi/h, but allows state and local authorities to allow LSVs for roads of up to 35 mi/h if they choose;*
- *Maryland limits LSVs to roads of 30 mi/h or less;*
- *Kansas allows LSVs to be operated on roads of up to 40 mi/h;*
- *Montana allows LSVs on roads of up to 45 mi/h;*
- *Colorado only authorizes municipalities to determine where LSVs may operate; the law does not set a speed limit maximum.*

The U.S. report also presents other differences and restrictions:

- *Rhode Island allows LSVs to operate only on Prudence Island and their use is restricted to between 6 a.m. and 6 p.m.;*
- *Michigan, unlike any of the other states, specifically requires LSVs to operate as far to the right side of the road as practicable;*
- *the laws of all of the 40 states, except for Oregon and Colorado, explicitly require LSVs to comply with the federal standards;*
- *Iowa, Michigan, Missouri, Texas, and West Virginia explicitly adopt the federal definition of a low speed vehicle by reference;*
- *more than half of the states allow state, county, or local authorities to restrict LSV operations, or even prohibit them entirely on some or all roads, if it is in the interest of public safety;*
- *in Wisconsin, LSVs can only be operated if a municipality adopts a permissive ordinance;*
- *Illinois allows LSVs only if a municipality has adopted a permissive ordinance. The Illinois law requires the municipality to consider the volume, speed, and character of traffic before approving an ordinance;*
- *Colorado only allows LSVs to operate when a local authority has permitted it by ordinance or resolution.*

The operating restrictions of LSVs on the state roads also include crossing restrictions. The same U.S. report indicates that of the 40 states that have granted statutory authority for LSVs to operate on certain types of roads, 30 allow LSVs to cross roads with higher speed limits. In addition:

- *most of the states that allow such crossings do so only at intersections;*
- *Maryland, Rhode Island, and Vermont designate the maximum speed of roads that may be crossed;*
- *Illinois, Maryland, and Vermont further limit the authority to cross to intersections that are "controlled", that is, governed by a traffic light or a four-way stop;*
- *New Jersey requires crossing at a signalized intersection, or at a non-signalized intersection if approved by a state, county, or local authority, when the road being crossed has more than two lanes, is divided, or has a speed limit over 35 mi/h;*
- *California permits crossing a state highway at an uncontrolled intersection only if the state highway agency approves it.*

4.2 Canadian LSV legislation

In Canada, the federal, provincial and municipal governments all have a role in the operation of motor vehicles.

The federal government maintains the Motor Vehicle Safety Regulations (MVSR), including the Canada Motor Vehicle Safety Standards (CMVSS), which define vehicle classes and set standards for manufacture of new vehicles that are to be sold across provincial borders, and vehicles that are imported into the country.

The provincial and territorial governments are responsible for licensing of vehicles and drivers, the rules governing operation of vehicles on the road, in-service vehicle standards, and insurance requirements. When a vehicle is manufactured and sold within a province, the province is responsible for defining the vehicle class and safety standards.

Municipal governments may limit where vehicles of a particular class can be driven.

4.2.1 Canadian Federal Legislation

In July 2000, Transport Canada adopted regulations introducing a new vehicle class, the "low-speed vehicle" (LSV), in response to industry requests for Canada to harmonize with the requirements developed in the United States under FMVSS 500. Transport Canada adopted equipment standards that were very similar to the U.S. standard for LSVs, as defined in section 500 of Schedule IV to the MVSR, referred to as Canadian Motor Vehicle Safety Standard 500 [2]. The low speed vehicle definition as introduced in July 2000 [19] stated that:

"low-speed vehicle" means a vehicle, other than an all-terrain vehicle, a truck or a vehicle imported temporarily for special purposes, that

(a) is powered by an electric motor,

(b) produces no emissions,

(c) is designed to travel on four wheels and has an attainable speed in 1.6 km of more than 32 km/h but not more than 40 km/h on a paved level surface; (véhicule à basse vitesse)

One important distinction between the Canadian and U.S. regulations is that the Canadian regulation prohibits the use of fuel-burning engines, while the U.S. regulation does not.

More recently, the Canadian LSV regulation was amended to add small trucks to the LSV class, to clarify the difference between an LSV and mainstream electric vehicles, and to remain compatible with the U.S. regulation [3]. The current regulation defines an LSV as follows:

“low-speed vehicle” means a vehicle, other than a restricted-use motorcycle or a vehicle imported temporarily for special purposes, that

(a) is designed for use primarily on streets and roads where access and the use of other classes of vehicles are controlled by law or agreement,

(b) travels on four wheels,

(c) is powered by an electric power train (an electric motor and, if present, a transmission) that is designed to allow the vehicle to attain a speed of 32 km/h but not more than 40 km/h in a distance of 1.6 km on a paved level surface,

(d) does not use fuel as an on-board source of energy, and

(e) has a GVWR of less than 1 361 kg;

In addition, the amendment replaced Section 500 of Schedule IV to the Regulations with the following text:

(1) Every low-speed vehicle shall conform to the requirements of Technical Standards Document No. 500, Low-speed Vehicles (TSD 500), as amended from time to time.

(2) Every low-speed vehicle shall be permanently marked with a slow-moving vehicle identification emblem (SMV emblem) that conforms to section 6 of American National Standard Slow Moving Vehicle Identification Emblem (SMV Emblem), ANSI/ASAE S276.6, published in January 2005 by the American Society of Agricultural Engineers.

(3) However, section 6 of ANSI/ASAE S276.6 is modified as follows:

(a) the dimensions of the SMV emblem may be greater than those specified in Figure 1 as long as each dimension is increased so that it has the same relation to the other dimensions as the dimensions specified in the Figure have to each other; and

(b) the recommendation in paragraph 6.2.6 is mandatory.

(4) The SMV emblem shall be mounted in accordance with paragraphs 7.1.1 and 7.1.2 of ANSI/ASAE S276.6. It shall be mounted on the centreline or as near to the left of the centreline of the vehicle as practicable, not less than 500 mm but not more than 1 500 mm above the surface of the roadway.

(5) The SMV emblem shall be affixed so that the view of the emblem is not obscured or obstructed by any part of the vehicle or any attachment designed for the vehicle.

(6) This section expires on June 1, 2013.

Transport Canada states [19] that the LSV class was created to allow for the manufacture, importation and nation-wide distribution of small, lightweight vehicles that could not meet safety standards appropriate for larger and heavier vehicles. These electric vehicles were intended for use on short trips for shopping, social and recreational purposes, primarily within retirement or other planned, self-contained communities.

As specified in Transport Canada's Technical Standards Document (TSD) No. 500 [20] "Low Speed Vehicles", an LSV as defined above shall be equipped with:

(1) Headlamps,

(2) Front and rear turn signal lamps,

(3) Tail lamps,

(4) Stop lamps,

(5) Reflex reflectors: one red on each side as far to the rear as practicable and one red on the rear,

(6) An exterior mirror mounted on the driver's side of the vehicle and either an exterior mirror mounted on the passenger's side of the vehicle or an interior mirror,

(7) A parking brake,

(8) A windshield that conforms to section 205, Glazing Materials, of the Motor Vehicle Safety Regulations (MVSR) the Federal motor vehicle safety standard on glazing materials (49 CFR 571.205).

(9) A VIN that conforms to the requirements of section 115, Vehicle Identification Number, of the MVSR part 565 Vehicle Identification Number of this chapter, and

(10) A Type 1 or Type 2 seat belt assembly conforming to section 209, Seat Belt Assemblies, of the Motor Vehicle Safety Regulations Sec. 571.209 of this part, Federal Motor Vehicle Safety Standard No. 209, Seat belt assemblies, installed at each designated seating position.

The text of TSD 500 is based on Federal Motor Vehicle Safety Standard No. 500 [15], *Low Speed Vehicles*, as published in the U.S. *Code of Federal Regulations*, Title 49, Part 571, revised as of October 1, 2005.

Table 1 compares the CMVSS regulations applicable to a passenger car with those applicable to an LSV [21]. There are 41 standards that may apply to a passenger car, as only one of CMVSS 301, 301.1 or 301.2 would apply to any particular vehicle. Only three of these apply to an LSV, though CMVSS 301, 301.1 and 301.2 would clearly not apply, and CMVSS 1106 should automatically be satisfied. Thus, LSVs are effectively exempted from 33 regulations developed to improve the safety of passenger cars.

Table 1: CMVSS regulations applicable to passenger cars and LSVs

CMVSS	Description	Car	Low-Speed Vehicle
101	Location and Identification of Controls and Displays	X	
102	Transmission Control Functions	X	
103	Windshield Defrosting and Defogging	X	
104	Windshield Wiping and Washing System	X	
106	Brake Hoses	X	
108	Lighting System and Retroreflective Devices	X	
108.1	Alternative Requirements for Headlamps	X	
110	Tire Selection and Rims for Motor Vehicles With a GVWR of 4 536 kg or Less	X	
111	Mirrors	X	
113	Hood Latch System	X	
114	Theft Protection and Rollaway Prevention	X	
115	Vehicle Identification Number	X	X
116	Hydraulic Brake Fluids	X	
118	Power-Operated Window, Partition and Roof Panel Systems	X	
124	Accelerator Control Systems	X	
135	Light Vehicle Brake Systems	X	
201	Occupant Protection	X	
202	Head Restraints	X	
203	Driver Impact Protection	X	
204	Steering Column Rearward Displacement	X	
205	Glazing Materials	X	X
206	Door Locks and Door Retention Components	X	
207	Anchorage of Seats	X	
208	Occupant Restraint Systems in Frontal Impact	X	
209	Seat Belt Assemblies	X	X
210	Seat Belt Assembly Anchorages	X	
210.1	User-ready Tether Anchorages for Restraint Systems	X	
210.2	Lower Universal Anchorage Systems for Restraint Systems and Booster Cushions	X	
212	Windshield Mounting	X	
213.4	Built-in Child Restraint Systems and Built-in Booster Cushions	X	
214	Side Door Strength	X	
215	Bumpers	X	
216	Roof Intrusion Protection	X	
219	Windshield Zone Intrusion	X	
301	Fuel System Integrity	X	
301.1	LPG Fuel System Integrity	X	

301.2	CNG Fuel System Integrity	X	
302	Flammability of Interior Materials	X	
305	Electrolyte Spillage and Electrical Shock Protection	X	
401	Interior Trunk Release	X	
500	Low-speed Vehicles		X
1106	Noise Emissions	X	

4.2.2 Canadian Provincial and Territorial Legislation

Provinces and territories regulate vehicle licensing, driver licensing, insurance requirements, vehicle standards and inspection, and the rules of the road.

Currently, Ontario, Québec and British Columbia are the only provinces that allow the use of LSVs on public roads, either freely or as part of pilot projects. Each has its own unique regulations.

Ontario

Ontario does not have a "low-speed vehicle" classification. In order to operate on public roads in Ontario, an LSV would currently be required to meet existing Highway Traffic Act (HTA) vehicle definitions and provincial equipment safety standards [22].

Regulation 449/06 under the Ontario Highway Traffic Act, effective September 19, 2006, authorized a five-year LSV pilot project [23]. The project’s scope is to evaluate the use of low-speed vehicles on roads in provincial parks, municipal parks and conservation areas. LSVs can only be operated by licensed park employees, and only on park roads with a posted speed limit of 40 km/h or less.

Québec

Québec does not have legislation that regulates the licensing and operation of LSVs. Despite this, a small LSV pilot project was carried out in 2001 [9]. Québec amended the Highway Safety Code (Code de la sécurité routière - L.R.Q., c. C-24.2) to authorize pilot projects, particularly to test new types of vehicle, such as LSVs. A new LSV pilot project was initiated in 2008 under this authority [24].

British Columbia

British Columbia has allowed LSVs to be licensed, registered and insured in the province since August 16, 2000, and to be operated in a fashion similar to slow-moving farm vehicles.

On June 6, 2008, regulations came into force in British Columbia allowing LSVs, termed “Neighbourhood Zero Emission Vehicles” (NZEV) on public roads. LSVs may operate on any road with a speed limit of 40 km/h or less, and any road between 40 and 50 km/h that displays a municipal sign (or in an unorganized area, a provincial sign) that designates the roadway as an LSV route. Prior to this, the Provincial regulations restricted LSVs to streets with a speed limit of 40 km/h or less. As part of the amendment, the Ministry of Transportation (MoT) has given

Municipalities the authority to create a by-law, which would allow LSVs on streets with a speed limit above 40 km/h, but no greater than 50 km/h.

The District of Oak Bay has taken advantage of this, and has passed a by-law [25] authorizing the use of NZEV's on roads with a speed limit up to 50 km/h. No provincial highways pass through Oak Bay, and there are no roads with a speed limit higher than 50 km/h.

Vancouver City Council proposed a recommendation to allow Low Speed Electric Vehicles on streets posted at 50 km/h or less [26]. However, the Vancouver Street and Traffic By-Law No. 2849 does not yet allow for NZEVs [27].

Alberta

Alberta does not have legislation to regulate the licensing and operation of LSVs. They are considered miniature vehicles, and therefore cannot be registered or operated on Alberta's roads [28].

Highlights of the Municipality of Jasper's June 10, 2008 Council meeting [29] stated that written confirmation had been received from Alberta Transportation to work with the Town of Jasper to grant a permit and cooperatively define the operating conditions for the use of a low speed electric vehicle within the town boundaries. Jasper's city representatives are awaiting a draft of the permit conditions and other details regarding the pilot project.

Saskatchewan

Current legislation does not allow for LSVs on Saskatchewan roads. A review of 41 bills before the current legislative session (1st Session, 26th Legislative Assembly) has not turned up any plan for such legislation [30].

Manitoba

The Government of Manitoba tabled Bill No.15 "The Climate Change and Emissions Reductions Act" to meet its Kyoto commitment by 2012 and set long-term goals for further greenhouse gas (GHG) reductions by 2020 and 2025. This received Royal Assent and was proclaimed on June 12, 2008 [31]. The bill includes an amendment to the Highway Traffic Act that enables the Lieutenant Governor in Council to make regulations permitting zero-emission and low-speed vehicles on highways, to establish rules of the road for their use, and to establish restrictions for LSVs to certain types of highways including those with specified speed limits.

The Government of Manitoba is currently assessing the manner in which the safe operation of LSVs can be facilitated on roads in the province. To support this process, the Government of Manitoba has contracted the Centre for Sustainable Transportation (CST), based at the University of Winnipeg, to undertake a review of issues/opportunities related to LSVs.

New Brunswick

Current legislation does not allow for LSVs on New Brunswick roads. A review of 86 bills before the current legislative session (2nd Session, 56th Legislature) has not turned up any plan for such legislation [32].

Nova Scotia

On May 13, 2008, Bill No. 171 was tabled [33], entitled the “Low-speed Motor Vehicles Regulations Act”. The Act would give the Governor in Council only one year to enact regulations pursuant to the Motor Vehicle Act:

- permitting the use on public highways, with a posted speed limit of not greater than 50 km/h, of motor vehicles that are designed for use on highways and that have a top operating speed of 40 km/h; and
- respecting the registration of such vehicles pursuant to the Motor Vehicle Act.

Newfoundland and Labrador

A review of the Newfoundland and Labrador legislation has not turned up any existing or planned LSV legislation.

Nunavut

When contacted, an official of the Nunavut Government stated that no bills concerning vehicle classes have been tabled since the forming of the Territory. He further elaborated that LSVs were unlikely to be popular in Nunavut, where local weather and road conditions may preclude the use of LSVs for large portions of the year.

Prince Edward Island

Current legislation [34] does not allow for LSVs on Prince Edward Island roads. A review of 37 bills before the current legislative session (2nd Session, 63rd General Assembly) has not turned up any plan for such legislation.

Yukon and Northwest Territories

A review of the Yukon and Northwest Territories legislation has not turned up any existing or planned LSV legislation.

4.3 European Quadricycle Legislation

Europe does not have a Low Speed Vehicle class as defined in U.S. and Canada, but a similar class of vehicles exists, called quadricycles. These vehicles are defined by the European Directive 2002/24/EC [35], which also specifies the technical requirements for such vehicles.

A quadricycle is defined as a motor vehicle with four wheels. Two quadricycle categories are defined in the directive, as follows:

- *Light quadricycles*
    - *whose unladen mass is not more than 350 kg (category L6e), not including the mass of the batteries in the case of electric vehicles,*
    - *whose maximum design speed is not more than 45 km/h, and*
    - *whose engine cylinder capacity does not exceed 50 cm^3 for spark (positive) ignition engines, or*
    - *whose maximum net power output does not exceed 4 kW in the case of other internal combustion engines, or*
    - *whose maximum continuous rated power does not exceed 4 kW in the case of an electric motor*
    - *these vehicles shall fulfill the technical requirements applicable to three-wheel mopeds of category L2e unless specified differently in any of the separate directives.*

- *Heavy quadricycles (quadricycles, other than light quadricycles defined above)*
    - *whose unladen mass is not more than 400 kg (category L7e, 550 kg for vehicles intended for carrying goods), not including the mass of batteries in the case of electric vehicles, and*
    - *whose maximum net engine power does not exceed 15 kW. These vehicles shall be considered to be motor tricycles and shall fulfill the technical requirements applicable to motor tricycles of category L5e unless specified differently in any of the separate Directives.*

The fact that quadricycles may be fuel-powered or electric makes them more like the U.S. LSV, and less like the Canadian LSV which can only be electric.

The technical requirements applicable to quadricycles, as presented in Annex I of the Directive are shown in Table 2.

Table 2: Technical requirements for quadricycles

No.	Directive	Description
1	2000/7/EC	Speedometer
2	93/14/EEC	Braking system
3	93/29/EEC	Identification of controls, tell-tales and indicators
4	93/30/EEC	Audible warning device
5	93/33/EEC	Devices to prevent unauthorised use of the vehicle
6	93/34/EEC	Statutory inscriptions (content, location and method of affixing)
7	93/92/EEC	Installation of lighting and light-signalling devices on the vehicle
8	93/93/EEC	Masses and dimension
9	93/94/EEC	Position for the mounting of rear registration plate
10	95/1/CE	Maximum design speed of the vehicle
11	95/1/CE	Maximum torque and maximum net power of engine, whether this is: • of the spark-ignition or compression-ignition type, or • electric
12	97/24/EC C 3	External projections
13	97/24/EC C 4	Rear-view mirror(s)
14	97/24/EC C10	Coupling devices and their attachment
15	97/24/EC C12	Windows; windscreen wipers; windscreen washers; devices for de-icing and de-misting for three-wheel mopeds, motor tricycles and quadricycles with bodywork
16	97/24/EC C2	Lighting and light-signalling devices on the vehicle the mandatory or optional presence of which is laid down in the installation requirements under heading No 32
17	97/24/EC C5	Anti-air pollution measures (**)
18	97/24/EC C6	Fuel tank (**)
19	97/24/EC C7	Anti-tampering measures for mopeds and motorcycles
20	97/24/EC C8	Electromagnetic compatibility
21	97/24/EC C9	Sound level and exhaust system (**)
22	97/24/EE C1	Tyres
23	97/24/EEC C11	Anchorage points for safety belts and safety belts for three-wheel mopeds, motor tricycles and quadricycles with bodywork

** Electrically-propelled vehicles are not subject to the requirements relating to this heading. This does not apply to twin-propulsion vehicles in which one of the systems of propulsion is electric and the other thermic.

4.4 Other Relevant Standards

4.4.1 ANSI/NGCMA Z130.1-1999

The National Golf Car Manufacturers Association (NGCMA) considered it necessary to develop guidelines concerning general safety practices, maintenance, fuel handling and storage/battery charging, operating safety rules and practices, as well as manufacturers' requirements for electric-powered and gasoline-powered carts. These guidelines were approved and adopted in 1999 as the American National Standard for Golf Cars - Safety and Performance Specification, (ANSI/NGCMA Z130.1-1999) [36]. The standard is voluntary, therefore its implementation cannot be mandated. However, according to NGCMA, all its manufacturer members have adopted the standard. The standard requires safety and operation warnings to be affixed to golf cars. When operated in accordance to these warnings, the golf cars are considered to be safe, according to industry experts.

4.4.2 SAE J2358

In March 2002, the Society of Automotive Engineers (SAE) published standard J2358 [37] defining the safety and performance requirements to promote safety in the design, manufacture, maintenance and operation of LSVs. This standard was largely based on the ANSI standard Z130.1-1999. This standard is also voluntary and non-binding. SAE J2358 does set higher safety requirements than the current Canadian and U.S. LSV federal standards, such as by requiring service brakes, performance standards for seat belt assemblies, and roof intrusion protection. It still does not require the same standard for occupant protection as for passenger vehicles. It has yet to be adopted federally.

4.4.3 ANSI/ASAE S276.6

ANSI/ASAE S276.6 is the American National Standard for the Slow Moving Vehicle Identification Emblem (SMV Emblem). It provides detailed guidance for the size, shape and location of the SMV emblem on a vehicle.

As of July 28, 2009, LSVs in Canada will be required to conform to certain portions of ANSI/ASAE S276.6, as imposed by the Motor Vehicle Safety Regulations, Part IV, Standard 500 (amended July 28, 2008, by SOR/2008-229).

4.4.4 Industry Standards

Automotive standards and test procedures for evaluating battery emissions and electromagnetic compatibility have been developed by the Society of Automotive Engineers (SAE) and the International Organization for Standardization (ISO). Such standards are:

- SAE J1113: Electromagnetic Compatibility Measurements Procedure for Vehicle Components [38];
- SAE J551: Vehicle Electromagnetic Immunity [39];
- ISO 11452: Road vehicles - Component test methods for electrical disturbances from narrowband radiated electromagnetic energy - Part 8: Immunity to magnetic fields [40];
- SAE J1718: Measurement of Hydrogen Gas Emission From Battery-Powered Passenger Cars and Light Trucks During Battery Charging [41];
- SAE J1673: High Voltage Automotive Wiring Assembly Design [42]; and
- Federal Communications Commission (FCC) requirements for unintentional emitted electromagnetic radiation, as identified in 47 CFR 15, Subpart B, “Unintentional Radiators” [43].

5 LSV PILOT AND INTEGRATION PROJECTS

Over the past decade, numerous LSV pilot and integration projects have been started and/or completed across North America. The background research conducted in this study focused on several North American jurisdictions that were considered to be representative and relevant for the purpose of this study.

5.1 Canadian Pilot Projects

5.1.1 Ontario LSV Project

The Ontario pilot project began in September 2006. During the 2007 park operating season, four 2002 model year LSVs were evaluated in four provincial parks:

- Bronte Creek Provincial Park;
- Balsam Lake Provincial Park;
- Emily Provincial Park; and
- Pinery Provincial Park.

Information was gathered from employees of the four parks involved, using the following criteria:

- safety aspects (speed, types of roads, lighting system, braking tire specifications, etc);
- LSVs as a mode of transportation (drivability, parkability, maneuverability, cruising speed, etc.);
- LSV performance (adverse weather conditions, hilly terrain, etc.);
- public response to the LSV (discussions with people and the main theme – positive/negative); and
- potential technical improvements.

Table 3 presents the operators' opinions [44].

Table 3: Ontario parks pilot project operator's feedback

Pros	Cons
Safety Aspects	
• sufficient speed within Provincial Park. • good for use in spring/summer/fall; not used in winter. • adequate braking and tire system. • adequate roll cage and seatbelts. • adequate horn. • felt it was a safe vehicle. • lighting was good; adequate lighting for night-time driving.	• big blind spots in front. • tires catch and spin a bit when turning. • had a broken passenger door on vehicle, which was unsafe.

Pros	Cons
LSV as a Mode of Transportation	
• easy to drive and manoeuvre. • once the vehicle got going the driving was smooth; the LSV is easy to park and brakes well. • the vehicle navigated the narrow roads of the campgrounds without any trouble. • able to maintain 40km/h with 4 people in the vehicle. • very happy that it is eco-friendly. • good for in park use.	• difficult to steer without power steering; especially on tight corners. • in areas it was difficult to manoeuvre and dangerous if you had to move to the side of the road. • starting the vehicle and stopping the vehicle was jerky. • found with accelerator that you had to push it down all the way, there was not really any gradual acceleration. • very bumpy ride, loud on the inside of vehicle. Whole car rattles when driving and steering is not smooth.
LSV Performance	
• fine – not an off road vehicle, but good on bumpy dirt roads. • drives well on wet gravel. • moves well over hills, gravel and grass. • good pick-up going up hill (even with 4 passengers onboard).	• leaks badly in the rain – window gaskets do not seal. • not suitable for adverse wet conditions. • slow when ascending a slope. • shocks are not that good. • traction somewhat difficult on gravel. • seats are uncomfortable. Needs improvement to seat comfort and seat bar (hits driver's tail bone). • doors do not lock properly anymore (Bronte Creek Provincial Park). • windows are stiff and/or missing handles – window levers and door levers should be made sturdier. • cannot open door from inside when on passenger side (Bronte Creek Provincial Park). • Ventilation system does not work well.
Public Response	
• public loved the car. People wanted to know more about the vehicle. Plenty of good/positive feelings. Public liked a non-fuel/non-emission vehicle in a park setting for obvious environmental concerns. • public commented on how quiet it was. • wanted to know where to get one. • high interest in this type of vehicle shows environmental ethics.	• no negative comments from the public.

<table>
<tr><th>Pros</th><th>Cons</th></tr>
<tr><th colspan="2">Technical Improvements Needed</th></tr>
<tr><td colspan="2">• seats are uncomfortable, needs improvement to seat comfort, seat bar hits drivers tail bone.
• shocks are not that good.
• doors do not lock properly anymore and windows are stiff and/or missing handles – window and door open levers should be made more sturdy.
• cannot open door from inside when on passenger side.
• improvements to window gaskets to prevent rain from getting into vehicle.
• whole car rattles when driving and steering is not smooth.
• ventilation system does not work well.
• increasing the range of the vehicle as battery technology improves.</td></tr>
<tr><th colspan="2">Overall Comments</th></tr>
<tr><td>• low impact vehicle.
• park staff enjoyed using it.
• great to be using a low emissions vehicle.
• the vehicle works very well for moving staff around between buildings. At the Pinery Provincial Park the vehicle was used by their Visitor Services program to move about the park to deliver their various programs, and appeared to work well.
• excellent way to get around the park while helping the environment.
• like it for in-park transportation of people and articles.
• positive image for provincial parks.</td><td>• the range of the vehicle is not very good and in a provincial park as elsewhere there are not always the facilities to plug the vehicle in and recharge it.
• the mechanical quality of the vehicle. The LSV used in Emily Provincial Park has not been working since mid-July, with no positive results from emails from dealerships on how to fix it.</td></tr>
</table>

No collisions were reported during the 2007 operating season. From the above summary, it appears there were some differing opinions on some of the topics, possibly due to the small sample of vehicles having different problems in different locations.

5.1.2 Québec projects

5.1.2.1 St. Jérôme Pilot Project

A pilot project was carried out in 2001 on the streets of St. Jérôme, Québec, a city with a population of approximately 60,000. The main goal of the pilot project was to *“assess the integration of LSVs into urban traffic from the perspectives of safety and reliability”*. The study focused on the LSV regulatory framework, and interest in LSVs as a mode of urban transportation.

The local police department agreed to allow LSVs to operate in mixed traffic on public roads with a posted speed limit of 50 km/h or less. Seven LSVs were used during the project, five provided by manufacturers and two offered by a company with a fleet of such vehicles. The pilot project was co-sponsored by the Ministère des Transports du Québec (MTQ) and the Program of Energy Research and Development (PERD) of Natural Resources Canada (NRCan).

The opinions of 53 operators and 126 pedestrians and motorists were collected and analyzed. Some of the findings presented in the report [9] showed that:

- *the level of safety felt by the drivers varied depending on the type of road and urban area. It was found that roads considered less safe for LSVs were those with 50 km/h speed limits where the actual speed of traffic was usually higher, and roads with single-lane traffic in areas where passing posed a greater risk;*
- *56 % of the LSV drivers said they felt safe at all times while driving the vehicles;*
- *one third of the LSV drivers felt the vehicles should have doors so that they would have a greater feeling of protection in the event of a collision;*
- *64 % of the LSV drivers said that the LSVs did not go fast enough to keep up with the flow of traffic at all times;*
- *97 % suggested that the top speed of the vehicles should be increased. However, 47% of the road users felt that 40 km/h was an appropriate speed in the city;*
- *acceleration, attractiveness and vehicle handling were seen as the main strong points;*
- *vehicle range was the most criticized aspect;*
- *83 % of the LSV drivers and 89 % of the road users felt that LSVs had their place in the city; and*
- *representatives of the MIRA Foundation said that in order to take persons with visual impairments into account, LSVs could be equipped with an appropriate system to warn people of their approach.* (Note: MIRA Foundation is a French-Canadian community-based organization that assists people with visual, auditory and physical disabilities.)

The report mentioned that "*it is important that its introduction to on-road use be accompanied by regulations, adequate safety measures and better matching of the product to consumer needs."*

An extensive list of recommendations was presented in the report, addressed to Federal and Provincial Governments, local authorities and manufacturers.

The same report mentions other demonstration projects that took place in the province of Québec:

- in 1997, four NEVs were used by approximately 480 people in the tourist resort city Mont Tremblant. The NEVs were operated on a predetermined route including roads with a maximum speed limit of 50 km/h;
- in 1998, three NEVs were used by the Montreal Urban Community Police Department on certain streets in Montreal, one in the downtown area, and the other two for monitoring parks; and
- from 1999 to 2001, eight NEVs were driven in Valcourt, a small town of approximately 2,500 residents. The NEVs were allowed to drive on roads with a maximum speed limit of 50 km/h.

No collisions were reported during any of these demonstration projects.

5.1.2.2 Québec Pilot Project - 2008

On June 17, 2008, Québec authorized a pilot project to allow models of two particular LSVs to operate on public roads where the posted speed limit was 50 km/h or less. The two LSVs, a small utility truck (Nemo) and a small two-passenger car (ZENN) "exceed the standards of Transport Canada" [46]. The pilot project was scheduled to start on July 17, 2008, however, based on recent information provided by SAAQ, no LSVs are yet on the roads, due to administrative delays. The pilot project will be carried out over a period of three years with an option to extend it for two additional years. The LSVs will be allowed to operate year-around, throughout Québec, subject to certain restrictions such as traffic regulation, speed limits, LSV equipment and operator qualifications.

The main goals of this pilot project are to:

- *test the use of LSVs on certain public roads;*
- *develop safe traffic rules regarding this type of vehicle; and*
- *establish norms with regard to safety equipment for LSVs.*

The LSV operators must respect the following rules:

- *the provisions of the Highway Safety Code;*
- *the prohibition against driving on public roads where the maximum speed limit is greater than 50 km/h;*
- *the prohibition against driving on limited access roads (e.g. highways) as well as on their entrance or exit lanes (ramps);*
- *the authorization to cross roads where the speed limit is greater than 50 km/h solely at intersections where traffic lights or stop signs are present, or at traffic circles;*
- *the obligation to drive in the right lane except if making a left turn, in which case drivers must signal their intention over a sufficient distance to ensure that they can perform the manoeuver without risk;*
- *the obligation to drive with the headlights on at all times;*
- *the prohibition against pulling a trailer or semi-trailer;*
- *the prohibition against driving up a slope whose incline is 15% or greater.*

The LSVs operated as part of the pilot project must be equipped with:

- *daytime running lights (failing that, drivers must keep their headlights on at all times);*
- *a slow moving vehicle identification emblem;*
- *a notice indicating the maximum speed of the vehicle;*
- *odometer;*
- *speedometer;*
- *windshield wipers;*
- *sound warning devices (horn and a proximity warning system);*
- *an information notice on the dashboard reminding drivers of the rules of the pilot project;*
- *defrosting and heating systems;*
- *three-point seat belts.*

The LSV operator must *"hold a class 5 (passenger vehicle) driver's licence and register their LSV with a "C" licence plate for road vehicles with restricted use. In addition, they must sign a* *declaration of commitment stating that they have read the operating rules for LSVs"* [46]. The declaration commits the users to provide certain information to SAAQ, such as kilometers driven, any incidents or collisions that occur over the duration of the pilot project, and other relevant comments. An information plate as shown in Figure 1 must be affixed on the passenger side dash of each vehicle in the project.

Figure 1: LSV pilot project information plate (SAAQ)

The number of LSVs that will be part of the pilot project is not currently known, as participation is voluntary.

5.1.3 British Columbia projects

Although no pilot or integration projects have been conducted in BC, some noteworthy initiatives have been taken by municipal jurisdictions:

- The City of Vancouver Council approved a recommendation [26] to amend several by-laws to:
  - allow Neighbourhood Zero Emission Vehicles to travel on streets with speed limits of 50 km/h or less; and to

- o restrict Neighbourhood Zero Emission Vehicles to the lane on the street that is closest to the right hand edge or curb of the street, except when a left hand turn is necessary or when passing another vehicle.

The City staff will “work together with the Insurance Corporation of British Columbia and the Vancouver Police Department to monitor the use of Neighbourhood Zero Emission Vehicles.”

- on July 8th, 2008, the City of Vancouver Council enacted By-law no. 9691 [47] to amend the Building By-law no. 9419 regarding green building strategies for one family homes, one family homes with secondary suites and two family homes. The by-law requires that the above mentioned homes have a rough in conduit (raceway) for a separate circuit for electric vehicle charging. This initiative was advocated by the Vancouver Electric Vehicle Association (VEVA), a member of Electric Mobility Canada (EMC) [48].

- Oak Bay, a district adjacent to the City of Victoria, has a population of approximately 18,000 and covers an area of approximately 10.38 km². The District of Oak Bay passed a by-law [25] authorizing the use of neighbourhood zero emission vehicles on roads with a speed limit up to 50 km/h. It should be noted that no provincial highways pass through Oak Bay and there are no roads with a speed limit higher than 50 km/h. Based on information supplied by a District of Oak Bay representative, there are no LSVs licensed to Oak Bay owners to date. The Mayor of Oak Bay drove a demonstrator for approximately one week after the by-law was passed. As of the time of writing of this report, no other municipalities in the Greater Victoria metro area have passed a similar by-law.

- Summerland is a community of approximately 11,000 people, located approximately 50 km south of Kelowna and 425 km east of Vancouver. Although currently there is no regulation regarding LSV use on public roads, the District’s Transportation Plan [49] presents policy/regulatory steps that need to be taken to facilitate LSV use on public roads, based on observations from other jurisdictions:

  - o *it is suggested that in Summerland LSVs be limited to two-lane roads with speed limits no greater than 50 km/h;*
  - o *the District may also create a plan specifically for golf carts, identifying preferred routes and the possibility of infrastructure upgrades to encourage LSV use, including public charging stations and dedicated LSV pathways. As a starting point, it is recommended that LSVs be limited to the downtown area;*
  - o *Palm Desert, California, for example, allows golf carts on public roads between one hour before sunrise and one hour after sundown. It is suggested that Summerland implement a similar regulation to ensure safety for LSV drivers;*
  - o *to ensure that LSVs on District roads are suitable and have not been altered or diminished from lack of maintenance, it is suggested that a vehicle permit system could be established by the District. This would allow the District to inspect LSVs to ensure they are fit for public roads, as well as better monitor the use of LSVs in Summerland; and*
  - o *it is suggested, should the District choose to establish an LSV program, that non-licensed users not be permitted to operate LSVs. As the program matures and should there prove sufficient demand from these users, the District may look at instituting a discretionary user-licensing system. This would require negotiations with Insurance Corporation of British Columbia, as LSVs are registered and insured.*

5.2 U.S. Pilot Projects

5.2.1 City of Lincoln, California

Lincoln is a city of approximately 42,000 people, covering an area of approximately 47.5 km², on the eastern edge of the Sacramento Valley, California. The city has grown at a fast pace since 1997 when its population was just 8,500. Part of this dramatic growth can be attributed to the development of the Sun City active adult community in Lincoln. The community in Sun City adopted a golf cart transportation plan to allow residents to move around the development using golf carts traveling at a maximum speed of 15 mi/h. However, the shopping centers were out of reach for golf cart users because the only way to access them was to drive on roads with a speed limit of up to 35 mi/h, which was illegal.

To allow golf carts and NEVs to move about the entire city, the Lincoln City Council drafted a bill (Assembly Bill 2353 [50], and the subsequent AB 2963 [51]) to create a pilot program. The program allowed the City of Lincoln and its neighbour, the City of Rocklin, to develop NEV transportation plans for NEV use within city limits. As a result, the City of Lincoln's Neighborhood Electric Vehicle (NEV) Transportation Plan was adopted in 2006 [52].

To allow NEVs to drive safely on roads with speed limits of up to 35 mi/h, significant road infrastructure improvements have been made as outlined in the Master Transportation plan, including special signage and lanes [53]: "*These specially striped lanes are seven feet wide and are used by both NEVs and bicycles. The city has spent about $800,000 on the lanes and signage. The NEV transportation plan proposes approximately 50 miles of NEV lanes and NEV designated routes. So far, Lincoln has completed about six miles of the special striping and expects to finish by 2009.*"

Three types of route have been presented in the Master Transportation Plan and implemented in the City of Lincoln:

- Class I LSV Route: These routes provide a completely separate right-of-way for the exclusive use of LSVs, pedestrians and bikes with cross-flow minimized;

- Class II LSV Route: These routes are designated as a separate striped lane adjacent to traffic. There is one striped lane for each travel direction. Bicycles may also use these lanes;

- Class III LSV Route: These routes provide for shared use with automobile traffic on streets with a posted speed limit of 35 mi/h (56 km/h) or less. This includes all residential streets.

Based on information obtained from a representative of Lincoln's NEV community group [54], there are approximately 600 NEVs in Lincoln today, though other sources suggest there may be as many as 800. The City is committed to increasing the number of NEVs in Lincoln to 5,000 by 2025.

The discussion with the Lincoln NEV Association's representative revealed that no serious injuries or collisions have been reported to date. Other remarks are listed below. It should be noted that the Lincoln NEV Association's representative is also an NEV owner and operator.

- the majority of drivers are 55 or older.
- mobile service is offered by NEV dealerships.

- NEVs have diminished range in colder weather.
- the NEV driving range is quite different than manufacturer’s specifications (approximately 50% less).
- NEVs handle well in wet weather conditions.
- LSVs cannot trigger the stop lights in dedicated lanes because of lack of road embedded sensors.
- LSVs rarely use Class III routes, and when they do it is only for short distances.

5.2.2 Borough of Belmar, New Jersey

Belmar is a Borough in Monmouth County, New Jersey, with a population of approximately 6,000 people, covering an area of approximately 4.4 km².

Senate Bill 1834 [55], that proposed the use of NEVs on New Jersey roads, was supported by Belmar’s Mayor and was presented to the Senate Transportation Committee in March 2005. According to that bill, the municipalities and counties could opt to authorize the use of NEVs on streets with speed limits of up of 35 mi/h. The law came into effect in April 2006.

Based on information provided by Belmar’s Mayor, currently there are five NEVs in use in Belmar:

- three two-seat NEVs are used by the Police Department for parking enforcement, and patrolling their boardwalk, parks and marina;
- one four-seat NEV is used by the recreation director for getting around town, and driving onto the fields (in turf mode);
- one four-seat NEV is used by the Mayor on a daily basis in town, and to take developers on tours of Belmar's redevelopment area.

The Department of Public Works would like to purchase additional two-seat models with long-beds and a utility body for use in maintaining Belmar’s parks and public restrooms.

According to the Mayor, Belmar and nearby towns consist mostly of 25 mi/h (40 km/h) streets. There have been no collisions reported to date. He also mentioned that:

- there is an LSV designation on LSV license plates;
- some drivers become occasionally impatient when driving behind LSVs. The LSV operator should use common sense and move to the side of the road to let the impatient driver pass if they are following too closely;
- LSVs can only cross roads with a higher speed limit at signalized intersections;
- LSVs are designed for everyday use, and should be charged whenever not in use;
- if LSVs are seasonally used, the batteries should be stored inside to protect them from freezing;
- Belmar representatives held preliminary discussions with an LSV rental company interested in providing LSV rentals on an hourly, daily and weekly basis during the summer season at Belmar’s train station and municipal marina.

5.2.3 City of Brillion, Wisconsin

Brillion is a city in Calumet County, Wisconsin, with a population of approximately 3,000 people, covering an area of approximately 6.7 km².

The Wisconsin Department of Transportation requires that NEVs operated on public roads be registered, operated by a licensed driver and operated only on local roads specifically approved for NEV operation by local ordinance [56]. Since May 2007, the City of Brillion allows, under special conditions, the operation of NEVs on designated City streets, with proper permits. The ordinance stipulates that only NEVs that have not been modified from the original manufacturer's condition be allowed on the roads.

Brillion's Police Chief, who initiated the project to allow NEVs on public roads, estimates that approximately 10 NEVs are currently registered and operate in Brillion, in addition to golf carts and ATVs. The total number of vehicles is approximately 60. Residents were initially concerned about the decision to allow NEVs in mixed traffic, and this was addressed through an awareness campaign, prior to allowing the vehicles on the road. Rules and regulation brochures were also handed out to the residents. To date, no complaints have been voiced by the residents of Brillion, who tend to "police themselves". The ATVs must not exceed 10 mi/h when operated within 150 ft of a residence, due to safety and noise issues. NEVs, ATVs and golf carts must yield to other motor vehicles.

NEVs are not allowed on the two mile stretch of U.S. Highway 10 that crosses Brillion, as it carries approximately 12,000 vehicles/day. NEVs and other motorized vehicles are also prohibited from driving on sidewalks, walking trails and skirtways.

Other remarks were made by the Police Chief:

- since NEVs, are only allowed to operate within city limits, an industrial park located one mile away cannot be accessed. An initiative to build a dedicated lane has been proposed;
- driving NEVs in winter conditions is not an issue given the short distances driven within city limits;
- physically handicapped people may operate NEVs without having to register them (similar to a motorized wheelchair).

5.2.4 Chicago Water District, Illinois

The Metropolitan Water Reclamation District (MWRD) of Greater Chicago purchased 30 car type LSVs in 2007 to replace some of the older vehicles in their maintenance fleet [57]. The MWRD is responsible for maintaining the main waterways and 1,300 streams within an 883-square-mile zone that includes the city of Chicago and 129 suburban municipalities. It also owns and controls more than 25,000 acres within four metro counties.

The LSVs were acquired for use by employees to perform maintenance duties inside the plant. The LSVs are not operated on public roads. As mentioned by MWRD's Fleet Manager in a phone conversation, after one year of operation their experience has been mostly positive. They are planning to purchase additional LSVs to be used as utility trucks inside the plant.

As all LSVs are parked inside overnight, the operators did not experience any issues, even during winter months. Dedicated overhead charging stations were installed inside plant facilities. In terms of performance, some operators complained about the performance of heating and defrosting system and others noticed that the LSVs speed decreases when driving on an up-slope.

No collisions were reported, however, there was one incident where the front wheel and suspension of an LSV was damaged when it drove over train tracks.

5.2.5 Peachtree City, Georgia

Peachtree City is a planned city in Fayette County, Georgia. It has a population of approximately 32,000, covers an area of approximately 61.9 km², and has a 90 mile network of multi-use paths for pedestrians, cyclists, and golf carts. Peachtree City residents can go from their neighborhood to shopping centers, schools, and parks via the path network [58].

The City allows NEVs (defined as Low Speed Motor Vehicles – LSMVs) to be operated on public roads with a speed limit of 35 mi/h or less, and on the 90 mile path network, subject to certain restrictions [59], some of which are as follows:

- all LSMVs must be registered with the Fayette County Tag Office;
- all LSMVs must be insured per state law;
- only persons possessing a valid license may operate an LSMV;
- to operate on the paths, an LSMV must have a setting that does not allow the vehicle to exceed 20 mi/h and operate in that mode at all times on the paths;
- no LSMVs may operate on, over, along, or across Hwy 54, Hwy 74, Peachtree Pkwy, or on Crosstown Rd., except in authorized crossings.

5.2.6 Other U.S. jurisdictions

Clean Cities [60] is a program sponsored by the U. S. Department of Energy (DOE), through the Vehicle Technologies Program (VTP), designed to contribute to the environment, energy and economic security of the United States. It brings together almost 90 coalitions, government agencies and private companies, which voluntarily participate in various initiatives. In 2007 Alternative Fuel Vehicles (AFVs) contributed significantly to the reduction of petroleum use, as presented in Figure 2. Many projects involving NEVs have been made possible by the Clean Cities program.

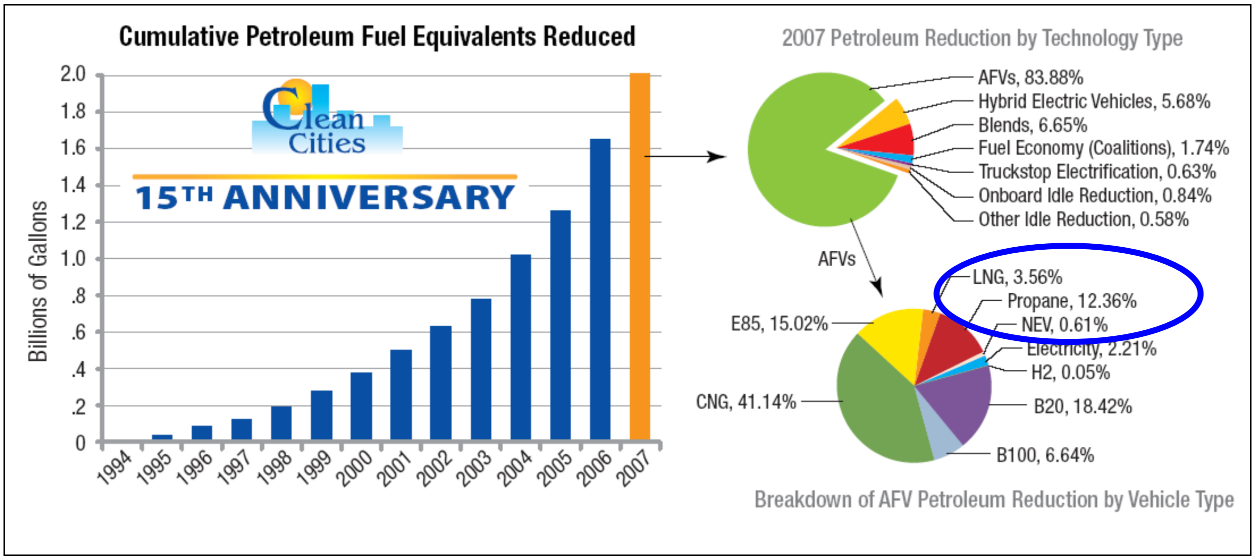


Figure 2: Clean Cities Program Overview [61]

"Guidelines for the Establishment of a Model Neighborhood Electric Vehicle (NEV) Fleet" was another program supported by the DOE's Advanced Vehicle Testing Activity (AVTA). It collected data and lessons learned from NEV testing activities in fleets from different jurisdictions and summarized the findings in a report prepared by the Idaho National Laboratory [7]. Four jurisdictions participated in this program:

- Luke Air Force Base (LAFB) is located 20 miles west of Phoenix, Arizona. The facility encompasses 4,200 acres. The maximum speed for any vehicle on the base is 25 mi/h. A total of 55 NEVs were tracked in the LAFB fleet. Mission selection was the prerogative of the individual squadron or department funding the NEV purchase, and no mission guidelines were provided other than the typically optimistic claims of range, charge time, and maintenance requirements provided by vehicle salesmen. Missions were typically categorized as on-base personnel transportation in a "motor pool" type environment. A few specific missions (e.g., flight line fire suppression system maintenance) were employed that often required vehicle modifications for hauling and/or towing equipment required for that assignment. Maintenance was also left up to the individual funding the NEV purchase. An NEV dealer typically performed maintenance.

- Marine Corps Recruit Depot San Diego (MCRDSD) is located in San Diego, California, and encompasses 385 acres. The posted speed limit on the base is 20 mi/h. The MCRDSD NEV test fleet consisted of 10 vehicles.

- Palm Springs is a desert city in Riverside County, California. It has a population of approximately 43,000 people and covers an area of approximately 246 km². A total of 31 NEVs were used in fleet testing in the City of Palm Springs area. Twelve of the 31 NEVs were allocated by the City of Palm Springs as follows:

    - five for airport services;
    - two for the Police Department;
    - two for the City Yard; and

    - one vehicle each to the Chamber of Commerce, Information Services/Print Shop, and City Hall.

  Six NEVs were used by the Agua Caliente Band of Cahuilla Indians, three by the Unified School District and five were rented out. Five NEVs were used by private individuals.

- Palm Valley is a suburb located 18 miles west of downtown Phoenix, Arizona. Five NEVs were typically used for personal transportation in the Palm Valley community, and for golf.

  During the testing program, a total of 168,419 miles were accumulated on 101 NEVs, which included 2-passenger, 4-passenger, long-bed and short-bed models. Some vehicles were modified with option packages to better accommodate functional use.

The Idaho National Laboratory report summarized the lessons learned from the fleet experiences in the four jurisdictions:

- *Mission Selection*

    - *mission selection can be done informally when the total daily operating range requirement is within the single-charge capability of the NEV;*
    - *mission selection must be more formally conducted when opportunity charging is required to extend vehicle range beyond single-charge capability;*
    - *mission requirements must be coordinated with charging infrastructure and vehicle selection.*

- *Charge Infrastructure*

    - *charge infrastructure is not an issue for vehicles owned and operated by individuals out of their home. Convenience outlets are available for charging and missions typically do not require opportunity fast charging;*
    - *charge infrastructure for fleet vehicles must be formally provided. Where multiple vehicles congregate, convenience outlets provided for normal building services are not sufficient to provide charging power. Additional charging outlets must be provided, preferably in close proximity to NEV parking locations;*
    - *fast charging can provide a backup to overnight charging when vehicles, for whatever reason, do not receive an overnight charge;*
    - *fast charging is not routinely used unless vehicle missions require opportunity fast charging.*

- *Maintenance*

    - *preventative and corrective maintenance must be available promptly and at a reasonable cost to support NEV operations. Fleets of even moderate sizes should consider establishing contract or in-house maintenance capabilities to support their NEV operations;*
    - *preventative maintenance (including battery watering) should be the function of contract or in-house maintenance staff and not a function of the operator.*

- *Operator Training*
    - *operators in all fleets must be made aware of vehicle range limitations, unique requirements (such as disconnect switches), and preventative maintenance requirements (such as battery watering).*

The report concluded that "*Although NEVs have significant performance limitations, NEV fleet data show that deploying NEVs in properly selected applications with adequate infrastructure can offer the fleet manager functionality at a fraction of the cost of traditional internal combustion engine vehicles. Typical successful applications of NEVs include closed campus environments that limit required operating range and highly structured missions with fixed operating range requirements.*"

5.3 LSV Market

5.3.1 North American Market

Many sources mention that there are currently approximately 60,000 LSVs in North America. One of these sources, the ITAQ report [11], also includes detailed production figures for many LSV manufacturers.

A report [62] prepared by International Market Solutions (IMS) provides current and estimated LSV production figures for the U.S. market. IMS estimates that production has risen from 6,500 units in 2000 to 6,600 in 2006. This figure includes production of both privately owned vehicles sold to consumers and utility vehicles produced for the commercial market. IMS' NEV production estimates are presented in Figure 3.

Estimate of NEV Production, 2000-2006 (Units)

	2000	2001	2002	2003	2004	2005	2006
NEV Production	6,500	6,100	5,500	5,200	5,000	6,000	6,600

Source: IMS

Figure 3: Estimate of NEV production in U.S., 2000-2006 [62]

According to the same IMS report, the only company with any significant production volume is Global Electric Motors. The company only reveals that in seven years of manufacturing activity, dating back from 2005, there were 30,000 GEMs operating or in inventory in the U.S. market. The report also said that current GEM production levels in all likelihood range between 4,000 to 4,500 units per year. Including all other brands, as well as imports, ICA estimated that total NEV production available on the U.S. market in 2006 amounted to 6,000-7,000 units per year.

Because of the unpredictability of the market, however, the IMS forecast is presented in ranges, as seen in Figure 4.

Forecast of the NEV Market, 2007-2012 (Units)

	2007	2008	2009	2010	2011	2012
NEV Production	7-7,500	8-9,000	10-12,000	15-17,000	18-20,000	21-25,000

Source: IMS

Figure 4: U.S. NEV market forecast, 2007-2012 [62]

5.3.2 European Market

Quadrycicle production figures in Europe are illustrated in Figure 5 for 2002 to 2005. In 2005, the total number of quadricycles manufactured was approximately 31,000. Almost half of the production came from a single manufacturer, Aixam

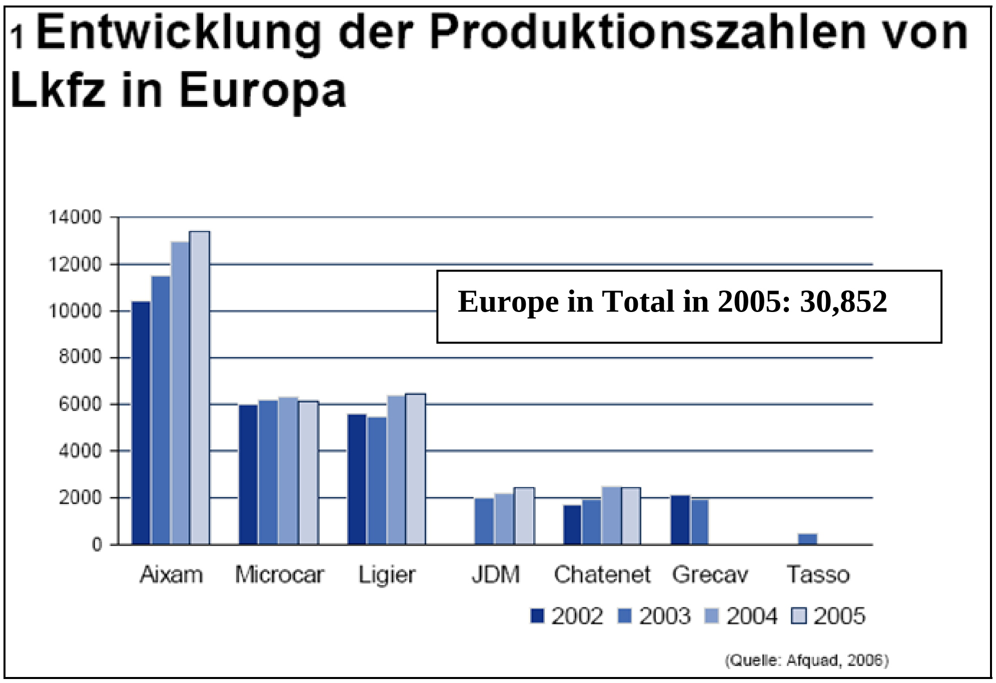


Figure 5: Quadricycle production figures in Europe [63]

6 LSV LICENSING, REGISTRATION AND INSURANCE

6.1 LSV Licensing and Registration

All North American jurisdictions that have enacted LSV legislation require that LSVs be registered. The LSV registration process is similar to the one applicable to passenger vehicles. Most jurisdictions have no specific requirements regarding the license plate.

LSV licensing requires periodic renewal in most jurisdictions, as for passenger cars. Sources from Canadian Council of Motor Transport Administrators (CCMTA) mentioned that some Provinces have an inspection program, where owners must have their vehicles periodically inspected for mechanical safety. Ontario only requires a safety inspection when the ownership of a vehicle changes.

In addition to the above, the following jurisdiction-specific requirements have been identified:

- Québec requires LSVs to have a distinct “C” licence plate. This is an existing plate type used for road vehicles with restricted use;
- British Columbia plans to license LSVs as for passenger vehicles, with the same license plate, and the body style noted as LSV on the vehicle registration. ICBC will add another body style for commercial LSVs;
- Ontario considers LSVs to be Motor Vehicles for the purposes of Ontario's Regulation 628, Vehicle Permits, under the Highway Traffic Act, so they can be registered the same as passenger vehicles.

6.2 LSV Driver Licensing

All North American jurisdictions that have enacted LSV legislation require that LSV operators have a driver’s license.

The class or license type required varies somewhat between states and provinces but typically a passenger vehicle driver’s license is the only requirement for operating an LSV. No other restrictions with respect to the driver’s license required to operate LSVs have been identified, although the City of Lincoln is considering a proposal for a separate classification of driver’s license for NEVs [52]. As mentioned in Lincoln’s Transportation Master Plan (TMP), the new license type would be “easier to get” with reduced requirements, catering to an aging population, enabling them to maintain mobility and providing easier access to a vehicle class that is more likely to be consistent with their lifestyles.

In Ontario, driver licensing falls under Regulation 340, Drivers' Licence [64] and Regulation 341, Drivers Licence Examination [65] of the Highway Traffic Act under Reg. 340, subsection 2(1), a table shows the Class of License needed for different Classes of Motor Vehicles. The LSV falls into the Class G License, as would a regular passenger vehicle.

Driver's license requirements for operating quadricycles in Europe are less restrictive than those for LSVs in North America. A summary of these requirements for selected European countries is shown in Figure 6. Light Weight Motor Vehicles (LWMVs) is the German term used to identify quadricycles. Quite often, a moped licence is the only requirement. The S class driving license is typically acquired by elderly people in Germany.

1 Driving licence provisions for LWMV in the EU (selected)

Country	Driving licence	Minimum age	Special provisions
Belgium	yes (moped)	16 (without passengers) 18 (with passengers)	DL born after 02/61
Germany	yes (S class)	16	
France	yes (moped)	16	DL born after 01/88
Great Britain	yes (B1)	17	
Italy	no	14	theory test born after 10/87
Netherlands	yes (moped)	16	DL born after 06/80
Norway	yes (moped)	18	
Austria	yes (moped)	16	
Portugal	yes (moped)	16	
Spain	yes (moped)	14 (without passengers) 16 (with passengers)	

Unfallforschung

Figure 6: Quadricycle driving licence provisions [66]

6.3 LSV Disclosure Documents

Disclosure documents are documents that are presented to, and signed by, an LSV buyer at the time of sale or registration of a vehicle.

The New York Department of Motor Vehicles (DMV) initiated new regulations in 2002 that include requirements for vehicle dealers who sell LSVs and the manufacturers of such vehicles. According to the new regulations, a vehicle dealer selling an LSV shall provide a written disclosure to be signed by the buyer at the time of purchase [67]. Form VS-1090 represents the written disclosure document, as shown in Figure 7. In addition, according to the same regulations *"On and after May 1, 2002, prior to the sale of a low speed vehicle, the dealer shall affix a permanent decal provided either by the manufacturer or the Department (form VS-1090) to the underside of the roof near the windshield on the driver side. Such decal shall: (1) be approximately 3 inches high by 5 inches wide; and (2) contain the disclosure statement."*

LOW SPEED VEHICLE DISCLOSURE

THE VEHICLE INVOLVED IN THIS TRANSACTION IS CLASSIFIED AS A LOW SPEED VEHICLE. THIS VEHICLE:

- has a maximum speed of greater than 20 miles per hour, but not greater than 25 miles per hour;
- shall not be operated on a public highway with a speed limit in excess of 35 miles per hour;
- may be a hazard on the roadways if it impedes traffic;
- may subject the driver to citations for impeding traffic; and
- may not be equipped with such safety features as bumpers, a padded dashboard, visors and a tamper-resistant odometer.

I have read the above disclosure and acknowledge receipt of a copy of this disclosure.

Buyer's name:_________________________________

Buyer's signature:_____________________________

Date:___________________

VIN:____________________

VS-1091(03/02)

Figure 7: New York State's LSV disclosure document [67]

From a Canadian perspective, ICBC is not aware of any plans for the province to make such a Disclosure Document. However, there may be the opportunity to add information to the "comments" section when registering a vehicle, since the field could potentially contain data specifically relevant to a vehicle class. ICBC will be considering the addition of a statement on the Certificate of Registration, License and Vehicle Insurance to indicate that regulated LSV limitations apply to the vehicle's operation.

6.4 LSV Insurance

6.4.1 Findings from U.S. Jurisdictional Review

Demonstration of Neighborhood Electric Vehicles, July 2002 - study commissioned by the California Energy Commission (CEC)

This study [6] commissioned in 2002 by the California Energy Commission (CEC) noted that several issues were encountered when trying to obtain insurance for the NEVs that were used during testing. The insurance premiums paid at that time are presented in Table 4. Many insurance companies refused to insure the test vehicles. The ones that did agree to insure the test vehicles required high premiums, which often exceeded the allocated budget.

Table 4: NEV insurance premiums [6]

Vehicle	Budgeted Amount	Rental Premium for Demonstration	Current Annual Personal Premium
Sparrow		$3,247.00	$722.00
GEM 4		$2,496.00	$1,120.00
GEM 2		$2,455.00	$990.00
Total Insurance Costs	$6,800.00	$8,198.00	$2,832.00

City of Lincoln, California

Early adopters of NEVs in the city of Lincoln operated these vehicles in gated or age-restricted communities. Their usage was considered low-risk and some insurance companies insured the NEVs as “recreational vehicles”, with premiums of approximately $150/year for complete coverage. However, recreational vehicle policy data is not transmitted electronically to the California Department of Motor Vehicles. As a result, when the proof of insurance is not received for a registered motor vehicle, a "Notice of Intent to Suspend," is issued and the registration will eventually be suspended, a process that is extremely difficult to reverse [68], once started. Currently, insurance companies in Lincoln use premiums similar to traditional passenger vehicles.

The Lincoln Hills LSV Group conducted a survey [69] in 2007 to gather information related to the cost of LSV insurance for Lincoln LSV owners. Approximately 75% of the Lincoln LSV Group members responded (83% of respondents owned licensed LSVs). Twelve insurance companies were represented. The LSV owners used auto (76%), homeowner (15%) or recreational vehicles (9%) policies to insure their LSVs, for premiums ranging from $30 to $595/year. A comparison of the rates offered by various insurance companies is shown in Figure 8.

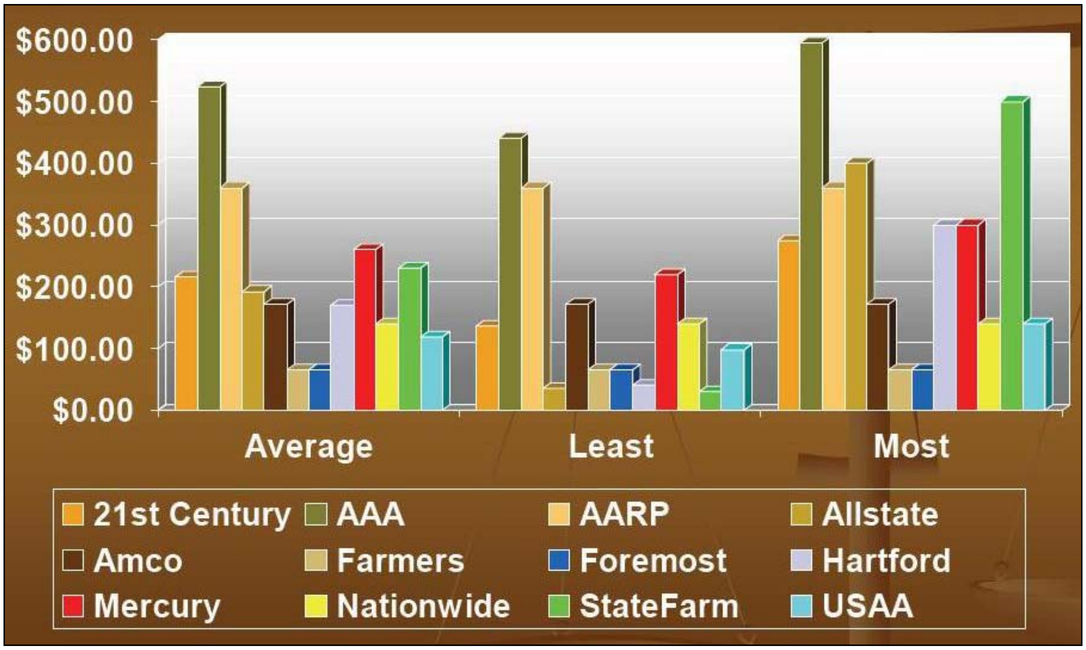


Figure 8: LSV insurance rates – cost by insurance company (Lincoln 2007 survey) [69]

As part of the survey, the Lincoln Hills LSV Group met with a Commercial Insurance broker. In regards to the possibility of a Group Policy being developed, the broker stated that it was possible, but would require a legal entity and would require 100% enrollment. He also mentioned that collision coverage was expensive due to the lack of a track record.

6.4.2 Findings from Canadian Jurisdictional Review

In British Columbia, a representative of ICBC provided insights on how ICBC has addressed past issues and intends to address future issues surrounding LSV insurance. As ICBC has not itself commissioned any studies regarding LSV safety, it will wait for official results of LSV crashworthiness testing from Transport Canada.

ICBC has been insuring LSVs since November 2000. Given the very low density of LSVs on BC roadways, ICBC utilizes known insurance rating categories (which are not specific to LSVs). Thus, the insurance rates are similar to other small passenger cars (e.g. Honda Civic, Toyota Echo, etc.). At last count, there were 21 licensed LSVs in BC.

While LSVs pose a higher risk of injury to occupants, which may increase the amount of a claim, they are (or have been) typically operated in lower risk environments where the potential for a claim is lower. ICBC does not have an adequate sample size of LSVs to assess the risk to be able to rate LSVs independently of regular on-road passenger vehicles. ICBC plans to monitor LSV claim history statistics and adjust their policies as required.

One issue that has been identified is the potential for LSV owners to modify the vehicles to allow them to achieve higher speeds. ICBC has indicated that an LSV capable of traveling faster than 40 km/h would be in violation of the terms of its vehicle class regulations, which would invalidate its licensing, and which could in turn potentially nullify the owner's recourse to insurance. The instances would have to be reviewed on a case-by-case basis by a review board. For now, ICBC will adopt a “wait and see” stance, but if it turns out to be problematic, potential solutions might involve an inspection and permit program and/or increased awareness for police services to educate them on the regulated operating limitations (in particular, greatest attainable speed) of LSVs.

7 COLLISION STATISTICS

The collision statistic reports in Canada and the U.S. include all motor vehicles involved, grouped by categories. LSVs are typically reported under “Others” category. While specific queries could be performed to identify vehicles in that category based on the VIN, no such filtered data were found during the background investigation and review phase of this study.

In the absence of LSV specific collision data, it is nonetheless pertinent to examine collision statistics for passenger vehicles in Canada and the US, and passenger vehicles and quadricycles in Europe, to gain an understanding of the current types, frequency and severity of collisions that occur on public roads.

7.1 Collision Statistics in Canada

Based on the background research and interviews with relevant sources, no LSV collision statistics have been identified in Canada, as there are currently only 21 LSVs registered in the country. All registered LSVs are in the province of BC, which is the only province that has passed LSV regulations (other than for pilot projects).

In the absence of LSV collision statistics, it is important to understand the past and current road environment and how collision statistics have evolved over the years.

The Canadian road fatalities and fatality rate have decreased since 1987, as presented in Figure 9, based on the latest available data from Transport Canada [70].

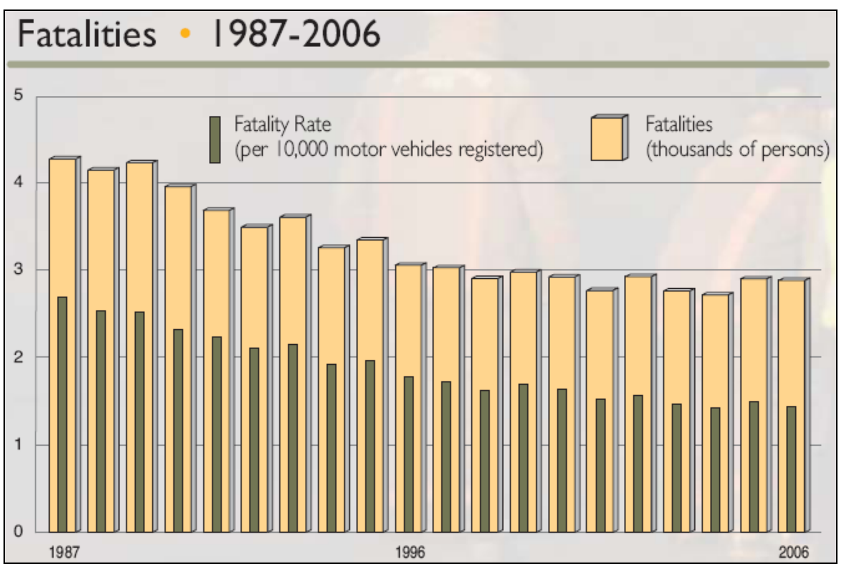


Figure 9: Road fatalities in Canada, 1987-2006 [70]

A breakdown of death and injury rates by province and territory for 2006 is illustrated in Figure 10, based on the same Transport Canada data.

Casualty Rates

	Per 100,000 Population		Per Billion Vehicle-Kilometres*		Per 100,000 Licensed Drivers	
	Fatalities	Injuries	Fatalities	Injuries	Fatalities	Injuries
Canada	8.9	604.0	8.9	604.2	13.0	884.5
N.L.	7.3	428.7	8.5	501.3	10.8	638.9
P.E.I.	18.8	604.2	25.0	803.6	26.8	863.9
N.S.	9.2	513.4	8.4	470.8	13.0	726.8
N.B.	14.1	519.1	12.3	452.3	19.9	729.5
Que.	9.4	649.9	10.3	711.1	14.8	1,027.1
Ont.	6.2	539.8	6.0	525.2	8.8	772.3
Man.	10.1	741.2	9.9	729.1	16.4	1,202.9
Sask.	13.9	686.6	12.2	604.4	20.2	999.8
Alta.	13.4	769.1	10.0	570.7	17.9	1,027.8
B.C.	9.6	586.0	12.9	789.5	14.0	855.3
Y.T.	41.6	746.1	24.2	434.5	55.3	991.1
N.W.T.	4.8	267.6	5.3	294.3	6.3	355.4
Nvt.	0.0	214.4	n.a.	n.a.	n.a.	n.a.

* Statistics Canada, "Canadian Vehicle Survey", Catalogue No. 53-223-XIE.
Note: Data for Ontario and Saskatchewan are preliminary for 2006.
n.a.: Data are not available.

Figure 10: Casualty rates by provinces and territories, Canada 2006 [70]

In 2006, driver fatalities accounted for more than half of the total number, while passenger fatalities accounted for 21.4%, as shown in Figure 11.

Percentage of Fatalities and Serious Injuries by Road User Class

Road User Class	Fatalities	Serious Injuries
Drivers	53.5	48.4
Passengers	21.4	25.8
Pedestrians	12.9	12.0
Bicyclists	2.5	3.3
Motorcyclists	7.6	8.7
Not stated/Other	2.1	1.8
Total	100.0	100.0

Figure 11: Casualties by road user class, Canada 2006 [70]

According to Statistics Canada's "2007 Annual Canadian Survey" [71], of the almost 20 million vehicles registered in Canada in 2007, approximately 36% were registered in Ontario, 23% in Québec. Alberta and BC accounted for approximately 13% each, while the other provinces and territories accounted for the rest, as shown in Figure 12. An estimate of the type of vehicles by body type that was registered in 2007 is presented in Figure 13. Passenger cars accounted for approximately 52%, while vans, SUVs and pickup trucks accounted for approximately 42%.

	Total, all vehicles	Vehicles up to 4.5 tonnes	Trucks 4.5 tonnes to 14.9 tonnes	Trucks 15 tonnes and over
Total - Canada	**19,988,268**	**19,198,981**	**461,152**	**328,135**
Newfoundland and Labrador	275,736	268,192	4,212	3,333
Prince Edward Island	82,146	77,874	1,478	2,795
Nova Scotia	564,822	548,112	8,743	7,967
New Brunswick	482,990	471,015	7,579	4,397
Quebec	4,562,806	4,464,900	59,298	38,609
Ontario	7,255,081	7,038,701	97,824	118,557
Manitoba	671,879	643,582	11,198	17,100
Saskatchewan	749,032	683,509	37,765	27,758
Alberta	2,655,335	2,453,493	114,790	87,053
British Columbia	2,632,364	2,499,240	115,417	17,707
Yukon Territory	28,994	25,816	1,796	1,383
Northwest Territories	23,615	21,452	831	1,332
Nunavut	3,467	3,097	223	147

Figure 12: Number of vehicles on the registration lists by type of vehicle and jurisdiction (2007) [71]

	Total, all vehicles	Vehicles up to 4.5 tonnes	Trucks 4.5 tonnes to 14.9 tonnes	Trucks 15 tonnes and over
Total, all vehicles body types	**19,710,912** A	**19,003,427** A	**392,608** A	**314,877** A
Car	10,153,484 A	10,152,717 A	...	...
Station wagon	302,047 B	302,047 B	...	...
Van	3,064,572 A	3,047,995 A	16,577 C	...
Sport utility vehicle	1,810,801 A	1,810,801 A	...	...
Pickup	3,718,848 A	3,631,305 A	87,529 B	F
Straight truck	409,856 A	44,939 E	264,203 A	100,714 B
Tractor trailer	232,489 A	...	15,563 D	213,730 A
Bus	F	...	F	...
Other vehicle type	17,291 E	F	6,480 E	F

Figure 13: Estimates of number of vehicles by type of vehicle and vehicle body type (2007) [71]

7.1.1 Collision Statistics in Ontario

The 2005 Ontario Road Safety Annual Report (ORSAR) [72] presents statistics showing that fatality and collision rates based on 10,000 licensed drivers are also improving on an annual basis. A comparison between 2004 and 2005 statistics is shown in Figure 14.

Road Safety in Ontario: By the Numbers

Category	2005	2004
Fatality Rate	0.87	0.92
Fatality per 100 million km	0.61	0.66
Number of Licensed Drivers	8,762,210	8,655,597
Number of Motor Vehicles	7,854,228	7,698,416
Number of Fatalities	766	799
Number of Major Injuries	3,619	3,565
Number of Minor Injuries	29,518	29,918
Number of Fatalities Involving Drinking and Driving	174	192

Figure 14: Ontario road safety summary, 2005 [72]

The number of fatalities has declined significantly since 1980, and reached an all time low of 766 in 2005, even though the number of licensed drivers increased by 75% over the same period, as illustrated in Figure 15.

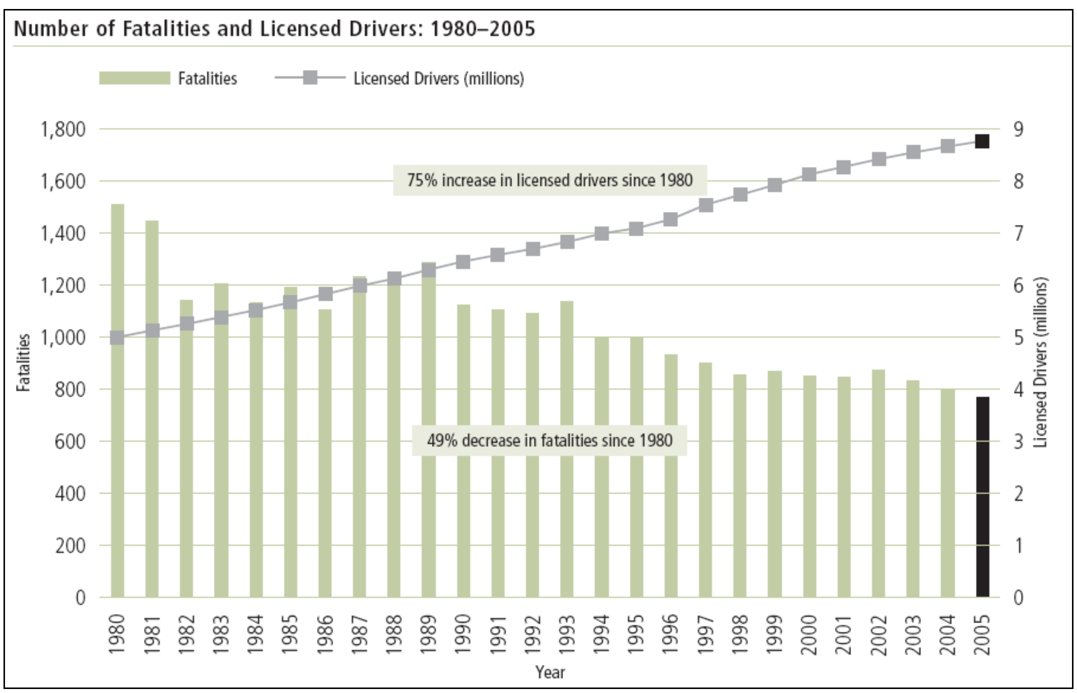


Figure 15: Ontario fatalities and licensed drivers, 1980-2005 [72]

Figure 16 presents selected key road safety statistics such as the total number of traffic fatalities, injuries, collisions, licensed drivers and registered vehicles.

Selected Statistics	2005
Total Reportable Collisions	230,258
Total Drivers Involved in Collisions	407,127
Total Vehicles Involved in Collisions	422,903
Fatal Collisions	684
Personal Injury Collisions	49,584
Property Damage Collisions	179,990
Persons Killed	766
Drivers Killed (excludes All-Terrain Vehicles* and Snow Vehicle Drivers)	466
Drivers Killed (Impaired or Had Been Drinking)	120
Passengers Killed	182
Pedestrians Killed	105
Other Road Users Killed	13
Persons Injured	71,850
Estimated Ontario Population (2005)	12,558,669
Licensed Drivers	8,762,210
Registered Motor Vehicles	7,854,228
Estimated Vehicle Kilometres Travelled (in millions)	125,102
Number of Persons Killed in Motor Vehicle Collisions per 100,000 People in Ontario	6.10
Number of Persons Killed in Motor Vehicle Collisions per 100 Million Kilometres Travelled	0.61
Collision Rate per 100 Million Kilometres Travelled	184.06
Fatal Collision Rate per 100 Million Kilometres Travelled	0.55
Number of Persons Killed in Motor Vehicle Collisions per 10,000 Licensed Drivers	0.87

* In this table, all-terrain vehicles includes two-wheel, three-wheel or four wheel off-road vehicles.

Figure 16: Ontario selected statistics, 2005 [72]

As mentioned in the ORSAR, the number of fatal and injury collisions in Ontario decreased slightly in 2005 as compared to 2004, as illustrated in Figure 17.

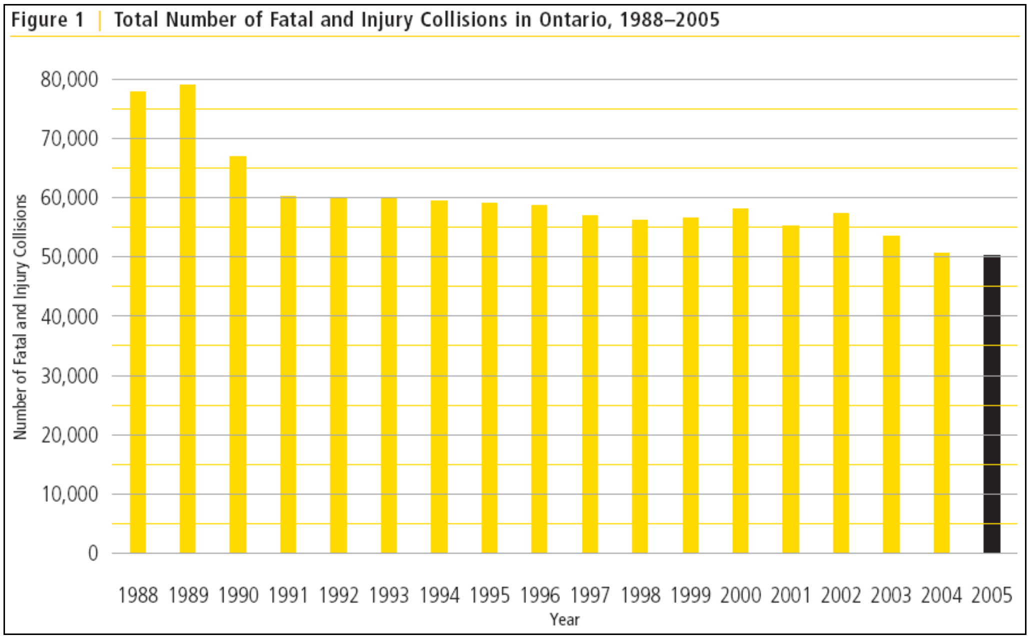


Figure 17: Ontario fatal and injury collisions, 1988-2005 [72]

In 2005, the fatal collision rate per 100 million kilometers travelled in Ontario was the lowest ever recorded in Ontario, as shown in Figure 18.

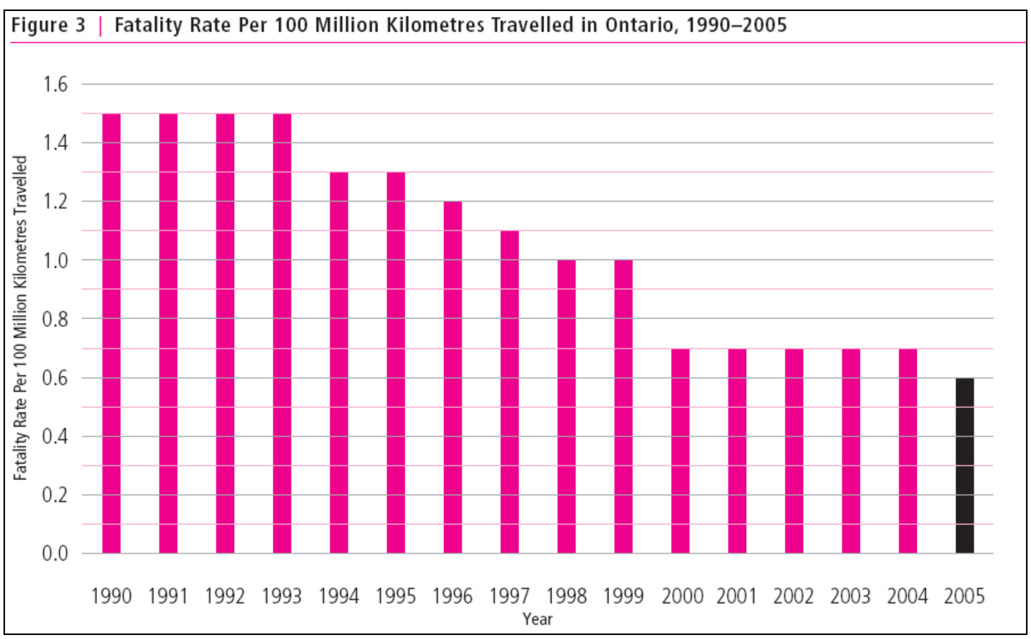


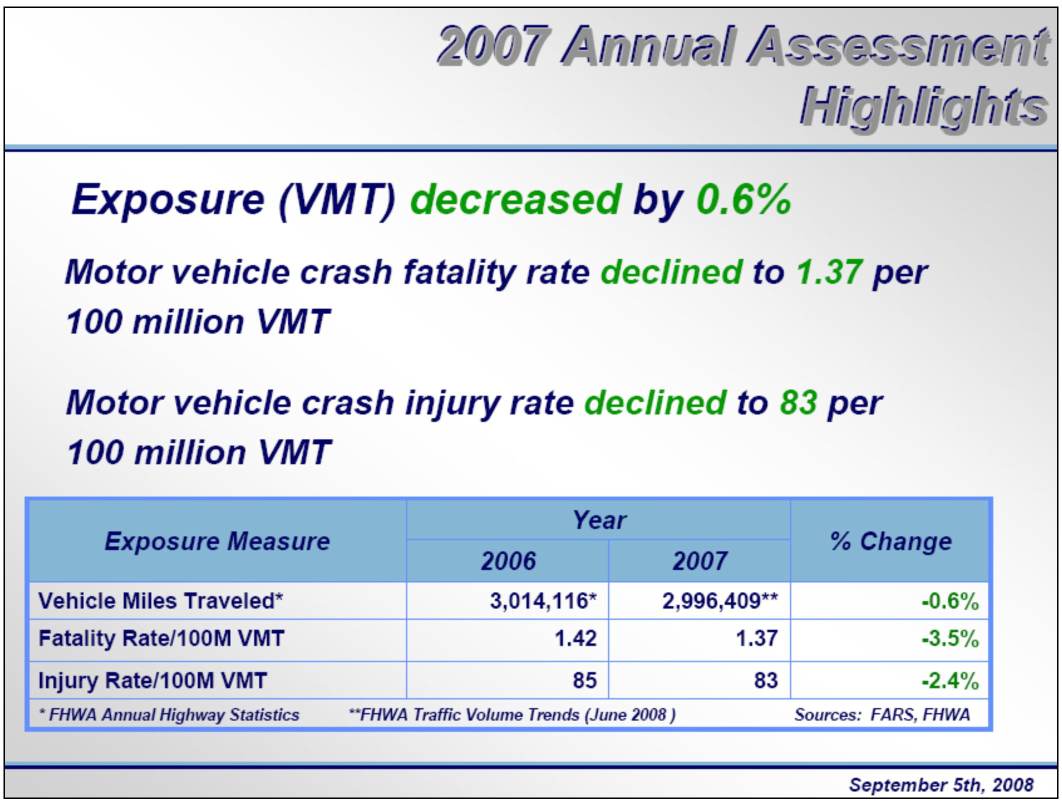
Figure 18: Ontario fatality rate per 100 million kilometers travelled, 1990-2005 [72]

7.2 Collision Statistics in U.S.

U.S. LSV collision statistics do not exist. In addition to U.S. passenger vehicle collision statistics, this chapter also presents U.S. golf cart collision statistics.

7.2.1 Passenger vehicle statistics

A NHTSA presentation [73], "Motor Vehicle Traffic Crash Fatality Counts and Estimates of People Injured for 2007" shows the latest U.S. motor vehicle registration and crash statistics. Figure 19 presents a comparison of the two most important exposure measures: motor vehicle crash fatality rate and crash injury rate, each based on an exposure measured in Vehicles Miles Travelled (VMT).



Exposure Measure	Year		% Change
	2006	2007	
Vehicle Miles Traveled*	3,014,116*	2,996,409**	-0.6%
Fatality Rate/100M VMT	1.42	1.37	-3.5%
Injury Rate/100M VMT	85	83	-2.4%

* FHWA Annual Highway Statistics **FHWA Traffic Volume Trends (June 2008) Sources: FARS, FHWA

Figure 19: U.S. annual assessment highlights, 2007 [73]

Two-vehicle collisions involving passenger vehicles and Light Truck Vehicles (LTVs) represent a significant proportion of the total collisions that occur on U.S. roads. The number of LTVs on U.S. roads has significantly increased in the past 20 years, at a much faster rate than the number of passenger cars over the same period. The occupants of the passenger vehicles are at greater risk of injury and death in these collisions, as shown by statistical data. Operators of LSVs are therefore further at risk, because of the low level of crash worthiness of LSVs compared to either LTVs or passenger cars, and because of the large differences in mass between LSVs and LTVs. The importance of relative masses of two colliding vehicles and the relation to risk of driver death is presented in Section 10.2.

Figure 20 illustrates that registration of LTVs, including SUVs, pickup trucks and other light trucks, increased significantly since 1988 so that in 2006, they accounted for 34% of the approximately 235 million total number of passenger vehicles.

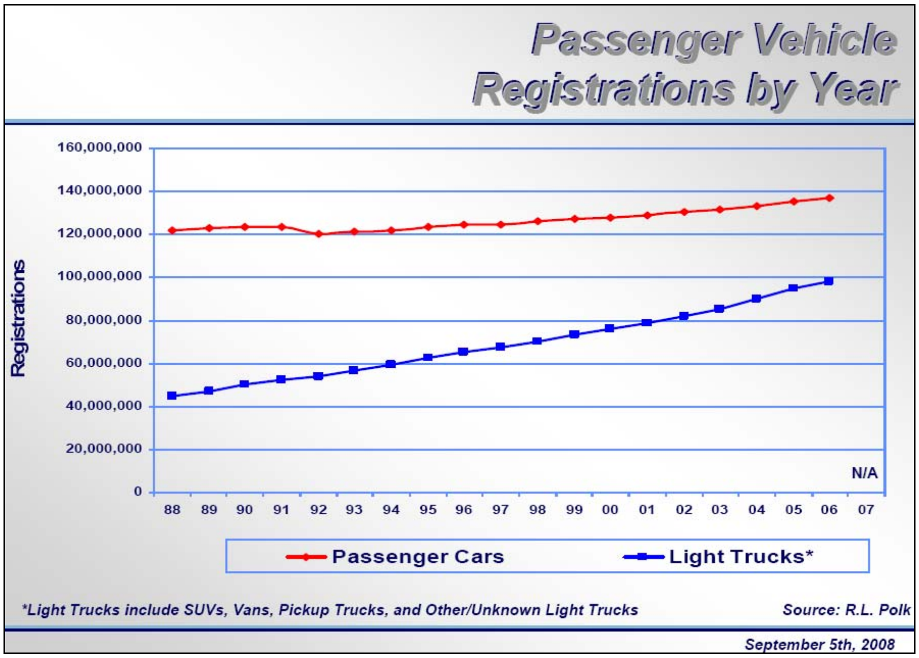


Figure 20: U.S. passenger vehicle registration by year [73]

Fatality rates per 100,000 registered vehicles, broken down by vehicle type, are presented in Figure 21.

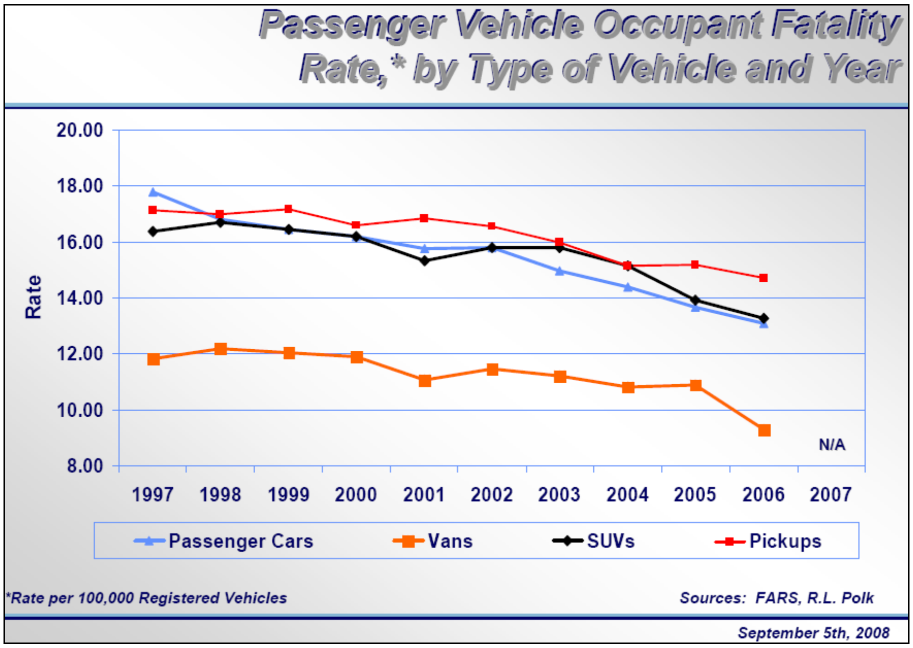


Figure 21: U.S. passenger vehicle occupant fatality rate, by vehicle type and year [73]

Two-vehicle crashes involving a passenger car and an LTV account for approximately 4,000 deaths each year, as shown in Figure 22.

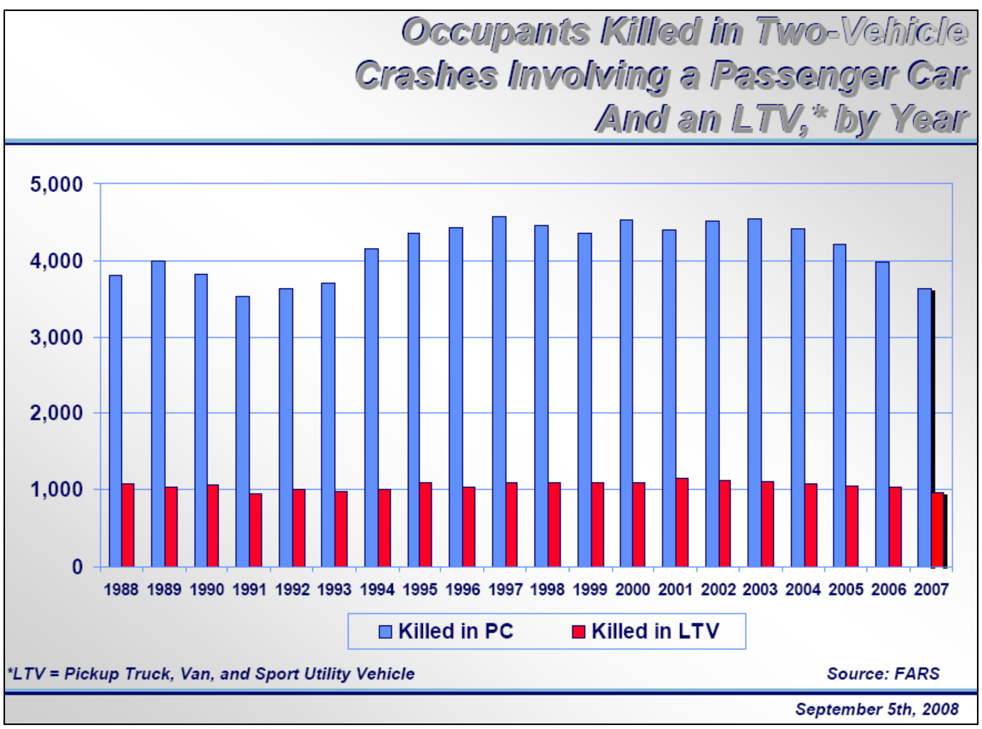


Figure 22: U.S. occupants killed in two-vehicle crashes, by year [73]

Of the total number of two-vehicle crashes involving a passenger vehicle and an LTV, the statistics shows that:

- in head-on collisions, 3.6 times as many passenger car occupants were killed as LTV occupants;
- when LTVs were struck in the side by a passenger car, 1.6 times as many LTV occupants were killed as passenger car occupants;
- when passenger cars were struck in the side by LTVs, 18 times as many passenger car occupants were killed as LTV occupants.

Among all of the crashes involving a passenger car and an LTV, those in which the LTV struck the passenger car on the side account for almost 50% of the deaths, as illustrated in Figure 23.

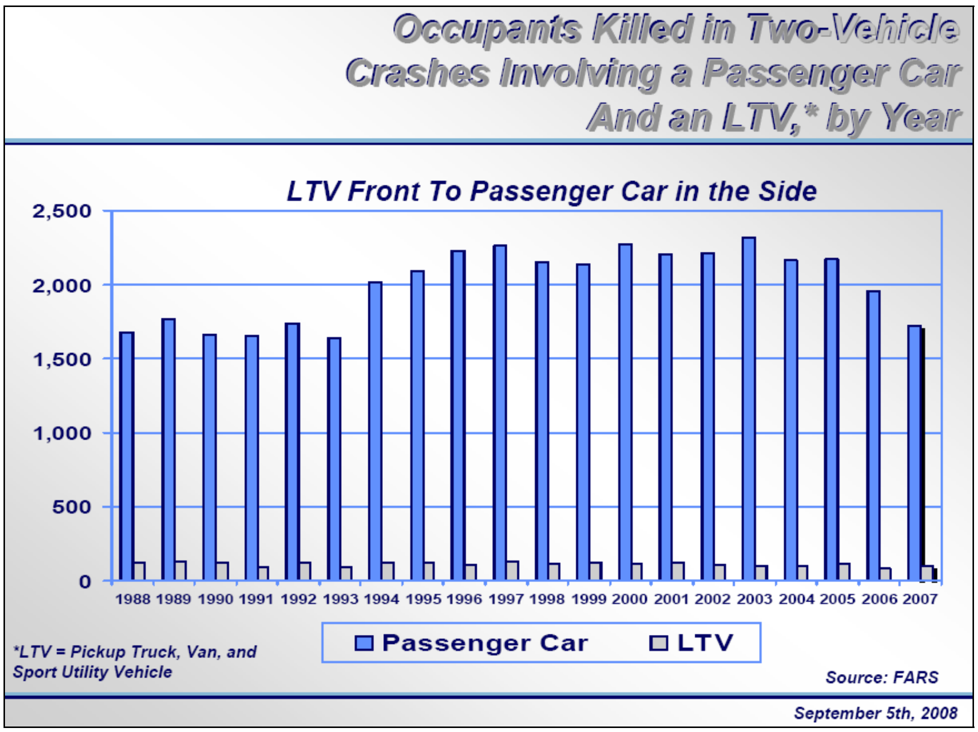


Figure 23: U.S. occupants killed in two-vehicle crashes: passenger car and LTV [73]

7.2.2 Golf cart injuries in U.S.

A study [74] published in the American Journal of Preventive Medicine in July 2008 presented an analysis conducted in 2007 to examine all cases of nonfatal golf cart–related injuries treated in U.S. emergency departments (EDs) from 1990 to 2006. The analysis was based on data from the National Electronic Injury Surveillance System (NEISS) database.

As shown in Figure 24, the majority of golf cart–related injuries with a reported location occurred at sports facilities (70.3%) and around a home or farm (14.5%), with the remainder (15.2%) occurring on streets or public property.

Description	Cases (*n*)	Weighted estimate (%)	95% CI
Age (years)			
Children (<16)	1169	46,117 (31.2)	43,170; 49,064
Adults (≥16)	2243	101,578 (68.8)	98,013; 105,144
Gender			
Male	2178	93,264 (63.1)	89,759; 96,768
Female	1234	54,432 (36.9)	51,270; 57,593
Diagnosis			
Soft tissue injury[a]	1553	70,523 (47.7)	67,102; 73,943
Fracture	798	32,914 (22.3)	30,370; 35,458
Laceration/amputation	494	22,926 (15.8)	20,666; 25,187
Concussion	86	3,176 (2.2)	2,348; 4,004
Internal organ injury	217	6,412 (4.3)	5,304; 7,520
Other[b]	264	11,745 (7.7)	10,134; 13,357
Body-part injured			
Head/neck[c]	856	33,262 (22.5)	30,735; 35,789
Trunk[d]	539	24,624 (16.7)	22,310; 26,937
Arm[e]	715	32,959 (22.3)	30,326; 35,591
Leg[f]	1226	53,948 (36.5)	50,840; 57,056
Other[g]	76	2,903 (2.0)	2,097; 3,709
Disposition			
Treated/released	3052	135,278 (91.6)	131,792; 138,764
Hospitalized[h]	340	11,544 (7.8)	10,031; 13,057
Other[i]	20	873 (.6)	419; 1,328
Location of injury			
Home/farm	326	14,979 (14.5)	13,108; 16,851
Street/public property	357	15,649 (15.2)	13,788; 17,510
Sports/recreational facility	1571	72,592 (70.3)	69,141; 76,042

[a]Includes sprain, strain, contusion, abrasion, hematoma
[b]Includes burns, crushing, dislocation, foreign body, dental injury, puncture, anoxia, poisoning, hemorrhage, electric shock, submersion, avulsion, not documented
[c]Includes head, neck, face, mouth, ear, eye
[d]Includes upper trunk, lower trunk, shoulder
[e]Includes upper arm, lower arm, elbow, wrist, hand, finger
[f]Includes upper leg, lower leg, knee, ankle, foot, toe
[g]Includes pubic region, injury to ≥20% of body, not documented
[h]Includes admitted, transferred, held <24 hours for observation
[i]Includes left against medical advice, not documented

Figure 24: Golf cart–related injuries treated in U.S. emergency departments (1990–2006) [74]

The same study showed that over the 17-year study period, the number of golf cart-related injuries increased steadily each year. In 2006, an increase of approximately 130% was observed compared to 1990, as illustrated in Figure 25. Unfortunately, statistics showing the number of golf carts in operation over the same period were not available.

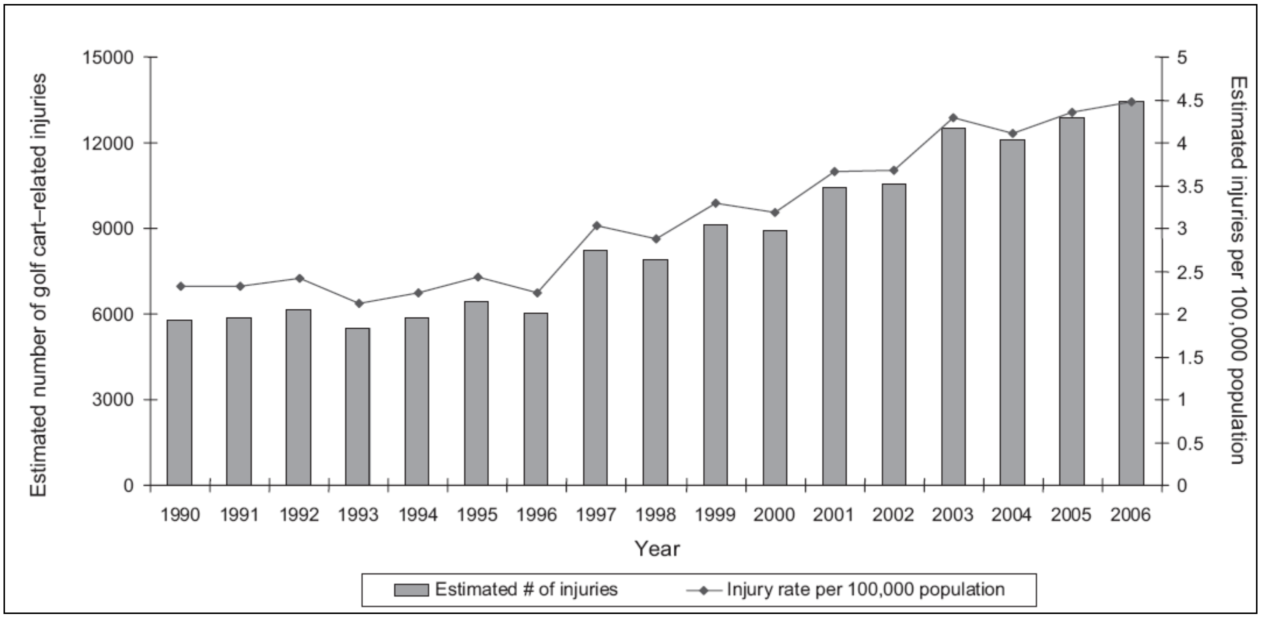


Figure 25: Estimated number and rate of U.S. golf cart–related injuries (1990–2006) [74]

7.3 Collision Statistics in Europe

The number of quadricycles on the road in Europe has been estimated to be approximately 305,000 in 2006, as mentioned in a recent presentation [66] based on a German Insurance Association (GDV - Gesamtverband der Deutschen Versicherungswirtschaft) [75] research project. The project, undertaken by GDV in collaboration with the Allianz Centre for Technology Munich, investigated the on-road and crash performance of Light-Weight Motor Vehicles (LWMVs), which is the German term used to identify quadricycles. Figure 26 illustrates the number of quadricycles in different European countries.

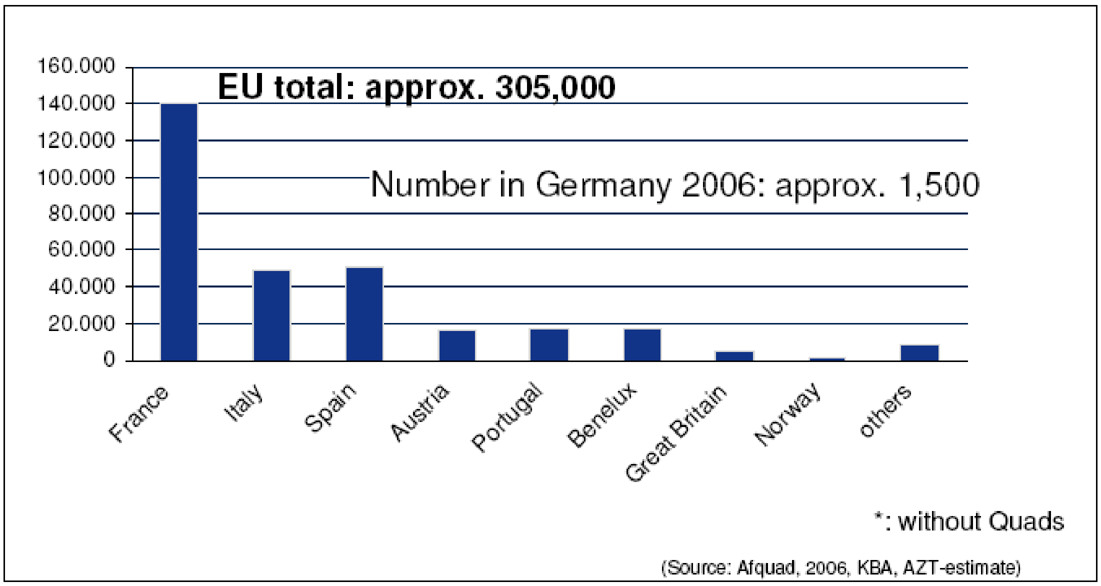


Figure 26: Quadricycles on the road in Europe, 2006 [66]

The 2008 ITAQ report [11] presented a detailed quadricycle ("voiturettes" in French) collision statistic based on data obtained from France's Observatoire national interministériel de sécurité routière (ONISR) or National Inter-Departmental Observatory on Road Safety (NIDORS), as shown in Figure 27. The figure shows the number of injuries and deaths resulting from collisions involving quadricycles in France, from 1993 to 2006.

Accidents and victims involving Quadricycles in France (1993-2004)

Year	# of Quadricycles involved	Total # of vehicles Involved	Quadricycle victims				Accidents involving at least one Quadricycle
			Deaths within 6 days	Injured	Seriously injured	Deaths per 100 victims	
1993	**371**	236462	**28**	325	102	7.93	366
1994	**361**	229247	**25**	307	86	7.53	350
1995	**384**	230347	**19**	332	77	5.41	366
1996	**368**	216578	**20**	289	70	6.47	360
1997	**351**	217737	**39**	293	76	11.7	350
1998	**378**	216551	**32**	307	87	9.44	372
1999	**354**	217407	**29**	292	68	9.03	348
2000	**335**	211550	**26**	275	47	8.64	334
2001	**299**	203301	**23**	243	61	8.65	298
2002	**272**	182027	**33**	225	46	12.8	272
2003	**265**	155087	**24**	203	38	10.6	265
2004	**203**	147308	**6**	159	37	3.64	202
Year	# of Quadricycles involved	Total # of vehicles Involved	Quadricycle victims				Accidents involving at least one Quadricycle
			Death within 30 days	Injured	Hospitalized	Deaths per 100 victims	
2005	**328**	145478	**12**	232	84	4.92	202
2006	**355**	137657	**23**	289	158	7.37	349

Source: Observatoire national interministériel de la Sécurité Routière (ONISR)

Figure 27: Quadricycle Injuries and fatalities, France 1993-2006 (translated) [11]

The same report shows two other graphs, Figure 28 and Figure 29:

- deaths per one million vehicles by vehicle type, France 2000-2006 (Figure 28)
- deaths per one million kilometers by vehicle type, France 2000-2006 (Figure 29); the authors estimated that quadricycles are driven approximately 5,000 km/year in France

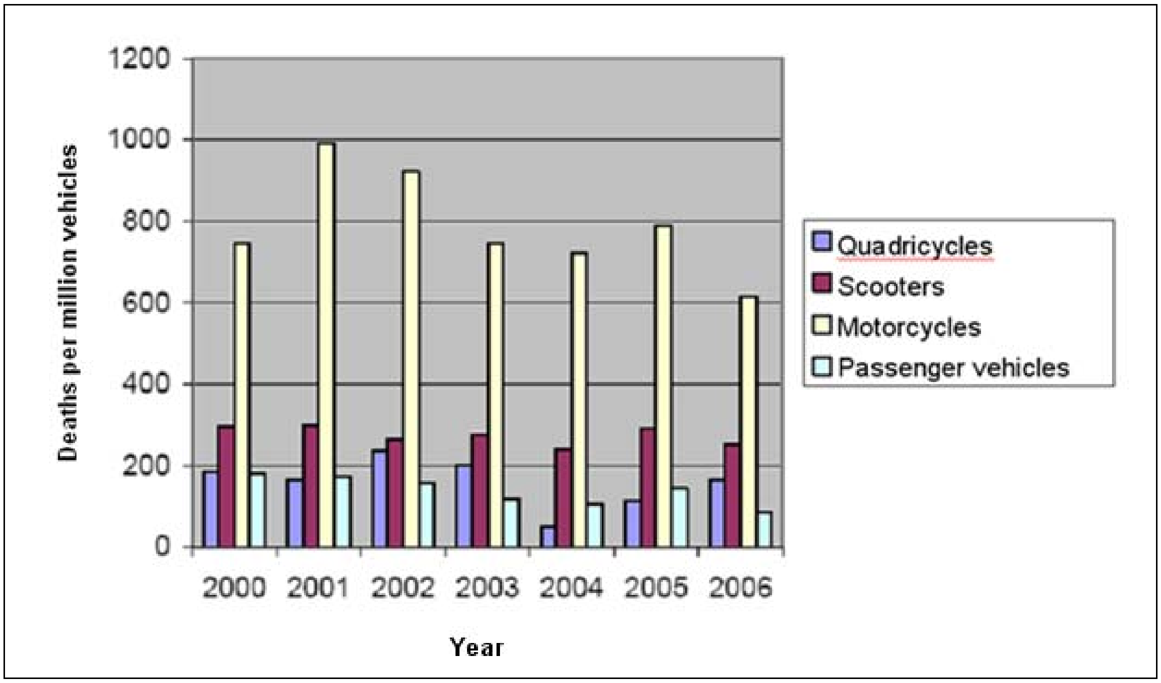


Figure 28: Deaths per one million vehicles by vehicle type, France 2000-2006 (translated) [11]

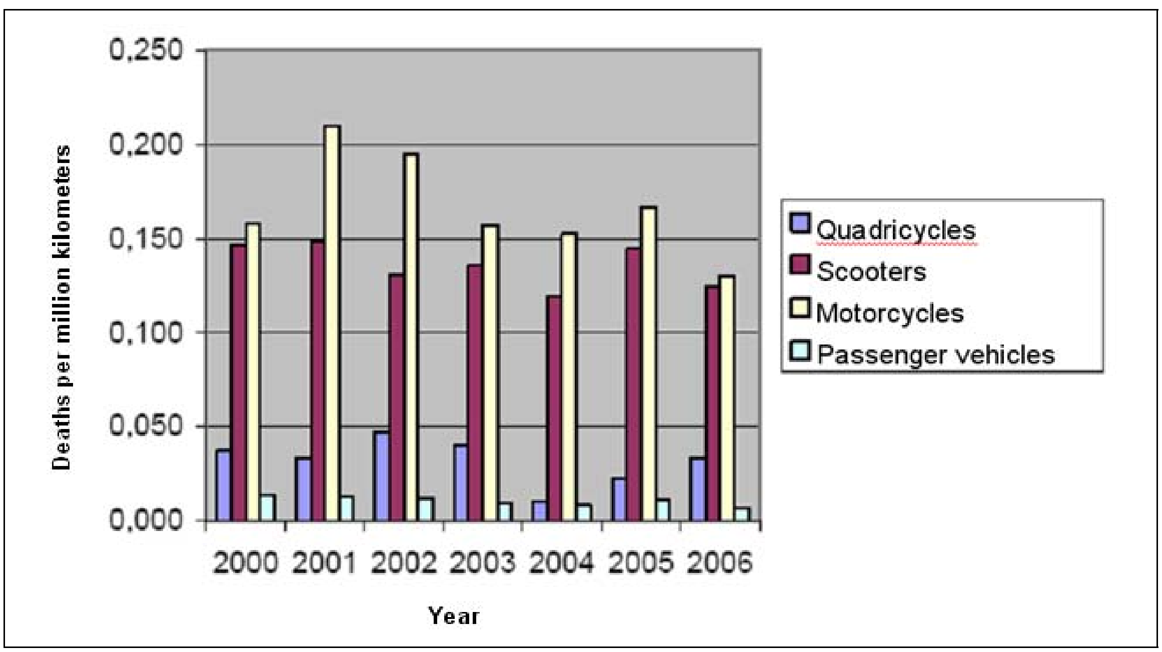


Figure 29: Deaths per one million kilometers by vehicle type, France 2000-2006 (translated) [11]

Additional data have been published by ONISR showing 2007 statistics for injuries (Figure 30) and deaths (Figure 31) that resulted from vehicle collisions.

Vehicles	Injuries, vehicle occupants[1]	Injuries, both vehicle occupants and other, involving at least one vehicle in the given class[2]	Parc on January 1st 2008	Injuries per million vehicles, vehicle occupants	Injuries per million vehicles, both vehicle occupants and other, involving at least one vehicle in the given class
Bicycles	4780	5424	21000000 [3]	227	258
Mopeds	15958	17847	1262000 [4]	12645	14141
Motorcycles	18638	21316	1248000 [4]	14934	17080
Quadricycles	335	536	140000 [5]	2293	3828
Passenger Cars	48796	87708	30550000	1597	2871
Minivans*	2745	8903	5655000	485	1574
Heavy Vehicles	728	5775	559000	1302	10330
Public Transit	863	1995	83000	_**	_**

* Due to problems that occurred this year in filling out analysis forms for this vehicle class, this data should not be used to support further analysis.
**Without data supporting the average occupancy of this class this figure is not possible to calculate.
Sources: 1. Vehicle occupant deaths involved in given class. ONISR, accident statistics.
2. Vehicle occupant and other deaths involved in given class. ONISR, accident statistics.
3. AFIT estimate, 1997.
4. Figure from 2006, Chambre syndicale nationale du motocycle.
5. Figure from 2006, Association européenne des fabricants de quadricycles.

Figure 30: Injuries by vehicle type, France 2007 (translated) [76]

Vehicles	Deaths, vehicle occupants[1]	Deaths, both vehicle occupants and other, involving at least one vehicle in the given class[2]	Parc on January 1st 2008	Deaths per million vehicles, vehicle occupants	Deaths per million vehicles, both vehicle occupants and other, involving at least one vehicle in the given class
Bicycles	142	153	21000000 [3]	6.8	7.3
Mopeds	325	343	1262000 [4]	258	272
Motorcycles	830	885	1248000 [4]	665	709
Quadricycles	24	32	140000 [5]	171	172
Passenger Cars	2464	3524	30550000	81	115
Minivans	131	420	5655000	23	74
Heavy Vehicles	68	662	559000	121	1184
Public Transit	35	107	83000	_**	_**

**Without data supporting the average occupancy of this class this figure is not possible to calculate.
Sources: 1. Vehicle occupant deaths involved in given class. ONISR, accident statistics.
2. Vehicle occupant and other deaths involved in given class. ONISR, accident statistics.
3. AFIT estimate, 1997.
4. Figure from 2006, Chambre syndicale nationale du motocycle.
5. Figure from 2006, Association européenne des fabricants de quadricycles.

Figure 31: Deaths by vehicle type, France 2007 (translated) [77]

The 2007 report prepared by ONISR “La sécurité routière en France: bilan de l'année 2007" [78], includes chapters covering French road safety policies and collisions statistics and includes a summary of the most important results and international comparisons. Such a comparison, extracted from that report, but from chapters [79] available in English is shown in Figure 32.

Main accidentology indicators for European countries in 2006

	Surface area (thousands of km²)	**Popula-tion** (millions)	**Density** (inhabi-tants/ km²)	**Vehicules in circula-tion** (thous-ands)	**Network length** (kilome-ters)	**Mileage** (millions vehicules x km)	**Nomber of vehicules per 100 inhabi-tants**	**Deaths by million inhabi-tants**	**Deaths per billion km driven**
Germany	357	82,5	231,2	54 910	644 480	689 729	66,5	61,7	7,4
Austria	84	8,4	100,1	5 339	106 962	82 270	63,6	87,0	8,9
Belgium	33	10,5	322,2	6 251	152 256	96 369	59,6	102,0	11,1
Cyprus	9	0,8	89,7	ND	ND	ND	ND	103,6	ND
Denmark	43	5,5	126,5	2 554	72 411	47 940	46,9	56,1	6,4
Spain	505	44,6	88,3	28 531	666 204	ND	64,0	92,0	ND
Estonia	45	1,3	28,7	ND	ND	ND	ND	156,9	ND
Finland	338	5,3	15,6	2 975	79 132	52 150	56,2	63,5	6,4
France	**551**	**61,5**	**111,6**	**37 476**	**1 000 960**	**555 500**	**60,9**	**76,5**	**8,5**
Greace	132	11,2	84,7	6 996	116 100	81 635	62,6	148,3	20,3
Hungary	93	10,1	108,6	3 457	180 994	ND	34,2	129,2	ND
Ireland	71	4,4	61,8	2 139	95 752	37 840	48,8	84,0	9,7
Italy	301	58,9	195,6	43 141	305 388	654 197	73,2	96,2	8,7
Lettonia	65	2,3	35,6	ND	ND	ND	ND	177,0	ND
Lituena	65	3,4	52,1	ND	ND	ND	ND	223,2	ND
Luxembourg	3	0,5	181,7	376	2 894	ND	80,0	76,6	ND
Malta	316	0,4	1,3	ND	ND	ND	ND	25,0	ND
Netherlands	42	16,5	396,1	8 716	117 430	133 800	53,0	44,4	5,5
Poland	323	38,0	117,9	18 035	282 615	ND	47,4	137,9	ND
Portugal	93	10,7	115,1	5 481	81 739	ND	51,4	90,9	ND
United kingdom	244	61,0	250,0	34 207	423 651	510 978	56,1	54,1	6,5
Slovaquie	49	5,3	108,1	1 834	17 755	13 402	34,6	109,2	43,2
Slovenia	20	2,0	98,7	1 167	20 236	15 971	58,4	131,0	16,4
Sweden	450	9,2	20,4	5 205	215 000	75 346	56,8	48,6	5,9
Czech Republic	79	10,2	129,3	4 951	55 510	51 686	48,5	104,2	20,6
Total EU	**4 309**	**464,4**	**107,7**	**273 741**	**4 637 469**	**3 098 813**	**59,0**	**84,9**	**12,7**
Other countries									
Iceland	103	0,3	2,9	236	91 916	2 848	78,7	103,3	10,9
Norway	324	4,7	14,6	3 030	92 863	37 143	64,2	51,3	6,5
Switzerland	41	7,5	181,9	5 108	71 027	63 069	68,0	49,3	5,9

ND : not avaliable.
Source IRTAD for the following data :
Number of car : 2006 except : Portugal 2005 ; Italy 2004 ; Irleland 2003 ;Slovaquia 2002.
Network length : 2006 sauf Spain 2005 ; Hungaria et Luxembourg 2004 ; Irelande2001; Slovaquia 2002 ; Iceland 2000 ; Netherland 1999 ; Portugal 1993 ; Italy 1992; Greace 1991.
Mielage : 2006 except Denmark 2004 ; Italy and Netherland 2003 ; Ireland 2001 ; Iceland and Slovaquia 2000 United Kingdomn and Greace 1998.
Population : source IRTAD except for Ireland, Luxembourg, Slovaquia, Sweden, Iceland and Norway : source INED.

Figure 32: Main road safety indicators for European countries in 2006 [80]

7.4 Selected metrics

A commonly used metric in North American collision statistics is the number of deaths and injuries per billion or a hundred million of kilometres (or miles) driven. Other relevant metrics presented include casualty rates per 100,000 population and also per 100,000 motor vehicles registered. While population and registered vehicle numbers can be very precise, the same cannot be said about the number of kilometres driven; that number must be estimated. Nonetheless, the number of casualties per one, one hundred or one thousand million kilometres travelled is presented in most road statistic reports around the world.

The selected collision statistics presented in Sections 7.1 to 7.3 illustrate an overall picture of the road safety environment in North America and several European countries. Selected metrics are shown in Table 5 for illustration purposes. For the cells marked N/A, the data are still available from statistic reports, but not from data presented in Sections 7.1 to 7.3.

Table 5: Selected collision statistic data

Jurisdiction	Injuries per 100 million kilometers travelled	Deaths per 100 million kilometers travelled	Injuries per million motor vehicles registered	Deaths per million motor vehicles registered
Canada	60.42*	0.89*	N/A	N/A
Ontario	52.52*	0.60*	N/A	97^
United States	53.12*	0.89*	N/A	N/A
France (passenger cars and minivans)	N/A	0.70**	1,982+	104+
France (quadricycles)	N/A	3.3**	2,293+	171+
Germany	N/A	0.74*	N/A	N/A
United Kingdom		0.65*		
European Union	N/A	1.27*	N/A	N/A

*2006 data, ^2005 data, +2007 data
** ITAQ report [11] estimated 13,164 km/year for ”voitures de tourisme” (passenger cars) and 5,000 km/year for “voiturettes” (quadricycles)

It is difficult to compare the numbers presented in Table 5 because there are numerous other factors that should be taken into consideration, such as structural (country size, density and quality of the road network, population, etc) and socio-economic differences (vehicle composition, user behaviour, etc.). Nonetheless, some similarities can be identified, such as the number of deaths per 100 million kilometers traveled.

Table 5 shows that the deaths per 100 million vehicle-kilometres of travel (VKT) in France (for passenger cars) are comparable to those for passenger cars in the U.K., Germany, the U.S., Canada and Ontario. However, the death rate for quadricycles (voiturettes) is almost five times higher. This is not directly useful, as the voiturette is much lighter than a North American LSV, and it is allowed to operate on roads with a speed limit up to 90 km/h. However, passenger cars in Europe tend to be lighter than passenger vehicles used in North America.

7.5 Passenger Vehicle Categories

The passenger vehicle landscape is quite different in North America compared to most European countries. Small and medium size vehicles represent the majority of passenger cars in Western European countries, as shown in Figure 33. The share of 4x4 vehicles (European term for all wheel drive vehicles or SUVs) has been increasing since 1990 to reach approximately 10% of the new passenger car registrations in 2007, as shown in Figure 34. By contrast, LTVs represent approximately 45% of all passenger vehicles in Canada and United States. The likelihood of a collision between a low weight vehicle or an LSV and a larger, heavier vehicle is significantly increased on Canada's roads compared to most of the European countries.

New Passenger Car Registrations - Breakdown by Segments and Bodies

Years	Passenger cars in W. Europe: breakdown by segments							Passenger cars in W. Europe: breakdown by bodies							
	Total Market	Small	Lower-Medium	Upper-Medium	Executive	Others	Unknown	Total Market	Saloons	Estates	Coupes	Convertibles	Mono-spaces (1)	Others	Unknown
2007	14792143	37.1	32.4	16.3	14.0	0.1	0.1	14792143	56.6	11.8	1.5	2.8	17.4	9.8	0.2
2006	14620864	35.2	32.9	12.4	10.9	8.5	0.1	14620864	57.3	13.0	1.2	2.7	18.3	7.4	0.2
2005	14497932	32.9	34.9	13.1	10.9	7.9	0.1	14497932	57.3	13.0	1.1	2.8	18.9	6.6	0.2
2004	14524450	33.9	34.9	13.1	10.9	7.9	0.1	14524450	57.3	13.1	1.1	2.8	18.9	6.6	0.2
2003	14212781	34.2	32.4	13.7	12.9	6.6	0.1	14212781	62.2	13.2	1.4	2.5	14.5	5.4	0.7
2002	13999372	32.7	33.9	14.8	12.7	5.7	0.1	13999372	65.9	12.5	1.7	2.0	12.7	5.2	0.1
2001	14418763	32.8	33.8	15.9	12.6	4.9	0.1	14418763	66.2	12.1	1.9	1.9	2.3	15.6	0.1
2000	14312085	32.7	34.2	15.7	12.7	4.6	0.1	14312085	67.5	12.6	2.2	1.5	2.3	13.8	0.1
1999	14635183	31.3	33.9	17.8	12.5	4.5	0.1	14635183	71.5	14.4	2.2	1.4	5.8	4.6	0.1
1998	13933908	31.1	33.2	18.9	12.9	3.8	0.1	13933908	73.4	14.4	2.0	1.5	4.6	3.9	0.1
1997	13007766	32.6	31.6	19.3	13.2	3.2	0.1	13007766	75.8	13.0	1.9	1.7	4.0	3.5	0.1
1996	12403108	32.3	32.3	18.8	13.6	2.9	0.2	12403108	79.3	11.1	2.1	1.4	2.5	3.5	0.2
1995	11631823	32.9	31.4	18.7	14.0	2.9	0.1	11631823	80.6	10.6	2.2	1.3	1.7	3.5	0.1
1994	11568006	31.9	31.6	20.0	13.1	2.7	0.7								
1993*	11126839	31.1	28.0	32.5	12.7	3.0	0.7								
1992*	13150203	31.6	30.7	21.7	12.5	2.7	0.8								
1991*	13137494	32.2	27.9	22.9	13.2	2.6	1.2								
1990*	13165421	30.4	27.7	22.9	13.0	2.4	2.7								

Source: Association Auxiliaire de l'Automobile (AAA)

NOTE: W.Europe includes: EU-15 countries + EFTA countries (Iceland, Norway, Switzerland).
*Market shares (%) from 1990 to 1993 do not include shares from Finland, Norway and Sweden, but do include shares from Switzwerland
(1) In 2002 there was a change in the definition of the monospace segment. This category now includes 'classic' monospaces, 'compact' monospaces and minispaces.

Figure 33: New Passenger Car Registrations in Europe - Breakdown by Segments and Bodies [81]

New Passenger Car Registrations in W.Europe

Breakdown by Specifications: Share of 4x4 (%)

4x4 (%)	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
AUSTRIA	7.1	6.0	6.0	5.9	4.9	5.7	6.6	6.5	5.5	6.5	6.9	6.6	7.9	8.8	10.3	12.5	13.6	15.3
BELGIUM	1.8	1.9	2.4	2.6	2.3	2.2	1.9	2.0	2.3	2.7	2.7	3.3	4.2	4.7	5.1	5.1	5.6	6.5
DENMARK	0.4	0.3	0.2	0.2	0.2	0.1	0.4	0.5	0.5	0.7	0.7	0.8	1.2	1.5	2.0	2.5	4.2	3.3
FINLAND	4.8	4.6	3.9	1.9	0.5	0.9	1.1	1.4	2.2	2.5	3.1	3.0	3.8	4.8	6.1	8.6	11.1	13.3
FRANCE	1.1	1.1	1.1	1.2	1.3	1.5	1.5	1.8	2.1	2.9	3.5	4.1	4.5	5.1	5.6	6.3	6.5	7.2
GERMANY	3.2	2.7	3.2	3.6	3.0	3.5	3.1	3.1	3.6	4.4	5.0	5.5	6.2	7.1	7.7	8.0	9.1	10.5
GREECE									4.6	5.9	5.6	5.2	7.3	10.6	10.2	10.3	10.6	11.0
IRELAND	0.1	0.1	0.2	0.9	1.1	1.2	0.8	1.1	1.8	2.0	2.5	3.4	4.0	4.5	5.5	6.4	6.8	7.3
ITALY	3.1	3.2	3.0	2.9	2.6	2.7	3.0	2.8	3.6	4.7	4.8	5.2	6.3	6.3	6.3	7.8	9.6	10.4
LUXEMBOURG	3.2	0.7	3.9	4.0	4.4	4.6	4.5	5.2	5.8	6.8	6.3	6.7	8.2	10.1	10.9	10.1	12.1	12.4
NETHERLANDS	0.7	0.4	0.5	0.6	0.6	0.8	0.8	1.1	1.6	2.4	2.5	3.2	3.5	4.1	4.6	5.4	5.7	6.5
PORTUGAL	0.4	0.5	0.5	0.4	0.2			0.1	0.3	0.3	0.3	3.4	1.8	2.1	2.2	2.4	2.8	3.1
SPAIN	0.8	0.2	0.1	0.1	0.1	0.2	0.1	0.2	0.4	0.4	0.3	0.5	0.3	0.8	0.8	0.9	1.2	10.4
SWEDEN	1.9	1.6	1.6	1.5	2.0	2.3	3.0	3.1	4.5	5.1	6.9	7.3	8.8	10.7	12.1	12.7	13.5	15.1
UNITED KINGDOM	2.3	2.7	3.3	3.8	4.1	4.5	4.3	4.3	5.0	5.3	5.5	6.5	6.8	7.6	8.5	8.9	8.5	8.7
EUROPEAN UNION (15)					2.4	2.7	2.6	2.7	3.2	3.8	4.1	4.7	5.3	6.0	6.4	7.0	7.7	9.4
ICELAND									33.5	31.3	36.8	40.5	39.4	39.8	41.2	41.7	41.9	43.5
NORWAY	0.6	0.8	1.3	2.4	1.9	1.9	3.8	6.0	8.5	8.8	11.1	11.0	13.8	17.0	20.5	21.3	27.5	21.9
SWITZERLAND	14.7	14.3	14.3	13.9	12.4	12.7	11.8	12.3	13.0	16.6	17.4	19.0	18.9	19.6	20.4	22.1	24.7	25.2
EFTA					9.9	10.0	9.3	10.3	12.4	15.3	16.6	17.6	18.1	19.5	20.4	22.8	26.2	24.9
WEST. EUROPE	2.6	2.5	2.7	2.9	2.6	2.9	2.8	2.9	3.5	4.1	4.5	5.0	5.6	6.3	6.8	7.5	8.2	9.9

Source: AAA (Association Auxiliaire de l'Automobile)

Figure 34: New Passenger Car Registrations in W. Europe, Share of 4x4 vehicles [82]

8 LSV EFFECT ON MIXED TRAFFIC FLOW

Transport Canada mirrored the NHTSA regulation and limited LSV top speed to 40 km/h. Ironically, such a speed restriction may present a safety hazard of its own. Many traffic safety studies over the years have shown that an increased dispersal of vehicle speeds (greater range of speeds) leads to a greater collision risk. The more compressed the vehicle speed range, the safer the roads tend to be. The further an individual vehicle's speed deviates from the average speed on the road, the higher the probability of collision [83]. Consequently, in mixed traffic, LSV collision severity is reduced by limiting top speed and performance, but the likelihood of collision occurrence is increased by such limitations, because the presence of LSVs on the road widens the range of vehicle speeds, and an LSV, by necessity, must travel more slowly than the average speed on the road.

In this report, roads with a posted speed limit of 50 km/h are examined. This is the class of public road that most closely matches the limited performance of LSVs. In Canada, few public roads have a posted speed limit less than 50 km/h. A limit lower than 50 km/h is often found in residential areas and school zones, where the speed limit is typically 40 km/h, and in parks or park-like settings.

Traffic operating speeds often exceed the posted speed limit. It is considered good practice to set the posted speed limit at about the 85th percentile speed, that speed which is exceeded by only 15% of the drivers. This is not always done, however. For purposes of this investigation, a typical 85th percentile speed on a road posted at 50 km/h is taken to be about 60 km/h.

A speed limit of 50 km/h is most common on roads in urban areas, but these roads may vary considerably, from low volume two-lane residential streets, to high volume multi-lane collectors and arterials.

As a result, the investigation needs to examine the effect of LSVs on mixed traffic flow on the following types of road:

- two-lane roads (range of volumes); and
- multi-lane roads (range of volumes).

The Canadian road system accommodates a wide range of road users, including conventional passenger vehicles, trucks, buses, tractors, motorcycles, scooters, power-assisted bicycles, bicycles and pedestrians, and in some locales, horse-drawn vehicles. Many of these vehicle classes cause “friction” or “interference” with passenger vehicles, to a greater or lesser degree. In urban areas, pedestrians are usually on sidewalks, and do not interfere with motor vehicle traffic except at intersections. Scooters, power-assisted bicycles, and bicycles are low speed vehicles, but usually do not occupy a full traffic lane. Motorcycles are higher-powered vehicles, and have no difficulty keeping up with normal traffic flow. Tractors and horse-drawn vehicles might be considered the closest to LSVs in terms of speed and acceleration characteristics, but are not usually found in urban areas. Trucks are found everywhere as a normal part of traffic flow. Their maximum speed is not a limitation, but their acceleration and braking performance is considerably less than those of passenger vehicles. As a result, trucks are usually considered, in capacity analyses, to have a passenger car equivalence (PCE), so that for example a truck with a PCE of 3 would be considered to equal three passenger vehicles in terms of its effect on capacity.

Other classes of vehicle or operation may also cause friction with passenger vehicles. Buses, trucks picking up municipal waste, postal and courier delivery trucks, and others, may all make frequent stops. It is not uncommon for the driver of a large vehicle to leave the vehicle parked in its traffic lane while making a delivery. Some of the vehicles that make frequent stops may also move quite slowly between stops. There are also other slow-moving vehicles, such as digging, grading and maintenance equipment, and snowploughs. These maintenance vehicles typically do not make long trips on roads, but they do travel on roads.

8.1 LSV Acceleration Characteristics and Effect on Traffic Flow

The Idaho National Laboratory conducted a study for the U.S. Department of Energy in 2006, titled “Guidelines for the Establishment of a Model Neighborhood Electric Vehicle (NEV) Fleet” [7]. This study established an acceleration performance goal of 0-20 mi/h (0-32 km/h) in 6.0 s for an LSV with a payload of 332 lb (150 kg), equivalent to two passengers. The report includes data sheets on numerous LSVs currently available. Their web site [84] contains data sheets on five more recent models of LSV, manufactured by GEM, Miles and ZENN in 2007 and 2008. All five were able to achieve the acceleration performance goal of 6.0 s. Some older vehicles could not achieve this goal, and had acceleration times from 0-20 mi/h ranging typically from 7 to 10 s, with a few vehicles having times as long as 25-30 s. Some LSVs on the market can achieve 0-20 mi/h in 4.5 s.

Extrapolating the vehicle performance curves in the above-cited report to 25 mi/h (40 km/h) yields a typical acceleration time from 0-25 mi/h (0-40 km/h) of about 8 s for those vehicles that could achieve an acceleration time from 0-32 km/h in 6.0 s. For 0-20 mi/h in 6.0 s, the average acceleration is 4.89 ft/s/s (or 3.33 mi/h/s, or 1.49 m/s/s, or 5.36 km/h/s). For 0-25 mi/h in 8.0 seconds, the average acceleration is 4.59 ft/s/s (or 3.13 mi/h/s, or 1.40 m/s/s, or 5.04 km/h/s).

The Institute of Traffic Engineers Transportation and Traffic Engineering Handbook, 1976, Table 2.4 [83], shows the typical acceleration from a standing start for various vehicle types. The information in Table 6 is extracted from that table, except that the last line for LSVs has been taken from the information above.

It can be seen that the average acceleration of the most recent LSVs is about three times that of heavy trucks. The comparison is actually slightly worse than that for LSVs, as the acceleration for the other vehicles, to the LSV top speed of 40 km/h, would be somewhat higher than shown in Table 6 for 48 km/h. However, the acceleration of LSVs is significantly better than that for heavy trucks and buses, and about 60% of that of a car or pickup.

The maximum acceleration to 40 km/h for the LSVs is therefore taken to be about three times that of heavy trucks, to the same speed, though a few of the newer models of LSV can accelerate somewhat faster than this. This is not likely to be of major significance in affecting road capacity, as it does not last very long, and it seems likely that LSVs will accelerate closer to their maximum rate than heavy trucks. This minimal effect of LSV acceleration on traffic flow is unlikely to be worse at intersections, until the maximum speed of the LSV is reached. The limited LSV maximum speed is likely to be more significant factor than the LSV acceleration. This does suggest, however, that it will be desirable to license for use on public streets only those LSVs which can achieve the performance goal of 0-20 mi/h (0-32 km/h) in 6.0 s.

Residential streets usually have a relatively low traffic volume, and few trucks. On more important roads in the network (collectors and arterials), even those with low speeds, traffic volumes and truck volumes may be higher. Even in central business areas, trucks may be quite common, as pickup and delivery operations depend on them. Where the LSV acceleration is likely to be most problematic (though even then, it is not likely to be as serious as the limited maximum speed) is on two-lane roads with high traffic volumes and few trucks. On such roads LSVs may more likely be seen as restricting traffic flow than on roads where motorist perception may attribute restricted flow to trucks as well as (or instead of) LSVs.

Table 6: Maximum acceleration for various vehicle types

Vehicle Type	Typical Maximum Acceleration to 30 mi/h (48 km/h) on a Level Road	
	mi/h/s	km/h/s
Large Car	7.0	11.3
Intermediate Car	5.0	8.0
Compact Car	5.0	8.0
Small Car	4.0	6.4
Composite Car	5.0	8.0
Pickup Truck	5.0	8.0
Two-axle, Single Unit Truck	1.0	1.6
Tractor semi-trailer Truck	1.0	1.6
LSV (best performance)	3.1*	5.0**

* to 25 mi/h ** to 40 km/h

In 2002, the Centre for Electric Vehicle Experimentation in Québec (CEVEQ) conducted a pilot study for Transport Canada, titled “Assessment of Low Speed Electric Vehicles in Urban Communities: Pilot Project”, Report TP 13942E [9]. Various types of low speed electric vehicle were made available to residents of St. Jérôme, Québec, who drove them on both two-lane and multi-lane roads. Focus groups and questionnaire surveys were used to gauge the response to LSVs of both LSV drivers and other road users. Neither group identified low acceleration as either a problem, or a nuisance. The LSV drivers were actually quite pleased with the acceleration of the vehicles.

8.2 LSV Speed Characteristics and Effect on Traffic Flow

Federal law sets the maximum speed of an LSV manufactured in Canada, or imported into Canada, at 40 km/h, primarily for safety reasons. The fact that they would be licensed to operate without meeting many of the safety standards required of conventional passenger cars means that the consequences of even a moderate-speed collision could be severe. For this reason, many of the U.S. states which permit their use in mixed traffic, limit their use to roads with a maximum normal regulatory posted speed of 35 mi/h (56 km/h).

As described in the previous section, the acceleration of an LSV is significantly better than that of heavy trucks, and about 60% of that of a car or pickup truck, so is unlikely to severely impact traffic operations. However, the maximum speed of an LSV is markedly less than that of most other vehicles on urban roads, and they are likely to have significantly more impact on traffic flow than other low-speed vehicles like bicycles and scooters, because they occupy the better part of the lane width.

The fact that federal regulations limit the maximum speed of an LSV to 40 km/h does not mean that they can all attain that speed, although all the newer models come very close. Some are believed to have significantly greater inherent speed capability, with a speed limiter set to 40 km/h. The 2007 and 2008 data for the LSVs included in the Idaho National Laboratory study cited above shows that maximum LSV speed may vary from 24.7 to 25 mi/h (39.8 to 40.2 km/h).

As noted above, the 85th percentile speed of vehicles on a road with speed limit of 50 km/h is taken to be about 60 km/h, with a mean of about 55 km/h. The mean maximum speed of a representative sample of LSVs is taken to be 40 km/h. The objective of this section is to determine, to the extent possible, the effect on capacity of 40 km/h LSVs in mixed traffic, the remainder of which is cars travelling at 55 km/h and trucks travelling at 50 km/h.

Many theoretical analyses and empirical traffic studies have been carried out over the last 50 years, and various editions of the U.S. Highway Capacity Manual [85] have been published over that time period. Yet none of them directly addresses the situation at hand in a satisfactory manner.

A. Tzedakis of the Transport Department of the Imperial College of Science and Technology, London, UK, wrote a paper titled “Different Vehicle Speeds and Congestion Costs.” [86]. A model was developed for the quantification of delay costs caused by slow-vehicle traffic to fast-vehicle traffic on a lane of a two-lane road. It is assumed in the model that overtaking is not possible. In the model, the speed of traffic does not depend upon the volume of traffic, that is, no speed-volume relationship is used. Analyses were carried out over a range of speeds, traffic volumes and road section lengths. Delay costs were calculated, using 1976 costs in pence, which makes them difficult to convert to current Canadian dollars. While it is not possible to derive relevant absolute delays and costs, Figure 35 shows a graph from that paper illustrating the sensitivity of travel cost to variations in several key variables, such as fast vehicle speed, slow vehicle speed, traffic volumes, and road section length.

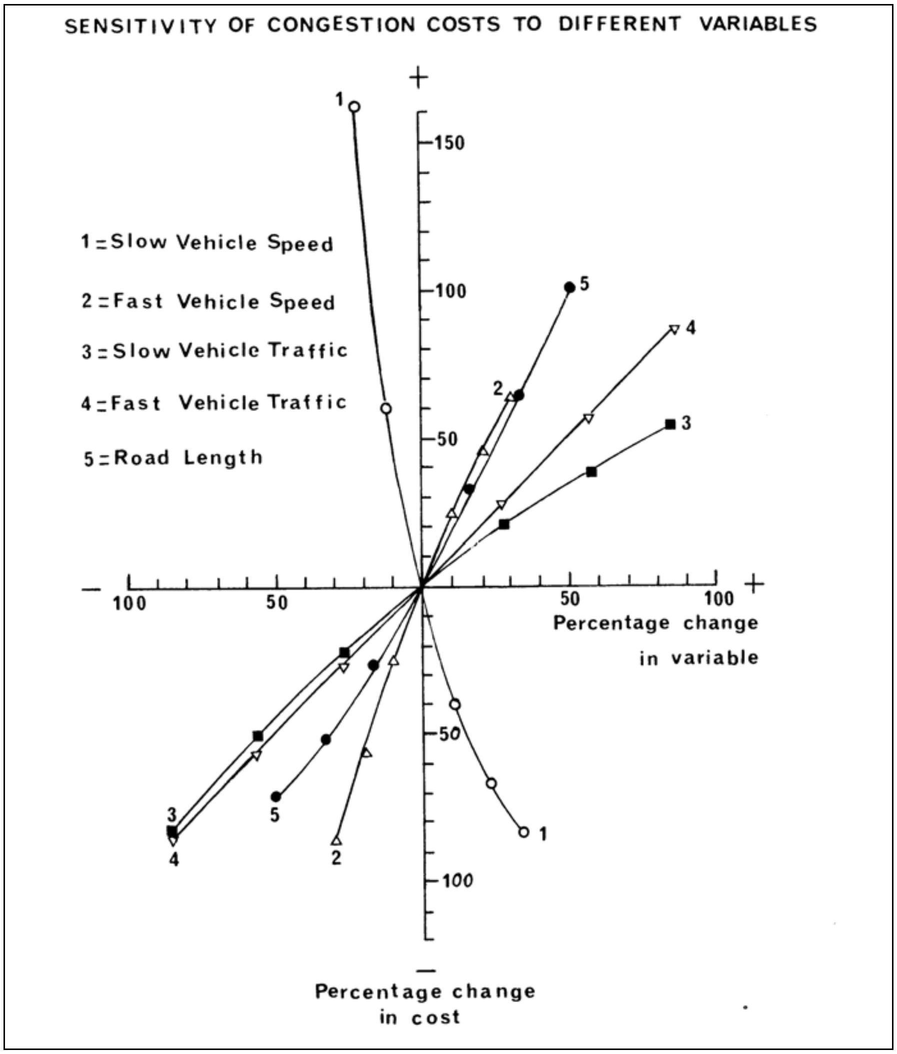


Figure 35: Sensitivity of congestion costs to different variables [86]

Figure 35 shows that, in this model, total congestion costs are highly sensitive to both the fast vehicle speed and the slow vehicle speed and road section length, and somewhat less, but still quite, sensitive to slow vehicle traffic volume and fast vehicle traffic volume. For example, using Curve 1 for Slow Vehicle Speed, the curve shows that if the speed is increased by 20%, the congestion cost is reduced by about 55%. The same curve shows that if the speed of slow vehicles is reduced by about 20%, the congestion cost is increased by about 100%. Curve 3 for Slow Vehicle Traffic volume shows that if the slow vehicle traffic volume is increased by 50%, the congestion cost is increased by about 35%; and if the slow vehicle traffic volume is decreased by 50%, the congestion cost is decreased by about 40%.

Jorge A. Laval and Carlos F. Daganzo of the Transportation Group, Department of Civil and Environmental Engineering, University of California at Berkeley wrote a paper in November, 2004, titled “Multi-lane Hybrid Traffic Flow Model: A Theory on the Impact of Lane-changing Maneuvers” [87]. In this paper, they developed theories for analyzing not only the effect of lane-changing maneuvers at bottlenecks (freeway ramp merges and lane drops), but also examined the effect of moving obstructions travelling at a constant slow speed on long freeway sections. Such freeway analyses are clearly not directly applicable to a situation of LSVs on low-speed non-freeways (since for non-freeways neither the shape of the curve nor the slope of the curve is known), but they are illustrative of the effect such obstructions can have. The authors found that their model agreed quite well with available observations in the range where data were available, that is, at slow-vehicle speeds greater than 30 mi/h (about 50 km/h). There were no available data for slow-vehicle speeds of less than 30 mi/h, and hence the model could not be validated for these lower speeds. Their observed data (30 mi/h and higher) and model predictions (all speeds) are shown in Figure 36, taken from their paper.

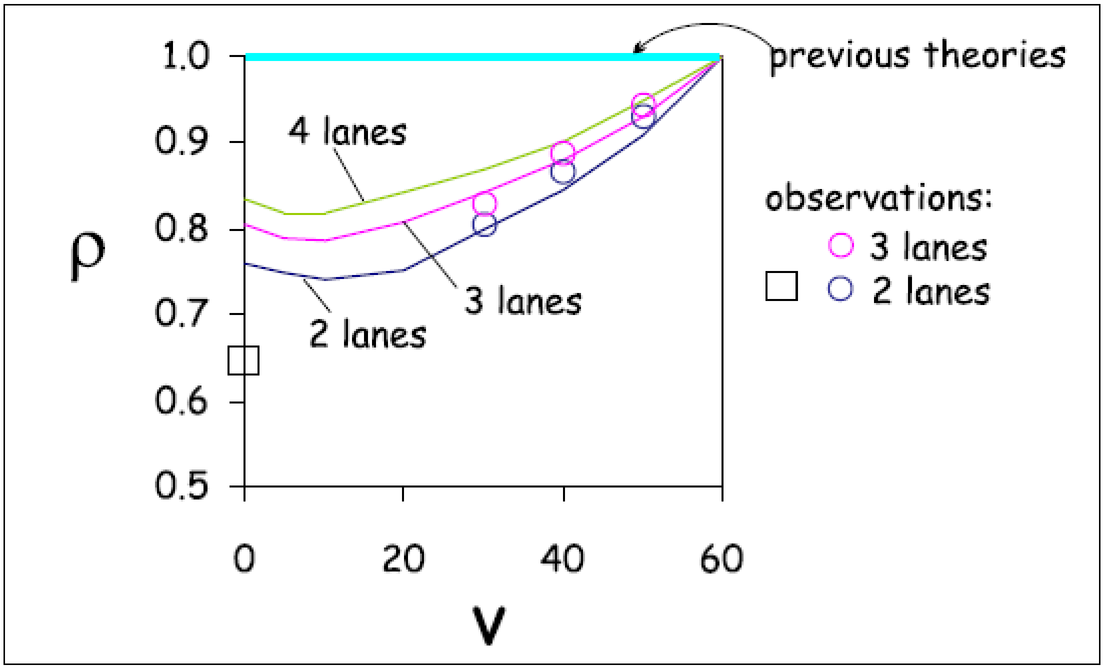


Figure 36: Dimensionless bottleneck discharge rate ρ as a function of the slow vehicle speed, V (mi/h) [87]

The model results suggest that the effect of moving slow-vehicle obstructions on traffic flow on a four-lane freeway (two lanes per direction) would be a reduction of capacity somewhere between 20% and 30% (discharge rate ρ of 70% to 80% of normal capacity). Again, however, this is included here for illustrative purposes only.

Samuel W. Malone, Carl A. Miller and Daniel B. Neill wrote a paper in February, 2001, titled “Traffic Flow Models and the Evacuation Problem” [88]. They examined, through the use of traffic flow models, various strategies for rapid evacuation from the South Carolina coast during times of hurricane threat. They used the models to examine, for both two-lane and four-lane highways, the effect on capacity of slow-moving vehicles at various proportions of the traffic flow. Again, however, the paper is not directly relevant to the LSV situation under consideration, since the high-speed vehicles on the four-lane highway were assumed to travel at 70 mi/h and low-speed vehicles were assumed to travel at 50 mi/h. In their models, the flow rate is decreased significantly by the presence of slow vehicles. If even 1% of the vehicles were slow, the flow rate decreased by 5%; if 5% of the vehicles were slow, the flow rate decreased by 15%. With 10% and 20% slow vehicles, the flow rates were decreased by 23% and 33% respectively. It is not possible to say how relevant these capacity decreases are to the 50 km/h LSV road situation.

M. M. Rahman, I. Okura, and F. Nakamura of the Department of Civil Engineering, Yokohama National University, Kanagawa, Japan, wrote a paper in December, 2003, titled “Effects of Rickshaws and Auto-Rickshaws on the Capacity of Urban Signalized Intersections” [89]. Auto-rickshaws are low-speed motorized vehicles widely used as taxis in parts of Asia, and possibly as vehicles somewhat similar to an LSV. The authors examined the effect of these vehicles on congestion at signalized intersections in Dhaka, Bangladesh, and calculated the PCEs of these two types of vehicles. Somewhat surprisingly, they found that the PCE of auto-rickshaws at signalized intersections was about 0.4 at about 5% of the traffic volume, rising linearly to a PCE of 1.0 at 100% of the traffic volume. The discharge rate varied from about 1,850 veh/h/lane with no auto-rickshaws to about 2,100 veh/h/lane at 60% auto-rickshaws. The increase in capacity at intersections with increasing proportion of auto-rickshaws was attributed to the smaller size of auto-rickshaws (about half the length of cars) and the shorter headways between them. The typical speed and acceleration characteristics of auto-rickshaws are not stated in the paper, so it is not possible to say how similar these are to LSVs. In addition, it is not known how transferable or applicable such findings might be to the effects of LSVs in Canadian mixed traffic. Still, the findings do suggest that capacity reductions caused by LSVs in mixed traffic are more likely to be caused by their low speeds than by their slightly lower accelerations.

Studies directly relevant to this application, that is, of the effects of significant volumes of LSVs on the capacity of relatively low speed two-lane and four-lane streets, have not been found in the literature, and may simply not exist because the use of LSVs to date in mixed traffic has been relatively rare.

For illustrative purposes, a few simulation runs have been conducted for this study, using the U.S. Federal Highway Administration (FHWA) Interactive Highway Safety Design Model (IHSDM) [90]. This model uses the TWOPAS microscopic traffic simulation model, the model that has been used for the last 20 years for the Highway Capacity Manual to analyze traffic flow on two-lane roads, measured in vehicles per hour (vph). The example runs were conducted for the following data sets:

- 300 vph per direction (600 vph total), for LSV volume of 0% (baseline), 5% and 15%.
- 600 vph per direction (1,200 vph total), for LSV volume of 0% (baseline), 5% and 15%.
- 900 vph per direction (1,800 vph total), for LSV volume of 0% (baseline), 5% and 15%.

The truck percentage was set at 5% throughout. The desired speed of cars was set at 55 km/h, of trucks at 50 km/h, and of LSVs at 40 km/h. A straight, level road-section of 2.3 km length was assumed, with no no-passing zones. The results of these sample simulations are shown in Table 7.

Table 7: Two-lane road simulation results, using FHWA IHDSM model illustrative, comparative example

Two-way Traffic Volume (vph)	LSV Percentage of Traffic Flow (%)	Average Travel Speed of Traffic (km/h)	Trip Time for 2.3 km (min/veh)	Total Delay over 2.3 km (min/veh)
600	0	51	2.7	0.16
600	5	48	2.8	0.22
600	15	47	3.0	0.28
1,200	0	48	2.8	0.27
1,200	5	45	3.0	0.44
1,200	15	42	3.3	0.61
1,800	0	45	3.0	0.47
1,800	5	42	3.2	0.65
1,800	15	40	3.5	0.78

- Straight, level road, 2.3 km long
- Desired car speed = 55 km/h
- Desired truck speed = 50 km/h
- Desired LSV speed = 40 km/h
- Standard deviation of speeds = 10% of desired speed for each class
- Truck percentage = 5% for all runs
- No-passing zones: None
- Directional traffic split: 50:50.

Some noteworthy observations are as follows:

- the average speed drops significantly, even with the introduction of only a few LSVs; this could lead to significant frustration for drivers of other vehicles;
- at lower traffic volumes, the delay per vehicle increases by about 35% with 5% LSVs, and by about 75% with 15% LSVs. At higher traffic volumes, the delay per vehicle also increases by about 40% with 5% LSVs, and by about 65% with 15% LSVs, but with a higher base level of delay;
- as the traffic volume and LSV percentage increase, the average travel speed approaches the desired LSV speed, as expected.

The most directly relevant information is that arising from studies of LSVs in real environments.

The first such report is “Field Operations Program – Neighborhood Electric Vehicle Fleet Use” by J. Francfort and M. Carroll of the Idaho National Engineering and Environmental Laboratory for the Department of Energy in July, 2001 [15]. The study examined 15 fleets operating a total of 348 LSVs in the U.S., to obtain data on vehicle use. The LSV fleets ranged in size from 2 to 82 vehicles; 56% were used on private roads, 32% on public roads and 12% on both public and private roads. The vehicles averaged 3,409 mi (5,488 km) per LSV annually. Most of the vehicles were operated in warm climates. The 15 fleet operators reported positive experiences with the LSVs. However, there were no comments, either positive or negative, about limitations in mixed traffic, and no data on the effects of the limited vehicle speeds and accelerations.

The second such report is the pilot study titled “Assessment of Low Speed Electric Vehicles in Urban Communities: Pilot Project”, Report TP 13942E [9], conducted for Transport Canada in 2002 by the Centre for Electric Vehicle Experimentation in Québec (CEVEQ), cited above. Various types of low speed electric vehicles were made available to residents of St. Jérôme, Québec, who drove them on both two-lane and multi-lane roads. During a 12-week period, seven LSVs provided by four manufacturers were driven a total of 6,067 km. The study was used to gather public opinion on the risks relating to using these vehicles in normal city traffic. A total of 53 participants from various backgrounds drove the LSVs for one-week periods and filled out an evaluation questionnaire. In addition, 126 other road users, including police officers and taxi drivers, were given the opportunity to submit their impressions of how well these vehicles integrated into city traffic.

Sixty-four percent of the LSV drivers said that the LSVs did not go fast enough to keep up with the flow of traffic at all times. More significantly, 97% suggested that the top speed of the vehicles should be increased; 65% wanted a speed of 50 km/h. However, 47% of the other road users felt that 40 km/h was an appropriate speed in the city. A total of 77% of the LSV drivers were pleasantly surprised by these small cars. Acceleration, attractiveness and vehicle handling were seen as the main strong points. Vehicle range was the most criticized aspect. In summary, 83% of the LSV drivers and 89% of the other road users felt that LSVs had their place in the city. Figure 37 shows some of the driver responses regarding drivability on various types of roads. The roads with a 50 km/h speed limit were major arterial roads, often in outlying urban areas.

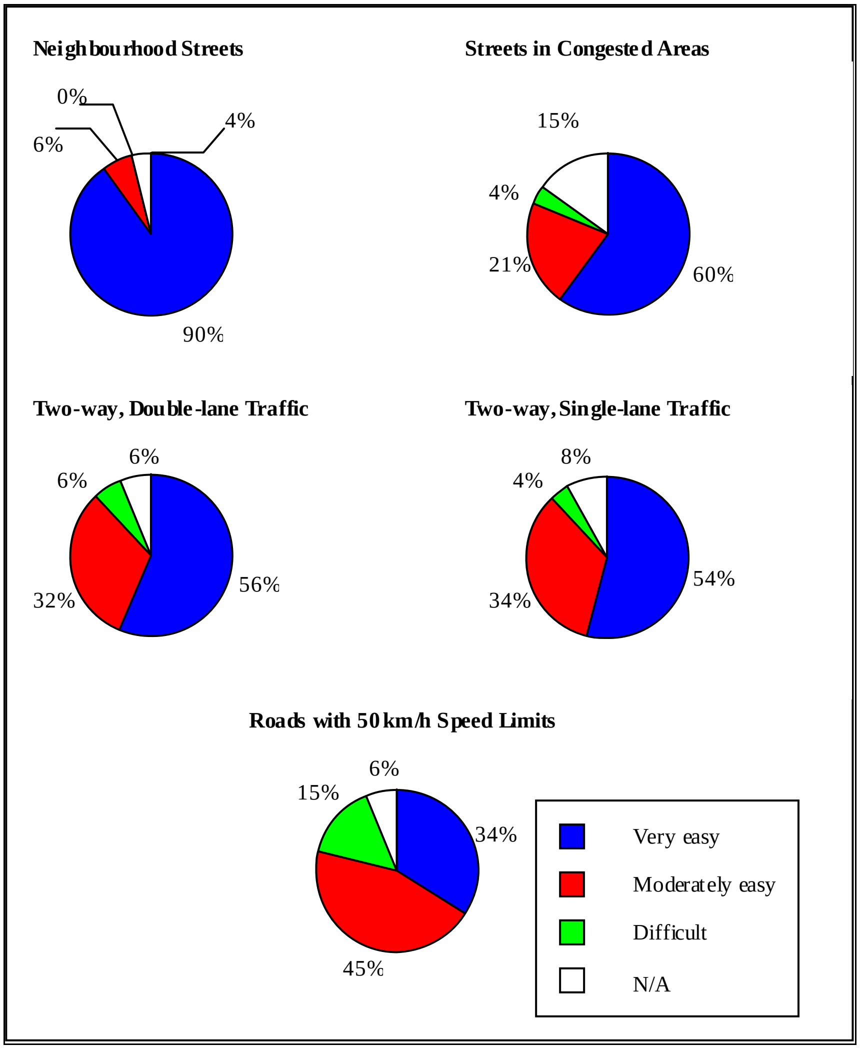


Figure 37: Assessment of drivability by road type [9]

According to the focus group participants, streets with two-way single-lane traffic (two-lane roads) were more difficult to drive than streets with two-way, double-lane traffic. (four-lane roads). On two-lane roads, LSV drivers felt pressured by the motorists behind them who were having a harder time trying to pass them. In these situations, they felt that they should move over to the right, which was potentially hazardous. This raises two other points not addressed in the report: (1) the availability or unavailability of suitable places for LSV drivers to pull over to let others pass; and (2) the ease or difficulty for LSV drivers to re-enter the traffic stream, the difficulty of which will increase with increasing traffic volume. However, the same drivers said that two-lane streets in residential neighbourhoods and streets with traffic lights at short intervals were not a problem. The concerns about speed limitations occurred in three types of situation:

- on major thoroughfares;
- when traffic was moving at a fast rate;
- on hills, where LSVs slowed down to a speed from 20-30 km/h.

The LSV drivers gave various reasons to support their suggested speed increase:

- it would avoid the risk of dangerous passing;
- 40 km/h is fast enough in a residential area, but not fast enough on busier streets;
- the vehicle is safe enough to be driven at city speed limits;
- it is the usual speed limit in the city;
- it would enable the vehicles to keep up with traffic better;
- other drivers following an LSV travelling at 40 km/h when the speed limit is 50 km/h are sometimes impatient; and
- they also suggested that the vehicles should be able to reach 40 km/h at all times, including hills.

Most of the LSV drivers wanted to increase the speed, whereas half of the road users did not find LSVs to be overly slow or disruptive. This may be because there were relatively few LSVs on the streets. If their number were to grow, it could possibly lead to intolerant attitudes on the part of road users, especially during rush hour.

The third such report is “The NEV Transportation Plan” of the City of Lincoln, California, June 2006 [52]. This is a more comprehensive approach to LSVs than in the first and second studies, as it is a broad-based plan to encourage the use of LSVs by planning the city to accommodate them. The objective is city-wide NEV routes that would “enable any resident to travel from his/her home to downtown Lincoln.” A NEV-ready city must have the necessary infrastructure, including charging facilities, pavement markings, signage, parking, and education to accommodate safe LSV travel. The plan envisions three types of LSV route:

- *Class I LSV Route: These routes provide a completely separate right-of-way for the exclusive use of LSVs, pedestrians and bikes with cross-flow minimized. The minimum paved width for a Class I route is 12 feet (3.65 m) (for two-way travel, or 6 ft per direction) with a minimum two-foot (600 mm) wide graded area provided adjacent to the pavement. Bicycles may also use these lanes;*

- *Class II LSV Route: These routes are designated as a separate striped lane adjacent to traffic. There is one striped lane for each travel direction. The desirable minimum width for a Class II LSV route is 7 feet (2.15 m). Bicycles may also use these lanes;*

- *Class III LSV Route: These routes provide for shared use with automobile traffic on streets with a posted speed limit of 35 mi/h (56 km/h) or less. This will include all residential streets.*

The city also examined its road network in terms of average daily traffic (ADT) volume level of service thresholds, and adopted the Highway Capacity Manual’s Level of Service C (LOS C) as their minimum criterion for urban area intersections and roadways. The feasibility of allowing LSVs to travel on area roads was evaluated by comparing the projected future 2025 ADT traffic volumes, street by street, with the daily volume LOS thresholds shown in Table 7. LSVs will not be permitted on those roads where the projected 2025 ADT traffic volume exceeds the values in Table 8.

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Table 8: Average daily traffic volume level of service thresholds for city of Lincoln, California [52]

Facility Type	Average Daily Traffic Volume Threshold Level of Service C (veh/day)
Two-lane Street	12,000
Two-lane Conventional Highway	7,900
Four-lane Undivided Arterial	24,000
Four-lane Divided Arterial	27,000

The report also defines LSV signs and pavement markings and where they are to be located.

It is not the purpose of this report to suggest that it is these specific ADT Level of Service criteria that should be used. If the findings on capacity reductions caused by slow-moving vehicles, cited above, are even approximately correct (ranging from a 5% capacity reduction for 1% slow-moving vehicles, to a 33% capacity reduction for 20% slow-moving vehicles, and a speed differential of 20 mi/h (32 km/h)), then a different threshold than LOS C might be considered. LOS C may be a suitable criterion where there is only a low percentage of LSVs, as they would probably not have a major effect on capacity. However, LOS B might be a more suitable criterion, for example, where the LSV percentage is 15% or higher, as the presence of so many LSVs might be sufficient to reduce the Level of Service to C or even D.

8.3 LSV Braking Characteristics and Effect on Traffic Flow

Somewhat curiously, the Canadian Motor Vehicle Safety Standards (CMVSS) do not contain any specific requirements for service brakes in LSVs, but do require that LSVs have a parking brake. The matter of service brakes is covered by provincial Highway Traffic Acts rather than by federal standards. The Ontario Highway Traffic Act, for example, addresses vehicle brakes in two places, Section 64 and Regulation 587. Section 64 (1) states the following:

Every motor vehicle, other than a motorcycle, when driven on a highway shall be equipped with at least two braking systems, each with a separate means of application and effective on at least two wheels, one of which shall be adequate to stop the vehicle as required by regulations made by the Ministry and the other of which shall be adequate to hold the vehicle stationary.

Regulation 587 (3) states the following:

The brakes required by Section 64 of the Act and this Regulation shall be adequate to stop the vehicle referred to in column 1 of the Table within a distance not greater than the distance set opposite the vehicle...in column 2 while being operated at a rate of speed of 20 mi/h (32 km/h) on a dry, smooth, hard asphalt or other paved surface free from loose material and having not more than 1 per cent gradient.

Under such conditions, Regulation 587 (3) requires a motor vehicle having a seating capacity of fewer than 10 persons to be able to stop within a distance of 25 ft (7.6 m).

The "Neighborhood Electric Vehicle Technical Specification" produced by NEV America in 2007 [8] requires brakes, but says little about them, except to state that the braking effort for converted vehicles should be similar to OEM models of comparable size and weight.

Performance specification sheets for a range of LSVs show that the stopping distances from 20 mi/h (32 km/h) range from about 18 to 26 feet (5.5 to 7.9 m). They all meet, or almost meet, the Ontario requirement of a stopping distance of 25 ft. Ontario Regulation 587 does permit some types of truck a stopping distance of 50 ft from 20 mi/h, which is double the stopping distance required of most passenger vehicles.

A stopping distance of 25 feet from 20 mi/h (7.6 m from 32 km/h) corresponds to an average deceleration of about 0.52 g, somewhat more than double normal braking rates [91].

Consequently, in normal traffic flow, most current LSVs exhibit satisfactory braking performance, since they meet provincial braking requirements for most passenger vehicles and since heavier vehicles are permitted longer braking distances. Braking performance of most current LSVs is not expected to adversely affect traffic flow.

8.4 Traffic Flow - Additional Considerations

A discussion with an OC Transpo bus driver with over 30 years of experience indicated a number of factors that he considered would be important to be taken into account while contemplating the idea of LSVs operating in mixed traffic on public roads with a 50 km/h speed limit:

- cars in a typical traffic stream drive approximately 10 km/h over the posted speed limit. As a result, on roads with a posted limit of 50 km/h, there is a good potential for a 20 km/h speed differential between regular vehicles and LSVs travelling at their top speed of 40 km/h.

- an LSV's speed of 40 km/h is only slightly higher than the speed of a good cyclist. A bicycle can be passed while traveling in the same lane, but an LSV cannot, as they occupy most of the lane.

- timing of lights will most likely be affected. The current timing is based on traffic speed assumptions that will no longer be valid. Consequently, there is a potential for a domino effect, where vehicles are missing light cycles, or are getting hung up at every set of traffic lights as opposed to the occasional occurrence. In addition to affecting traffic flow, this could increase the amount of time vehicles are idling, which would then reduce the overall environmental benefits that LSVs would have.

- both bus schedules and operating costs would be negatively affected by the presence of LSVs. There would have to be more buses to make up for the schedule slips, which means more pollution and expense, and there would be a massive domino effect which would affect all bus scheduling, including how connections between buses are made. OC Transpo schedules are practically "to the second". This type of disturbance would have a significant negative impact on the schedule system.

- vehicle drivers today do not always see or pay attention to signage. Despite the rules being clear, LSV drivers would probably venture onto roadways where they are not allowed (even those roads that are 50 km/h but that have been specifically tagged as "not for LSVs").

An interview with an OC Transpo transit route planner:

- over the course of several city blocks, bicycles and buses tend to "leapfrog" each other, since they both have an effective average speed of 15-20 km/h. The bicycle is constant and slow. The bus is faster but stops fairly often. If, because of the typical bus and bicycle traffic in the right hand lane, LSVs end up having an effective average speed in this range it could engender non-trivial disruptions, depending on the LSV density, which would be a function of their popularity. The engendered disruption would be amplified by the fact that LSVs are not likely to be as easy to pass as a bicycle.

- there are many bridges in Ottawa (for instance). Typically bridges are "chokepoints" since they are much less numerous than the streets leading to them. This fact, and the absence of cross-streets, lend themselves to bridges typically being posted at higher speeds. This would effectively trap LSVs on one side of the river or the other.

- although buses currently have to negotiate slow moving vehicles occasionally (tractors, snow removal equipment, etc.) these occurrences are rather rare and are dealt with as they come up. A constant presence of low speed vehicles in the right-hand lanes would certainly disrupt bus route planning and scheduling.

9 LSVs AND HUMAN FACTORS

In this section, driver behaviour is considered from the perspective of human factors, an interdisciplinary area, applying knowledge from the human sciences (psychology, physiology, etc.) to engineering design, with the aim of understanding human limitations in the operation of tools and equipment and guiding design so that errors and injuries are avoided.

The integration of LSVs on public roadways, especially when they have the same appearance as standard vehicles but reduced operating capabilities, may surprise drivers moving at higher speeds, resulting in conflicts. Speed differences are a concern because drivers have limitations in perception of closing velocity, which may lead to a delayed decision to brake. Slow vehicles ahead can also result in frustration to following drivers, and aggressive behaviour. Finally, electric vehicles are quiet. This can be problematic for pedestrians and cyclists who may rely on hearing approaching vehicles and do not carry out a full visual search before stepping into traffic.

Human factors issues considered below are:

- driver expectation;
- perception of closing velocity;
- aggressive driving behaviour; and
- lack of audibility by pedestrians and cyclists.

9.1 Importance of Driver Expectation

Low speed vehicles, especially when they have the same appearance as standard vehicles, may surprise drivers moving at higher speeds. This can result in conflicts in various situations, for example:

- when a driver is approaching a traffic signal expecting the low-speed vehicle in front to go through and it stops; and
- when a driver is going through an intersection and a left-turning driver takes longer to complete a turn than expected.

Drivers respond best when the situation matches their expectations. In fact, driver expectation is considered to be such an important factor in determining driver response that it is explicitly considered in highway design through the "positive guidance" approach to highway design. This approach is based on a combination of human factors and traffic engineering, which was developed in the early 1970s by Alexander and Lunenfeld and elaborated on in a series of documents published by the U.S. Federal Highway Administration [92]. Design according to driver expectations increases the likelihood of drivers responding to situations and information correctly and quickly. A concern when expectation of other drivers is violated by an LSV is that a rear-end crash may result due to delayed detection of a substantial speed difference with the LSV ahead.

9.2 Perception of Closing Velocity

While the unexpected situation of a stopped or very slow-moving vehicle on a roadway alone increases the possibility of drivers responding too late, there is a further difficulty which greatly adds to the problem. That is the difficulty that drivers have in perceiving closing speed and in distinguishing between a relatively safe situation in which one is slowly catching up, from a more dangerous situation in which one is rapidly catching up to another vehicle.

One of the main cues to determining the rapidity with which one is closing on another vehicle is the apparent change in the size of the rear of the vehicle ahead. The determination of closing velocity is difficult. At a distance, the apparent size of the rear of the vehicle is small. As the driver approaches, the angle created at the eye gets gradually larger and larger. As indicated in Figure 38, this is a very non-linear cue, making the judgment of the rate of closing velocity very difficult. Studies suggest that alerted subjects in experimental situations do not **begin** to recognize rapid closing until the change in angle is on average 0.17 degrees per second. Since 0.17 degrees per second is an average value, half of drivers will need a larger angular change, and get closer before beginning to sense rapid closing. Until this threshold is reached, all the driver perceives is that the gap is closing, something that happens regularly in traffic and does not precipitate emergency action.

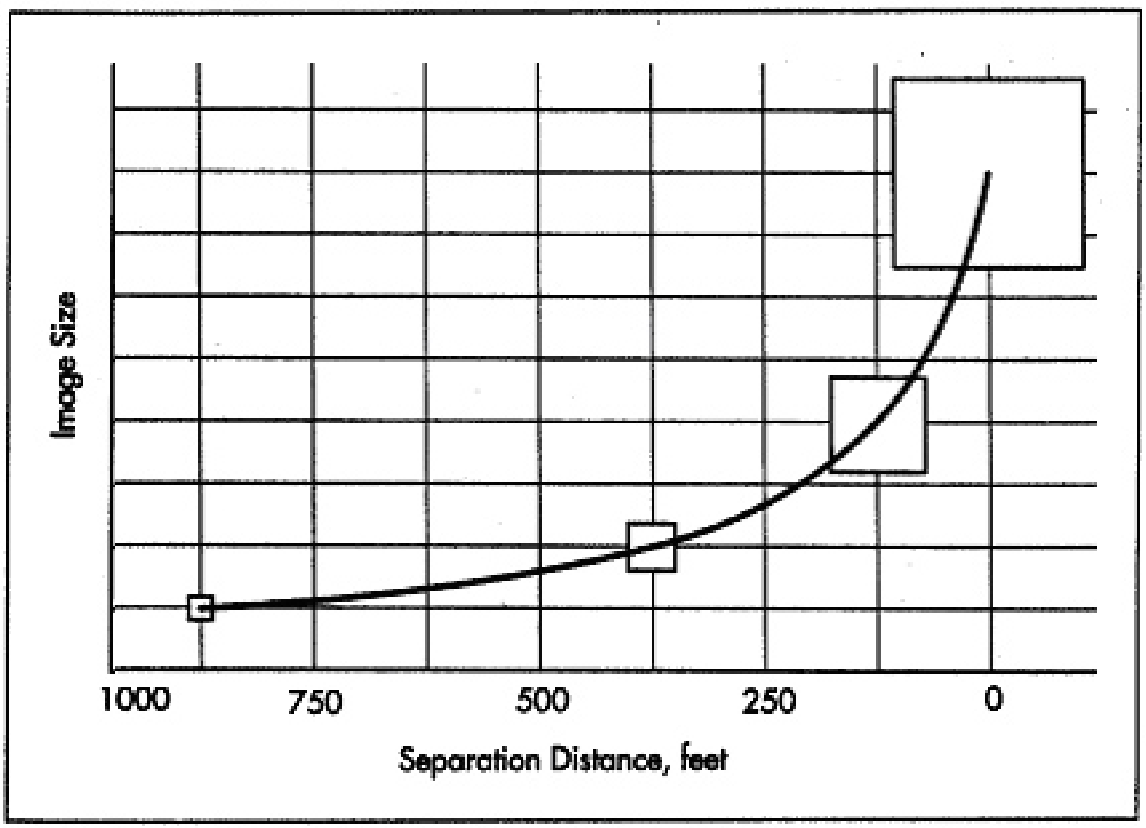


Figure 38: The relationship between viewing distance and image size [93]

Table 9 indicates time to collision at which the average driver would begin to perceive a rapid closing speed, for various LSV speeds (stopped, 10 km/h, 20 km/h, 30 km/h and 40 km/h) for situations in which the following vehicle is travelling 20, 30 and 40 km/h faster than the LSV. A width of 1.5 m has been assumed for the electric vehicle. As can be seen, depending on relative speeds, the threshold varies from 6.2 to 9.0 s to collision.

Table 9: Time at which rapid closing speed would be detected by the average driver

LSV Speed (km/h)	Following Vehicle Speed (km/h)	Time to Collision (sec)	Distance (metres)
0	20	9.0	50
	30	7.2	60
	40	6.2	70
10	30	9.0	50
	40	7.2	60
	50	6.2	70
20	40	9.0	50
	50	7.2	60
	60	6.2	70
30	50	9.0	50
	60	7.2	60
	70	6.2	70
40	60	9.0	50
	70	7.2	60
	80	6.2	70

Fifty percent of drivers will have less time to collision than indicated above, due to individual differences. Furthermore, these times signify the start of an ability to differentiate different speeds of closure. Drivers require some time to assess closing speed. One study looked at the impact of exposure times of 0.5, 1, 2 and 4 seconds on the threshold change in angular velocity at which alerted experimental subjects detected that stimuli simulating taillights were separating (simulating the view of a driver approaching a vehicle ahead). Improvements in assessment of closing speed were found as exposure increased from 0.5 to 2 seconds [94]. Therefore, a driver would be expected to take on the order of 2 seconds to perceive that the gap was closing rapidly, once angular velocity was above threshold for perception.

In a study with alerted experimental subjects, those who had to respond to a hazard in the roadway for the first time had response times to move foot from accelerator to brake ranging from 0.38 to 0.73 seconds, the range of the 50th to 90th percentile [95]. Since experimental subjects would be abnormally alert, it is appropriate to use the high end of this range as estimate of response time, once perception has been completed. Thus if perception that the closing velocity was high took 2 s and response about 0.7 s then 2.7 s or more, in the case of a driver not expecting this situation, could pass before any braking would be initiated.

Another basis for estimating perception-reaction time in this situation is a study in Australia in which subjects reacted to changes in headway between themselves and a lead vehicle. The longer the initial headway, the longer the time drivers took to respond to deceleration or acceleration. In the case of the vehicle ahead decelerating, response times for alerted subjects in daylight conditions averaged 3.8 s [96], [97]. This study included some situations in which the speed of opening or closing of the gap may initially have been below threshold, which would contribute to longer response times. On the other hand, this is offset by the fact that these times were measured for alerted subjects expecting to respond to an accelerating or decelerating lead vehicle. The mean value of 3.8 seconds in this situation is considerably longer than the frequently used 1½ seconds reaction time, and more appropriate given the difficult nature of the perceptual task involved.

If the LSV is moving slowly, say at 30 km/h, and a following vehicle is approaching at 70 km/h, then Table 9 indicates that the threshold of angular change for the width of such a vehicle is not reached for the average alerted experimental subject, until about 70 m away, or about 6.2 s from collision. Even in the alerted situation, half of drivers will have thresholds larger than average, and will be closer than 70 m before realizing the emergency nature of the situation. Assuming a perception-response time of 2.7 s in this situation, the lower of the two estimates discussed above, a following driver travelling at 70 km/h would travel 53 m during the time it takes to realize the vehicle ahead is moving more slowly and initiate braking. During this time the LSV ahead, at a speed of 30 km/h, would travel 23 m. The distance between the vehicles would be reduced to 30 m. Slowing from 70 to 30 km/h would require 21 m using emergency braking (0.75g). However, comfortable braking (0.25 g) would require 63 m, more than twice the distance available. Longer distances would be required on wet or icy pavement. The greater the speed difference, the less time is available where the angular change of the LSV ahead is above the threshold for detecting angular change for the following driver. This suggests that limiting the use of LSVs to speed limits of 50 km/h, which anticipates other vehicle speeds of 60 km/h or lower, would be appropriate to avoid situations in which following drivers are surprised by the low speed of an LSV ahead, resulting in hard braking or an avoidance manoeuvre.

9.3 Aggressive Driving Behaviour

A concern about the integration of LSVs with normal traffic is that drivers of other vehicles will be frustrated by the low speed of an LSV, and will respond aggressively, increasing crash risk. Aggression is a complex issue, with numerous contributing factors and varied responses. Figure 39 shows a model illustrating the interaction between personality characteristics, situational variables and overt behaviours of aggressive driving [98], [99].

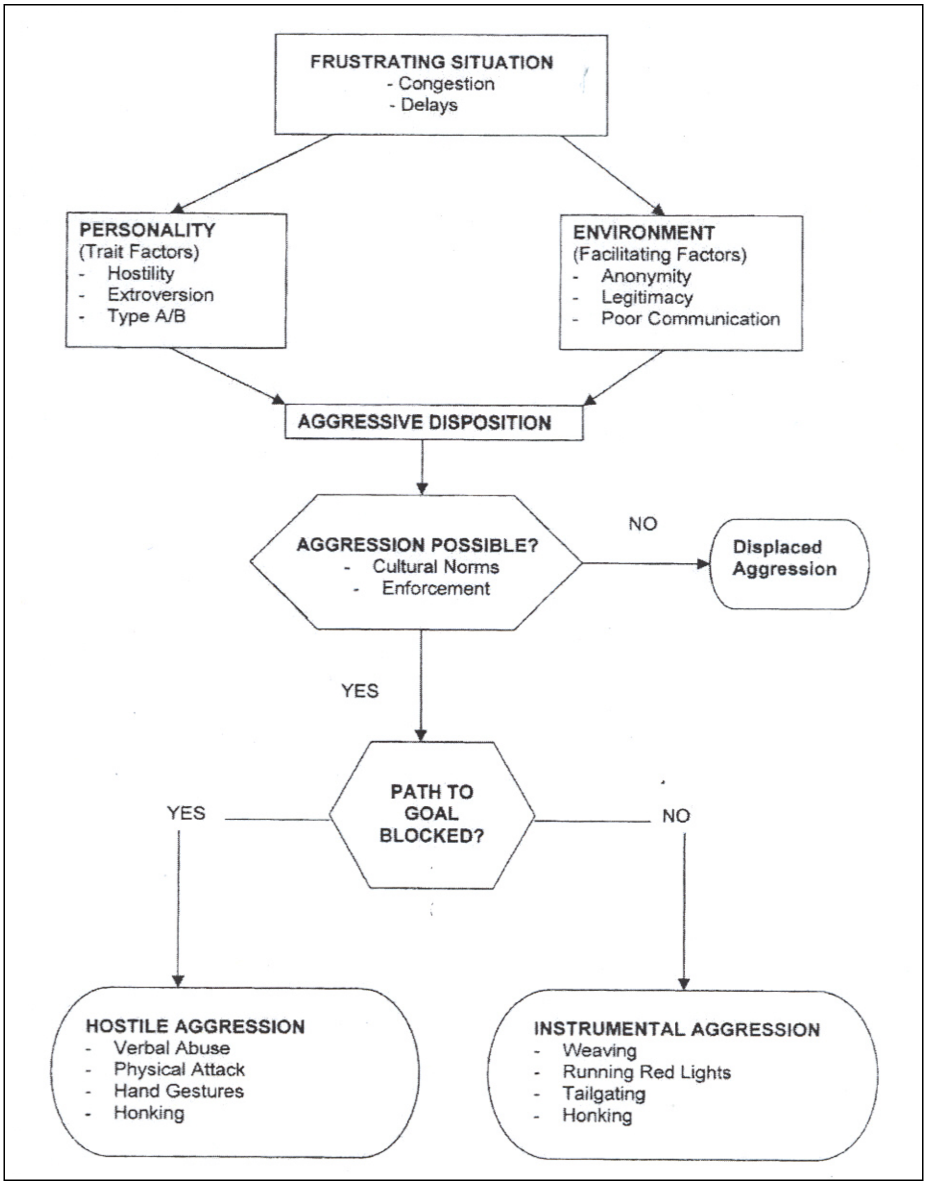


Figure 39: Model illustrating the interaction between personality characteristics, situational variables and overt behaviours of aggressive driving [98]

Aggression is a characteristic of all drivers, but the set point at which it is manifested depends on individual characteristics such as social maladjustment, risk-taking and sensation-seeking, all of which are linked to masculine characteristics and age.

A survey of 1,382 American drivers, representative of the U.S. driving population in age, sex, income and education, asked drivers to indicate their agreement with statements concerning how frequently they exhibited various behaviours [98], [100]. The most frequently reported aggressive behaviours were saying bad things to yourself about another driver and complaining/yelling about another driver to your passenger, giving other drivers dirty looks (62% and 52% respectively indicating sometimes or often). Honking/yelling at someone through the window and making obscene gestures occurred less frequently (20% and 7% respectively indicating sometimes or often). Tailgating others to force them to move was reported by less than 0.1% of drivers as occurring often, and by 6% of drivers as occurring sometimes. For the vast majority of drivers this behaviour was reported as occurring rarely or never.

Aggressive behaviour has been studied by means of a technique pioneered by Doob and Gross, involving having a researcher drive up to a traffic signal, immediately after the signal has turned red [101]. When the signal turns green, the researcher remains stationary and records the behaviour of the driver that is detained behind. The shorter the green interval is, the more quickly the following driver will honk his/her horn. Similarly, more rapid honking occurs in rush hour than on weekends [99].

This and a number of other studies indicate that aggressive behaviour follows a dose-response curve, increasing in aggression with increased frustration. Thus the more different the LSV operating characteristics, in particular, acceleration capability and maximum speed are from those of other vehicles, and the more LSVs there are in traffic, the greater the frustration of other drivers on the same or conflicting paths is likely to be. Higher volume traffic is likely to be associated with more aggression as it becomes more difficult to escape from behind a slower driver. On the other hand, one of the results of congestion is a slowing of traffic, lessening the difference in speed between LSV and other vehicles.

Aggression is less evident when drivers see a reason for the obstruction or perceive that the obstruction is justified. In a study described by Shinar, “a pedestrian stepped off the curb just as an approaching driver reached a critical point at which he or she would have to slow down or stop in order to allow the pedestrian to cross” [98]. Half of the attempted crossings occurred at an intersection and half at mid-block. Half of the crossings in each location were made with the pedestrian appearing as an able-bodied person, and half with the same pedestrian using crutches. At the intersection, where drivers are required by law to yield to pedestrians, two-thirds yielded to the able-bodied person and virtually all to the disabled person. At the mid-block crossing, where drivers are not required by law to yield, two-thirds still yielded to the disabled person but very few to the able-bodied person. Thus, the driver’s perception of the legitimacy of the impediment is likely to affect the presence of aggressive behaviours.

9.4 Lack of LSV Audibility by Pedestrians and Cyclists

Pedestrians, bicyclists and drivers frequently come into conflict at intersections where they cross each other’s paths. Because of the visual and mental demands in this situation, drivers are prone to error during vehicle turning movements, especially left-turning movements, making pedestrians vulnerable. A study of pedestrian crashes at signalized intersections on a one-way grid system in New York showed that left-turn movements were approximately twice as dangerous to pedestrians as right-turn movements, and four times more dangerous to pedestrians than through movements [102]. During right-turning manoeuvres, pedestrians and drivers were equally at fault in failing to yield the right of way; during left-turning manoeuvres, drivers failed to yield to the pedestrian 62% of the time, compared with a 38% failure rate for the pedestrian. This is a concern because LSVs are quiet, and quiet vehicles are more likely than others to be undetected by pedestrians, especially during turning movements.

Pedestrians and bicyclists contribute to conflicts with vehicles when they fail to carry out a proper search. In a Florida study at signalized downtown intersections, researchers observed pedestrian search behaviour, with and without various auditory signals [103]. To be scored as checking for a particular threat, the pedestrian had to orient his or her head toward the direction the vehicle would be coming from prior to entering the vehicle path and within three seconds of entering the vehicle path.

Results showed that in the baseline condition, without auditory signals, which is typical of most signalized intersections, depending on the observation period, between 8% and 25% of pedestrians did not look for threats. Search varied with respect to the three types of threats: vehicles coming from behind require the greatest head movement and were searched for least – approximately 30% of pedestrians looked for such vehicles. Search for vehicles coming from the side and from ahead, was more frequent – approximately 50% and 60% of pedestrians respectively. It seems likely that many pedestrians who do not look directly at traffic are nonetheless alerted by vehicle sounds. Since LSVs are quiet they will not be detected by pedestrians who do not look for them. This study shows this is a significant portion of the pedestrian population.

9.5 Human Factors Additional Considerations

An Ottawa Police representative pointed out other potential issues, such as:

- an LSV driver would likely be distracted by several additional factors, such as a requirement for increased awareness of the potential for traffic to be building up behind them, as well as probably a heightened state of alertness in looking for vehicles that may be headed for them (this awareness would help them avoid a non-fault collision, for instance). These additional sources of distraction, albeit important, reduce the percentage of concentration that the driver is focusing on what is ahead of him in general.

- drivers that own multiple vehicles, or drivers whose work requires them to operate a passenger vehicle or truck during the day would need to get used to "switching modes" when they enter their LSV.

10 LSVs AND TRAFFIC SAFETY

10.1 Introduction

This section considers road safety from the perspective of expected safety issues related to introduction of LSVs. Safety is measured by means of expected multi-vehicle collisions, collisions between a vehicle and a pedestrian or a bicyclist, or single-vehicle collisions. Collisions are expressed in terms of their frequency, severity, and type. The safety impacts of different planning, design and operational decisions are estimated by safety evaluation studies, if available. In the absence of these studies, the estimation of risk and engineering judgement are required.

Urban municipal environments in Ontario comprise roads categorized as arterial, collector, and local. The posted speed limits on these road categories typically range from 70 km/h on some arterials to 40 km/h, with some traffic-calmed residential streets posted at 30 km/h. Some cities, such as Toronto, also have expressways with a posted speed limit of 100 km/h. Typically, the 85th percentile operating speed is higher than the posted speed limit. For most of the municipal road network, the mix of traffic is broad and can includes cars, buses, multi-axle trucks, SUVs and a variety of other specialized vehicles.

LSVs are permitted in a number of states in the U.S., in Québec, and in British Columbia. LSV laws typically permit the use of LSVs in mixed traffic on urban roadways with a posted speed limit not higher than 35 mi/h (56 km/h). In the U.S., any crashes involving LSVs are classified in the “other” crash type, which includes a diverse range of vehicles, so their crash history is unknown. Few LSV crashes in North America have been documented, so sound conclusions regarding crash risk are not possible based on crash history. An alternative approach is to consider the factors which increase the risk of a crash and injury to a road user, including vehicle occupants, with increasing LSV travel in mixed traffic conditions. These factors, discussed below, include vehicle size, vehicle speed, vehicle acceleration and deceleration rates.

10.2 Traffic Safety and Small and Lightweight Vehicles

LSVs are limited, by definition in Canada, to a gross vehicle weight rating of less than 1,361kg. The Insurance Institute of Highway Safety in Washington, D.C., published a status report on the subject of the increase of LSVs in the U.S. [104]. Figure 40, taken from that report, shows that the highest death rates and lowest fuel consumption are for the lightest passenger cars; these light and small vehicles offer the least protection for occupants in the event of a crash. The crash data are not separated by environment or road type.

The relationships in Figure 40 are for passenger cars and light trucks that complied with the full range of motor vehicle safety standards that were applicable at the time of manufacture. In contrast, LSVs in Canada and the U.S. currently only need to comply with a very small subset of those safety standards. As a result, injury severity or probability of death in an LSV crash will likely be substantially higher than for a passenger car or a light truck involved in the same accident.

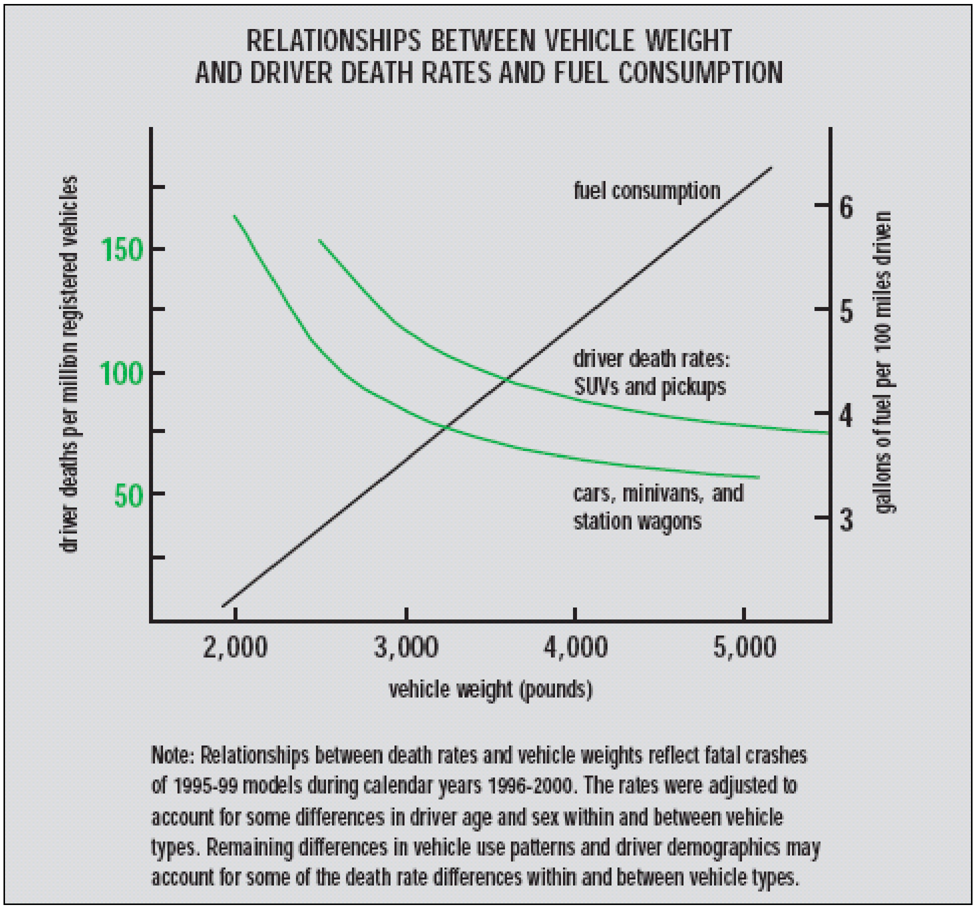


Figure 40: Relationship between vehicle weight and driver death rates and fuel consumption [104]

Federal LSV standards in the U.S. and Canada address the windshield, safety belts, and parking brake. LSVs do not have to have doors or bumpers installed, or meet occupant protection standards (CMVSS 202), or anchorage of seats standards (CMVSS 207). Despite these key differences between electric LSVs and other light passenger cars, road users, including owners of the LSVs, may be unaware of the risk of injury in the event of a collision. For example, the ZENN vehicle, produced in Canada and widely found in North America closely resembles other small passenger cars. It does not look like a typical neighbourhood electric vehicle based on a golf cart.

In 2004, Evans conducted an analysis of data in the U.S. Fatal Accident Reporting System (FARS) from 1975 to 1989 to determine the relationships between point of impact and injury severity for different occupants [105]. He concluded that in general, a right-front passenger is 2.74 times more likely to die as the driver if the collision impact is from the right, and a driver is 2.63 times more likely to die as is the right-front passenger if the impact is from the left. Drivers and right-front passengers are at similar fatality risks from front impacts, and also at similar risks from rear impacts, while back seat occupants are at greater fatality risk from rear impacts. In summary, the occupants that are sitting near the collision impact point are at greater risk than those occupants that are far from the point of contact. It is noted that a rear impact to an LSV (a 2-person vehicle) will not be “cushioned” by the rear occupants or rear seat furniture as in the case of a 4-door car.

In a two-car crash, the mass and size of each vehicle influence the level of severity of harm. To demonstrate how mass is a factor in the outcome of a crash, a comparison of collision results can be made for cars in three weight classes. The LSV class is represented by a typical vehicle with a weight of 1,400 lb. The next weight range above the LSV class is represented by the Smart Car, and a compact car is represented by the Honda Civic. Table 10 shows the characteristics of these vehicles.

Table 10: Vehicle characteristics

Vehicle	Curb Weight (lb)
LSV	1,400
2008 Smart Car [106]	1,825
2007 Honda Civic Sedan [107]	2,643

The probability of death for drivers of these three different vehicles is estimated for head-on, angle and rear-end collision in the following four sections.

10.2.1 Head-on crash

Evans [105] developed a risk equation based on FARS data for speed differences between the colliding vehicles less than 114 km/h. This equation provides an estimate of the impact of collisions between vehicles in urban streets:

$$R = (m_2/m_1)^{3.54}$$

where R = ratio of the risk of death to drivers in the two vehicles
m_2 and m_1 = masses of the two vehicles [105].

From the weights in Table 10, a head-on crash between an LSV and a Honda sedan shows that the driver in the LSV would be 9.5 times more likely to be killed than the driver of the sedan, and a head-on collision between an LSV and a Smart car shows that the LSV driver would be 2.5 times more likely to be killed than the driver of the Smart car.

10.2.2 Right-side Impact

A right-side impact collision may occur when an LSV is turning left and a vehicle travelling straight through in the opposite direction strikes it. The modest acceleration of the LSV gives a longer clearance time for an LSV turning left, so increases its exposure to this type of collision. In the next sections, this topic will be further discussed. The risk of death for drivers when involved in such a right-side impact is:

$$R = \alpha(m_2/m_1)^{3.47}$$

where α is parameter reflecting other attributes besides mass ratio, with a value of 4.53 [105].

From the weights in Table 10, a right-side crash between an LSV and a Honda sedan shows that the driver in the LSV is 40 times more likely to be killed than the driver of the sedan.

10.2.3 Left-side Impact

A left-side impact collision may occur when the signal phase is terminated before an LSV vehicle is able to slowly accelerate from a stop position and clear the intersection (going through or left turn) and is struck by a vehicle entering the intersection in the green phase. The risk of death for drivers when involved in such a left-side impact is:

$$R = \alpha(m_2/m_1)^{3.24}$$

where α is a parameter reflecting other attributes besides mass ratio, with a value of 10.08 [105].

From the weights in Table 10, a left-side crash between a LSV and a Honda sedan shows that the driver in the LSV is 78 times more likely to be killed than the driver of the sedan.

10.2.4 Rear-end Crash

A rear-end collision may occur at an intersection or at a driveway due to the low acceleration of an LSV from a stop condition and the following driver's limitation in assessing the closing velocity especially when it is not expected. The risk of death for drivers when involved in such a rear-end impact is:

$$R = \alpha(m_2/m_1)^{3.71}$$

where α is a parameter reflecting other attributes besides mass ratio, with a value of 1.09 [105].

From the weights in Table 10, a rear-end crash between an LSV and a Honda sedan show that the driver in the LSV is 11.3 times more likely to be killed than the driver of the sedan.

10.2.5 Summary

The driver of an LSV would have at least ten times greater risk of death compared to the driver of a compact car in any type of high-speed crash involving these vehicles.

This section has developed the relative crash risk of LSVs compared to current models of small car, as if each were free to drive on any road. The vehicles used to develop the equations given above to estimate the relative risk of death from a fatal crash were from model years 1975 to 1989, and met all applicable FMVSS relating to crashworthiness for their model year. There have been marked improvements in the crashworthiness of vehicles since then, particularly with regard to side impact. However, it is not known whether the equations would change significantly as a consequence of this.

It is also important to note that this analysis is based on an assumption that LSVs are equipped with the same safety equipment as the other vehicles, but are just lighter. In practice, since LSVs have very little in the way of comparable safety equipment (e.g. no air bags, side intrusion protection, etc.), it can be expected that LSV drivers and passengers will be at a substantially greater risk then this weight-based analysis suggests.

10.3 Traffic Safety and Low Speed Vehicles

The increasing congestion in some urban road networks is causing a general reduction of operational speeds for some periods of the day. This trend fits the introduction of LSVs at those times. Even at low speeds, there are risks associated with certain crash types, in particular those in which vulnerable road users are involved, or those that involve right-angle impacts.

10.3.1 Pedestrians

It is noted that vulnerable road users can still be seriously injured and killed at low speeds. Figure 41 shows the probability of a pedestrian being killed if struck by a vehicle at different impact speeds. At 40 km/h, there is about 20% probability of a pedestrian fatality.

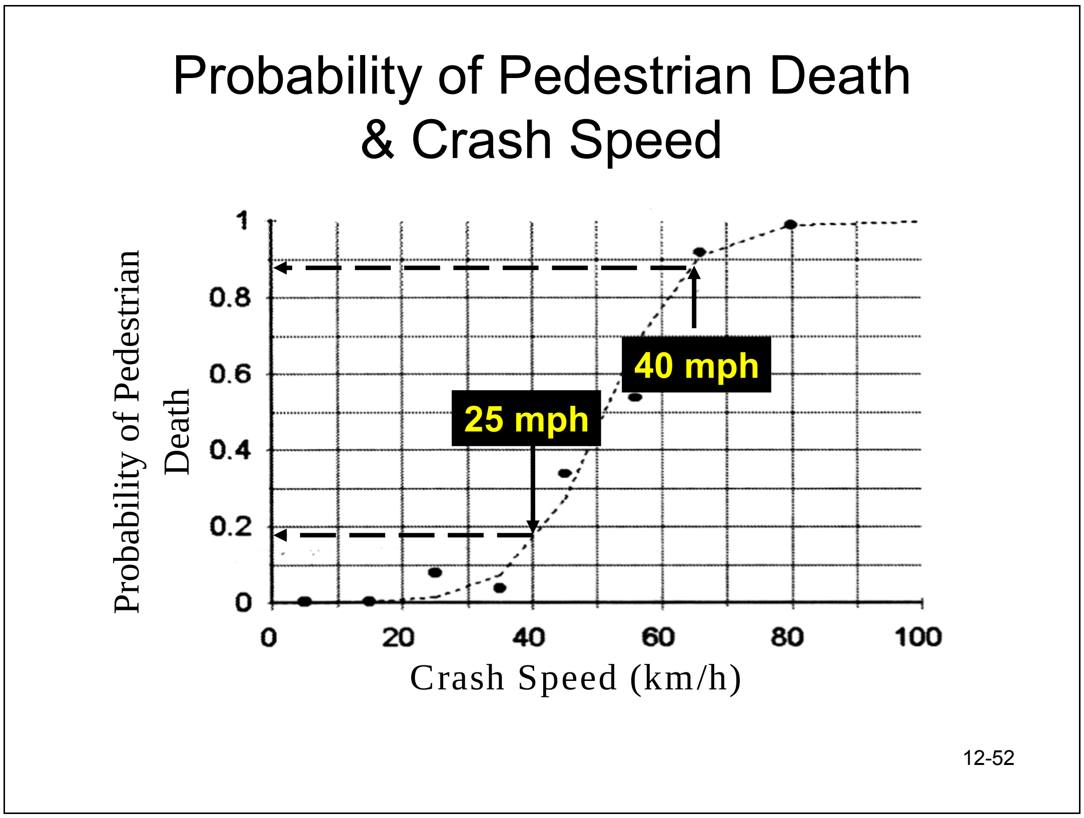


Figure 41: Probability of pedestrian death at different crash speeds

10.3.2 Intersection Control Devices

Traffic signals are coordinated based on the speed limit (or operating speed) of the corridor, thus LSVs will not be within the coordination pace. As an example, the best performance of passenger-car like LSVs is to accelerate from 0 - 32 km/h in 6 s, or from 0 - 40km/h in 8 s. These translate to a maximum acceleration of 5.04 km/h/s to 40 km/h which is about 20% lower than 6.4 km/h/s of a typical small car, and 37% lower than 8km/h/s of a compact car or a pickup truck or a composite car [108]. The rates all apply for level roads.

Because of its lower acceleration, an LSV will require a longer intersection clearance phase (amber and first part of red) than typically designed for the mixed traffic conditions, especially from a stopped condition. Thus, a left-turning LSV may still be in the intersection area when the opposing direction of traffic faces a green signal. This situation may lead to serious angle collisions as discussed in Section 10.2. It is also important to understand that increasing the yellow signal time will create a greater and undesirable decision dilemma zone condition. The dilemma zone is created during a Green-Yellow signal transition period, when drivers in a road section approaching the intersection usually have a difficult time in making a decision whether to go or to stop, a condition that can lead to a rear-end crash. These operational limitations require mitigating measures, such as:

1. Consider coordination of the signals upstream as to minimize the opposing platoon dispersion creating longer gaps for LSV turning left during the green interval (i.e. In other words, the vehicles coming in the opposite direction to the LSV will come as close to one single group so that there is a larger time gap before the end of the green phase); and

2. Consider left-turn protected phase only, although the design of the phase will need a longer start-up time and clearance time than typically required for mixed urban traffic in order to accommodate the LSV, and will reduce the rate with which traffic can be moved through the intersection.

The low acceleration will also create another conflict situation when the LSV turns right (or left) at the end of its own green phase or during the clearance phase just before the platoon start-up in the opposing direction, or on red during a gap, or from a minor road onto a major road. As the LSV accelerates more slowly than expected, following drivers may not adapt their speed and find themselves involved in a rear-end crash with the LSV or another slow vehicle following the LSV. Another operational effect of the low acceleration of an LSV is the creation of queues which may be lengthened to the point they cause delays and decrease the capacity of the road network, unless special signal coordination is implemented on LSV routes.

The braking distances found in the LSV specification sheets may be used to calculate the deceleration of these vehicles. For example, an LSV stopped in 19.5 ft from 20 mi/h for a 0.69 g average deceleration, which is approximately 30% less than that for typical cars. The Honda Civic came to a stop in 126 ft from 60 mi/h, for an average deceleration of 0.95 g [109]. Thus, an LSV will require a longer stopping sight distance. Extension of green time through advance detection (by means of magnetic loops in the pavement to detect an approaching vehicle and delay the onset of the yellow phase until the vehicle can clear the stop bar) will be needed to accommodate an LSV at a signalized intersection. Advance warning of yellow phase would assist the driver of an LSV, but the negative impact due to behavioural change, i.e., drivers accelerate to enter the intersection “before the end of the phase”, would overall be detrimental to safety.

10.4 Traffic Safety and Speed Differential

Operating speeds in urban and municipal road networks typically vary from 30 to 80 km/h, excluding expressways. Thus, it can be expected that the speed differential between general traffic and LSVs will be in the range of 0 to 50 km/h. Studies have shown that the greater the speed difference between two vehicles, the greater the probability of a rear-end collision. The human factors issue underlying this effect is the difficulty that drivers have in detecting closing velocity, especially in situations where the following vehicle catches up with the slower vehicle in front. An extensive analysis of two-car, rear-end collisions was used to calculate the risk of rear-end collisions, given various closing speeds. Speed observations and/or interviews were made with nearly 300,000 drivers. While 47% of two-car, rear-end collisions involved speed differences greater than 32 km/h, only 7% of randomly selected pairs of cars in normal traffic exhibited speed differences this high. Thus where the speed difference between following vehicles was greater than 32 km/h, collision risk increased by a factor of 6.7 times. As the speed difference grew, collision risk soared exponentially. In an urban area posted at 60 km/h, an LSV may be travelling at a speed of 40 km/h, its maximum speed, while the following driver may be travelling at 70 km/h or more [110]. Based on this study a speed difference of 30 km/h would be expected to increase risk substantially.

It is noted that most studies of the effects of speeds on crashes, including the one cited above, are based on crashes that occurred on rural roads with speed limits of 55 to 70 mi/h [111]. An Australian study by Kloeden et al. analyzed crashes in metropolitan Adelaide in speed zones with a 60 km/h speed limit, and found that there was a statistically significant increase in the probability of involvement in an injury (fatal and injury combined) crash with increasing travel speed above, but not below the speed limit [112]. If we assume that LSVs will only be allowed on municipal roads with speed limits of 40 km/h, their involvement in injury crashes with another vehicle may not be a concern. However, if LSVs are allowed on any urban roads where the operating speeds are higher than the speed limits, there may be an increase of crashes between LSVs and those drivers travelling above the speed limit. It is noted that this study did not include crashes with vehicles slowing to turn or stop. Studies relating crash probability and speed on residential streets were not found.

Thus, it is concluded that there is a higher probability that LSVs will be involved in crashes with vehicles travelling at speeds over the speed limits, which are typically found on arterial and collector streets. In other words, the speed dispersion on urban arterials and collectors will increase the crash occurrence.

10.5 Additional Safety Concerns

In September 2008, NHTSA denied a request to increase the GVWR for LSVs from 3,000 lb to 4,000 lb. The two reasons for denying the petition were first, the belief that vehicles with a GVWR greater than 3,000 lb are capable of complying with all requirements imposed by FMVSS, and second, that increasing the GVWR would “encourage the use of LSVs in circumstances where it could pose an unreasonable risk to safety” [16].

At the same time, NHTSA denied a second petition that requested the creation of a new class of motor vehicle, called “medium speed vehicles”, capable of attaining a maximum speed of 35 mi/h. The reason for denying the petition was “because the introduction of such a class of motor vehicles without the full complement of safety features required for other light vehicles such as passenger cars would result in significantly greater risk of deaths and serious injuries” [16].

Various sources have expressed concerns about the safety of LSVs, as follows:

- in a presentation [113] made by Prof. Dr. Schindler at the 2007 European Symposium on the Safety of Low Weight Vehicles, it is acknowledged that some low weight vehicles exist to solve “real problems”, such as urban and rural commuting for persons without appropriate class driving, licence, mobility for young population and mobility for elderly or disabled citizens. At the same time, it is pointed out that significant improvements have to be made to these vehicles so they are able to keep up with surrounding traffic and demonstrate adequate performance in terms of braking. More importantly, it is critically important that these vehicles have adequate crash performance, in particular when they are involved in collisions with heavier and faster vehicles.

- The Governors Highway Safety Association (GHSA) is a coalition representing all states, that addresses highway safety related issues. As mentioned in GHSA’s 2008-2009 Policies and Priorities document [114], GHSA recommends that LSVs “meet additional federal vehicle conspicuity standards so that they are more visible to nighttime drivers. Further, GHSA urges states to review their regulations for low speed vehicles to ensure that more vehicles are registered, licensed and limited to roadways where there would be few potential conflicts with higher speed vehicles.”

- The Consumer Safety Commission (CSC) is a French independent public authority created in 1983 to address safety concerns arising from any products used by the public in France. A complaint filed in 2007 by a quadricycle owner prompted CSC to look closer into the matter of quadricycle safety issues. The consumer questioned the solidity and stability of a quadricycle purchased in 2006. He complained of “numerous breakdowns and premature body degradation, and the lack of vehicle stability after the minicar toppled over at low speed while negotiating a traffic circle.” [115]

  In 2008, CSC put forth recommendations aimed at improving the safety of quadricycles to stakeholders including public authorities, manufacturers, dealers, insurers and consumers. For example, CSC recommended enhancing the quadricycle collision statistics by improving the reporting system and performing better analyses of the circumstances of the collisions involving quadricycles. Another recommendation was to adopt a mandatory regular technical inspection program.

- The Vancouver Police Department (VPD) expressed concerns over the use of LSVs on city roads [26]. One of their concerns is related to a greater risk of being involved in a collision due to the speed differential between LSVs that could travel at a maximum speed of 40 km/h, and regular traffic travelling at 50 km/h or more. Another concern is about the LSV’s level of protection in an event of a collision, especially with a full size vehicle or truck, as the LSVs are not designed and manufactured with the same standards as typical passenger vehicles.

- The ITAQ report [11] presented concerns expressed by representatives of the U.S. Insurance Institute for Highway Safety (IIHS) and Germany’s Allianz Zentrum Für Technik (AZT). Their comments are listed below, in French, from the report, and also translated in English:

  - Russ Rader, Insurance Institute For Highway Safety (U.S.):

    - *L’IIHS n’a pas testé les VBV mais elle a quelques réticences concernant l’utilisation de ces véhicules sur la voie publique;* Translation: *The IIHS has not tested NEVs but has shown reticence concerning their use on public roads).*

  - *L'IIHS considère le VBV comme une voiturette de golf modifiée (glorified electric golf carts);* Translation: *The IIHS considers the NEV to be a modified golf cart ("glorified electric golf carts").*
  - *L'IIHS est contre l'utilisation des VBV sur la voie publique;* Translation: *The IIHS is against the use of NEVs on public roads.*
  - *Le président de l'IIHS, Brian O'Neill, qualifie les VBV comme «un problème sécuritaire en devenir;* Translation: *The president of the IIHS, Brian O'Neill, describes NEVs as a "safety problem waiting to happen".*

- Heike Stretz, Allianz Zentrum Für Technik (AZT), Germany:

  - *L'AZT considère que les quadricyles ne sont pas assez sécuritaires pour circuler sur la voie publique;* Translation: *The AZT considers that quadricycles are not safe enough to be used on public roads.*
  - *Les quadricycles sont particulièrement vulnérables lors d'impacts frontaux;* Translation: *Quadricycles are particularly vulnerable in frontal collisions.*
  - *Le quadricycle devrait avoir les mêmes normes de sécurité que les autres voitures;* Translation: *Quadricycles should be made to adhere to the same safety standards as other cars.*
  - *La réglementation européenne devrait être réévaluée.* Translation: *The European laws should be re-evaluated.*

11 LSV Technical Considerations

11.1 LSV Design

LSVs currently available in North America are based on:

- enhanced golf cart technology (for example, GEM);
- glider technology (for example, Miles and ZENN); or
- original design (for example Dynasty and Nemo).

The LSVs based on enhanced golf cart technology or on an original design are typically designed from the ground up by their manufacturer. A glider-based LSV uses an existing vehicle body supplied by a third party, that includes the steering and braking system and suspension components, but without the internal combustion engine (ICE) and associated powertrain systems.

The golf-cart-based LSVs such as those made by GEM look more like a golf cart than a passenger vehicle. They typically feature an “open” passenger compartment but have doors available as an option.

By contrast, glider-based LSVs look like a passenger car. Miles’ LSVs are based on a Daihatsu Move, a model that has been in production since 1995. The electric powertrain design and integration is done by Miles and the vehicles are manufactured in China using mostly U.S. supplied electrical components. ZENN LSVs are based on a Microcar MC1 glider which is imported to Canada, where the vehicles are assembled. The electric powertrain design and integration is done by ZENN in collaboration with other Canadian companies.

Designing a vehicle is a complex process that is based on specific requirements for each vehicle system [116]. For example, drive-off dynamics are specified in terms of vehicle body rotation about the pitch axis (squat), time to speed, time to distance, grade ability and power to weight ratio, to name just a few. Braking dynamics are specified in terms of stopping distance and vehicle body rotation about the pitch axis (dive). Other requirements relate to ride, steering and handling performance. The dynamic behaviour and performance of vehicle systems are influenced by vehicle parameters and attributes, such as:

- curb weight;
- curb weight distribution;
- overall height;
- ground clearance;
- center of gravity;
- sprung-mass centre of gravity;
- unsprung mass centres of gravity;
- body ride frequency ratio; and
- front and rear roll center heights.

For example, the distance of the centre of gravity and sprung-mass center of gravity from the front or rear axle and their height above ground directly impact braking and acceleration dynamics, brake system design and driving stability [117].

Ride comfort and dynamic wheel load are determined by the springing and damping characteristics, which also affect handling and body movement about the pitch and roll axes. The softer the springing, the lower the natural frequency for a specified body mass and accordingly the greater the ride comfort.

Batteries are heavy, so a glider-based LSV may have a curb weight that is considerably greater than the curb weight of the base vehicle as equipped with an internal combustion engine. It is assumed that an LSV manufacturer using glider technology would address the effect of the added mass by upgrading key components to sustain the structural integrity, crashworthiness and dynamic performance of the glider. Some of the affected components include:

- spring and shock package changes to maintain the ride height and dynamic loads;
- tires may need a higher load rating;
- braking system, where larger rotors/drums and calipers may be required;
- steering components such as tie rod ends and the rack and pinion, to handle the increased weight and braking forces;
- wheel bearings and rubber bushings, which may experience added wear;
- anchor points for steering and suspension components on the frame/sub frame, which may need to be reinforced.

In addition, if the added mass is placed significantly above the original centre of gravity (CG) then the spring rate of any roll bar will need to be increased. If the added mass is centered above the CG, the rollover threshold is reduced and the vehicle could experience a higher rollover rate. It will also cause more nose diving and axle load transfer under severe or hard braking and this will change the front-to-rear brake balance requirements.

11.1.1 LSV Energy Storage System

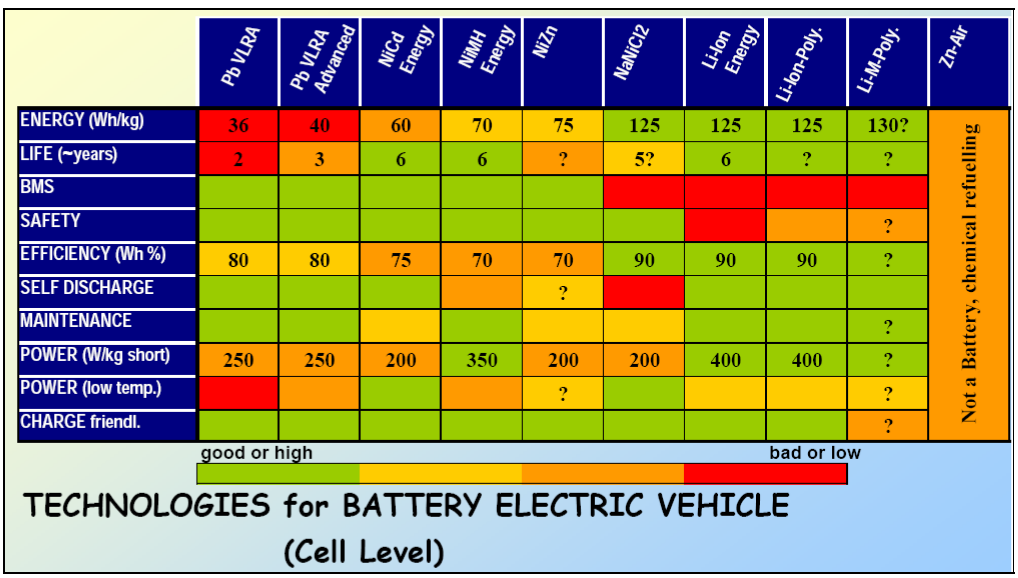
All LSVs currently available in North America use lead-acid batteries in their energy storage system (ESS). Valve Regulated Lead Acid (VRLA) batteries, either absorbent glass mat or gel type, have become the norm for the majority of LSVs available, however, some manufacturers choose to equip vehicles with flooded lead-acid (FLA) batteries, and offer VRLA batteries as an option. The electrolyte (battery acid) used in VRLA batteries is either absorbed in a fiber glass mat or combined with a silica fume to become gel-like and immobile. One of the advantages offered by the VRLA batteries compared to FLA batteries is that the former can be mounted in any position, as the electrolyte is better contained. Because of the “sealed” design, VRLA batteries are maintenance free. However, they are more expensive than FLA batteries.

The lead-acid battery, in both the FLA and the VRLA forms is inferior to other newer battery technologies, as shown in Table 11. However, it is a proven technology, and is relatively low cost compared to other battery technologies, so it is preferred by LSV manufacturers.

Table 11: Battery technology comparison [118]

Electric Vehicle Battery Technology				
Technology	**Specific Energy (Wh/Kg)**	**Energy Density (Wh/l)**	**Specific Power (W/kg)**	**Cycle Life (Cycles)**
BatScap Lithium-Metal-Polymer	110	110	320	
Avestor Prototype LMP	121	143	241	300
Li-ion	138	210	430	550
NiMH	63	150	200	800
Ni-Cad	50	90	120	800
Lead-Acid	36	86	180	600

A further comparison of different battery technologies applicable to electric vehicles is presented in a European report [119] and illustrated in Figure 42. In addition to specific characteristics, maintenance, charging and safety considerations are also illustrated.



	Pb VLRA	Pb VLRA Advanced	NiCd Energy	NiMH Energy	NiZn	NaNiCl2	Li-Ion Energy	Li-Ion-Poly.	Li-M-Poly.	Zn-Air
ENERGY (Wh/kg)	36	40	60	70	75	125	125	125	130?	Not a Battery, chemical refuelling
LIFE (~years)	2	3	6	6	?	5?	6	?	?	
BMS										
SAFETY									?	
EFFICIENCY (Wh %)	80	80	75	70	70	90	90	90	?	
SELF DISCHARGE					?					
MAINTENANCE									?	
POWER (W/kg short)	250	250	200	350	200	200	400	400	?	
POWER (low temp.)					?				?	
CHARGE friendl.									?	

Figure 42: Electric vehicle battery technologies [119]

Battery performance dictates the operating range of an LSV. If an LSV is operated outside its batteries' specified temperature operating range, the battery performance degrades and the LSV's operating range decreases.

The greatest limitation affecting current LSVs is the limited operating range, which in turn is directly influenced by the battery technology. Lead-acid batteries are used by all LSV manufacturers and the trend is likely to continue.

It is widely known that FLA batteries require specific maintenance and handling procedures compared to their VRLA counterparts. While FLA batteries have slowly started to be replaced by VRLA batteries in LSVs, it is still necessary to understand the risks associated with the use and maintenance of both types.

FLA batteries require regular watering, and poor maintenance will significantly affect battery life. Improper charging can significantly influence the life cycle of an FLA battery, and over-discharging significantly reduces battery life. FLA batteries are considered hazardous material and therefore are subject to certain handling, shipping and storage rules. Recycling and disposal procedures are similar to those for passenger vehicle batteries.

VRLA batteries are maintenance free, although periodic inspection for terminal corrosion is still required. Improper charging can significantly affect the life cycle of a VRLA battery. They are intolerant of overcharge. Similar to FLA batteries, over-discharging significantly reduces battery life. They are not considered hazardous material, and recycling and disposal procedures are similar to those for passenger vehicle batteries.

The two types of battery should not be interchanged, as the charger must be matched to the type of battery. Should the need to switch from one technology to the other arise, the dealer or an approved garage should be the only parties authorized to perform the modification. Battery servicing and replacement is done by the dealer, whether at their premises or through mobile teams.

Since no LSV crash test results are currently publicly available, it is difficult to anticipate secondary effects arising from a collision involving an LSV. Securement of the battery system, and its structural integrity, are both significant concerns. Failure of either or both provides the potential for hazardous material spillage during and after a collision. LSV occupants, and emergency personnel attending a crash scene, may be at risk.

Charging and parking should be also taken into consideration. Ideally, an LSV should be parked indoors, especially in winter, and there should be an electrical outlet that allows overnight charging. An LSV owner living in a high-rise building typically has indoor parking, but there may not be a convenient, or any, electrical outlet. An LSV owner living in a house should have access to an electrical outlet, but may not have indoor parking.

11.1.2 Electromagnetic Interference and Compatibility

Electromagnetic interference (EMI) can disrupt the proper operation of an electronic device or system. EMI is caused by electromagnetic fields. There are several concerns for an electric vehicle with no EMI testing or certification:

1. Personal safety from exposure to motor or system fields.

   There have been concerns over exposure of humans to fields from CRTs, motors and other systems operating at higher voltages. Although there may be little chance of exposure, there should be an investigation to determine if any systems have field strengths at levels above permissible exposure levels. Canadian standards exist.

2. Interference to other vehicles

   If the systems on the vehicle have electromagnetic emissions across a broad spectrum, there could be interference to other vehicles, such as communication systems installed on emergency vehicles, or to equipment installed in buildings along the route of the LSV.

3. Interference from outside sources

   External sources, such as radio transmitters, may affect the proper operation of various systems and components of a vehicle.

Electromagnetic compatibility (EMC) is concerned with the study of unintentional generation, propagation and reception of electromagnetic energy with reference to the unwanted effects that such energy may induce. EMC certification ensures that the systems are compatible with themselves and with their intended operating environment. Emission tests evaluate the extent to which a system is emitting enough electromagnetic energy to cause itself or other devices to fail. Susceptibility or immunity tests evaluate the extent to which the equipment will continue to operate in the presence of specific electromagnetic energy.

EMC standards and test procedures aimed at reducing the electromagnetic interference have been developed by SAE, ISO and auto manufacturers. Some of these standards include:

- SAE J1113: Electromagnetic Compatibility Measurements Procedure for Vehicle Components [38];
- SAE J551: Vehicle Electromagnetic Immunity [39]; and
- ISO 11452 for immunity concerns [40].

A recent study, “The Engineer’s Guide To Global EMC Requirements: 2007 Edition” presents the current EMC regulations in many countries around the world. According to the guide [120]:

In U.S., the Federal Communications Commission (FCC) establishes the compliance regulations for radios, digital devices and other unintentional radiators. It does not regulate immunity, except in a few special cases. Typical emissions standards are Parts 15 (RF devices) and 18 (ISM equipment). Some applications of digital devices are exempted from the FCC’s technical standards, as is the case with test equipment, transportation vehicles, appliances, utilities or industrial plant.

Relevant EMC regulations include:

- *Department of Defense (DoD), for military EMC. A common EMC standard is MILSTD-461E (1999) Requirements for the control of electromagnetic interference; characteristics of subsystems and equipment. EMC testing can be witnessed by DoD inspector; lab accreditation is helpful;*
- *SAE (Society of Automotive Engineers) EMC standard series J551/x, J1113/x is a start. However, the individual auto manufacturers (Ford, GM, DaimlerChrysler, Toyota, etc.) have their own EMC standards that differ from the SAE's standards. EMC report is submitted by device vendor to auto manufacturer; lab accreditation is important.*

The regulation of EMC in Canada is similar to that in the U.S.:

- *Industry Canada (IC) establishes the compliance regulations for radios, digital devices and other unintentional radiators. Typical emissions standards are ICES-003 (ITE) and ICES-001 (ISM equipment). Some applications of digital devices are exempted from IC technical standards, in a manner similar to the FCC;*
- *Health Canada (HC) designates consensus device standards for medical devices. It recognizes IEC 60601-1-2:2001+A1:2004 (general medical EMC)*

LSV components are typically off-the-shelf automotive parts certified to EMC standards, and thus the risks of exposure and interference should be low. However, the integration of certified EMC-certified components does not necessarily mean that the compatibility at system level will be at par with component performance.

11.2 LSV Equipment

11.2.1 Corrosion Protection

The installation of batteries and other fittings in a glider may require modification to the structure of the body and/or frame. Any cutting or welding may affect the corrosion resistance of the vehicle. It is desirable that corrosion protection be restored, to at least the original level.

11.2.2 Child seat provisions

LSVs come in different shapes and sizes, with two to six seats. The majority provide seating for four. For safety reasons, NHTSA, Transport Canada and other organizations maintain that children age 12 and younger should ride in the back seat of standard motor vehicles. Regulations regarding child seats exist and regular passenger vehicles must conform to these standards. LSVs are not required to meet the requirements of Standard 210.2 (Lower Universal Anchorage Systems for Restraint Systems and Booster Cushions) and Standard 213.4 (Built-in Child Restraint Systems and Built-in Booster Cushions). There are not known to be provisions for installation of child seats in LSVs.

11.2.3 Towing/Recovery

Towing/recovery provisions exist for some LSVs, but generally, the towing procedures are subject to several limitations, due to the unique architecture of an electric LSV, similar to sophisticated all-wheel-drive vehicles. Towing an LSV requires specific procedures. Quite often, the manufacturer specifies that an LSV can only be towed by an approved contractor.

While technically possible, towing a trailer using an LSV may lead to dangerous situations related to increased gross combination weight, increased overall length, reduced dynamic stability and reduced braking performance. It appears appropriate to limit or prohibit towing of trailers until the safety performance of LSVs is better understood. MTQ included such a prohibition for all LSVs that will be part of the Québec pilot project.

11.2.4 Auxiliary systems

Auxiliary systems such as ventilation, heating, air conditioning and lighting are either powered from a DC to DC converter, or a dedicated auxiliary battery. While the heavy use of some of these systems would impact the operating range of the vehicle, the power requirements of lights in general and hazard lights in particular are low. Ideally they would be able to operate for a long time after the batteries have been depleted to a level that causes an LSV to stop moving.

As Daylight Running Lights (DRL) are mandatory for all motor vehicles in Canada, it appears reasonable that LSVs should adopt this technology. CMVSS 108, regulating the use and specifications of DRLs does not apply to LSVs yet. As an alternative, driving with the low beam headlights on at all times could be made mandatory, as required for the Québec pilot project.

11.3 Operating Environment

The environment has also a significant effect on an LSV's operating range, as temperature affects the performance of the batteries. In colder temperatures, the operating range can decrease as much as 50% or more, depending on the usage of auxiliary systems such as Heating, Ventilation and Air Conditioning (HVAC) and lighting.

A recommendation put forth by the authors of the St-Jerome LSV pilot project [9] was to forbid the use of LSVs during the winter months. It is not uncommon for winter-like weather in Ontario to last from November to March, or approximately five months. Temperature is not the only winter factor that might adversely affect the vehicle's performance. Snow accumulation and slush on the roads increases the rolling resistance of the tires, and icy roads might prove to be a difficult surface for a vehicle not equipped with traction control (to prevent wheel spin) or advanced braking systems (to prevent wheel lock-up).

The environment in which LSVs operate significantly influences the vehicle's performance. In the U.S., LSVs have mostly been adopted in states like California with its Mediterranean subtropical climate of wet winters and dry summers, Florida with its mostly humid subtropical climate, and Arizona which is a desert. By contrast, Ontario's climate ranges from humid continental in the south, with chilly winters, warm summers and lots of humidity, to sub-arctic in the north [121].

11.4 LSV Testing

All manufacturers interviewed mentioned that testing is performed at their own facilities for performance evaluation and validation purposes. Several manufacturers sent LSVs for testing at the Idaho National Laboratory, where testing was performed according to NEV America program requirements [8]. The list of requirements is comprehensive, with compliance requirements to several industry accepted standards, including:

- SAE J1718 (Battery Gas Evolution) [41];
- SAE J1673 JUL96 (High Voltage Automotive Wiring Assembly Design) [42]; and
- Federal Communications Commission (FCC) requirements for unintentional emitted electromagnetic radiation, as identified in 47 CFR 15, Subpart B, “Unintentional Radiators” [43].

11.4.1 Cold Weather and EMI/EMC Testing

It appears that limited cold weather testing has been conducted by manufacturers. EMI/EMC testing has been taken into account by at least one of the LSV manufacturers interviewed, but not by testing against current standards.

It is anticipated that much will be learned from Québec’s pilot project as it enters its first winter.

11.4.2 Crashworthiness Testing

LSVs and quadricycles are not required to comply with frontal and side impact test standards. However, it is useful to review crash tests that have been conducted on quadricycles to normal passenger car standards, because quadricycles are probably the closest match to LSVs in terms of dimensions and intended purpose.

All passenger cars and light trucks are currently crash tested by propelling the test vehicle into a fixed barrier. Such a test simulates an impact with a vehicle of the same weight as the test vehicle, and travelling at the same speed. Whereas these tests are standardized, vehicle-to-vehicle crash tests are not. The standardized crash tests represent the minimum requirements that passenger car and light truck manufacturers need to meet for approval, and they vary slightly between countries:

- In the U.S., FMVSS 208 [122] requires front impact tests at 48 km/h and FMVSS 214 [123] requires side impact tests at 56 km/h;
- in Canada, CMVSS 208 [124] is similar to the FMVSS 208. However, CMVSS 214 [125] does not include a dynamic test requirement;
- in Europe, UN/ECE R-94 (or EU Directive 96/79 [126]) requires front impact tests at 56 km/h and R-95 (or EU Directive 96/27 [127]) requires side impact tests at 50 km/h.

By contrast, other agencies, whose testing is not performed for certification purposes, conduct crash tests using similar procedures, but at higher speeds. The U.S. New Car Assessment Program (U.S. NCAP) was created by NHTSA to improve occupant safety by developing and implementing meaningful and timely comparative safety information. The program encourages manufacturers to improve the safety of their vehicles voluntarily. Since its inception, the program has strongly influenced manufacturers to build vehicles that consistently achieve high ratings, thereby increasing the safety of vehicles. Euro NCAP is a voluntary program as well, originally created by UK's Transport Research Laboratory (TRL). Although the test procedures are slightly different, the program's role is to provide comparative safety information to consumers and manufacturers alike. NCAP crash tests are conducted for the following conditions:

- U.S. NCAP [128]: frontal impact test at 56 km/h (35 mi/h) and side impact test at 62 km/h (38.5 mi/h, 3,015 lb moving barrier) and dynamic rollover test;
- Euro NCAP [129]: frontal impact test at 64 km/h (40 mi/h) and side impact test at 50 km/h (30 mi/h) and pole test at 29 km/h.

Transport Canada has performed crash tests on a small number of LSVs. Crashworthiness research reports have been shared with the manufacturer of each test article. However, the LSV research program has not been completed and no reports have been publicly released to date. Transport Canada mentions [130] that:

- *The Canadian government undertook a safety assessment of various LSVs including testing of their performance in the types of collisions that could occur on streets with low speed limits. The assessment confirmed that the LSV lacked many of the standard safety features that are common in passenger cars and would also pose significantly greater risks of death and serious injury to occupants, compared to fully safety certified vehicles;*

- *Transport Canada has purchased and will continue to purchase various low-speed vehicles to conduct safety and research crash tests. The tests represent collisions that typically happen on city streets where the speed limit is 50 km/h or lower. Transport Canada regularly conducts crash tests to monitor the safety of passenger vehicles. The crash tests are designed to evaluate the protection of occupants, and if that protection could be improved. The test results to date confirm that low-speed vehicles provide a substantially lower level of occupant protection than conventional passenger cars and that the injury risk in these vehicles is disproportionate to the severity of crash.*

11.4.2.1 German Insurance Association Research Program

Based on a research project undertaken by the German Insurance Association (GDV) in collaboration with Allianz Centre for Technology Munich, Dr. Gwehenberger [66] presented a series of test results of low speed crash testing of LWMVs at a meeting in June 2007. Two LWMVs (also known as quadricycles) were selected for testing, as shown in Figure 43. The two LWMVs represent light quadricycles, with a maximum curb weight of 350 kg and a maximum speed of 45 km/h.

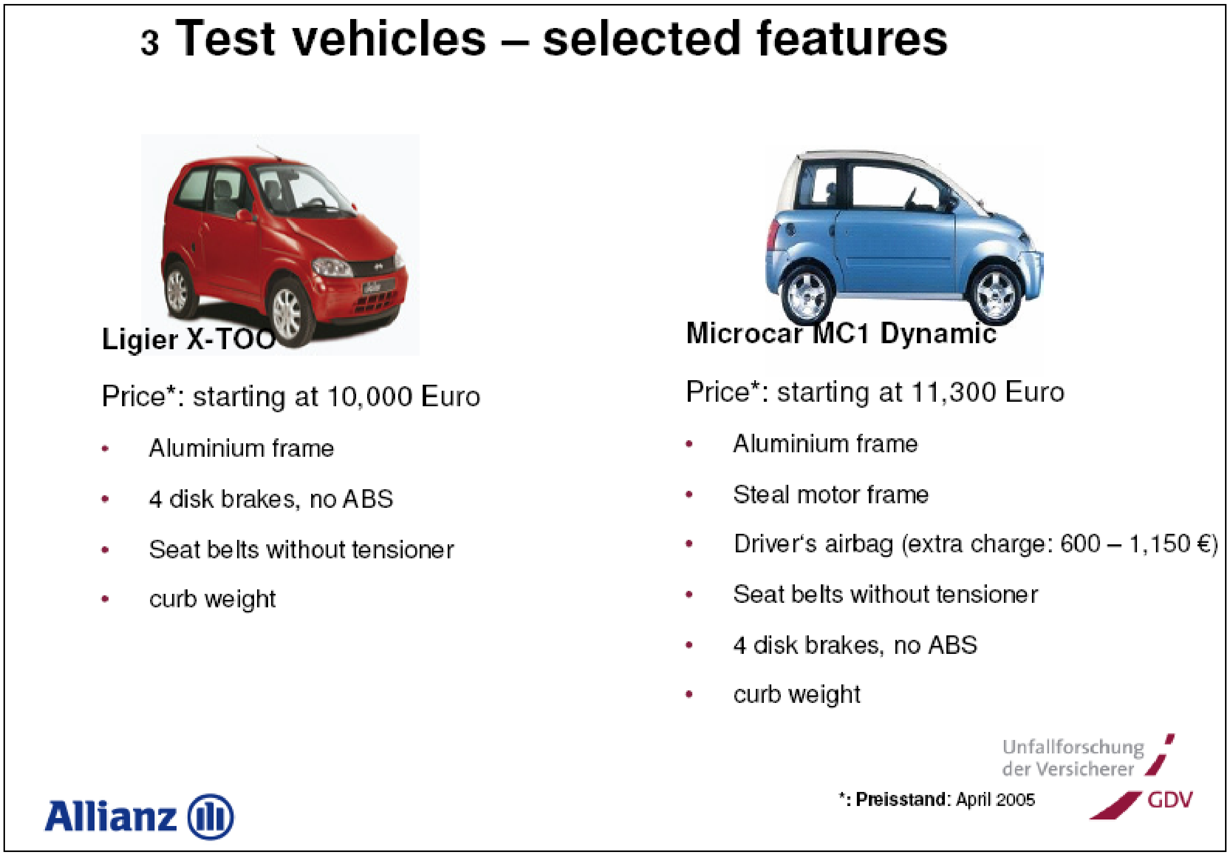


Figure 43: Allianz & GDV test vehicles [66]

The test vehicles are representative for the quadricycle class. Their design consists of an aluminum frame and Acrylonitrile Butadiene Styrene (ABS) body panels, as seen in Figure 44 and Figure 45.

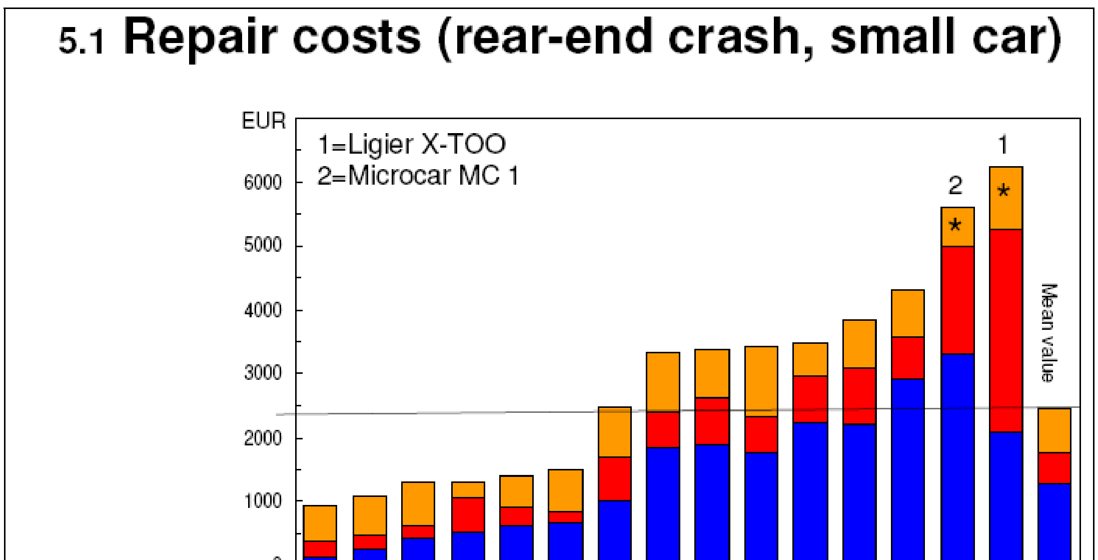
Figure 44: Microcar MC1 test vehicle [66]

Figure 45: Ligier X-TOO test vehicle [66]

According to Allianz, these vehicles lack a structure designed to absorb and control the impact energy developed in a collision. The ABS body panels are glued or fastened to an aluminum frame. On-road testing performed by Allianz revealed that LWMVs are often perceived as obstructions to traffic and represent a high risk for causing collisions due to hazardous overtaking manoeuvres performed by other road-users. Quadricycles can travel on roads with a maximum speed limit of 90 km/h in Europe.

Rear-end low speed crash tests were executed according to GDV procedures, with an impacting car weighing 1,400 kg, traveling at 15 km/h, with 40% barrier overlap and 10° barrier angle. The test setup is shown in Figure 46. Comparative repair costs are shown in Figure 47. The repair costs of the two tested quadricycles were almost twice as high as the mean value of the repair cost of thirteen regular passenger vehicles involved in a similar collision, and almost 50% of the price of a new quadricycle.

Figure 46: Rear impact test setup [66]



	133	127	118	111	107	110	135	106	88	90	93	102	98	156	158	M
total repair costs	931	1071	1312	1314	1385	1496	2490	3334	3377	3419	3478	3853	4291	5603	6227	2442
paint work	538	612	686	269	477	641	799	939	758	1073	516	771	727	622	968	677
spare part costs	262	189	194	513	285	193	682	563	725	590	713	887	661	1670	3173	497
bodyshop/auto mechanic labor cost	131	270	431	531	624	662	1009	1833	1894	1756	2248	2195	2903	3311	2087	1268

Figure 47: Allianz & GDV tests, repair costs [66]

The same presentation showed LWMV seat testing procedures and results. Static seat tests were performed according to the International Insurance Whiplash Prevention Group (IIWPG) protocol. Test results and comparisons with other vehicles are shown in Figure 48. It can be seen that the whiplash results for the Microcar and the Ligier LWVMs were at the transition between good performance and marginal performance.

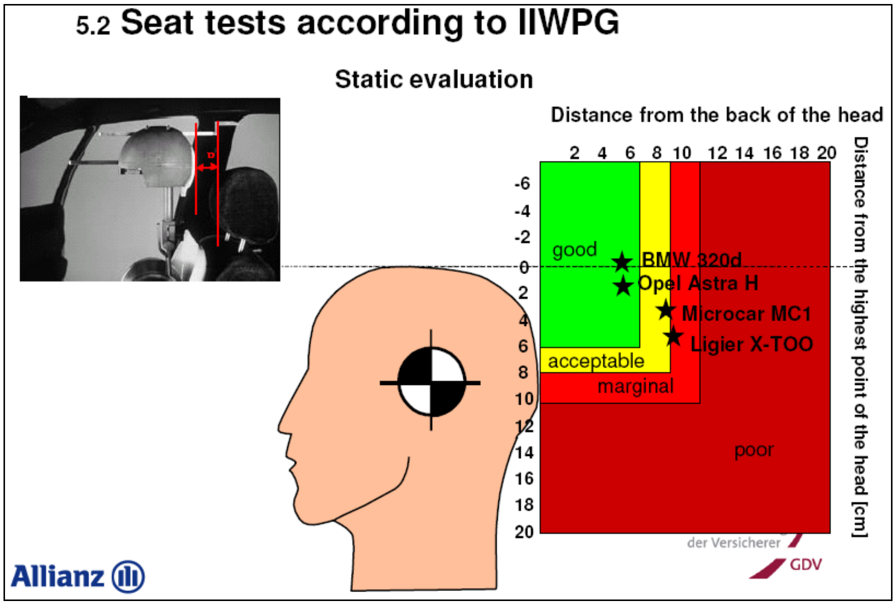


Figure 48: Allianz & GDV tests, static seat evaluation [66]

Dynamic seat tests were also performed according to the IIWPG protocol. Figure 49 illustrates the position of the seats and dummies after the test.

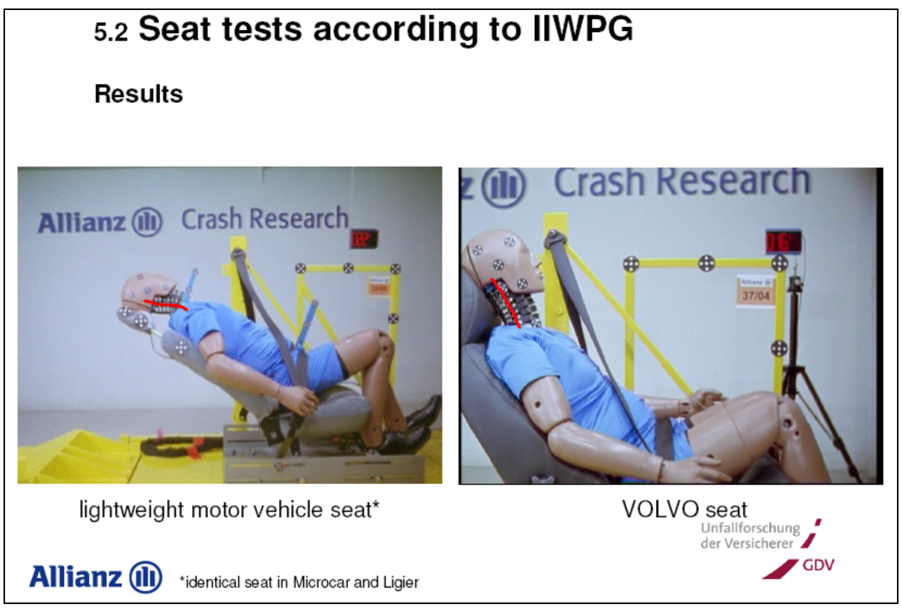


Figure 49: Allianz & GDV tests, dynamic seat evaluation [66]

The Allianz report indicated that the LWMV seats did not provide appropriate protection against cervical spine injuries. The measured neck forces were ten times higher than those measured in the Volvo seat.

Based on the same GDV and Allianz research project [131], Dr. Kühn presented [132] high-speed crash performance testing procedures and results for the two LWMVs. The crash tests were executed according to existing United Nations Economic Commission for Europe (UN/ECE) regulations [133], R-94 for frontal impact test and R-95 for side impact test.

The frontal test setup and results for Microcar MC1 test vehicle are presented in Figure 50 and Figure 51.

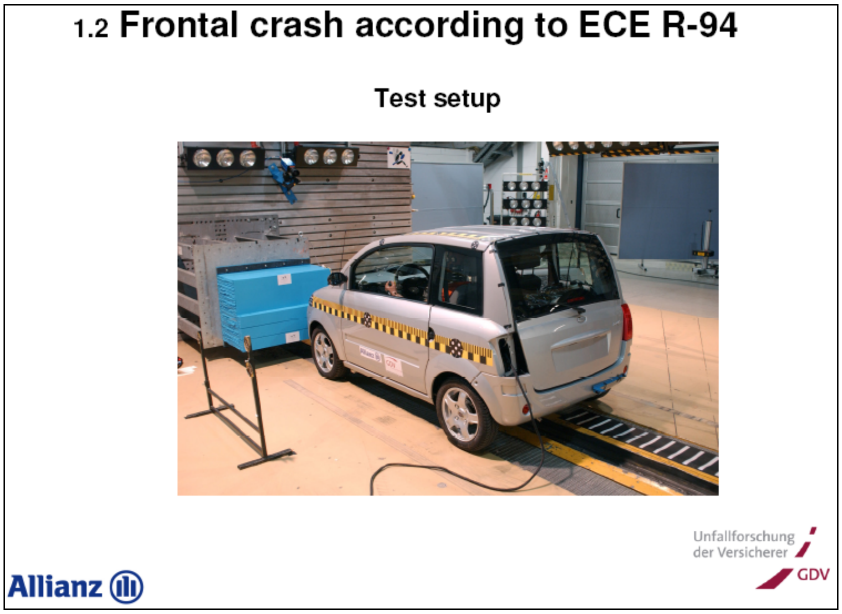


Figure 50: Microcar MC1 frontal crash test setup [132]

1.2 Frontal crash according to ECE R-94

Passenger performance values (selected)

		Microcar MC1	
Test criterion	**limit value**	**driver**	**front-seat passenger**
Head injury criterion (HIC)	1000	341	203
Neck moment	57 Nm	33 Nm	61,3 Nm
Thoracic compression	50 mm	36,9 mm	42,7 mm
Thorax injury criterion (VC)	1 m/s	0,4 m/s	0,2 m/s
Left femur force	9,07 kN	1,33 kN	1,64 kN
Right femur force	9,07 kN	1,54 kN	1,41 kN

Figure 51: Microcar MC1 frontal crash test selected results [132]

While the test results revealed that only the neck moment exceeded the limit value, Allianz noticed that after the impact, the steering wheel shifted in the z-direction, exceeding the allowed travel limit value, as shown in Figure 52. In addition, the vehicle rotated more than 180°after the impact, which typically leads to an increased risk of secondary collision, such as a side impact with an object or another vehicle.

Figure 52: Microcar MC1 after crash test [132]

The presentation concluded that ECE R-94 reflects a collision involving two vehicles of the same weight, which is unlikely for LWVMs, and the risk of injury would increase dramatically in a collision with a heavier vehicle.

The side crash test setup and results for Ligier X-TOO test vehicle are presented in Figure 53 and Figure 54.

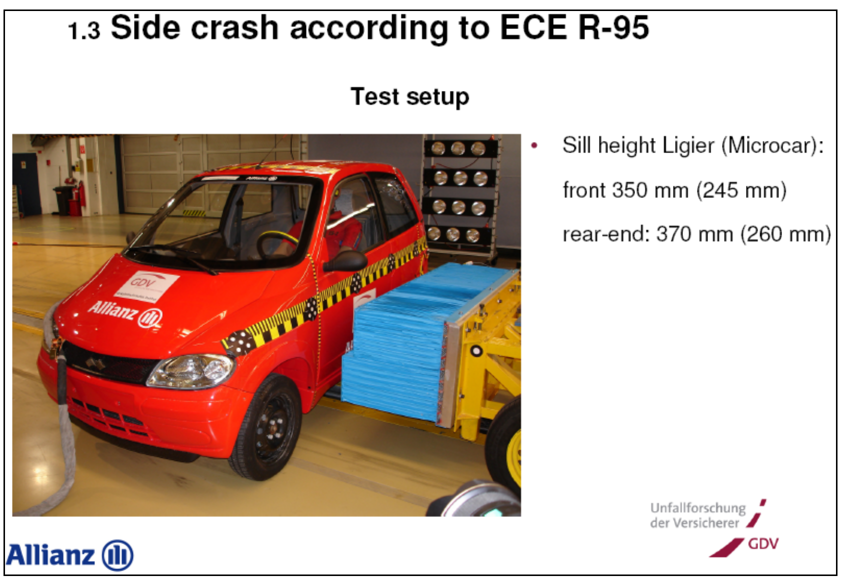


Figure 53: Ligier X-TOO lateral crash test setup [132]

1.3 Side crash according to ECE R-95

Passenger performance values (selected)

Test criterion	limit value	driver
Head performance criterion (HPC)	1000	239
Upper rib deflection	42 mm	23,4 mm
Upper thorax injury criterion (VC)	1 m/s	0,21 m/s
Middle rib deflection	42 mm	34 mm
Middle thorax injury criterion (VC)	1 m/s	0,42 m/s
Lower rib deflection	42 mm	44,8 mm
Lower thorax injury criterion (VC)	1 m/s	0,8 m/s
Pubic symphysis force	6 kN	4,26 kN
Abdomen force	2,5 kN	0,89 kN

Figure 54: Ligier X-TOO lateral crash test results [132]

While the test results revealed that only the lower rib deflection exceeded the limit value, the report indicated that during the impact the driver dummy's head protruded through the front door's window, as shown in Figure 55. That would expose the driver to a very high risk of injury in a real crash. In addition, both doors were torn out and the longitudinal sill beams separated from the frame at the A-pillar.

Figure 55: Ligier X-TOO after the lateral crash test [132]

The test executed according to ECE R-95 revealed that the vehicle structure sustained significant damage, as the passenger compartment structural members separated at the A-pillar section. The impact barrier intruded into the passenger compartment significantly, even though the weight of the barrier was lighter than a regular passenger vehicle. The consequences of such an impact in a real crash would likely be more severe.

11.4.2.2 UK Quadricycle Crashworthiness Testing

Another quadricycle type vehicle, REVA's G-Wiz electric vehicle, was subjected in 2007 to a frontal crash test using the current Euro NCAP procedure, at 64 km/h. Partial results published in May 2007 in U.K.'s Top Gear auto magazine sparked a heated debate, as the test results showed that: *"The front part of the G-Wiz collapsed into the driver's legs, leaving almost no space between various hard metal parts and the rigid underseat battery case. In addition, the steering wheel intruded deep into the driver's abdomen, and his head crashed into the top of the steering wheel and the windscreen. Moreover, the driver's door flew open while the passenger's stuck shut."*

The Euro NCAP tests on the G-Wiz were performed by the Transport Research Laboratory (TRL). The agency's report mentioned that *"The passenger compartment sustained significant intrusion with the driver's side A-pillar deforming rearwards by approximately 397 mm at the waist beam level. At the sill level the A-pillar deformed rearwards by approximately 299 mm. Intrusion of this magnitude has the potential to cause serious or life-threatening injuries to the vehicle occupants as structures such as the steering column and pedals intrude into the compartment..."*

During the same week that TRL conducted the Euro NCAP test, the UK Department of Transport conducted a statutory-type crash test according to UN/ECE R-94 (56 km/h). The test results highlighted serious safety concerns and prompted the Department of Transport to propose a review of the European regulations for quadricycles.

In a press release [134] issued in May 2007 by the UK Department of Transport, the Roads Minister, Dr. Stephen Ladyman, said:

- *The safety regulations that govern this type of vehicle were designed at a time when it was thought they would cover four-wheeled motorcycles and some small, specialised commercial vehicles. Not city run-abouts that resemble small cars.*
- *But, given increasing environmental concerns, new vehicles that qualify as quadricycles have come to the market and are becoming more popular for urban use. Therefore it is right that we reconsider the regulations for this type of vehicle and whether safety regulations should be made more stringent.*
- *Now we have the initial findings of our tests we will be taking this up with the European Commission and manufacturers, and will publish more information when the full programme of tests is complete.*

According to an article [135] published in December 2007, the G-Wiz manufacturer teamed up with Lotus and corrected the problems revealed by the crash tests earlier in the year. According to the article: "the new 2008 G-Wiz "has been independently, voluntarily frontal crash tested for city speed driving conditions at 25 mi/h by ARAI (the Automotive Research Association of India) following the addition of the Lotus assisted safety package".

11.4.2.3 Quadricycle Manufacturers Crashworthiness Testing

Other European quadricycle manufacturers, such as AIXAM, Ligier and Grecav, indicate that although the quadricycles are not required to meet European frontal and side crash standards, they voluntarily perform these tests, and their vehicles have passed the tests. For example:

- Aixam says [136]: “AIXAM was the first "no-licence" car manufacturer to prioritize user safety. In 1988, although there was no legal requirement to do so, the company chose to put its "no licence" car through a head-on crash-test (collision). AIXAM was then the first and only manufacturer to get its vehicles approved in this way. Since then, AIXAM has constantly intensified its safety policy by successfully putting all its models through head-on, rear and side crash-tests. At present, AIXAM is still the only "no licence" car manufacturer to have passed all its crash-tests.”

- Ligier mentions in its Ligier X-TOO brochure [137], shown in Figure 56, that they perform frontal crash tests at 50 km/h.

Figure 56: Ligier X-TOO brochure extract

- Grecav says [138]: “European Law doesn’t provide for specific tests for light quadricycles like EKE. Anyway Grecav has had his vehicle subjected to a series of crash tests that are usually compulsory only for cars. These tests have been got through perfectly by EKE. After shock EKE showed to be a safe vehicle as the structure remained the same and the inside compartment hasn’t been damaged”.

12 DISCUSSION – SAFETY RISKS

The low-speed vehicle (LSV) has developed from the golf cart and similar vehicles that have come into use in the U.S. for local transportation in, and sometimes around, areas with controlled traffic such as gated communities. The capability and range of LSVs has developed, and NHTSA in the U.S. and Transport Canada have now defined the low-speed vehicle as a class, and set a standard for it. Both agencies in their respective rule-makings stated that they considered that LSVs were intended for use in areas with controlled traffic, and not on public roads [12], [16]. After careful review of the capabilities and likely safety performance of LSVs, it appears that this is an appropriate use for such vehicles, in their current form.

Notwithstanding the current rule-makings, LSVs are now allowed on public roads, in many states in the U.S., in British Columbia, and in Québec, either relatively freely, or in pilot projects under various sets of rules. Ontario Ministry of Transportation is considering allowing LSVs on public roads, and has asked NRC-CSTT to identify the risks, and to provide strategies for mitigating these risks associated with:

- safely integrating LSVs for operation in mixed traffic on public roads in Ontario; and

- continued safe operation of LSVs in mixed traffic following their introduction onto public roads in Ontario.

If LSV usage becomes mainstream in Ontario, the risk mitigation strategies need to ensure outcomes that are to the benefit of the community at large.

One distinction that should be stressed is a definition of the overall purpose of Ontario's proposed LSVs. At first glance it may seem as though the purpose of introducing the vehicles is to provide a zero-emission vehicle for those people wishing to make short distance trips. However, the original intent of these vehicles was to provide a means to travel short distances at low speeds in a vehicle that was significantly less expensive than a conventional passenger vehicle. The fact that they are zero-emission vehicles may, in fact, be a by-product of other factors or a secondary effect. In fact, many LSVs in the United States are powered by internal combustion engines and are therefore not zero-emission vehicles at all.

Care should be taken to fully understand the maturity of technology with respect to other types of zero-emission vehicles that may be fully compliant with all the relevant CMVSS motor vehicle standards. It is very likely that within two years there will be a handful of readily available, and affordable, vehicles that produce zero emissions but are constructed to satisfy all of Canada's CMVSS motor vehicle standards and able to travel at least 60 km on a single charge. These vehicles would have all the zero-emission benefits of the LSVs studied in this report and would have similar overnight charging requirements but would be comparable to fuel-powered vehicles with respect to safety, conspicuity, speed and winter driveability. For these reasons it will be critical to clearly define if the use of LSVs is an attempt to open Ontario's roads to low speed vehicles for those people who are not willing, or able, to drive at higher speeds or if it is a transitional stage towards the ultimate goal of increasing the use of full size zero-emission vehicles in Ontario.

If the ultimate goal is to improve air quality via zero-emission vehicles, it may be imprudent to invest large sums of money to modify infrastructure to suit an LSV technology that may, in the relative short term, be displaced by a breed of vehicles that meets all CMVSS. This point is particularly important should the original purchase price of an LSV begin to approach the cost of a full size zero-emissions vehicle, which presumably will have many more options and safety features.

If improving air quality via zero-emission vehicles is the ultimate goal, full size zero-emission vehicles will likely be available as soon as 2010.

Allowing the current generation of LSVs on public roads may be a transitional phase in the development of electric vehicles. This phase will be successful if it would spur industry to develop a new generation of electric vehicle that would meet all applicable safety standards so that it could operate freely on all roads. LSVs could then be designated to more appropriate use in an environment specifically adapted to LSV operation.

12.1 Road Safety

Canadian, U.S. and European statistics clearly show a reduction in the number of injuries and deaths caused by passenger vehicle collisions in the last thirty years. Numerous factors have contributed to this desirable declining trend. These include:

- crash avoidance measures such as those mandated by CMVSS in the 100 series, adopting legislation for high-mounted brake lights and voluntary measures adopted by industry such as air bags and antilock brake systems;

- crashworthiness measures, such as those mandated by CMVSS in the 200 series, and campaigns to ensure seatbelts are used;

- forgiving road design (traversable slopes, protection of roadside obstacles, lane edge rumble strips) and improved traffic control device design (more conspicuous signs and signals, coordinated traffic signals, long distance detection to avoid drivers having to stop in the "dilemma zone");

- campaigns against driving under the influence of alcohol, and now increasingly while distracted by a cell phone or equivalent device; and

- crash protection of roadside structures.

These measures have resulted in a continuous and dramatic decrease in death and injury rates, despite a large increase in the numbers of vehicles and drivers.

Unfortunately, collisions are a reality on our roads today and although significant efforts have been made to reduce the number of road casualties, it is very likely that these numbers will not sharply decline in the near future. Logically, a vehicle operated in such an environment is subject to the risks affecting all traffic participants: motorists, pedestrians and others alike.

The question is not if LSVs operated on public road in mixed traffic will be involved in collisions, but rather when and how severe those collisions will be, especially on Ontario's roads where almost every second passenger vehicle is a van, SUV or light truck. As shown by U.S. statistics, the crashes where a light truck or van struck a passenger car on the side account for almost 50% of the deaths caused by all crashes between these categories of vehicles, with more than

90% of those deaths attributed to passenger vehicle occupants (Figure 23). LSV's are lighter and less crashworthy than passenger cars. Consequently, the outcomes of collisions involving an LSV and a car will be more serious than those involving two cars, and the outcomes of collisions involving an LSV and van, SUV or light truck will be more serious than those involving a car and one of those vehicles.

There has been no evidence from LSV manufacturers that their vehicles comply with safety standards in excess of CMVSS 500, nor is it anticipated that superior results will be observed from Transport Canada's ongoing crash test program. Therefore, it is reasonable to assume that the crash risk to LSV occupants can only be minimized to a certain extent by restricting LSVs to roads where there is the least differential between the 40 km/h maximum speed of the LSV and the typical speed of other traffic. These roads typically have a posted speed limit of no greater than 50 km/h. This would minimize the occurrence of crashes at a high relative speed, but the crashworthiness of the LSV would still remain questionable.

12.2 Effect of LSVs on Mixed Traffic Flow

The effect of LSVs on mixed traffic flow, on roads with a posted speed limit of 50 km/h or lower, has been examined with regard to LSV acceleration, maximum speed, and braking capabilities.

Acceleration Capabilities
Although LSVs have somewhat lower acceleration capabilities than other light vehicles (e.g., cars and pickups) in mixed traffic, this lower acceleration performance is unlikely to have an adverse effect on vehicle flow or congestion, especially since LSV acceleration is about three times that of heavy trucks.

Maximum Speed Capabilities
The LSV maximum speed, restricted by law to 40 km/h, can have a significant effect on road congestion, depending on the proportion of LSVs as a percent of total traffic volume, and the volume of traffic itself. As the relative proportion of LSVs on the road and/or total traffic volume increase, congestion due to relative speed differences of LSVs and other vehicles on the road would be expected to increase.

Traffic typically travels at 60 km/h to 70 km/h on a 50 km/h road, but will be restricted to a governed speed of 40 km/h when following an LSV. All vehicles travelling in the same direction on a two-lane road will be limited to a governed speed of 40 km/h. On a four-lane road most vehicles will be able to pass the LSVs eventually. However, this will be particularly problematic for buses that stop and start frequently. It will effectively limit their maximum speed to 40 km/h, and thus reduce their average speed.

Braking Capabilities
LSV braking rates are comparable to those of conventional passenger vehicles and are not expected to adversely affect traffic flow.

Road Selection
The Ontario Ministry of Transportation does not have a traffic management system that covers municipal roads. It only covers provincial highways (including freeways). However, provincial guidelines for determining roads suitable for use by LSVs would still be a good idea, with the municipalities actually deciding which roads could be used by these vehicles. With these

guidelines in place, municipalities could then set specific requirements through by-law. These requirements would include both general and specific permissions, and general and specific prohibitions.

Table 12: Identified risks related to the effect of LSVs on mixed traffic flow

12.2-1	As the density of LSVs on public roads increases, the 40 km/h maximum speed capability of the vehicles may impede traffic flow. This is especially relevant for buses that use the same lane, and that will not be able to leap-frog LSVs the way they do bicycles, because of LSVs greater width.

12.3 Human Factors

The following noteworthy human factors issues were identified in this study:

Driver Expectation
The integration of LSVs on public roadways, especially when they have the same appearance as standard vehicles but reduced operating capabilities, may surprise drivers moving at higher speeds. A concern when expectation of other drivers is violated by an LSV is that a rear-end crash may result due to delayed detection of a substantial speed difference with the LSV ahead.

Perception of Closing Velocity
Drivers may not expect the slower acceleration and lower maximum speed of LSVs, leading to speed differences between successive vehicles, which can be detected too late by the following driver. Large speed differences can be difficult to detect because of human perceptual limitations, and may result in the need for hard braking with the potential for increased rear-end collisions.

Aggressive Behaviour
The most significantly different operating characteristic of an LSV relative to other vehicles is its low maximum speed. The difference in acceleration is less significant, but still relevant. The more these LSV operating characteristics differ from those of other vehicles, and the more LSVs there are in traffic, the greater the frustration of other drivers is likely to be. Slower moving traffic is likely to be associated with more aggression as it becomes more difficult to escape from behind a slower driver.

Where drivers are slow for some reason, the driver’s perception of the legitimacy of the impediment is likely to affect the presence or degree of aggressive behaviour. It is not clear yet how much respect drivers will have for eco-friendly LSVs.

Lack of Audibility
Roads with a speed limit of 50 km/h or less are those most frequented by pedestrians. The silent nature of an LSV’s electric power train may contribute to pedestrians, who often rely on hearing the approaching traffic, to step out at an intersection without looking for turning vehicles. The lack of noise during operation also represents a risk to pedestrians in parking lots. Modern passenger vehicles are much quieter than older models, but even at idle or low engine speed, the noise level they emit is around 65 dB. Hybrid cars operating in electric mode and electric

powered vehicles emit very low levels of powertrain noise, which makes their approach difficult to detect. For persons with visual impairments this represents a serious concern, as expressed by the MIRA Foundation during the Québec pilot projects [9]. Even though the collision speed may be low, pedestrians are still vulnerable: 5% of those hit at 30 km/h are fatally injured. At 40 km/h, there is about 20% probability of a pedestrian fatality.

Table 13: Identified risks related to human factors

12.3-1	Drivers of other vehicles may expect LSVs to perform like typical passenger cars on public roads, which may increase the potential for collisions when they do not.
12.3-2	It may be difficult for drivers of other vehicles to detect large closing speed differences with LSVs, which may increase the potential for rear-end collisions.
12.3-3	Drivers of other vehicles may exhibit aggressive driving behaviour due to slower moving traffic caused by LSVs.
12.3-4	The lack of noise generated by LSVs may result in increased collisions with both pedestrians (in particular, the visually impaired) and cyclists.

12.4 Traffic Safety

Risk to Drivers of Low Weight Vehicles

An analysis of the expected risk to drivers in collisions between an LSV and a compact car, and considering only the relative masses of the two vehicles, suggests that an LSV driver would have a significantly greater risk of death or injury than the driver of the compact car in a variety of accident scenarios. The light weight and small size of LSVs will result in a higher injury and fatality rate than for other vehicles, even with the conservative assumption that they are equipped according to the same safety standards. For example, the computation of risks to the driver for collisions between an LSV and one of two types of passenger vehicles showed that:

- in a right-side collision between an LSV and a Honda Civic sedan, in which the Honda Civic sedan strikes the LSV on the right side, the driver of the LSV is 40 times more likely to be killed than the driver of the Honda Civic sedan. Interestingly, even in a right-side collision between an LSV and a Honda Civic sedan in which the LSV strikes the Honda Civic sedan on the right side, the driver of the LSV is still twice as likely to be killed as the driver of the Honda Civic sedan;

- in a left-side collision between an LSV and a Honda sedan, in which the Honda Civic sedan strikes the LSV on the left side, the driver of the LSV is 79 times more likely to be killed than the driver of the Honda Civic sedan. For comparison, in a left-side collision between an LSV and a Honda Civic sedan in which the LSV strikes the Honda Civic sedan on the left side, the driver of the Honda Civic sedan is 1.29 times more likely to be killed as the driver of the LSV;

- in a rear-end collision between an LSV and a Honda Civic sedan, in which the Honda Civic sedan rear-ends the LSV, the driver of the LSV is 11.5 times more likely to be killed than the driver of the Honda Civic sedan. Similarly, even in a rear-end collision between an LSV and a Honda Civic sedan in which the LSV rear-ends the Honda Civic sedan, the driver of the LSV is still nearly 10 times as likely to be killed as the driver of the Honda Civic sedan;

- in a head-on collision between an LSV and a Honda sedan, the driver in the LSV would be 9.5 times more likely to be killed than the driver of the sedan; and

- in a head-on collision between an LSV and a more comparably sized Smart car shows that the LSV driver would be 2.5 times more likely to be killed than the driver of the Smart car.

These analyses assumed that the LSV had the same inherent crashworthiness as the other vehicles, which met all applicable FMVSS. Modern vehicles are somewhat more crashworthy than the sample of vehicles used to develop the equations, and the LSV is presumed to be much less crashworthy. Consequently, the risk of injury or death for drivers and passengers of LSVs is likely to be considerably higher (i.e. worse) than that outlined above.

Beyond this, there may be LSVs that are lighter than the 1,400 lb assumed here, and there are certainly many other vehicles that are heavier than the heaviest considered here. Each of these factors will further increase the risks estimated above.

Traffic Signals

The relatively lower acceleration of LSVs may require consideration during traffic signal design to minimize angle and rear-end crashes. As the volume of these vehicles increases, warrants and guidance concerning LSV signal phasing may need to be analyzed to determine changes in phasing that would be appropriate to accommodate low-acceleration vehicles at traffic signals.

Ideally, traffic signals would be programmed to recognize the demand when an LSV is present. Such identification of a vehicle by weight, size, and speed is possible but will require investment in the traffic control infrastructure, and may create difficulties with maintaining signal co-ordination along a corridor.

Speed Differentials

There is a higher probability that LSVs will be involved in crashes with vehicles travelling at speeds over the maximum speed attainable by LSVs (40 km/h). These vehicles traveling at higher speeds are typically found on arterial and collector streets. The data indicates that the speed dispersion in urban arterials and collectors will increase the crash occurrence.

Table 14: Identified risks related to traffic safety

12.4-1	There may be a substantially higher driver injury and fatality rate amongst LSV operators due to the relatively low mass of LSVs compared to other vehicles on public roads.

12.4-2	LSVs may pose a threat to pedestrians because of their inherently quiet operation.
12.4-3	LSVs may be unable to clear a red or yellow light in the signal times typically allocated for clearance on public roads.
12.4-4	There may be an increased occurrence of collisions between 40 km/h LSVs and other vehicles travelling at higher speeds on public roads due to their large differentials in speed.

12.5 LSV Equipment

State or Provincial Equipment Standards
Many North American jurisdictions that enacted LSV regulations require LSVs to comply with state/provincial Motor Vehicle Act regulations with respect to equipment. For example, the province of British Columbia requires LSVs to comply with provincial safety standards applicable to all motor vehicles [139] as prescribed under the Motor Vehicle Act Regulations. These requirements include the ability to meet prescribed stopping distances, and the installation of specific equipment (i.e., windshield wipers, bumpers, horn, etc.). In the U.S., the state of New York requires that LSVs be equipped with bumpers, tamper resistant odometers and headlamps compliant with federal regulations. They are required to be equipped in the same manner as a motor vehicle registered pursuant to Vehicle and Traffic Law Section 401(6) (passenger automobile) [67].

Many manufacturers have already equipped their LSVs with additional equipment, in excess of federal requirements, and thus may be able to meet some or all of the requirements imposed by existing or prospective provincial regulations.

Daytime Running Lights (DRL)
Daytime Running Lights (DRLs) have been required by CMVSS 108 [140] on all new vehicles made in Canada or imported after January 1, 1990. The U.S. allows the use of DRLs, but they are not mandated. LSVs are not currently equipped with DRLs.

Back-up Lights and Audible Warning System
Although not required by legislation, most LSVs have back-up lights and some have an audible buzzer that sounds when reverse gear is engaged.

Spare Tire
Not all LSVs carry a spare tire, which could be for weight reduction purposes, or due to a lack of available storage volume. Some passenger vehicles also do not carry a spare tire, however, such vehicles are typically equipped with run flat tires and/or with a tire repair kit.

EMI/EMC Considerations
LSV components are typically off the shelf automotive parts certified to EMC standards, and thus the risks of electromagnetic emission and susceptibility should be low. However, the integration of certified EMI/EMC components does not necessarily mean that the compatibility at system level will be at par with component performance.

LSVs using AC motors may incorporate high-voltage switching power supplies, which may increase the electromagnetic emissions at a system level.

Batteries
FLA batteries require specific maintenance and handling procedures compared to their VRLA counterparts. While VRLA batteries have slowly started to replace FLA batteries in LSVs, it is still necessary to understand the risks associated with the use and maintenance of both types of batteries.

Lead-acid batteries of the FLA type are considered hazardous materials and therefore are subject to certain handling, shipping and storage rules. Recycling and disposal procedures are similar to those for passenger vehicle batteries.

Since no LSV crash test results are currently publicly available, it is difficult to anticipate secondary effects arising from collisions involving LSVs. One of the major concerns is related to the battery securement system and the potential of hazardous material spillage during and after a collision involving an LSV. LSV occupants, other vehicle occupants, and emergency personnel attending the crash scene may be at risk.

Federal Safety Standards
The current Canadian federal standard for LSVs does not require them to meet a majority of safety standards that are required for passenger cars (see Table 1).

Results of crash tests conducted on European quadricycles, which are light weight vehicles somewhat similar to the North American LSVs, are not encouraging. Transport Canada has conducted crash tests on some LSVs, but has not released any results to date except to say (section 11.4.2) that “the injury risk in these vehicles is disproportionate to the crash”. It is quite possible that the crashworthiness of North American LSVs is even lower than that of European quadricycles.

Quadricycles are different from Canadian LSVs because they use an ICE for propulsion, weigh less, have a slightly higher maximum speed of 45 km/h and are allowed to operate on European roads with a posted speed limit of 90 km/h. Nonetheless, quadricycles are probably the closest match to LSVs in terms of dimensions and intended purpose. While LSVs need to meet the requirements of only three CMVSS standards, quadricycles are required to meet 20 European standards, as shown in Table 2. Neither LSVs nor quadricycles are required to meet any crash test standards.

Passive safety systems are designed to minimize the injury to the driver and passengers of a vehicle involved in a collision. One such system is seatbelts, which are designed to absorb energy and limit forward motion of an occupant. Another such system is airbags, which are designed to prevent impacts between the head and upper body of drivers and passengers and hard surfaces such as the steering wheel, dash, doors, roof and windows. While some quadricycles are equipped with air bags, none of the LSVs identified in this study had such passive safety features.

All quadricycles have to meet the requirements of standard 97/24/EEC C11, "Anchorage points for safety belts". By contrast, LSVs do not have to comply with CMVSS 210, "Seat Belt Assembly Anchorages". LSVs must have seat belts that comply with CMVSS 209, and yet those belts may be of questionable value if the seat belt assembly anchorage performance is not of comparable strength.

Crashworthiness occupant protection and seat belt anchorage performance are just a few of the 33 CMVSS standards with which LSVs do not comply. All of the standards listed in Table 1, and the associated FMVSS standards in the U.S., have been developed over the course of approximately forty years in response to a shocking record of death and injury. There have been approximately two million deaths on U.S. highways since the mid 1960s. In Canada, about 200,000 have died in traffic accidents in the past 50 years.

Careful review of the design deficiencies of automobiles and the ways that they can be cost-effectively improved has resulted in Motor Vehicle Safety Standards that existing passenger cars and light trucks meet, and that substantially reduce the risk of death.

Child Seats

Due to the lack of child seat provisions compliant with applicable safety standards for passenger vehicles, child seats cannot be installed in LSVs. Consequently, children who would be required to use such a seat in a passenger car cannot be carried in an LSV.

Towing

While technically possible, towing a trailer using an LSV may lead to dangerous situations related to increased gross combination weight, increased overall length, reduced dynamic stability and reduced braking performance. It appears appropriate to limit or prohibit towing of trailers until the safety performance of LSVs is better understood.

Vehicle Modification

In Canada, the federal government, through Transport Canada's Motor Vehicle Safety Regulations, establishes technical requirements and restrictions for original equipment manufacturer (OEM) vehicles, i.e., the vehicles as manufactured. The provincial governments (and to some extent, municipal governments) regulate the licensing, requirements and operation of vehicles as they are used on the road by the way of legislation or by-law.

It is reported that some individuals have developed modifications to LSVs that will enable their operation at higher speeds, such as 55 km/h rather than 40 km/h as defined in the federal standards. This may address the potential desires of some LSV drivers for higher speeds, but could expose such drivers to greater hazard in case of collision, since LSVs do not meet all of the federal safety standards imposed on higher speed vehicles. MTO may want to consider whether a new offence should be created if an LSV is modified so it no longer complies with the standard for its class, such as to achieve a speed higher than 40 km/h, or whether an existing offence would apply.

Table 15: Identified risks related to LSV equipment

12.5-1	LSVs may not comply with some of Ontario’s motor vehicle equipment standards and therefore may not have adequate braking, lighting, etc.
12.5-2	The crashworthiness of LSVs is unknown, and may be very low.
12.5-3	The LSVs identified in this study do not have airbags and may cause serious injury to occupants.
12.5-4	The performance of the seat belt assembly anchorage in LSVs is unknown. The seat belt assembly anchorage may fail in accidents.
12.5-5	LSV operators or first responders may be injured while handling lead-acid batteries that have been damaged in a crash.
12.5-6	The LSVs identified in this study do not have daytime running lights and thus it may be difficult for other drivers to see them.
12.5-7	An LSV operator may try to install a child seat in an LSV when there is no provision for such seats. This could result in seat failure and serious injury or death to the child in a severe crash.
12.5-8	On some LSV models, it is possible to conduct vehicle modifications to achieve speeds greater than 40 km/h, resulting in a greater severity of collision should a collision occur.
12.5-9	Some LSVs identified in this study do not have back-up warning systems.
12.5-10	The EMC at the vehicle level of the LSVs identified in this study is unknown, and may cause erratic behaviour of electronic systems in other automobiles.
12.5-11	Towing a trailer using an LSV may be unsafe.

12.6 Road Infrastructure

To address safety issues, a mix of road infrastructure enhancements/modifications and operating restrictions are required. The City of Lincoln, California is an example of a successful LSV/NEV ready infrastructure derived from thorough planning, as outlined in their Master Transportation Plan (MTP).

As noted in Sections 5 and 8, the City of Lincoln developed a broad-based plan to encourage the use of LSVs by planning the city's roads to accommodate them. The objective of the MTP was to create city-wide NEV routes that would "enable any resident to travel from his/her home to downtown Lincoln." An NEV-ready city should ideally have the necessary infrastructure, including dedicated lanes, charging facilities, pavement markings, signage, parking, and education to safely accommodate LSV travel. To develop and achieve a route network amenable to LSVs, the city identified three classes of LSV routes:

- Class I routes (separate right-of-way for use of LSVs, pedestrians and bicycles, 3.65 m wide for two-way travel);
- Class II routes with a separate striped lane on each side of the road, 2.1 m wide (Figure 57); and
- Class III routes (shared use with mixed traffic on roads with a speed limit of 35 mph or less).

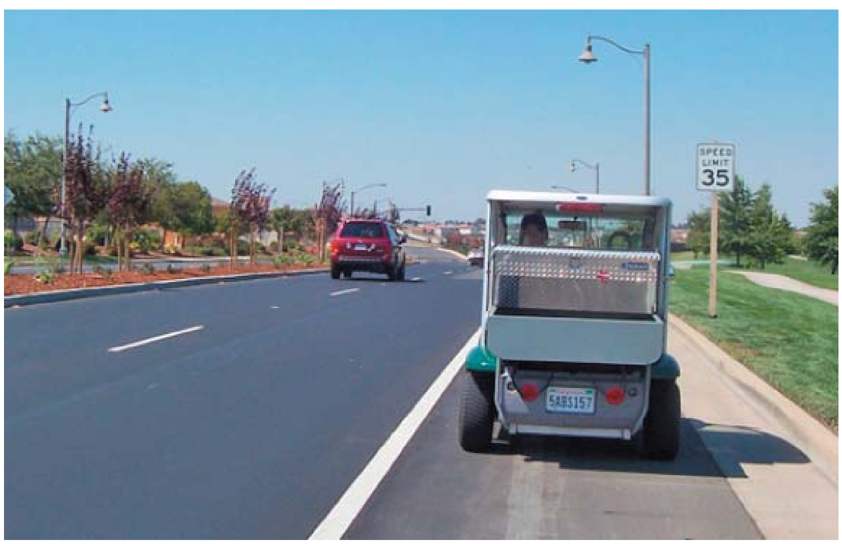


Figure 57: City of Lincoln, dedicated NEV lane [141]

Road Network
Permitting the use of LSVs on low speed roads, without considering the connectivity of such road sections to permit LSV travel to multiple desired destinations, represents a risk. A municipality might have a number of isolated or partly connected street sections where LSVs could be operated, but there would be no comprehensive network plan to facilitate the use of LSVs beyond these sections. A potential negative result is that owners of LSVs could find themselves limited to operating in tightly confined areas. This could lead to frustration and eventual disregard for operating restrictions on high-speed routes, and could also severely hinder the uptake of LSVs in areas for which they would otherwise be well suited.

Infrastructure Upgrades
The cost of upgrading the road infrastructure to benefit LSVs is significant, and a decision by the municipalities for implementing such changes would have to be supported by the potential density of LSVs.

From a Canadian perspective, ICBC has not conducted any specific studies in BC to try to determine future LSV density, and no formal plans are in place to increase road infrastructure.

Road infrastructure improvements should be addressed by municipalities, as part of their transportation planning process. To be cost effective, such initiatives should be supported by the density of LSVs and complementary infrastructure upgrades, such as dedicated parking spaces and charging stations.

In the end, municipalities would determine the extent to which LSVs become a practical means of transportation. This will largely be determined by the very difficult issue of access, or providing connectivity between local road networks. There are (at least) three major issues:

1. LSVs are likely to be precluded from using key road sections in desired road networks because of congestion concerns;

2. LSVs cannot use an arterial road with a speed limit over 50 km/h to cross a river, ravine, freeway or other linear barrier; and

3. LSVs cannot reach certain facilities located on an urban arterial road with a speed limit over 50 km/h, as there is no back entrance from a side street.

These issues will be addressed if a municipality feels the need, which will be based on whether there is enough LSV traffic to warrant the effort and cost. The municipalities will need creativity, and there will be costs.

Additionally, the dedicated LSV lanes constructed in Lincoln, CA may not have the same utility in Ontario during the winter season, as significant snowfall may lead to partially blocked passages. This represents an additional risk to LSV operators, who would potentially be required to deviate into the higher-speed lanes.

Table 16: Identified risks related to road infrastructure

12.6-1	The existing road connectivity may limit LSV drivers to operating in a confined area. This could result in LSV operators eventually taking unsafe risks and driving on higher speed roads.
12.6-2	Dedicated LSV lanes could be blocked or partially blocked by snow during the winter, and by debris or inoperable vehicles at any time, forcing LSV operators to drive in the higher-speed lanes.

12.7 Licensing, Insurance and Disclosure Documents

Vehicle Licensing
In most jurisdictions that have passed LSV legislation, the LSV licensing process is identical to the passenger vehicle licensing process. In BC, LSVs are issued license plates identical to those for passenger vehicles. The Québec pilot project requires distinct “C” licence plates. Based on current Ontario legislation, LSVs might be registered as regular passenger vehicles.

MTO may want to consider whether a new offence should be created if an LSV is modified so it no longer complies with the standard for its class, such as to achieve a speed higher than 40 km/h, or whether an existing offence would apply.

Some provinces have mandatory periodic inspection programs for passenger vehicles, for safety purposes. Such a requirement does not exist in Ontario. However, an emission test is required every two years for vehicles that are five years old or older. Used passenger vehicles in Ontario are subject to Regulation 628, which covers the requirement for emissions inspection and safety standard certificate of a used vehicle for which someone is seeking a permit. The requirement of a safety inspection for a used vehicle in Ontario applies only when the vehicle ownership changes, and is not a biannual requirement for all vehicles. While an emission inspection does not apply to LSVs, a safety inspection would be applicable to LSVs according to Ontario Regulation 611 [142].

Driver Licensing
European countries have less demanding driver’s license requirements for quadricycle operators. By contrast, all North American jurisdictions that have adopted LSV legislation require a passenger vehicle driver’s license to operate an LSV on public roads.

An LSV should be considered as a vehicle that requires a class G or higher-class license to be driven in Ontario. It would be appropriate for MTO to determine whether there should be restrictions on drivers with less than a full Class G license.

Insurance
As learned from some U.S. jurisdictions, insurance could be expensive due to the lack of collision statistics. However, ICBC will insure LSVs using the same rate as for the Honda Civic class of vehicles. If LSV collision records accumulate, it would be expected that premium rates would be adjusted to reflect the risk. The tests performed by the German Insurance Association (GDV) on quadricycles showed that even after a low speed rear end collision, the cost associated with the repairs was approximately 50% of the new vehicle price and approximately 40% higher than the repair cost of a regular passenger vehicle involved in a similar collision.

The findings from the interviews with the various insurance organizations indicate that there appears to be no reason why an LSV should not be subject to the same insurance requirements as those for a passenger car. It is expected that the insurance industry will initially set a conservative rate for such a class of vehicle, which has no previous history, and that this rate will subsequently be adjusted to reflect the actual crash rate and repair costs of LSVs, and the occupant injury experience. This may result in high initial insurance costs for anyone who does not already own a car.

Although the Insurance Bureau Of Canada (IBC) has not commissioned any independent research regarding LSVs, decisions or recommendations that IBC will be making regarding

LSVs will take into consideration several factors, such as safety features of LSVs, likelihood of bodily injury, likely degree of bodily injury and draft regulations regarding LSV use on roadways including requirements for driver, damageability and repairability of LSVs.

Disclosure Documents

As part of the Québec Pilot Project, LSV owners or long term renters are required to read and sign a form that explains the limitations of LSVs. SAAQ expects that this practice will be continued if the pilot project converts into full scale legislation. The intent of the limitations form is to ensure that the owners and renters are fully familiar with the reduced safety features, limited maximum speed and other limitations.

New York State has legislated that LSV dealers must have buyers sign a "Disclosure Document" at the point of sale, explaining what the technical and performance limitations are of LSVs. Legally speaking, a Disclosure Document relates to a secret. New York State’s use of the term "Disclosure Document" is not strictly correct, since there is no "secret" being divulged. Since the information is publicly available and since the goal is to ensure that the buyer is aware of these limitations, a better term would be "Notice of Limitations". In Ontario, although having buyers acknowledge and sign a "Notice" will increase awareness, it cannot be used as a device to indemnify the dealer or manufacturer from the product liability laws. Even if a buyer signs the notice, if he/she is injured as a result of the operation of the LSV he/she has grounds to pursue the manufacturer.

Table 17: Identified risks related to licensing and disclosure documents

12.7-1	If LSVs are licensed as passenger cars, it may be difficult to collect collision data for statistical purposes.
12.7-2	LSVs may be operated by drivers who possess a lower-class driver’s license. These drivers tend to have less experience and may not be aware of the safety risks to which they expose themselves.
12.7-3	If a “Notice of Limitations” document is not presented to prospective clients during the sale process, they may not be aware of the performance limitations and reduced safety features of the vehicle.

12.8 LSV Operating Restrictions

Seasonal and Temporal Restrictions
For the purpose of the pilot project in Québec, winter driving of LSVs is not prohibited by law. However, the LSVs must be equipped with a defrosting and heating system. In addition, new Québec legislation [143] requires all Québec registered passenger vehicles to have winter tires installed between December 15 and March 15 of any given winter season. This legislation also applies to LSVs.

Speed Restrictions
The study [9] conducted by CEVEQ for Transport Canada, made recommendations to various government segments, as guidelines for LSV use and for facilitating, promoting and regulating the use of LSVs. One recommendation was to authorize LSVs to operate on roads with maximum speed limits of 50 km/h, except in areas where actual speeds of traffic were higher than the posted speed limit (for example arterial roads). However, since actual speeds are typically higher than the posted speed limit on almost all roads, such a recommendation would exclude LSVs from almost all roads.

Linear Barriers
A ravine, river, freeway, green belt, or hydro right-of-way in an urban area is a linear barrier to vehicle travel. Examples are the Rideau River in Ottawa, Highway 417 in Ottawa, or Highway 401 in Toronto. Such a linear barrier typically has a limited number of points at which it can be crossed, and the crossings are primarily urban arterial roads that typically have a speed limit of at least 60 km/h. If LSVs are strictly prohibited on roads with a speed limit higher than 50 km/h, then LSVs might be so tightly restricted that they would not be useful for people living close to a linear barrier who frequent facilities on the other side of the barrier.

Bridges are used to cross ravines, rivers and as an overpass at some freeway locations, while an underpass is provided at other freeway locations. A green belt or hydro right-of-way is typically crossed at-grade. If there is a link from a crossing arterial road either to a freeway or another road running parallel to and beside the linear barrier, then there are usually traffic signals at one or more intersections, which may tend to calm traffic. Traffic on an arterial road tends to travel at high speed on such a crossing when there is no link to another highway along the linear barrier.

There seems little point in allowing LSVs without providing some safe way for them to cross a linear barrier. LSVs would have limited usefulness to people living close to such a barrier unless safe routes can be devised for LSVs that do not involve travel with other traffic on these roads. The cost of such upgrades to the road infrastructure to benefit LSVs may be significant. If there are no crossings there may be few LSVs, and there would presumably be little demand for the crossings.

A separate LSV/bicycle lane at crossings of linear barriers, like that shown in Figure 57, would be a desirable option, but may be impractical, for example, on a freeway overpass that is also a full interchange.

Bus Routes
Congestion effects on transit are likely to be of concern primarily in large cities with dense networks and buses operating at short headways, and where LSV density is high.

Table 18: Identified risks related to operating restrictions

12.8-1	LSVs' operating performance in winter conditions is not well understood. The increased need for use of ventilation, heating and defrosting systems and the low ambient temperatures may significantly affect the operating range (distance) of the vehicle. Thus, LSV operators may become stranded with little or no warning, depending on the LSV's power management system performance. The major risk though is that LSV owners may start trading safety features such as heating and defrosting for operating range.
12.8-2	LSVs may be difficult to see in the dark by other motorists and pedestrians/cyclists, as the lighting system may not provide adequate conspicuity.
12.8-3	LSVs may be tightly restricted due to a lack of road connectivity and the existence of linear barriers. LSV owners may venture onto roads with higher speed limits, or other roads where LSVs are not allowed to operate.
12.8-4	If the density of LSVs on public roads is high, traffic congestion may become a concern in larger cities with dense transit networks.

13 RECOMMENDATIONS

Based on the survey of U.S. and Canadian jurisdictions, information gathered from relevant sources, reports from subject matter experts and data analysis, this section constitutes a comprehensive list of recommendations for mitigating the risks associated with:

- safely integrating LSVs for operation in mixed traffic on public roads in Ontario; and
- continued safe operation of LSVs in mixed traffic following their introduction onto public roads in Ontario.

The recommendations, outlined in Tables 19 through 22, present mitigating strategies for the risks identified in Section 12 as they relate to:

- integrating LSVs safely into mixed traffic on Ontario's public roads;
- additional LSV safety features;
- additional road infrastructure enhancements; and
- initiatives to increase public awareness of LSV features.

Table 19: Risk mitigating strategies for integrating LSVs safely into mixed traffic on public roads

<table>
<tr><th colspan="4">Integrating LSVs Safely into Mixed Traffic on Public roads</th></tr>
<tr><th colspan="2">Mitigating Strategy</th><th>Identified Risk</th><th>Risk #</th></tr>
<tr><td rowspan="2">13.1</td><td rowspan="2">LSVs should be equipped, at minimum, with the same features required by the 2008 MTQ pilot project:

• daytime running lights (failing that, drivers must keep their headlights on at all times);
• a slow moving vehicle identification emblem;
• a notice indicating the maximum speed of the vehicle;
• odometer;
• speedometer;
• windshield wipers;
• sound warning devices (horn and a proximity warning system);
• an information notice on the dashboard reminding drivers of the rules of the pilot project;
• defrosting and heating systems;
• three-point seat belts.

In addition, LSVs should demonstrate compliance with the applicable sections of the Ontario motor vehicle equipment standard, such as Section 62, Lamps, Section 64, Brakes, Section 69, Tires and Wheels and Section 72, Safety Glass (Highway Traffic Act, R.S.O. 1990, Chapter H.8, Part VI).

MTO may wish to impose further requirements on vehicle owners/drivers if they decide that the use of LSVs in mixed traffic is to be subject to a pilot project, where data are collected and evaluated.</td><td>Unknown whether LSVs are compliant to Ontario’s motor vehicle equipment standard</td><td>12.5-1</td></tr>
<tr><td>Lack of conspicuity</td><td>12.8-2</td></tr>
<tr><td>13.2</td><td>The transportation of infants and children in an LSV on public roads should not be allowed if the infants or children would be required to use infant or child seats in a regular passenger vehicle.</td><td>Lack of child seat provisions</td><td>12.5-7</td></tr>
</table>

13.3	Battery maintenance, charging and handling instructions should be clearly indicated by the LSV manufacturers in the owner's manual.	Injuries caused by handling lead-acid batteries	12.5-5
13.4	LSVs should be licensed as passenger cars, though MTO may wish to create a special category for them for statistical purposes. Additional license fees should be established by each municipality, as required.	LSV collision data may not be identifiable	12.7-2
13.5	MTO should initially allow only G class or higher-class licensed drivers to operate LSVs on public roads in mixed traffic. In controlled areas such as a university campus, park or military base, a lower-class, such as G2, driver's licence could be initially accepted. This approach would protect less experienced drivers from hazardous situations that could occur on public roads in mixed traffic. The LSV driver must follow all provisions of the Highway Traffic Act regarding rules of the road. Separate legislation should be developed to prevent an LSV operator from towing any type of trailer.	LSVs may be operated by less experienced drivers Towing a trailer using an LSV may lead to dangerous situations	12.7-2 12.5-11
13.6	MTO should require that LSV buyers sign a "Notice of Limitations" document at the time of sale that explains what the LSVs' performance and safety limitations are.	Lack of a "Notice of Limitations" document	12.7-3

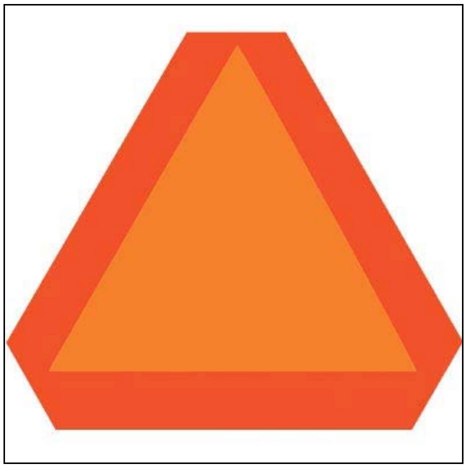
13.7	LSVs should only be operated on a public road when the posted or un-posted speed limit of that road is not greater than 50 km/h. LSVs must not be driven on a limited access road, such as a 400 series highway, or on any entrance ramp to, or exit ramp from, such a highway. LSVs should only be driven across a road with a posted or un-posted speed limit greater than 50 km/h at an intersection where there is a traffic light, or all-direction stop signs are present. LSVs should be driven on routes specified and appropriately signed by a municipality. LSVs must not be driven on a road with a speed limit not greater than 50 km/h where travel on that road is prohibited by the municipality.	LSVs may impede traffic flow Limited road connectivity for accommodating LSVs LSVs may be limited to operating in confined areas due to the presence of linear barriers	12.2-1 12.6-1 12.8-3
13.8	MTO may grant the municipalities the authority to impose further restrictions on LSVs use, such as permitting LSVs only where the projected future ADT is less than a predetermined threshold, such as Level of Service C shown in Table 8, for each type of road. Where key road sections in a desired road network would preclude LSV use because of anticipated congestion concerns, municipalities should consider filling in those gaps by use of a separate right-of-way (Class I routes) or separated, adjacent LSV/bicycle lanes (Class II routes).	LSVs may impede traffic flow	12.2-1

13.9	Permit LSV operation in mixed traffic on two-lane streets with a maximum posted speed limit of 50 km/h, provided the projected future time horizon ADT does not exceed a threshold traffic volume for two-lane roads as determined by the road authority or the Level of Service C traffic volume as shown in Table 8. Many of these streets will be residential streets, with relatively low traffic volume, though some two-lane streets will have significantly higher traffic volume. On higher volume two-lane streets, with few passing opportunities, LSVs may reduce the capacity of the road. This is not likely to be a problem if the proportion of LSVs to total traffic is low, but is likely to be a problem if this proportion is high. The worst situation will arise if the split of LSVs to conventional cars is 50:50. The problem can be ameliorated to some extent if the road has some space at the edge of the roadway where LSVs can pull over to let faster vehicles pass.	LSVs may impede traffic flow	12.2-1
13.10	Permit LSV operation in mixed traffic on two-lane conventional highways with a maximum posted speed limit of 50 km/h, provided the projected future time horizon ADT does not exceed a threshold traffic volume for two-lane highways as determined by the road authority or the Level of Service C traffic volume as shown in Table 8.	LSVs may impede traffic flow	12.2-1
13.11	Permit LSV operation in mixed traffic on four-lane streets with a maximum posted speed of 50 km/h, provided the projected future time horizon ADT does not exceed a threshold traffic volume for four-lane roads as determined by the road authority or the Level of Service C traffic volume as shown in Table 8. At low traffic volumes and/or low percentages of LSV traffic, the LSVs are unlikely to contribute significantly to congestion. As traffic volume and the percentage of LSVs increase, the risk of congestion increases. At high traffic volumes and high percentages of LSVs, the risk of congestion is substantial. The advantage over two-lane roads is that faster vehicles can use the passing lane to overtake the LSVs.	LSVs may impede traffic flow	12.2-1

13.12	Where LSVs are permitted to operate on four-lane roads, the LSV driver must drive in the right lane, except if making a left turn, in which case the driver must signal their intention over a sufficient distance at least to ensure that they can make the turn without risk.	LSVs may impede traffic flow Increased occurrence of collisions due to speed differentials	12.2-1 12.4-4
13.13	MTO and municipalities should reject all requests to allow LSVs to travel in mixed traffic on roads with a speed limit greater than 50 km/h.	There may be an increased occurrence of collisions between LSVs and other vehicles on public roads due to differential speeds	12.4-4
13.14	Ontario provincial legislation should be created/updated to include a regulatory provision prohibiting modification or tampering with the maximum speed control or limiter of LSVs.	Modification of LSVs to achieve higher operating speeds	12.5-8

Table 20: Risk mitigating strategies related to additional LSV safety features

Additional LSV Safety Features			
Note: While not a federal requirement, it is preferable that LSVs be compliant with federal crash worthiness standards for passenger vehicles. In the absence of compliance, it is recommended that, as a minimum, MTO consider the risk mitigating strategies outlined in this table.			
Mitigating Strategy		Identified Risk	Risk #
13.15	LSVs seat belt anchors should comply with CMVSS 210.	Higher injury and fatality rate due to low mass of LSVs Unknown performance of LSVs seat belt assembly anchorage	12.4-1 12.5-4
13.16	LSVs should meet the applicable crashworthiness occupant protection standards defined by CMVSS in the 200 series, such as CMVSS 201 “Occupant Protection”, CMVSS 206 “Door Locks and Door Retention Components”, CMVSS 214 “Side Door Strength” and CMVSS 216 “Roof Intrusion Protection”.	Unknown LSV crashworthiness Higher injury and fatality rate due to low mass of LSVs	12.4-1 12.5-3
13.17	LSVs should be equipped with Daytime Running Lights and comply with CMVSS 108; as an interim solution, LSVs should only be operated with the headlights on.	Lack of DRLs Lack of conspicuity	12.5-6 12.8-2
13.18	LSVs should meet the appropriate EMC standards.	Unknown EMC certification at vehicle level	12.5-10
13.19	LSVs should be equipped with backup warning systems.	Lack of backup warning system	12.5-9

13.20	The minimum LSV conspicuity requirements should be revisited. Currently, the federal legislation requires that LSVs be permanently marked with a slow-moving vehicle (SMV) identification emblem, as shown in Figure 58:  **Figure 58: Slow-moving vehicle emblem** Such a sign would warn drivers approaching from behind that the vehicle ahead has lower speed and acceleration capabilities than standard vehicles, and could reduce the risk of rear-end collisions due to failure to detect the speed difference with the vehicle ahead until it is too late. The addition of a SMV emblem to the sides of the vehicle should also be taken into consideration as this would warn drivers seeing the vehicle cross in front or turning at intersections that it has lower speed and acceleration and may not clear the intersection as quickly as would be expected with a regular passenger vehicle.	Increased potential for collisions due to other drivers expectation Increased potential for rear-end collisions due to difficulty of detecting speed differences	12.3-1 12.3-2
13.21	The maximum speed of 40 km/h should be marked on the back of the LSV, similar to the marking used for the 2008 Québec pilot project.	Aggressive driving behavior of other drivers	12.3-3

13.22	LSVs should be fitted with equipment capable of emitting an audible signal for pedestrians. Pedestrians frequently do not visually search for traffic, relying on hearing to detect approaching vehicles. This is obviously a particular issue for the visually impaired pedestrian. An audible signal, connected to the LSV turn signal, would assist in warning pedestrians of an approaching LSV, at intersections where pedestrians may depend on the traffic signal to give them the right of way.	Increased collisions with pedestrians and cyclists due to LSVs' quiet mode of operation LSVs threat to pedestrians because of their inherent silent operation	12.3-4 12.4-2

Table 21: Risk mitigating strategies related to road infrastructure enhancements

Additional Road Infrastructure Enhancements			
Mitigating Strategy		**Identified Risk**	**Risk #**
13.23	Road infrastructure improvements should be addressed by municipalities, as part of their transportation planning process. To be cost effective, such initiatives should be supported by the density of LSVs and complementary infrastructure upgrades, such as dedicated parking spaces and charging stations. Municipalities adopting LSV regulations should develop LSV routes prior to allowing LSVs on public roads. The routes may consist of existing roads and newly created road infrastructure, such as LSV dedicated lanes. The route planning should address limitations imposed by linear barriers.	Limited road connectivity for accommodating LSVs LSV dedicated lanes usability during winter months LSVs may be limited to operating in confined areas due to the presence of linear barriers	12.6-1 12.6-2 12.8-3
13.24	Adjacent municipalities should coordinate LSV routes to allow LSVs to travel across their common boundaries.	Limited road connectivity for accommodating LSVs LSVs may be limited to operating in confined areas due to the presence of linear barriers	12.6-1 12.8-3

13.25	Provincial standards for LSV-related signs and pavement markings should be developed for use throughout the province.	Limited road connectivity for accommodating LSVs LSVs may be limited to operating in confined areas due to the presence of linear barriers	12.6-1 12.8-3
13.26	Large municipalities with dense bus networks and frequent bus service may need to consider carefully whether it would be appropriate to allow LSVs on bus routes.	Traffic congestion may affect buses operation	12.8-4
13.27	Traffic signals may need to be programmed to recognize the demand when the LSV is present. Such identification of vehicle by weight, size, and speed is possible, but will require investment in the traffic control infrastructure, and may create difficulties with maintaining signal co-ordination along a corridor.	LSVs may not be able to clear traffic lights	12.4-3

Table 22: Risk mitigating strategies for increasing operator and public awareness of LSV features

Initiatives to Increase Operator and Public Awareness of LSV Features			
Mitigating Strategy		**Identified Risk**	**Risk #**
13.28	LSVs should have a clear warning sign affixed inside the vehicle in a highly visible location to alert the potential buyers of significant risk exposure due to lack of safety features. The warning message should be similar to the one proposed by the Insurance Institute of Highway Safety in a notice to the National Highway Traffic Safety Administration issued in 2002: *"WARNING: This vehicle is a LOW-SPEED VEHICLE and it should only be used in low-speed and low-density traffic. Occupants of this vehicle face a significant risk of serious injury or death in collisions with larger vehicles."*	Higher injury and fatality rate due to low mass of LSVs Increased occurrence of collisions due to speed differentials Unknown LSV crashworthiness	12.4-1 12.4-4 12.5-2
13.29	If LSVs are allowed on public roads, the public should be informed of their crashworthiness and operating limitations through public information campaigns that would also explain the meaning of the SMV emblem.	Risks related to human factors Risks related to traffic safety Unknown LSV crashworthiness	12.3 12.4 12.5-2
13.30	MTO should consider organizing in collaboration with LSV manufacturers, test driving campaigns on closed courses, under various weather conditions, to allow potential LSV owners to better understand the performance and limitations of such vehicles.	LSVs' operating performance in winter conditions	12.8-1
13.31	MTO should consider conducting awareness campaigns aimed at firefighters, paramedics and other collision response personnel, to inform them about the particular features of LSVs and the potential risks posed by battery electrolyte spillage.	Injuries caused by handling lead-acid batteries	12.5-5

13.32 In addition to the risk mitigating strategies outlined in the tables above, it is strongly recommended that further analysis be performed on CMVSS standards to determine their applicability to the safe operation of LSVs in mixed traffic on public roads.

13.33 It is recommended that MTO undertake a pilot project with a wider scope than that currently being run in Ontario. The Québec pilot project, which allows the operation of what will likely be a larger sample size of LSVs, and on carefully selected public roads, appears to be a good model to follow, but still would require tailoring to Ontario's unique requirements.

It is recommended that the pilot project be developed by city professionals, including experts in traffic signals, safety, planning, emergency services and driver and public education, in conjunction with experts in test program development to ensure complete and relevant data are collected and analyzed. This pilot project would be expected to lead to a better understanding of the safety issues associated with operating on public roads in mixed traffic and would help to develop LSV policies that are appropriate for Ontario, such as: operation in the slow lane only, marked lanes and times of operation in the urban network (during day and night and specific months of the year). It would also lead to consideration of traffic signalization and warrants for special timing and phasing for LSV needs.

13.34 MTO may also want to consider, either during a pilot project and/or during an eventual full integration of LSVs on public roads, harmonization of LSV policy, operating restrictions and safety requirements with neighboring jurisdictions, in particular Québec, New York state and Michigan.

14 NEXT STEPS

The introduction of LSVs in mixed traffic is a recent trend in Canada. Nowhere are they yet in sufficient numbers to affect large scale traffic movements or crash patterns. However, it is important to consider the ways in which low maximum speeds, relatively low acceleration and other differences from current passenger vehicles will affect the response by other drivers and traffic safety.

In Section 13, it was recommended that a pilot study similar to the Québec pilot be undertaken by Ontario. The pilot study should be carried out to determine how LSV drivers might behave (e.g., do they accept larger gaps in traffic when turning, in anticipation of slower acceleration), as well as to determine the response of other drivers to LSVs in mixed traffic (e.g., aggressive behaviour, including close following, shorter time to collision in lead vehicle following situations). The effectiveness of conspicuity devices such as the slow moving vehicle sign should be evaluated. Driver comprehension of these devices should be tested to ensure drivers understand that vehicles that appear to be in every respect internal combustion or fossil fuel powered vehicles, are not, and have lower acceleration and maximum speeds.

In parallel to the pilot study, it is strongly recommended that further analysis be performed on CMVSS standards to determine their applicability to the safe operation of LSVs in mixed traffic on public roads.

From the perspective of traffic management, it is important to determine the percent LSV's threshold at which changes in signal phasing should be considered to accommodate these slower vehicles.

With respect to crash experience, conservative estimates indicate, based on vehicle weight alone, a very negative impact. NRC-CSTT understands that there are on-going crash tests aimed at determining the harm to occupants in the LSVs in the event of a crash and anticipates that additional vehicle standards, presently required for other passenger vehicles, will need to be established for LSVs. However, it is important that the public be informed about the risks they are taking in driving light vehicles, even at speeds as low as 40 km/h.

It is also important to inform the public about the performance limitations of LSVs, especially in cold weather conditions. Although this is not a regulatory issue, it is strongly suggested that future testing be performed on LSVs to better assess these limitations and improve the performance of these vehicles in these conditions. Such testing should be complemented with dynamic testing activities performed on low friction and snow covered surfaces. Last, but not least, testing to determine EMC compliance at vehicle level should be performed according to existing industry standards.

15 PROJECT TEAM

The project team consisted of the following people:

- Stephan D'Aoust, P. Eng. (NRC-CSTT), associate researcher.
- Gordon Poole, MASc, MBA, P. Eng., PMP (NRC-CSTT), project manager.
- Rick Zaporzan, IMBA (NRC-CSTT), client account manager and report reviewer/editor.
- Jeff Patten, P. Eng. (NRC-CSTT), report reviewer/editor.
- Jon Preston-Thomas, P. Eng. (NRC-CSTT), report reviewer/editor.
- John Billing, consultant to NRC-CSTT, report reviewer/editor.
- Alison Smiley, Ph. D., CCPE (Human Factors North, Inc.), co-author of report "Low Speed Electrical Vehicles And Human Factors And Road Safety Impacts"
- Tom Smahel, M. Arch., CCPE (Human Factors North, Inc.), co-author of report "Low Speed Electrical Vehicles And Human Factors And Road Safety Impacts"
- Geni Bahar, P. Eng. (NAVIGATS, Inc.), co-author of report "Low Speed Electrical Vehicles And Human Factors And Road Safety Impacts"
- Milton Harmelink, P. Eng. (Harmelink Consulting Inc.), author of report "Effect of Low Speed Vehicles on Mixed Traffic Flow.

16 LIST OF ACRONYMS/ABBREVIATIONS

AASHTO	American Association of State Highway and Transportation Officials
ABS	Acrylonitrile Butadiene Styrene
ABS	Antilock Brake System
ADT	Average Daily Traffic
AC	Alternating Current
AFV	Alternative Fuel Vehicles
ANSI	American National Standards Institute
ATV	All Terrain Vehicle
ARAI	Automotive Research Association of India
ASAE	American Society of Agricultural Engineers
ATVP	Advanced Technology Vehicles Program
AVTA	Advanced Vehicle Testing Activity
AZT	Allianz Zentrum Für Technik
BC	British Columbia
CA	California
CAA	Canadian Automobile Association
CCMTA	Canadian Council of Motor Transport Administrators
CCPE	Canadian College for the Certification of Professional Ergonomists
CEC	California Energy Commission
CEVEQ	Centre d'expérimentation des véhicules électriques du Québec
CFR	Code of federal Regulations
CG	Centre of Gravity
CMVSS	Canadian Motor Vehicle Safety Standard
CNG	Compressed Natural Gas
CSC	Consumer Safety Commission
CST	Centre for Sustainable Transportation
CSTT	Centre for Surface Transportation Technology
CVO	Commercial Vehicles Operation
DMV	Department of Motor Vehicles
DND	Department of National Defence
DOE	Department of Energy
DRDC	Defence Research and Development Canada
DRL	Daylight Running Lights
EC	European Community
ECE	Economic Commission of Europe
ED	Emergency Department
EMC	Electromagnetic Compatibility
EMC	Electric Mobility Canada
EMI	Electromagnetic Interference
ESC	Electronic Stability Control
ESS	Energy Storage System
EU	European Union
EV	Electric Vehicle
FHWA	Federal Highway Administration
FLA	Flooded Lead Acid
FMVSS	Federal Motor Vehicle Safety Standard
GDV	German Insurance Association
GHG	Greenhouse Gases
GHSA	Governors Highway Safety Association

GVWR	Gross Vehicle Weight Rating
HTA	Highway Traffic Act
IBC	Insurance Bureau of Canada
ICBC	Insurance Corporation of British Columbia
ICE	Internal Combustion Engine
IHSDM	Interactive Highway Safety Design Model
IIHS	Insurance Institute for Highway Safety
IIWPG	Insurance Whiplash Prevention Group
IMS	International Marketing Solutions
ISO	International Organization for Standardization
ITAQ	Institut du Transport Avancé du Québec
ITE	Institute of Transportation Engineers
ITS	Intelligent Transportation Systems
L	Litre
LAFB	Luke Air Force Base
LOS	Level of Service
LOS C	LOS Class C
LOS D	LOS Class D
LPG	Liquefied petroleum gas
LRQ	Lois et règlements Québec
LSMV	Low Speed Motor Vehicle
LSV	Low Speed Vehicle
LTV	Light Truck Vehicle
LWMV	Light Weight Motor Vehicle
MCRDSD	Marine Corps Recruit Depot San Diego
MPI	Manitoba Public Insurance
MTI	Ministry of Transportation and Infrastructure
MTP	Master Transportation Plan
MTO	Ministry of Transportation Ontario
MTQ	Ministry of Transportation Québec
MVSR	Motor Vehicle Safety Regulation
MWRD	Metropolitan Water Reclamation District
NCAP	New Car Assessment Program
NEISS	National Electronic Injury Surveillance System
NEV	Neighbourhood Electric Vehicle
NGCMA	National Golf Car Manufacturers Association
NHTSA	National Highway Traffic Safety Administration
NRC	National Research Council Canada
NRCan	Natural Resources Canada
OPP	Ontario Provincial Police
ORSAR	Ontario Road Safety Annual Report
PCE	Passenger Car Equivalence
PERD	Program of Energy Research and Development
SAAQ	Société de l'assurance automobile du Québec
SAE	Society of Automotive Engineers
SMV	Slow Moving Vehicle
TC	Transport Canada
TCS	Traction Control System
TDC	Transportation Development Centre
TRB	Transportation Research Board
TRL	UK Transport Research Laboratory

TSD	Technical Safety Document
UK	United Kingdom
UN	United Nations
US	United States
VEVA	Vancouver Electric Vehicle Association
VKT	Vehicle Kilometers Travelled
VMT	Vehicle Miles Travelled
VPD	Vancouver Police Department
VPH	Vehicle per hour
VRLA	Valve Regulated Lead Acid
VTP	Vehicle Technologies Program
W	Watt
Wh	Watt hour

17 REFERENCES

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18 APPENDIX A: LOW SPEED ELECTRICAL VEHICLES AND HUMAN FACTORS AND ROAD SAFETY IMPACTS STUDY

FINAL REPORT

LOW SPEED ELECTRICAL VEHICLES AND HUMAN FACTORS AND ROAD SAFETY IMPACTS

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1 INTRODUCTION

According to the Ministry of Transportation Ontario website, a low-speed vehicle (LSV) is “a vehicle powered by an electric motor, is designed to travel on four wheels, and must have an attainable speed of 32 km/h, but not exceed 40 km/h, on a paved level surface (Transport Canada definition).” Low speed electric vehicles are an attractive option for drivers given their potential to reduce greenhouse gas emissions. If these vehicles are permitted on public roadways they also have the potential to affect driver behaviour and traffic safety. The effects may be both positive and negative. The purpose of this report is to consider human factors and traffic safety issues which may arise should low speed electric vehicles be integrated into traffic, as well as restrictions and mitigating measures related to these issues.

In this report, driver behaviour is considered from the perspective of human factors, an interdisciplinary area, applying knowledge from the human sciences (psychology, physiology, etc.) to engineering design, with the aim of understanding human limitations in the operation of tools and equipment and guiding design so that errors and injuries are avoided. In this report, road safety is considered from the perspective of expected safety impacts of introduction of LSVs and potential roadway and traffic treatments. Safety is measured by means of expected multi-vehicle collisions, collisions between a vehicle and a pedestrian or a bicyclist, or single-vehicle collisions. Collisions are expressed in terms of their frequency, severity, and type of collision. The safety impacts of different planning, design and operational decisions are estimated by safety evaluation studies, if available. In the absence of these studies, the estimation of risk and engineering judgement are required.

Section 2 deals with human factors issues, Section 3 with road safety issues, Section 4 with suggested restrictions and mitigating measures and Section 5 with future research.

2 HUMAN FACTORS ISSUES

The integration of LSVs on public roadways, especially when they have the same appearance as standard vehicles but reduced operating capabilities, may surprise drivers moving at higher speeds, resulting in conflicts. Speed differences are a concern because drivers have limitations in perception of closing velocity, which may lead to a delayed decision to brake. Slow vehicles ahead can also result in frustration to following drivers, and aggressive behaviour. Finally, electric vehicles are quiet. This can be problematic for pedestrians and cyclists who may rely on hearing approaching vehicles and do not carry out a full visual search before stepping into traffic. As will be discussed in the section on road safety, pedestrians and cyclists are very vulnerable to injury even at low speeds.

Human factors issues considered below are:

- Driver expectation
- Perception of closing velocity
- Aggressive driving behaviour
- Lack of audibility by pedestrians and cyclists

2.1 Importance of Driver Expectation

Low speed vehicles, especially when they have the same appearance as standard vehicles, may surprise drivers moving at higher speeds. This can result in conflicts in various situations, for example:

- When a driver is approaching a traffic signal expecting the low-speed vehicle in front to go through and it stops

- When a driver is going through an intersection and a left-turning driver takes longer to complete a turn than expected

Drivers respond best when the situation matches their expectations. In fact, driver expectation is considered to be such an important factor in determining driver response that it is explicitly considered in highway design through the "positive guidance" approach to highway design. This approach is based on a combination of human factors and traffic engineering, which was developed in the early 1970s by Alexander and Lunenfeld and elaborated on in a series of documents published by the U.S. Federal Highway Administration (Alexander & Lunenfeld, 1975). Design according to driver expectations increases the likelihood of drivers responding to situations and information correctly and quickly. A concern when expectation of other drivers is violated by an LSV is that a rear-end crash may result due to delayed detection of a substantial speed difference with the LSV ahead.

2.2 Perception of Closing Velocity

While the unexpected situation of a stopped or very slow-moving vehicle on a roadway alone increases the possibility of drivers responding too late, there is a further difficulty which greatly adds to the problem. That is the difficulty that drivers have in perceiving closing speed and in distinguishing between a relatively safe situation in which one is slowly catching up, from a more dangerous situation in which one is rapidly catching up to another vehicle.

One of the main cues to determining the rapidity with which one is closing on another vehicle is the apparent change in the size of the rear of the vehicle ahead. The determination of closing velocity is difficult. At a distance, the apparent size of the rear of the vehicle is small. As the driver approaches, the angle created at the eye gets gradually larger and larger. As indicated in Figure 1, this is a very non-linear cue, making the judgment of the rate of closing velocity very difficult. Studies suggest that alerted subjects in experimental situations do not **begin** to recognize rapid closing until the change in angle is on average 0.17 degrees per second. (Since 0.17 degrees per second is an average value, half of drivers will need a larger angular change, and get closer before beginning to sense rapid closing.) Until this threshold is reached, all the driver perceives is that the gap is closing, something that happens regularly in traffic and does not precipitate emergency action.

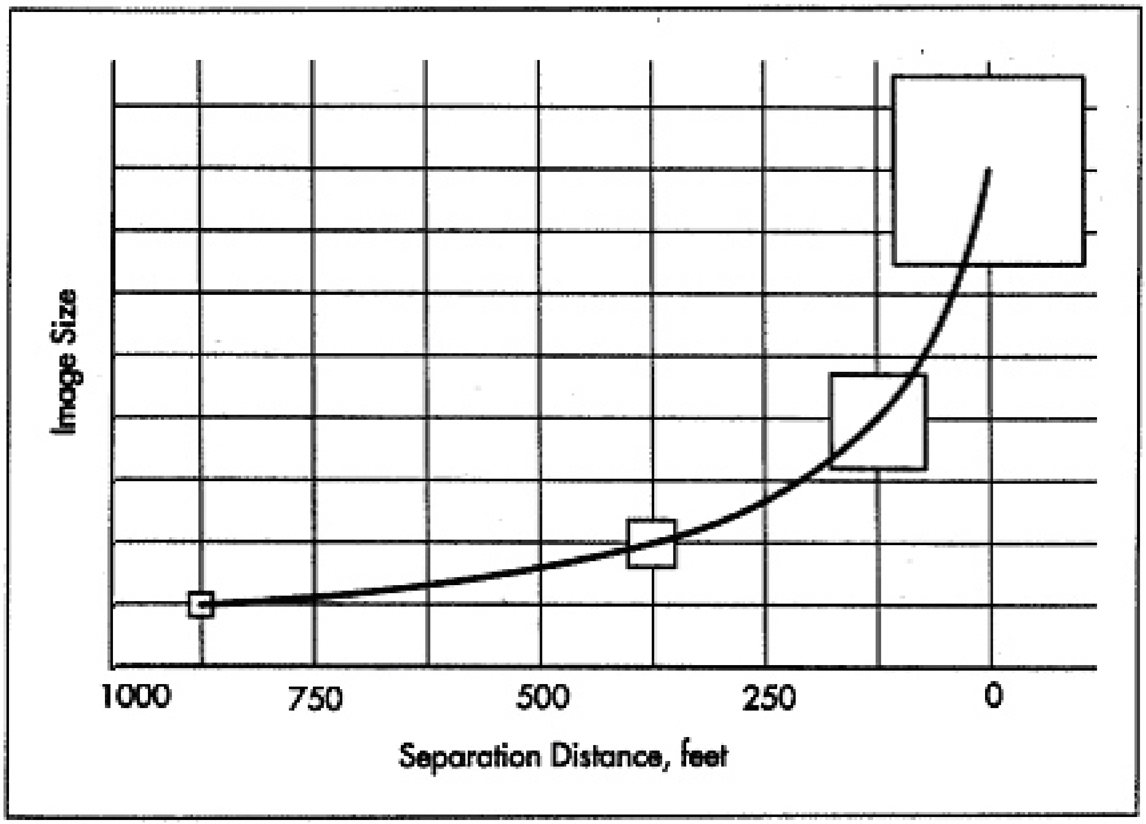

Figure 1: The relationship between viewing distance and image size (Olson & Farber, 2003)

Table 1 indicates time to collision at which the average driver would begin to perceive a rapid closing speed, for various LSV speeds (stopped, 10 km/h, 20 km/h, and 30 km/h) for situations in which the following vehicle is travelling 20, 30 and 40 km/h faster than the LSV. A width of 1.5 m has been assumed for the electric vehicle. As can be seen, depending on relative speeds, the threshold varies from 6.2 to 9.0 seconds to collision.

Table 1: Time at which rapid closing speed would be detected by the average driver

LSV Speed (km/h)	Following Vehicle Speed (km/h)	Time to Collision (sec)	Distance (metres)
0 km/h	20 km/h	9.0	50
	30 km/h	7.2	60
	40 km/h	6.2	70
10 km/h	30 km/h	9.0	50
	40 km/h	7.2	60
	50 km/h	6.2	70
20 km/h	40 km/h	9.0	50
	50 km/h	7.2	60
	60 km/h	6.2	70
30 km/h	50 km/h	9.0	50
	60 km/h	7.2	60
	70 km/h	6.2	70
40 km/h	50 km/h	9.0	50
	60 km/h	7.2	60
	70 km/h	6.2	70

Fifty percent of drivers will have less time to collision than indicated above, due to individual differences. Furthermore, these times signify the start of an ability to differentiate different speeds of closure. Drivers require some time to assess closing speed. One study looked at the impact of exposure times of 0.5, 1, 2 and 4 seconds on the threshold change in angular velocity at which alerted experimental subjects detected that stimuli simulating taillights were separating (simulating the view of a driver approaching a vehicle ahead). Improvements in assessment of closing speed were found as exposure increased from 0.5 to 2 seconds (Janssen, Michon, & Harvey, 1976). Therefore, a driver would be expected to take on the order of 2 seconds to perceive that the gap was closing rapidly, once angular velocity was above threshold for perception.

In a study with alerted experimental subjects, those who had to respond to a hazard in the roadway for the first time had response times (time to move foot from accelerator to brake) ranging from 0.38 to 0.73 seconds (50^{th} to 90^{th} percentile) (Olson, Cleveland, Fancher, Kostyniuk, & Schneider, 1984). Since experimental subjects would be abnormally alert, it is appropriate to use the high end of this range as estimate of response time, once perception has been completed. Thus if perception that the closing velocity was high took 2 seconds and response about 0.7 seconds then 2.7 seconds or more, in the case of a driver not expecting this situation, could pass before any braking would be initiated.

Another basis for estimating perception-reaction time in this situation is a study in Australia in which subjects reacted to changes in headway between themselves and a lead vehicle. The longer the initial headway, the longer the time drivers took to respond to deceleration or acceleration. In the case of the vehicle ahead decelerating, response times for alerted subjects in daylight conditions averaged 3.8 seconds (Armour, 1979) (quoted in NHTSA, 1985) (National Highway Traffic Safety Administration, 1985). This study included some situations in which the speed of opening or closing of the gap may initially have been below threshold, which would contribute to longer response times. On the other hand, this is offset by the fact that these times were measured for alerted subjects expecting to respond to an accelerating or decelerating lead vehicle. The mean value of 3.8 seconds in this situation is considerably longer than the frequently used 1½ seconds reaction time, and more appropriate given the difficult nature of the perceptual task involved.

If the electric vehicle is moving slowly, say at 30 km/h, and a following vehicle is approaching at 70 km/h, then Table 1 indicates that the threshold of angular change for the width of such a vehicle is not reached for the average alerted experimental subject, until he or she is about 70 m away, or about 6.2 seconds from collision. Even in the alerted situation, half of drivers will have thresholds larger than average, and will be closer than 70 m before realizing the emergency nature of the situation. Assuming a perception-response time of 2.7 seconds in this situation, the lower of the two estimates discussed above, a following driver travelling at 70 km/h would travel 53 m during the time it takes to realize the vehicle ahead is moving more slowly and initiate braking. During this time the LSV ahead, at a speed of 30 km/h, would travel 23 m. The distance between the vehicles would be reduced to 30 m. Slowing from 70 to 30 km/h would require 21 m using emergency braking (0.75g). However, comfortable braking (0.25g) would require 63 m, more than twice the distance available. Longer distances would be required on wet or icy pavement. The greater the speed difference, the less time is available where the angular change of the electric vehicle ahead is above the threshold for detecting angular change for the following driver. This suggests that limiting the use of LSVs to speed limits of 50 km/h (anticipating vehicle speeds of 60 km/h or lower) would be appropriate to avoid situations in which following drivers are surprised by the low speed of an LSV ahead, resulting in hard braking.

2.3 Aggressive Driving Behaviour

A concern about the integration of LSVs with normal traffic is that drivers of other vehicles will be frustrated by the low speed of LSVs and respond aggressively, increasing crash risk. Aggression is a complex issue, with numerous contributing factors and varied responses. Figure 2 shows a model illustrating the interaction between personality characteristics, situational variables and overt behaviours of aggressive driving (Shinar, 2007) reprinted from (Shinar, 1998).

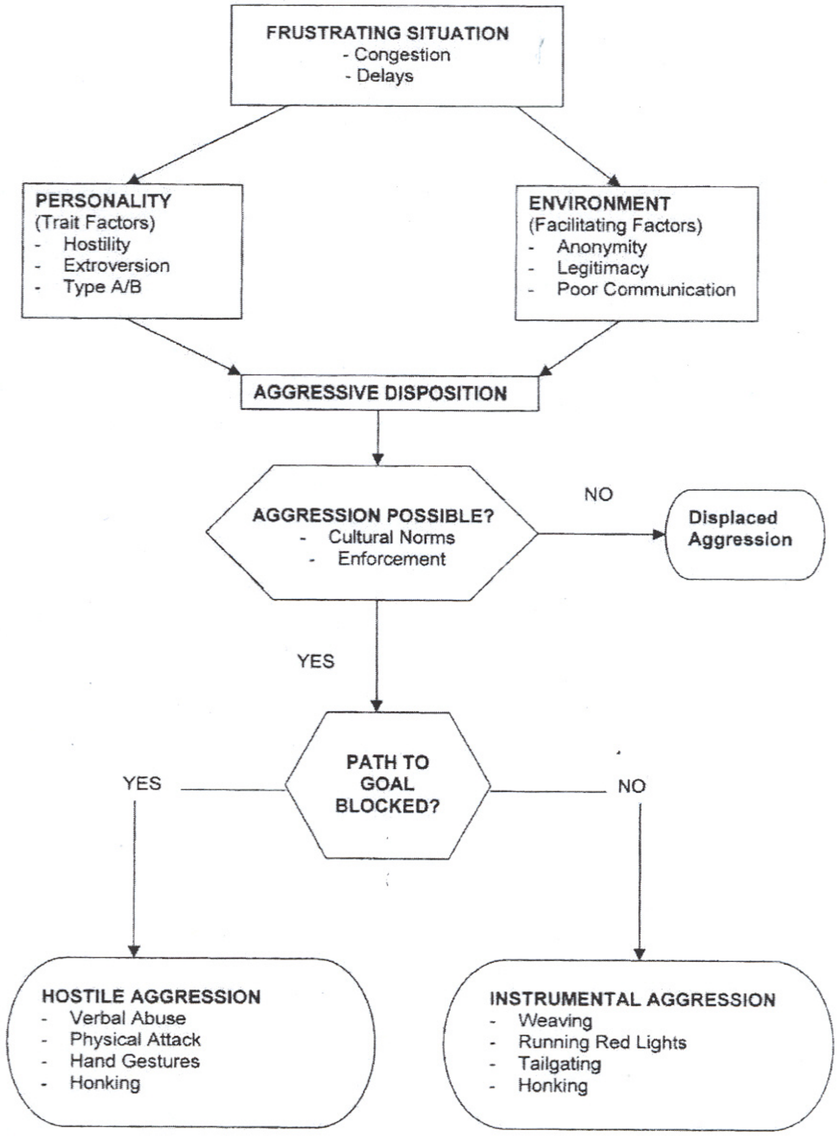

Figure 2: Model illustrating the interaction between personality characteristics, situational variables and overt behaviours of aggressive driving (Shinar, 2007)

Aggression is a characteristic of all drivers, but the set point at which it is manifested depends on individual characteristics such as social maladjustment, risk-taking and sensation-seeking, all of which are linked to masculine characteristics and age.

A survey of 1,382 American drivers, representative of the U.S. driving population in age, sex, income and education, asked drivers to indicate their agreement with statements concerning how frequently they exhibited various behaviours (Wells-Parker, Ceminsky, Hallberg, Snow, Dunaway, Guiling, Williams, & Anderson, 2002) from (Shinar 2007). The most frequently reported aggressive behaviours were saying bad things to yourself about another driver and complaining/yelling about another driver to your passenger, giving other drivers dirty looks (62% and 52% respectively indicating sometimes or often). Honking/yelling at someone through the window and making obscene gestures occurred less frequently (20% and 7% respectively indicating sometimes or often). Tailgating others to force them to move was reported by less than 0.1% of drivers as occurring often, and by 6% of drivers as occurring sometimes. For the vast majority of drivers this behaviour was reported as occurring rarely or never.

Aggressive behaviour has been studied by means of a technique pioneered by Doob and Gross, involving having a researcher drive up to a traffic signal, immediately after the signal has turned red (Doob & Gross, 1968). When the signal turns green, the researcher remains stationary and records the behaviour of the driver that is detained behind. The shorter the green interval is, the more quickly the following driver will honk his/her horn. Similarly, more rapid honking occurs in rush hour than on weekends (Shinar 1998).

This and a number of other studies indicate that aggressive behaviour follows a dose-response curve, increasing in aggression with increased frustration. Thus the more different the LSV operating characteristics, in particular acceleration capability and maximum speed, are from those of other vehicles, and the more LSVs there are in traffic, the greater the frustration of other drivers on the same or conflicting paths is likely to be. Higher volume traffic is likely to be associated with more aggression as it becomes more difficult to escape from behind a slower driver. On the other hand, one of the results of congestion is a slowing of traffic, lessening the difference in speed between LSV and other vehicles.

Aggression is less evident when drivers see a reason for the obstruction or perceive that the obstruction is justified. In a study described by Shinar, "a pedestrian stepped off the curb just as an approaching driver reached a critical point at which he or she would have to slow down or stop in order to allow the pedestrian to cross" (Shinar 2007). Half of the attempted crossings occurred at an intersection and half at mid-block. Half of the crossings in each location were made with the pedestrian appearing as an able-bodied person, and half with the same pedestrian using crutches. At the intersection, where drivers are required by law to yield to pedestrians, two-thirds yielded to the able-bodied person and virtually all to the disabled person. At the mid-block crossing, where drivers are not required by law to yield, two-thirds still yielded to the disabled person but very few to the able-bodied person. Thus, the driver's perception of the legitimacy of the impediment is likely to affect the presence of aggressive behaviours.

2.4 Lack of LSV Audibility by Pedestrians and Cyclists

Pedestrians, bicyclists and drivers frequently come into conflict at intersections where they cross each other's paths. Because of the visual and mental demands in this situation, drivers are prone to error during vehicle turning movements, especially left-turning movements, making pedestrians and bicyclists vulnerable. A study of pedestrian crashes at signalized intersections on a one-way grid system in New York showed that left-turn movements were approximately twice as dangerous to pedestrians as right-turn movements, and four times more dangerous to pedestrians than through movements (Habib, 1980). During right-turning manoeuvres, pedestrians and drivers were equally at fault in failing to yield the right of way; during left-turning manoeuvres, drivers failed to yield to the pedestrian 62% of the time, compared with a 38% failure rate for the pedestrian. This is a concern because LSVs are quiet and quiet vehicles are more likely than others to fail to be detected by pedestrians especially during turning movements.

Pedestrians and bicyclists contribute to conflicts with vehicles when they fail to carry out a proper search. In a Florida study at signalized downtown intersections, researchers observed pedestrian search behaviour, with and without various auditory signals (Van Houten, Malenfant, Van Houten, & Retting, 1997). To be scored as checking for a particular threat, the pedestrian had to orient his or her head toward the direction the vehicle would be coming from prior to entering the vehicle path and within three seconds of entering the vehicle path.

Results showed that in the baseline condition, without auditory signals, which is typical of most signalized intersections, depending on the observation period, between 8% and 25% of pedestrians did not look for threats. Search varied with respect to the three types of threats: vehicles coming from behind require the greatest head movement and were searched for least – approximately 30% of pedestrians looked for such vehicles. Search for vehicles coming from the side and from ahead, was more frequent – approximately 50% and 60% of pedestrians respectively. It seems likely that many pedestrians who do not look directly at traffic are nonetheless alerted by vehicle sounds. Since LSVs are quiet they will not be detected by pedestrians and bicyclists who do not look for them. As this study shows, this is a significant portion of the population.

2.5 Human Factors Summary

In summary, drivers may not expect the slower acceleration rate and lower maximum speed of LSVs, leading to speed differences between successive vehicles, which are detected too late by the following driver. Large speed differences can be difficult to detect because of human perceptual limitations, until hard braking is required, increasing the potential for rear-end collisions. The lesser operating capabilities of LSVs may lead to frustration and aggression on the part of other drivers. Finally, the silent nature of an electrical engine may contribute to pedestrians and bicyclists, who rely on the hearing approaching traffic, to move into an intersection without looking for turning vehicles.

3 ROAD SAFETY ISSUES

Low-speed vehicles differ from other vehicles and safety-related issues are as follows:

1. Light weight and size and related crashworthiness
2. Limited maximum operating speed
3. Low rate of acceleration and deceleration
4. Limited application in snow conditions

The extent of these limitations is not consistent among the types of LSVs available in the market. These limitations may affect their operation in mixed traffic conditions, and the safety of the LSV occupants and other road users.

Urban municipal environments in Ontario comprise roads categorized as arterial, collector, and local. The speed limits posted on these road categories typically range from a high of 70 km/h to a low of 40 km/h with some exceptions posted at 30 km/h along traffic calmed residential streets. Some cities, such as Toronto, also have expressways which are signed to speed limits of 80 km/h – 100 km/h. Typically, 85^{th} percentile operating speeds are higher than the posted speed limits. For most of the municipal road network, the mix of traffic is broad and can include buses, multi-axle trucks, and SUVs.

LSVs are permitted in a number of states in the U.S., in Québec, and British Columbia. LSV laws typically permit the use of LSVs in mixed traffic on urban roadways with posted speed limits not higher than 35 mph (56 km/h). In the U.S., any crashes involving LSVs are classified in the “other” crash type, thus the crash history is unknown. Few LSV crashes have been documented and as a result sound conclusions regarding crash risk are not possible based on crash history. An alternative approach is to consider the factors which increase the risk of a crash and injury to a road user (including vehicle occupants) with increasing LSV travel in mixed traffic conditions. These factors, discussed below, include vehicle size, vehicle speed, vehicle acceleration and deceleration rates, and weather.

3.1 Traffic Safety and Small and Lightweight Vehicles

LSVs are limited, by definition in Canada, to a gross vehicle weight rating of less than 1,361kg. The Insurance Institute of Highway Safety in Washington, D.C., published a status report on the subject of the increase of LSVs in the U.S. (Insurance Institute for Highway Safety, 2002). Figure 3 shows that the highest death rates and lowest fuel consumption are for the lightest passenger cars; these light and small vehicles are the least occupant protective in the event of a crash. The crash data are not separated by environment or road type. It is noted that, in contrast to a handful of standards currently required of LSVs in Canada and U.S., all safety standards were applied to these light and small vehicles, and the standards have progressed in the past 10 to 15 years, for example the installation of front and side airbags, etc. Thus, the crash experience of LSVs is likely to be much worse than for other light vehicles.

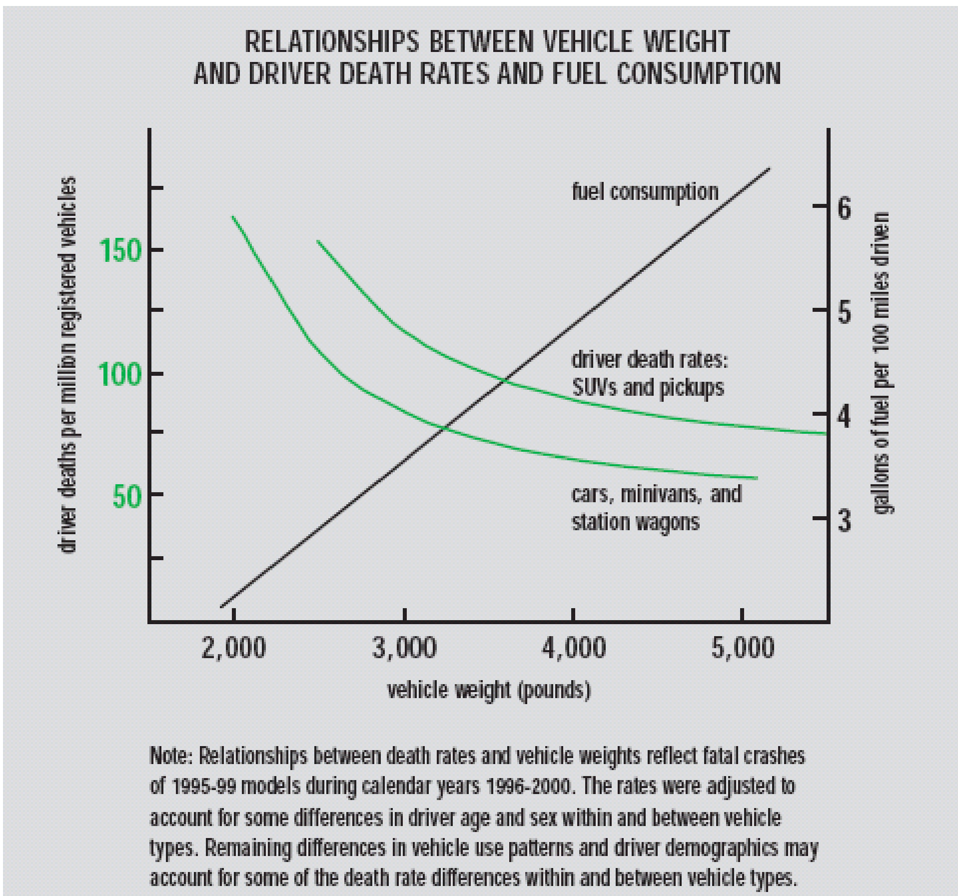

Figure 3: ***Relationship between vehicle weight and driver death rates and fuel consumption: Source: IIHS Status Report Vol. 37, No.4, April 6, 2002 "Improve Fuel Economy without Negative Safety Consequences"***

Of particular concern in the introduction of LSVs in the U.S. and in Canada is the lack of safety standards applied to LSVs. The current few requirements are windshield, mirrors, signal lights, tail and brake lights, reflectors, safety belts, and parking brake. LSVs do not have to have doors or bumpers installed, or to meet occupant protection standards, (CMVSS 202) or anchorage of seats standards (CMVSS 207). Despite these key differences between electric LSVs and other light passenger cars, road users including owners of the LSVs, may be unaware of the risk of injury in the event of a collision. For example, the ZENN vehicle, produced in Canada and widely found in North America, is not a typical neighbourhood electric (NEV) vehicle which resembles a golf cart (Dynasty-type); while other LSV vehicles such as ZENN vehicles, resemble other passenger cars (http://www.zenncars.com/).

Based on FARS data (1975 to 1989) analysis of the principal point of impact and the greatest injury, it can be concluded that in general, a right-front passenger is 2.74 times as likely to die as the driver if the collision impact is from the right; a driver is 2.63 times as likely to die as is the right-front passenger if the impact is from the left (Evans, 2004) (pp. 55-56). Drivers and right-front passengers are at similar fatality risks from front impacts, and also at similar risks from rear impacts, while back seat occupants are at greater fatality risk from rear impacts. In summary, the occupants that are sitting near the collision impact point are at greater risk than those occupants that are far from the point of contact. It is noted that a rear impact to an LSV (a 2-person vehicle) will not be “cushioned” by the rear occupants or rear seat furniture as in the case of a 4-door car.

In a 2-car crash, the mass and size of each vehicle influence the level of severity of harm. To demonstrate how mass and size are factors in the outcome of a crash; we have selected passenger-car like LSV, the Smart Car, and the Honda Civic which represents a popular light car. Table 2 shows the characteristics of these cars.

Table 2: Vehicle Characteristics of LSV, Smart Car and Honda Civic

Vehicle Type	Mass (curb weight) (pounds)	Length (inches)	Width (inches)	Height (inches)
LSV	1,404	120.8	58.8	55.9
Smart Car	1,825			
2007 Honda Civic				
• Sedan	2,643	176.7	68.9	56.4
• Coupe	2,597	173.2	68.8	53.4

Source of LSV information: http://www.zenncars.com/
Source of Smart Car information: http://www.thesmart.ca/
Source of Honda Civic information: http://www.canadiandriver.com/buyers-guide/2007/honda/civic.php

Four crash types will be considered in our estimate of the probability of death for drivers when involved in a collision, based on the different masses of their cars.

1. Head-on crash

Equation 4.9 (Evans 2004, page 71) was developed based on FARS data for speed differences between the colliding vehicles less than 114 km/h. This equation can be used to estimate the impacts of future collisions with an LSV in urban streets:

$R = (m_2/m_1)^{3.54}$
where:

R – ratio of the risks of death to drivers in the two vehicles
m_2 and m_1 – masses of the two vehicles

The computations for a head-on crash between a LSV and a Honda sedan shows that the driver in the LSV is 9.34 times more likely to be killed than the driver of the sedan; while computations for a head-on collision between an LSV and a Smart car shows that the LSV driver is 2.53 times more likely to be killed than the driver of the Smart car.

2. Angle Crash

a. Right-side impact

A right-side impact collision may occur when an LSV vehicle is turning left and the through vehicle strikes it. The low rate of acceleration will demand a longer clearance time for an LSV turning left. In the next sections, this topic will be further discussed. Using the Table 4-2 values (Evans 2004, page 75), the risk of death for drivers when involved in such a right-side impact is:

$R = \alpha(m_2/m_1)^{3.47}$
where α – parameter reflecting other attributes besides mass ratio = 4.53

When two vehicles of identical masses collide with each other, the parameter α measures the risk in one car compared to that in the other car. Thus, the driver in a right-side impacted vehicle is 4.53 times more likely to be killed than the driver in the vehicle with frontal impact, when both vehicles have identical masses.

The computations of a right-side crash between an LSV and a Honda sedan shows that the driver in the LSV is 40 times more likely to be killed than the driver of the sedan.

b. Left-side impact

A left-side impact collision may occur when the signal phase is terminated before an LSV vehicle is able to slowly accelerate from a STOP position and clear the intersection (going through or left turn) and is struck by a vehicle entering the intersection in the green phase. Using the Table 4-2 values (Evans 2004, page 75), the risk of death for drivers when involved in such a left-side impact is:

$R = \alpha(m_2/m_1)^{3.24}$
where α – parameter reflecting other attributes besides mass ratio = 10.08

The computations of a left-side crash between an LSV and a Honda sedan shows that the driver in the LSV is 77.9 times more likely to be killed than the driver of the sedan.

3. Rear-end Crash

A rear-end collision may occur at an intersection or at a driveway due to the low rate of acceleration of the LSV from a stop condition and the following driver's limitation in assessing the closing velocity especially when it is not expected. Using the Table 4-2 values (Evans 2004, page 75), the risk of death for drivers when involved in such a rear-end impact is:

$R = \alpha(m_2/m_1)^{3.71}$
where α – parameter reflecting other attributes besides mass ratio = 1.09

Thus, the driver in a rear-end impacted vehicle is 1.09 times more likely to be killed than the driver in the vehicle with frontal impact, when both vehicles have identical masses.

The computations of a rear-end crash between an LSV and a Honda sedan show that the driver in the LSV is 11.34 times more likely to be killed as the driver of the sedan.

It is noted that all vehicles used in the analysis of fatal crashes (1975 to 1989) in the U.S. were approved after meeting the standards and regulations. It is also expected that airbags and other vehicle safety improvements since 1990 would have reduced the occupant fatal injury for light vehicles. Thus, the risk of a fatal harm to occupants of LSVs, vehicles which are subject to only a handful of standards, is likely to be worse than for other light vehicles.

3.2 Traffic Safety and Low Speed Vehicles

The increasing congestion in some urban road networks is causing a general reduction of operational speeds for some periods of the day. This trend fits the introduction of LSVs at those times. Even at low speeds, there are risks associated with certain crash types, in particular those in which vulnerable road users are involved, or those that involve right-angle impacts.

Pedestrians: It is noted that vulnerable road users can still be seriously injured and killed at low speeds. Figure 4 shows the probability of a pedestrian being killed if struck by a vehicle at different impact speeds. At 40 km/h, there is about 20% probability of a pedestrian fatality.

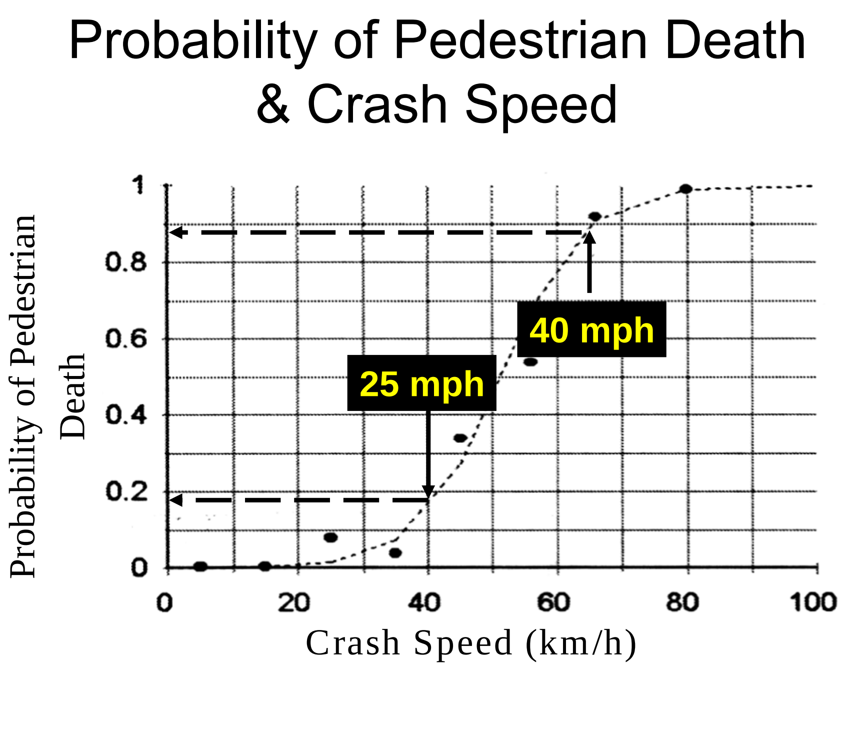

Figure 4: Probability of pedestrian death at different crash speeds

Intersection Control Devices: Traffic signals are coordinated based on the speed limit (or operating speed) of the corridor, thus LSV vehicles will not be within the coordination pace. As an example, the best performance of passenger-car like LSVs are as per their design to reach an acceleration of 0 – 32 km/h in 6 seconds or for 0 – 40km/h in 8 seconds, on level roads. These translate to a maximum acceleration rate of 5.04 km/h/s to 40 km/h which is about 20% lower than 6.4 km/h/s of a typical small car, and 37% lower than 8km/h/s of a compact car or a pickup truck or a composite car (LSV rates from Harmelink Consulting Inc.; non-LSV rates from The Institute of Traffic Engineers Transportation and Traffic Engineering Handbook, 1976, Table 2.4) (Harmelink Consulting Inc., 2008; Institute of Transportation Engineers, 1976).The rates apply to level roads.

Because of its lower acceleration rate, an LSV may require a longer intersection clearance phase (amber and red) than typically designed for the mixed traffic conditions, especially from a stopped condition. Thus, a left-turning LSV may still be in the intersection area when the opposing direction of traffic faces a green signal. This situation may lead to serious angle collisions, as discussed in the previous section. It is also important to understand that increasing the yellow time will create a greater and undesirable decision dilemma zone condition. The dilemma zone is created during a Green-Yellow signal transition period, when drivers in a road section approaching the intersection usually have a difficult time in making a decision whether to go or to stop, a condition that can lead to a rear-end crash. These operational limitations require mitigating measures, such as:

1. Consider coordination of the signals upstream as to minimize the opposing platoon dispersion creating longer gaps for LSV turning left during the green interval (i.e. In other words, the vehicles coming in the opposite direction to the LSV will come as close to one single group so that there is a larger time gap before the end of the green phase).
2. Consider left-turn protected phase only, although the design of the phase will need a longer start-up time and clearance time than typically required for mixed urban traffic in order to accommodate the LSV, and will reduce the rate with which traffic can be moved through the intersection.

Ideally, traffic signals would be programmed to recognize the demand when the LSV is present; such identification of vehicle by weigh, size, and speed are possible but will require investment in the traffic control infrastructure, and may create difficulties with maintaining signal co-ordination along a corridor.

The relatively low rate of acceleration will also create another conflict situation when the LSV turns right (or left) at the end of its own green phase or during the clearance phase just before the platoon start-up in the opposing direction, or on red during a gap, or from a minor road onto a major road. As the LSV accelerates more slowly than expected (almost 40% slower than a compact car or a pick-up truck), following drivers may not adapt their speeds and find themselves involved in a rear-end crash with the LSV or another slow vehicle following the LSV. Another operational effect of the relatively low rate of acceleration of an LSV is the creation of queues which may be lengthened to the point of causing potential delays and decrease in the capacity of the road network, unless special signal coordination is implemented on LSV routes.

The braking distances found in the LSV specification sheets show the low rate of deceleration of these vehicles. For example, the passenger-car like LSV has as best performance a braking distance from 20 mph of 19.49 feet corresponding to 0.64g deceleration rate which is considerably less than typical cars; the Honda Civic, considered an average performer has a 0.89g (tested from 60 mph, came to stop at 126 feet). (http://usnews.rankingsandreviews.com/cars-trucks/2008-Honda-Civic/Performance/). Thus, an LSV will require a longer stopping sight distance. Extension of green time through advance detection (by means of magnetic loops in the pavement to detect an approaching vehicle and delay the onset of the yellow phase until the vehicle can clear the stop bar) will be needed to accommodate an LSV at a signalized intersection. Advance warning of yellow phase would assist the driver of an LSV, but the negative impact due to behavioural change, i.e., drivers accelerate to enter the intersection "before the end of the phase", would overall be detrimental to safety.

3.3 Traffic Safety and Speed Differential

Operating speeds in urban, municipal road networks typically vary from 30 to 80 km/h, excluding expressways. Thus, it can be expected that the speed differential between the general traffic and LSVs will be in the range of 0 to 50 km/h. Studies have shown that the greater the speed difference between two vehicles, the greater the probability of a rear-end collision. The human factors issue underlying this effect is the difficulty that drivers have in detecting closing velocity, especially in situations where the following vehicle catches up with the slower vehicle in front. An extensive analysis of two-car, rear-end collisions was used to calculate the risk of rear-end collisions, given various closing speeds. Speed observations and/or interviews were made with nearly 300,000 drivers. While 47% of two-car, rear-end accidents involved speed differences greater than 32 km/h, only 7% of randomly selected pairs of cars in normal traffic exhibited speed differences this high. Thus where the speed difference between following vehicles was greater than 32 km/h, accident risk increased by a factor of 6.7 times. As the speed difference grew, accident risk soared exponentially. In an urban area posted at 60 km/h, an LSV may be travelling at a speed of 40 km/h, its maximum speed while the following driver is travelling at 70 km/h (Solomon, 1964). Based on this study a speed difference of 30 km/h would be expected to increase risk substantially.

It is noted that most studies of the effects of speeds on crashes, including the one cited above, are based on crashes that occurred on rural roads with speed limits of 55 to 70mph (Transportation Research Board, 1998) (pp. 43-46). An Australian study by Kloeden et al. analyzed crashes in metropolitan Adelaide in speed zones with 60km/h speed limits, and found that there was a statistically significant increase in the probability of involvement in a injury (fatal and injury combined) crash with increasing travel speed above, but not below the speed limit (Kloeden, McLean, Moore, & Ponte, 1997). If we assume that LSVs will only be allowed on municipal roads with speed limits of 40 km/h, their involvement in injury crashes with another vehicle may not be a concern. However, if LSVs are allowed on any urban roads where the operating speeds are higher than the speed limits, we may see an increase of crashes between LSVs and those drivers travelling at higher speeds than the speed limit. It is noted that this study did not include crashes with vehicles slowing to turn or stop. Studies relating crash probability and speed on residential streets were not found.

Thus, it is concluded that there is a higher probability that LSVs will be involved in crashes with vehicles travelling at speeds over the speed limits, which are typically found on arterial and collector streets. In other words, the speed dispersion in urban arterials and collectors will increase the crash occurrence. Many other factors will also play a role in crash occurrence on urban roads and some of these are found in Section 3.2.

3.4 Traffic Safety and Weather Conditions

The Dynasty and GEN LSVs are NEVs not suitable for wet, snowy, and icy conditions. Other passenger-car like LSVs are equipped with winter tires and covered as to enable use during adverse conditions. However, even they will be vulnerable when the snow is too high and when there is high precipitation in a short time period. No research was found addressing this issue.

3.5 Road Safety Summary

In summary, LSVs raise a number of significant safety issues. The most critical is that their light weight and size will result in higher injury and fatality rates than for other vehicles, even with the conservative assumption that they are equipped according to the same safety standards. For example, the computations of a right-side crash between an LSV and a Honda sedan shows that the driver in the LSV is 40 times more likely to be killed than the driver of the sedan. Pedestrians are at risk from turning LSVs because they are so quiet. Even though collision speed may be low, pedestrians are still vulnerable: 5% of those hit at 30 km/h are fatally injured. Traffic signal phasing may need to be adjusted to account for the relatively lower acceleration rate and lower maximum speed of LSVs. Otherwise such vehicles may be at risk for being unable to clear a red or yellow light in time. The lower maximum speed of LSVs will result in speed differences between vehicles in mixed traffic. Studies have shown that the greater the speed difference between two vehicles, the greater the probability of a rear-end collision. Finally, winter conditions may pose safety risks for lighter vehicles such as LSVs.

4 POTENTIAL TREATMENTS

As discussed above, the unexpected low speed and relatively low rate of acceleration and deceleration in relation to other similar vehicles, and the lack of in-vehicle protective devices are some of the issues that require countermeasures be considered. The treatments suggested are the result of our understanding of the possible chain of events leading to a crash with an LSV. The treatments include:

- Increasing the conspicuity of the LSV
- Adding an auditory signal connected to the turn signal to warn pedestrians of turning vehicles
- Warning potential buyers of the crash-worthiness and operating limitations
- Public education campaigns concerning speed and acceleration differences
- Develop warrant and guidance for LSV signal phasing

A pilot test should be developed with city professionals, including traffic signals, safety, planning, emergency services and educational experts. This pilot test would be expected to lead to LSV policies such as: stay in the slow lane, marked lanes, etc., times of operation in the urban network (during day and night and specific months of the year). It would also lead to consideration of signalization and warrants for special timing and phasing for LSV needs.

4.1 Increase the Conspicuity of the LSV

Currently the law requires that low-speed vehicles be permanently marked with a slow-moving vehicle identification emblem (SMV emblem) as shown in Figure 5. The requirement is outlined in Appendix A. Such a sign would warn approaching drivers from behind that the vehicle ahead has lower speed and acceleration capabilities than standard vehicles, and reduce the risk of rear-end collisions due to failure to detect the speed difference with the vehicle ahead until it is too late. In addition to placing this emblem on the rear of the vehicle, it should also be placed on the sides so that it can be identified by drivers approaching an intersection as a low speed vehicle when it is turning.

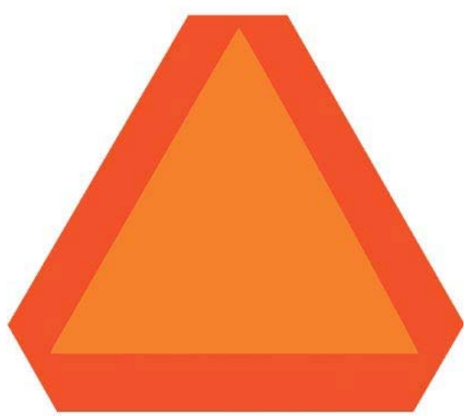

Figure 5: Slow-moving vehicle emblem

4.2 Audible Signal for Pedestrians

Pedestrians frequently do not search for traffic, relying on hearing approaching vehicles. This is obviously a particular issue for the visually impaired pedestrian. An audible signal, connected to the LSV turn signal, would assist in warning pedestrians of an approaching LSV, at intersections where pedestrians may depend on the traffic signal to give them the right of way, and so do not search.

4.3 Add Clear Warning to Potential Buyers

In 2002, the Insurance Institute of Highway Safety issued a notice to the National Highway Traffic Safety Administration that, based on the very limited safe operating environment for LSVs, it is recommending the following warning to potential users of LSVs:

"WARNING: This vehicle is a LOW-SPEED VEHICLE and it should only be used in low-speed and low-density traffic. Occupants of this vehicle face a significant risk of serious injury or death in collisions with larger vehicles."

In 2002, there were already 17 states that have laws concerning LSVs on public streets with speed limits up to 35 mph. Kansas allows LSVs on streets with speed limits up to 40 mph. There are six states that prohibit LSVs from public streets, and 27 states that do not have specific laws on LSVs but whose current laws allow LSVs to be driven on public roads.

4.4 Public Information Campaign

If LSVs are allowed on public roads the public should be informed of their crash-worthiness and operating limitations through advertising on television and radio, in shopping centres, etc.

4.5 Develop Warrant and Guidance for LSV Signal Phasing

As discussed above, the relatively low rate of acceleration of LSVs would require consideration during the signal design to minimize angle and rear-end crashes. As the volume of these vehicles increases, warrants and guidance concerning LSV signal phasing would need to be analyzed to determine whether changes in phasing would be appropriate to accommodate the LSVs at traffic signals.

5 FURTHER RESEARCH

The introduction of LSVs in mixed traffic is a recent trend. Nowhere are they yet in sufficient numbers to affect large scale traffic movements or crash patterns. However, it is important to consider the ways in which low maximum speeds, low acceleration rates and other differences from current passenger vehicles will need to affect the response by other drivers and traffic safety. With foresight, appropriate countermeasures can be applied to reduce some of the negative effects.

Pilot studies should be carried out to determine how LSV drivers might behave (e.g., do they accept larger gaps in traffic when turning, in anticipation of slower acceleration), as well as to determine the response of other drivers to LSVs in mixed traffic (e.g., aggressive behaviour, including close following, shorter time to collision in lead vehicle following situations). The effect of conspicuity devices such as the slow moving vehicle sign should be determined. Driver comprehension of these devices should be tested to ensure drivers understand that vehicles that appear to be in every respect gasoline-powered vehicles are not, and have lower acceleration rates and maximum speeds.

From the perspective of traffic management, it is important to determine the threshold of percent LSVs at which changes in signal phasing might be considered to accommodate these slower vehicles.

With respect to crash experience, conservative estimates indicate, based on vehicle weight alone, a very negative impact. We understand that there are on-going crash tests which will determine the harm to occupants in the LSVs in the event of a crash and we anticipate that additional vehicle standards, presently required for other passenger vehicles, will be established for LSVs. However, it is important that the public be informed about the risks they are taking in driving lighter vehicles at speeds even as low as 40 km/h.

Finally, LSVs are generally lighter vehicles with a slower deceleration rate and may experience more difficulty in snow and ice conditions. Test track studies are required to assess safety with respect to winter operations.

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APPENDIX A

LOW SPEED VEHICLE WARNING REGULATION

2008-08-06 *Canada Gazette Part II, Vol. 142, No. 16*
3. Section 500 of Schedule IV to the Regulations is replaced by the following:

(1) Every low-speed vehicle shall conform to the requirements of *Technical Standards Document No. 500, Low-speed Vehicles* (TSD 500), as amended from time to time.

(2) Every low-speed vehicle shall be permanently marked with a slow-moving vehicle identification emblem (SMV emblem) that conforms to section 6 of American National Standard *Slow Moving Vehicle Identification Emblem (SMV Emblem)*, ANSI/ASAE S276.6, published in January 2005 by the American Society of Agricultural Engineers.

(3) However, section 6 of ANSI/ASAE S276.6 is modified as follows:

(*a*) the dimensions of the SMV emblem may be greater than those specified in Figure 1 as long as each dimension is increased so that it has the same relation to the other dimensions as the dimensions specified in the Figure have to each other;
and

(*b*) the recommendation in paragraph 6.2.6 is mandatory.

(4) The SMV emblem shall be mounted in accordance with paragraphs 7.1.1 and 7.1.2 of ANSI/ASAE S276.6. It shall be mounted on the centreline or as near to the left of the centreline of the vehicle as practicable, not less than 500 mm but not more than 1500 mm above the surface of the roadway.

(5) The SMV emblem shall be affixed so that the view of the emblem is not obscured or obstructed by any part of the vehicle or any attachment designed for the vehicle.

The Gazette writes: ..” Since there are virtually no safety or other performance requirements related to the LSV class, it is important that the vulnerable character of LSV is clearly stated in the vehicle class definition.”

The Gazette also writes: … “Initial consultations with the provinces and territories regarding the new definition brought to light a concern that it is important for an LSV to be identified as a slow-moving vehicle. To accomplish this, the Canadian safety standard is amended to require LSV to be permanently marked with a slow-moving vehicle emblem. Such identification will raise other road users’ awareness of the vulnerable character of low-speed vehicles, their comparatively inferior acceleration, and limited top speed of LSV. This requirement is in keeping with other vehicles that travel at speeds of less than 40 km/h such as farm tractors.” …

19 APPENDIX B: EFFECT OF LOW SPEED VEHICLES ON MIXED TRAFFIC FLOW

Effect of Low Speed Vehicles on Mixed Traffic Flow

for

National Research Council Report on Low Speed Vehicles

for

Ministry of Transportation Ontario

October, 2008

by

Harmelink Consulting Inc.

NRC STUDY ON
LOW SPEED VEHICLES
October, 2008

Report Section
Effect of Low Speed Vehicles on Mixed Traffic Flow

Effect of Low Speed Vehicles on Mixed Traffic Flow

1. Introduction

As noted elsewhere in this report, the Canada Motor Vehicle Safety Regulations, largely in harmony with the U.S. standard, define Low-Speed Vehicles (LSVs) as vehicles that:

- Are designed for use primarily on streets and roads where access and the use of other classes of vehicles are controlled by law or agreement;
- Travel on four wheels;
- Are powered by an electric power train and travel up to 40 km/h on a paved level surface, and attain a speed of 32 km/h, but not more than 40 km/h in a distance of 1.6 km on a paved level surface;
- Do not use fuel as an on-board source of energy; and
- Have a gross vehicle weight rating of less than 1,361 kg.

To heighten other drivers' awareness of the character of LSVs (low acceleration and limited top speed), an LSV must be permanently marked with a slow-moving vehicle identification emblem, mounted on the centreline of the vehicle or close to it on the left, and not less than 500 mm or more than 1500 mm above the surface of the roadway.

The LSV does not have the same legal status as a passenger car, which is a class that must meet a far greater number of safety standards. An electric passenger car must meet the standards required by the Motor Vehicle Safety Act (MVSA) that apply to all passenger cars.

Transport Canada's "Low-speed vehicle information sheet", available on their web site, states that "LSVs were established as a separate class of vehicles by the U.S. Department of Transportation in 1998. They were originally intended for short shopping trips and social and recreational use, primarily within retirement or other planned, gated communities". Some might interpret this to suggest that the federal government feels that these vehicles should not be used on public roads in mixed traffic. "In July, 2000, the LSV class was created in Canada. Canada's LSV class was created to allow companies to make, import and sell these small, lightweight limited purpose vehicles that could not meet the safety standards applied to larger and heavier mainstream vehicles that operate on public roads".

"Transport Canada regulates the manufacture and importation of LSVs to promote the safety of the travelling public and to reduce the risk of death, injury and damage to property and the environment, through the Motor Vehicle Safety Regulations (MVSR), including the Canada Motor Vehicle Safety Standards (CMVSS). Provinces and territories regulate vehicle licensing and have authority to determine the appropriate operating environments for LSVs via their Highway Traffic Acts and similar legislation". This includes the regulation of their use on public roads. The issue of licensing LSVs for use on public roads has also arisen in the U.S. As of January, 2007, approximately 25 of the states now permit use of LSVs on public roads (with varying degrees of restrictions) with normal posted speed limits up to 35 mph (about 55 km/h).

The purpose of this section of the report is to investigate how well LSVs can integrate with mixed traffic. Safety aspects of LSVs are addressed in other sections of this report.

2. Scope of Investigation

For safety reasons, and because LSVs are not required to meet the same safety standards as other road vehicles, Transport Canada has limited LSV top speed to 40 km/h. Ironically, such speed restrictions may present safety hazards of their own. Many traffic safety studies over the years have shown that increased dispersal of vehicle speeds (greater range of speeds) leads to greater collision risk. The more compressed the vehicle speed range, the safer the roads tend to be. The further an individual vehicle's speed deviates from the average speed on the road, the higher the probability of collision. (See The Institute of Traffic Engineers **Transportation and Traffic Engineering Handbook**, 1976, Figure 4.20, Vehicular involvement (in collisions) vs. Vehicular speed, for urban streets.) Consequently, in mixed traffic, LSV collision <u>severity</u> is reduced by limiting top speed and performance, but the likelihood of collision <u>occurrence</u> is increased by such limitations, because the presence of LSVs on the road widens the range of vehicle speeds, and an LSV, by necessity, must travel more slowly than the average speed on the road.

In this investigation, roads with normal regulatory posted speed limits of 50 km/h are examined. This is the class of public roads that most closely matches the limited performance of LSVs. In Canada, few public roads have a normal regulatory posted speed limit of less than 50 km/h. Limits lower than 50 km/h are found principally in school zones, where the speed limit is typically 40 km/h, and in parks or park-like settings.

It is noted that traffic operating speeds often exceed the normal regulatory posted speed limits. It is often good practice to set the normal regulatory posted speed limit at about the 85th percentile speed, that speed which is exceeded by only 15% of the drivers. This is not always done, however. For purposes of this study, a typical 85th percentile speed on a road posted at 50 km/h is taken to be about 60 km/h.

Speed limits of 50 km/h are most common on roads in urban areas, but these roads may vary considerably, from low volume two-lane residential streets to high volume multi-lane collectors and arterials in the urban street network.

As a result, the investigation needs to examine the effect of LSVs on mixed traffic flow on the following types of road:

- Two-lane roads (range of volumes)
- Multi-lane roads (range of volumes)

The investigation considers the effects of LSV acceleration, top speed, and braking characteristics.

Relevant to the consideration is the fact that the Canadian road system accommodates and permits a wide range of road users, including conventional passenger vehicles, trucks, buses, tractors, motorcycles, scooters, power-assisted bicycles, bicycles and pedestrians, and in some locales, horse-drawn vehicles. Many of these vehicle classes cause “friction” or “interference” with passenger vehicles, to a greater or lesser degree. In urban areas, pedestrians are usually on sidewalks, and do not interfere with motor vehicle traffic except at intersections. Scooters, power-assisted bicycles, and bicycles are low speed vehicles, but usually do not occupy a full traffic lane. Motorcycles are higher-powered vehicles, and have no difficulty keeping up with normal traffic flow. Tractors and horse-drawn vehicles might be considered the closest to LSVs in terms of speed and acceleration characteristics, but are usually not found in urban areas. Trucks are found everywhere as a normal part of traffic flow. Their maximum speed is not a limitation, but their acceleration and braking performance is considerably less than those of passenger vehicles. As a result, trucks are usually considered, in capacity analyses, to have a passenger car equivalence (PCE), so that for example a truck with a PCE of 3 would be considered to equal three passenger vehicles in terms of its effect on capacity.

3. LSV Acceleration Characteristics and Effect on Traffic Flow

The Idaho National Laboratory conducted a study for the U. S. Department of Energy in 2006, titled **Guidelines for the Establishment of a Model Neighborhood Electric Vehicle (NEV) Fleet**, by Brayer, Karner, Morrow and Francfort. This study established an acceleration performance goal for LSVs of 0-20 mph (0-32 km/h) in 6.0 seconds, for a payload of 332 pounds (150 kg) (two passengers). The report includes data sheets on numerous LSVs as currently available. Their web site, http://avt.inl.gov/nev.shtml, contains data sheets on five more recent models of LSVs, manufactured by GEM, Miles and Zenn in 2007 or 2008. The five 2007 and 2008 vehicles were able to achieve the acceleration performance goal of 6.0 seconds. (Some of the older vehicles could not achieve this goal, and had acceleration times from 0-20 mph ranging typically from 7 to 10 seconds, with a few vehicles having times as long as 25-30 seconds.) Some vehicles on the market could achieve 0-20 mph in 4.5 seconds or even less.

Extrapolating the vehicle performance curves in the above-cited report to 25 mph (40 km/h) yields a typical acceleration time from 0-25 mph (0-40 km/h) of about 8 seconds for those vehicles that could achieve an acceleration time from 0-32 km/h in 6.0 seconds. The average acceleration may be calculated using the formulas:

$s = \frac{1}{2}(u+v)t$ (Equation 1) and $s = ut + \frac{1}{2}at^2$ (Equation 2)

where s = distance travelled (feet)
v = final velocity (feet/sec)
u = initial velocity = 0.
a = average acceleration (feet/sec/sec or fpsps)
t = acceleration time (sec)

Equation 1 is used to calculate the distance travelled. Equation 2 is then used to calculate the average acceleration. Solving for ‘a’ yields $a = (2s)/t^2$

For 0-20 mph in 6.0 seconds, the distance travelled is ½ vt = 0.5*20(88/60)*6.0 = 88 feet. The average acceleration is (2*88)/(6*6) = 4.89 fpsps = 3.33 mph/s (= 1.49 metres/sec/sec = 5.36 km/h/s).

For 0-25 mph in 8.0 seconds, the distance travelled is ½ vt = 0.5*25(88/60)*8.0 = 147 feet. The average acceleration is (2*147)/(8*8) = 4.59 fpsps = 3.13 mph/s (= 1.40 metres/sec/sec = 5.04 km/h/s)

The Institute of Traffic Engineers **Transportation and Traffic Engineering Handbook**, 1976, Table 2.4, shows typical maximum motor vehicle acceleration rates from standing starts for various vehicle types. The information in Table 1 is extracted from that table, except for the last line for LSVs, taken from the information shown above.

It may be seen that the average maximum acceleration rate of the most recent LSVs is about three times as high as that of heavy trucks. The comparison is actually slightly worse than that for LSVs, as the acceleration rate for the other vehicles, to the same LSV top speed of 40 km/h, is somewhat higher than the rates shown in Table 1 for 48 km/h. However, the acceleration rate for LSVs is significantly better than that for heavy trucks, and about 60% that of a composite car or pickup.

The maximum acceleration rate to 40 km/h for the LSVs is therefore taken to be about three times that of heavy trucks, to the same speed. (A few of the new model LSVs can accelerate somewhat faster than this.) This is not likely to be of major significance in affecting road capacity, as it does not last very long, and it will probably be more likely for LSVs to accelerate at the maximum rate than for heavy trucks. This minimal effect of LSV acceleration on traffic flow is unlikely to be worse at intersections, until maximum speed of the LSVs is reached. (The limited LSV maximum speed is likely to be more significant than the LSV acceleration rate.) This does suggest, however, that it will be desirable to license for use on public streets only those LSVs which can achieve the performance goal of 0-20 mph in 6.0 seconds.

Residential streets usually have a relatively low traffic volume, and few trucks. On more important roads in the network (collectors and arterials), even those with low speeds, traffic volumes and truck volumes may be higher. Even in central business areas, trucks may be quite common, as pickup and delivery operations depend on them. Where the LSV acceleration rate is likely to be most problematic (though even then, it is not likely to be as serious as the limited maximum speed) is on two lane roads with high traffic volumes and few trucks. On such roads LSVs may more likely be seen as restricting traffic flow than on roads where motorist perception may attribute restricted flow to trucks as well as (or instead of) LSVs.

Table 1
Maximum Acceleration Rates for Various Vehicle Types

Vehicle Type	Typical Maximum Acceleration Rate on Level Roads, to 30 mph (48 km/h)	
	mphps	km/h/s
Large Car	7.0	11.3
Intermediate Car	5.0	8.0
Compact Car	5.0	8.0
Small Car	4.0	6.4
Composite Car	5.0	8.0
Pickup Truck	5.0	8.0
Two-axle, Single Unit Truck	1.0	1.6
Tractor semi-trailer Truck	1.0	1.6
LSV (best performance)	3.1 to 25 mph	5.0 to 40 km/h

In 2002, the Centre for Electric Vehicle Experimentation in Quebec (CEVEQ) conducted a pilot study for Transport Canada, titled **Assessment of Low Speed Electric Vehicles in Urban Communities: Pilot Project**, Report TP 13942E. Various types of low speed electric vehicles were made available to residents of St. Jérôme, Quebec, who drove them on both two-lane and multi-lane roads. Focus groups and questionnaire surveys were used to gauge the response to LSVs of both LSV drivers and other road users. Neither group identified low acceleration rates as a problem or nuisance. The LSV drivers were actually quite pleased with the acceleration rates of the vehicles.

This CEVEQ report also has some good recommendations to make LSVs more suitable/acceptable for use on public roads, directed to the federal government, provincial governments, municipal governments and manufacturers. See also Section 6 below.

4. LSV Speed Characteristics and Effect on Traffic Flow

By federal law, the maximum speed of LSVs manufactured in Canada or imported into Canada is set at 40 km/h, primarily for safety reasons. The fact that they would be licensed to operate without meeting many of the safety standards required of conventional passenger cars means that the consequences of even a moderate-speed collision could be severe. For this reason, many of the U. S. states which permit their use in mixed traffic limit their use to roads with a maximum normal regulatory posted speed of 35 mph (56 km/h). The Ministry of Transportation Ontario is contemplating licensing LSVs for use on public roads with a maximum speed limit of 50 km/h (30 mph). The terms of reference of this study call for an assessment of the effects of LSVs on traffic flow on streets where their use may be permitted.

As noted in Section 2, ironically, such maximum speed restrictions may present safety hazards of their own. Many traffic safety studies over the years have shown that increased dispersal of vehicle speeds (greater range of speeds) leads to greater collision risk. The more compressed the vehicle speed range, the safer the roads tend to be. The further an individual vehicle's speed deviates from the average speed on the road, the higher the probability of collision. (See The Institute of Traffic Engineers **Transportation and Traffic Engineering Handbook**, 1976, Figure 4.20, Vehicular involvement (in collisions) vs. Vehicular speed, for urban streets.) Consequently, in mixed traffic, LSV collision severity is reduced by limiting top speed and performance, but the likelihood of collision occurrence is increased by such limitations, because the presence of LSVs on the road widens the range of vehicle speeds, and an LSV, by necessity, must travel more slowly than the average speed on the road.

As described in Section 3, the acceleration of high-performance LSVs is about three times that of heavy trucks, and is unlikely to have much impact on traffic operations. However, the maximum speed of LSVs is a different matter. The maximum speed of LSVs is markedly less than that of most other vehicles on urban roads, and they are likely to have significantly more impact on traffic flow than other low-speed vehicles (bicycles, scooters) because they occupy the better part of the lane width.

The fact that federal regulations limit the maximum speed of LSVs to 40 km/h does not mean that they can all attain that operating speed, although all the newer models come very close. The 2007 and 2008 data for the LSVs included in the Idaho National Laboratory study cited above shows that maximum LSV speed may vary from 24.7 to 25 mph (39.8 to 40.2 km/h).

As noted above, the 85th percentile speed of vehicles on a road with speed limit of 50 km/h is taken to be about 60 km/h (with a mean speed of about 55 km/h). The mean maximum speed of a representative sample of LSVs is taken to be 40 km/h. The objective of this section is to determine, to the extent possible, the effect on capacity of 40 km/h LSVs in mixed traffic, the remainder of which traffic is travelling at 55 km/h (cars) and 50 km/h (trucks) respectively.

Many theoretical analysis and empirical traffic studies have been carried out over the last 50 years, and various editions of the U. S. Highway Capacity Manual have been published over that time period. Yet none of them directly address the situation at hand in a satisfactory manner.

A. Tzedakis of the Transport Department of the Imperial College of Science and Technology, London, UK, wrote a paper titled "Different Vehicle Speeds and Congestion Costs." A model was developed for the quantification of delay costs caused by slow-vehicle traffic to fast-vehicle traffic on a lane of a two-lane road. It is assumed in the model that overtaking is not possible. In the model, the speed of traffic does not depend upon the volume of traffic, that is, no speed-volume relationship is used. Analyses were carried out over a range of speeds, traffic volumes and road section lengths. Delay costs were calculated, using 1976 costs in pence, which makes them difficult to convert to current Canadian dollars. While it is not possible to derive relevant absolute delays and costs, Figure 1 from that paper illustrates the sensitivity of travel cost to variations in several key variables, such as fast vehicle speed, slow vehicle speed, traffic volumes, and road section length.

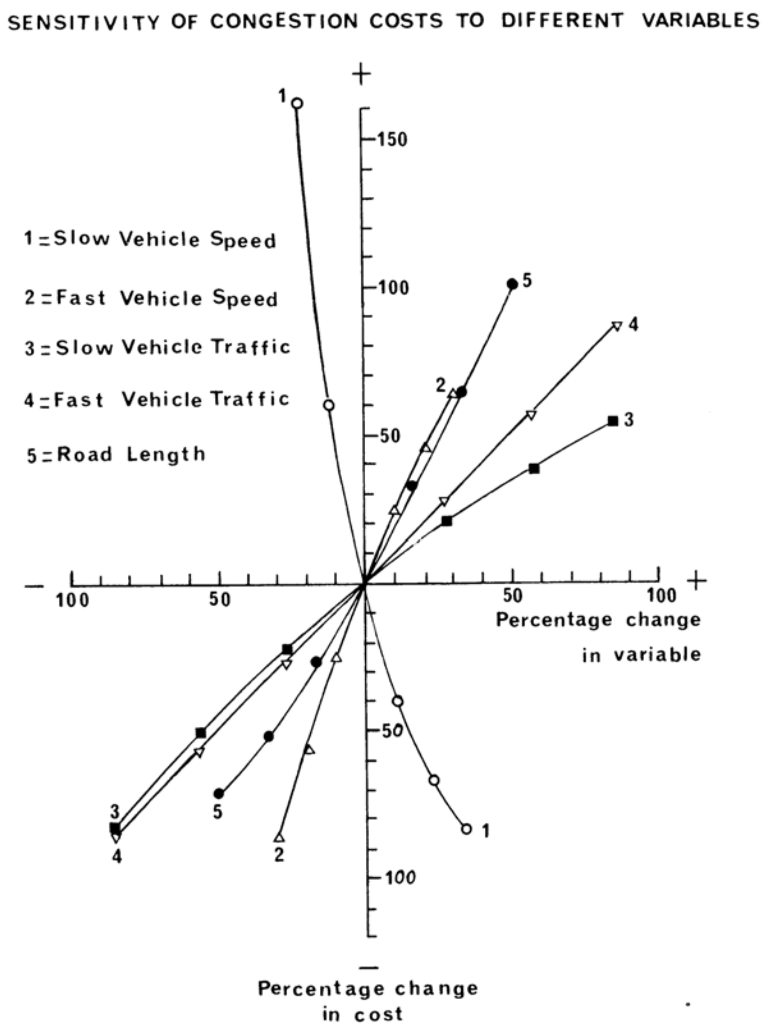

Figure 1 **Sensitivity of Congestion Costs to Different Variables (Source: Tzedakis)**

Figure 1 shows that, in this model, total congestion costs are highly sensitive to both the fast vehicle speed and the slow vehicle speed and road section length, and somewhat less, but still quite, sensitive to slow vehicle traffic volume and fast vehicle traffic volume. For example, using Curve 1 for Slow Vehicle Speed, the curve shows that if the speed is increased by 20%, the congestion cost is reduced by about 55%. The same curve shows that if the speed of slow vehicles is reduced by about 20%, the congestion cost is increased by about 100%. Curve 3 for Slow Vehicle Traffic volume shows that if the slow vehicle traffic volume is increased by 50%, the congestion cost is increased by about 35%; and if the slow vehicle traffic volume is decreased by 50%, the congestion cost is decreased by about 40%.

Jorge A. Laval and Carlos F. Daganzo of the Transportation Group, Department of Civil and Environmental Engineering, University of California at Berkeley wrote a paper in November, 2004, titled “Multi-lane Hybrid Traffic Flow Model: A Theory on the Impact of Lane-changing Maneuvers”. In this paper, they developed theories for analyzing not only the effect of lane-changing maneuvers at bottlenecks (freeway ramp merges and lane drops), but also examined the effect of moving obstructions travelling at a constant slow speed on long freeway sections. Such freeway analyses are clearly not directly applicable to a situation of LSVs on low-speed non-freeways (since for non-freeways neither the shape of the curve nor the slope of the curve is known), but they are illustrative of what effect such obstructions can have. The authors found that their model agreed quite well with available observations in the range where data were available, that is, at slow-vehicle speeds greater than 30 mph (about 50 km/h). There were no available data for slow-vehicle speeds of less than 30 mph, and hence the model could not be validated for these lower speeds. Their observed data (30 mph and higher) and model predictions (all speeds) are shown in Figure 2, taken from their paper.

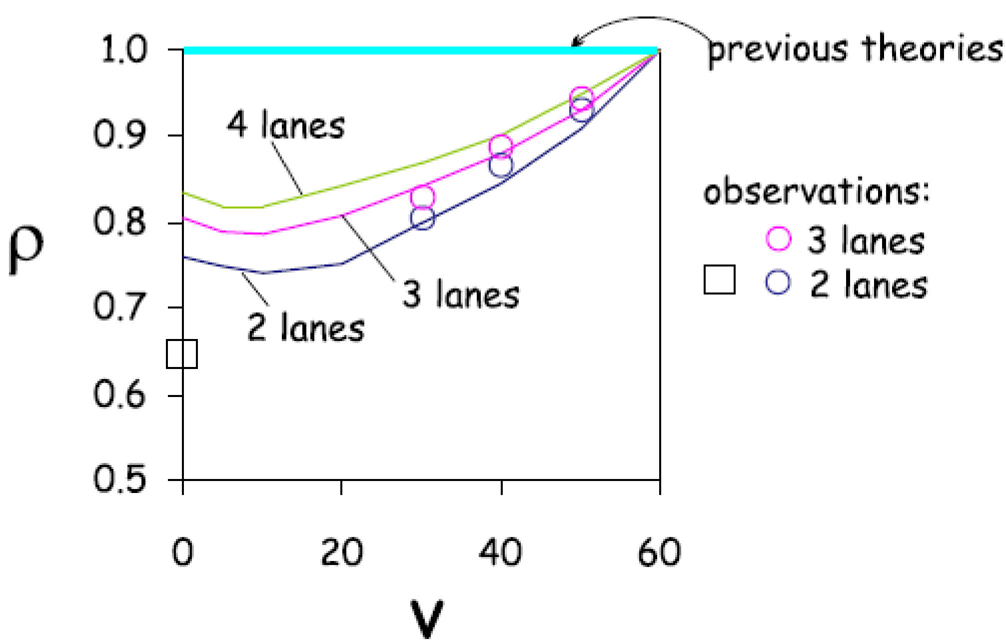

Figure 2 **Dimensionless Bottleneck Discharge Rate ρ as a Function of the Slow Vehicle Speed, V (mph)**
(Source: Laval & Daganzo)

The model results suggest that the effect of moving slow-vehicle obstructions on traffic flow on a four-lane freeway (two lanes per direction) would be a reduction of capacity somewhere between 20 % and 30 % (discharge rate of 70 % to 80% of normal capacity). Again, however, this is included here for illustrative purposes only.

Samuel W. Malone, Carl A. Miller and Daniel B. Neill wrote a paper in February, 2001, titled “Traffic Flow Models and the Evacuation Problem.” They examined, through the use of traffic flow models, various strategies for rapid evacuation from the South Carolina coast during times of hurricane threat. They used the models to examine, for both two-lane and four-lane highways, the effect on capacity of slow-moving vehicles at various proportions of the traffic flow. Again, however, the paper is not directly relevant to the LSV situation under consideration, since the high-speed vehicles on the four-lane highway were assumed to travel at 70 mph and low-speed vehicles were assumed to travel at 50 mph. In their models, the flow rate is decreased significantly by the presence of slow vehicles. If even 1% of the vehicles were slow, the flow rate decreased by 5%; if 5% of the vehicles were slow, the flow rate decreased by 15%. With 10% and 20% slow vehicles, the flow rates were decreased by 23% and 33% respectively. It is not possible to say how relevant these capacity decreases are to the 50 km/h LSV road situation.

M. M. Rahman, I. Okura, and F. Nakamura of the Department of Civil Engineering, Yokohama National University, Kanagawa, Japan, wrote a paper in December, 2003, titled "Effects of Rickshaws and Auto-Rickshaws on the Capacity of Urban Signalized Intersections". (Auto-rickshaws are low-speed motorized vehicles, probably the vehicles most similar to LSVs.) The authors examined the effect of these vehicles on congestion at signalized intersections in Dhaka, Bangladesh, and calculated the PCEs of these two types of vehicles. Somewhat surprisingly, they found that the PCE of auto-rickshaws at signalized intersections was about 0.4 at about 5% of the traffic volume, rising linearly to a PCE of 1.0 at 100% of the traffic volume. The discharge rate varied from about 1850 veh/hr/lane with no auto-rickshaws to about 2100 veh/hr/lane at 60% auto-rickshaws. The increase in capacity at intersections with increasing proportion of auto-rickshaws was attributed to the smaller size of auto-rickshaws (about half the length of cars) and the shorter headways between them. The typical speed and acceleration characteristics of auto-rickshaws are not stated in the paper, so it is not possible to say how similar these are to LSVs. Also, it is not known how transferable or applicable such findings might be to the effects of LSVs in Canadian mixed traffic. Still, the findings do suggest that capacity reductions caused by LSVs in mixed traffic are more likely to be caused by their low speeds than by their slightly lower accelerations.

Studies directly relevant to this application, that is, of the effects of significant volumes of LSVs on the capacity of relatively low speed two-lane and four-lane streets, have not been found in the literature, and may simply not exist because the use of LSVs to date in mixed traffic has been relatively rare.

For illustrative purposes, a few simulation runs have been run for this study, using the U.S. Federal Highway Administration (FHWA) Interactive Highway Safety Design Model (IHSDM). This model uses the TWOPAS microscopic traffic simulation model, the model that has been used for the last twenty years for the Highway Capacity Manual to analyze traffic flow on two-lane roads. The example runs have been run for the following data sets:

- 300 vph per direction (600 vph total), for LSV of 0% (baseline), 5% and 15%.
- 600 vph per direction (1200 vph total), for LSV of 0% (baseline), 5% and 15%.
- 900 vph per direction (1800 vph total), for LSV of 0% (baseline), 5% and 15%.

The truck percentage was set at 5% throughout. The desired speed of cars was set at 55 km/h, of trucks at 50 km/h, and of LSVs at 40 km/h. A straight, level road-section of 2.3 km length was assumed for the simulations. There were no no-passing zones in the simulations. The results of these sample simulations are shown in Table 2.

Table 2
Two-lane Road Simulation Results, using FHWA IHDSM Model
Illustrative, comparative example

Two-way Traffic Volume (vph)	LSV Percentage of Traffic Flow (%)	Average Travel Speed, (km/h)	Trip Time for 2.3 km (min/veh)	Total Delay over 2.3 km (min/veh)
600	0	51	2.7	0.16
600	5	48	2.8	0.22
600	15	47	3.0	0.28
1200	0	48	2.8	0.27
1200	5	45	3.0	0.44
1200	15	42	3.3	0.61
1800	0	45	3.0	0.47
1800	5	42	3.2	0.65
1800	15	40	3.5	0.78

- Straight, level road, 2.3 km long
- Desired car speed = 55 km/h
- Desired truck speed = 50 km/h
- Desired LSV speed = 40 km/h
- Standard deviation of speeds = 10% of desired speed for each class
- Truck percentage = 5% for all runs
- No-passing zones: None
- Directional traffic split: 50:50.

A few observations are as follows:

- The average speed drops significantly, even with the introduction of only a few LSVs; this could lead to significant frustration for drivers for other vehicles;
- At lower traffic volumes, the delay per vehicle increases by about 35% with 5% LSVs, and by about 75% with 15% LSVs. At higher traffic volumes, the delay per vehicle also increases by about 40% with 5% LSVs, and by about 65% with 15% LSVs, but with a higher base level of delay.
- As the traffic volume and LSV% increase, the average travel speed approaches the desired LSV speed, as expected.
- Further simulations would have been desirable, but project budget did not permit more extensive simulation model runs.

The most directly relevant information is that arising from studies of LSVs in real environments.

The **first** such report is **Field Operations Program – Neighborhood Electric Vehicle Fleet Use** by J. Francfort and M. Carroll of the Idaho National Engineering and Environmental Laboratory for the Department of Energy in July, 2001. The study examined 15 fleets operating a total of 348 LSVs in the U.S., to obtain data on vehicle use. The LSV fleets ranged in size from 2 to 82 vehicles; 56% were used on private roads, 32% on public roads and 12% on both public and private roads. The vehicles averaged 3,409 miles (5,488 km) per LSV annually. Most of the vehicles were operated in warm climates. The 15 fleet operators reported positive experiences with the LSVs. However, there were no comments, either positive or negative, about limitations in mixed traffic, and no data on the effects of the limited vehicle speeds and accelerations.

The **second** such report is the pilot study titled **Assessment of Low Speed Electric Vehicles in Urban Communities: Pilot Project**, Report TP 13942E, conducted for Transport Canada in 2002 by the Centre for Electric Vehicle Experimentation in Quebec (CEVEQ), cited above. Various types of low speed electric vehicles were made available to residents of St. Jérôme, Quebec, who drove them on both two-lane and multi-lane roads. During a 12-week period, seven LSVs provided by four manufacturers were driven a total of 6,067 km. The study was used to gather public opinion on the risks relating to using these vehicles in normal city traffic. A total of 53 participants from various backgrounds drove the LSVs for one-week periods and filled out an evaluation questionnaire. In addition, 126 other road users, including police officers and taxi drivers, were given the opportunity to submit their impressions of how well these vehicles integrated into city traffic.

Sixty-four percent of the LSV drivers said that the LSVs did not go fast enough to keep up with the flow of traffic at all times. More specifically, 97% suggested that the top speed of the vehicles should be increased; 65% wanted a speed of 50 km/h. However, 47% of the other road users felt that 40 km/h was an appropriate speed in the city. A total of 77% of the LSV drivers were pleasantly surprised by these small cars. Acceleration, attractiveness and vehicle handling were seen as the main strong points. Vehicle range was the most criticized aspect. In summary, 83% of the LSV drivers and 89% of the other road users felt that LSVs had their place in the city. Figure 3 shows some of the driver responses regarding drivability on various types of roads.

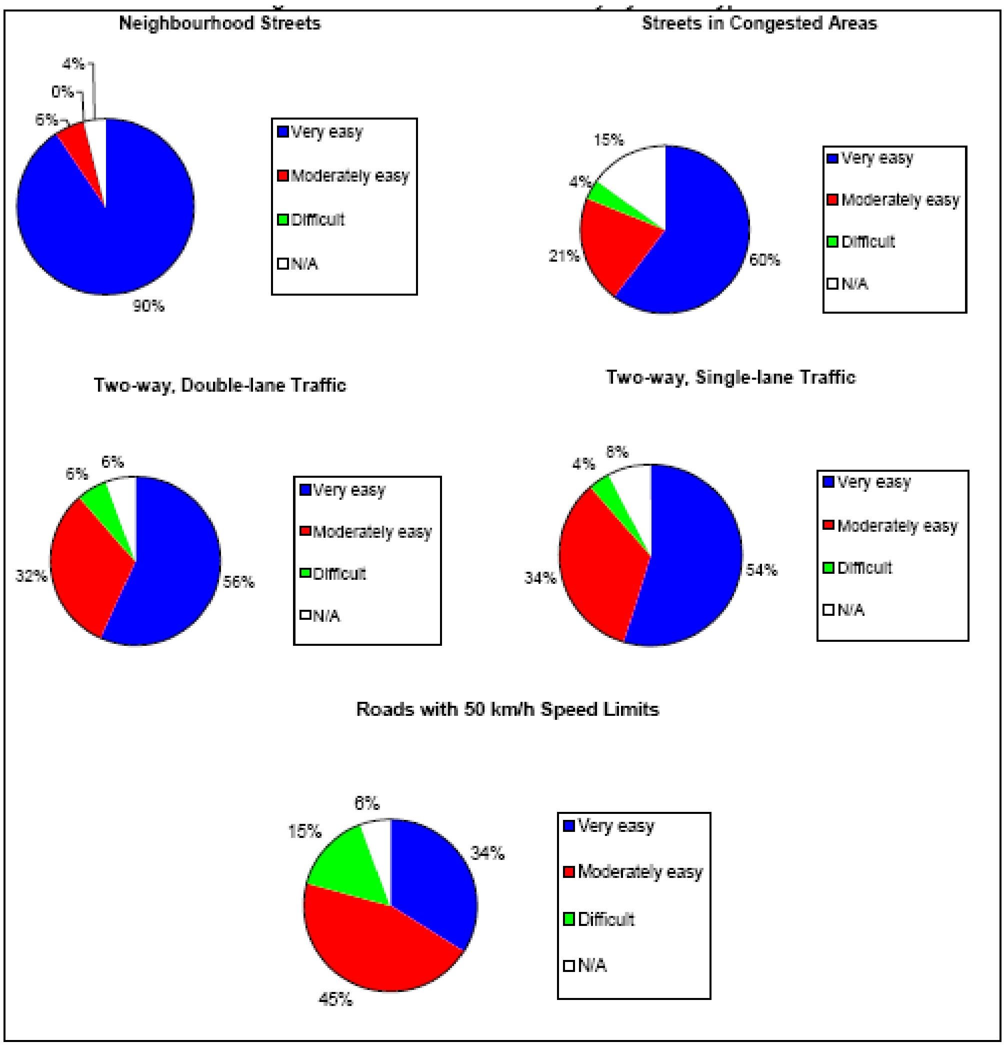

Figure 3 Assessment of Drivability by Road Type (Source: Transport Canada CEVEQ Report, St. Jérôme, PQ)

(Note: the roads with 50 km/h speed limits were major arterial roads, often in outlying urban areas)

According to the focus group participants, streets with two-way single-lane traffic (two-lane roads) were more difficult to drive on than streets with two-way, double-lane traffic. (four-lane roads). On two-lane roads, LSV drivers felt pressured by the motorists behind them who were having a harder time trying to pass them. In these situations, they felt that they should move over to the right, which was potentially hazardous. This raises two other points not addressed in the report: (1) the availability or unavailability of suitable places for LSV drivers to pull over to let others pass; and (2) the ease or difficulty for LSV drivers to re-enter the traffic stream, the difficulty of which will increase with increasing traffic volume. However, the same drivers said that two-lane streets in residential neighbourhoods and streets with traffic lights at short intervals were not a problem. The concerns about speed limitations occurred in three types of situations:

- on major thoroughfares;
- when traffic was moving at a fast rate;
- on hills, where LSVs slowed down to a speed from 20-30 km/h.

The LSV drivers gave various reasons to support their suggested speed increase:

- It would avoid the risks of dangerous passing;
- 40 km/h is fast enough in a residential area, but not fast enough on busier streets;
- The vehicle is safe enough to be driven at city speed limits;
- It's the usual speed limit in the city;
- It would enable the vehicles to keep up with traffic better;
- Other drivers following us at 40 km/h when the speed limit is 50 km/h are sometimes impatient.
- They also suggested that the vehicles should be able to reach 40 km/h at all times, including hills.

Most of the LSV drivers wanted to increase the speed, whereas half of the road users did not find LSVs to be overly slow vehicles that were disruptive. This may be because there were relatively few LSVs on the streets. If their number were to grow, it could possibly lead to intolerant attitudes on the part of road users, especially during rush hour.

Regarding the last point above, that vehicles should be able to reach 40 km/h at all times, including hills, this would appear worth further investigation, and in fact, is one of the recommendations to manufacturers made in the study report. It has been said that LSV speed reductions on moderate grades are not a question of insufficient power, but rather that the control system is based on controlling (limiting) the power output. A power output set for level terrain will not be sufficient to maintain speed on an upgrade. If the control system could be set up to maintain constant speed (such as conventional cruise control) rather than constant power, this might address the concern of speed reduction on hills.

The **third** such report is **The NEV Transportation Plan** of the City of Lincoln, California, June, 2006. This is a more comprehensive approach to LSVs than in the first and second studies, as it is a broad-based plan to encourage the use of LSVs by planning the city so as to accommodate them. The objective is city-wide NEV routes that would "enable any resident to travel from his/her home to Downtown Lincoln." An NEV-ready city must have the necessary infrastructure, including charging facilities, pavement markings, signage, parking, and education to safely accommodate LSV travel. The plan envisions three types of LSV routes:

- Class I LSV Route: These routes provide a completely separate right-of-way for the exclusive use of LSVs, pedestrians and bikes with cross-flow minimized. The minimum paved width for a Class I route is 12 feet (3.65 m) (for two-way travel) with a minimum two-foot (600 mm) wide graded area provided adjacent to the pavement. Bicycles may also use these lanes.

- Class II LSV Route: These routes are designated as a separate striped lane adjacent to traffic. There is one striped lane for each travel direction. The desirable minimum width for a Class II LSV route is 7 feet (2.15 m). Bicycles may also use these lanes.

- Class III LSV Route: These routes provide for shared use with automobile traffic on streets with a posted speed limit of 35 mph (56 km/h) or less. This will include all residential streets.

The city also examined its road network in terms of average daily traffic (ADT) volume level of service thresholds, and adopted the Highway Capacity Manual's Level of Service C (LOS C) as their minimum criterion for urban area intersections and roadways. The feasibility of allowing LSVs to travel on area roads was evaluated by comparing the projected future 2025 ADT traffic volumes, street by street, with the daily volume LOS thresholds shown in Table 2. LSVs will not be permitted on those roads where the projected 2025 ADT traffic volume exceeds the values in Table 3.

Table 3
Average Daily Traffic Volume Level of Service Thresholds
City of Lincoln, California

Facility Type	Average Daily Traffic Volume Threshold Level of Service C (veh/day)
Two-lane Street	**12,000**
Two-lane Conventional Highway	**7,900**
Four-lane Undivided Arterial	**24,000**
Four-lane Divided Arterial	**27,000**

The report also defines LSV signs and pavement markings and where they are to be located.

It is not the purpose of this report to suggest that it is these specific ADT Level of Service criteria that should be used. If the findings on capacity reductions caused by slow-moving vehicles, cited above, are even approximately correct (ranging from a 5% capacity reduction for 1% slow-moving vehicles, to a 33% capacity reduction for 20% slow-moving vehicles, and a speed differential of 20 mph (32 km/h)), then a different threshold than LOS C might be considered. LOS C may be a suitable criterion where there is only a low percentage of LSVs, as they would probably not have a major effect on capacity. However, LOS B might be a more suitable criterion, for example, where the LSV percentage is 15% or higher, as the presence of so many LSVs might be sufficient to bump the Level of Service down to C or even D. The approach is sound, however. It is recommended that municipalities considering permitting the use of LSVs on their streets use this approach or one similar to it, to identify those streets where LSVs will be permitted in mixed traffic.

In summary, based on available information, the following recommendations are made:

1. Two-lane Streets

Permit LSV operation in mixed traffic on two-lane streets with a maximum posted speed of 50 km/h, provided the projected future time horizon ADT does not exceed a threshold traffic volume for two-lane roads as determined by the road authority or the Level of Service C traffic volume as shown in Table 3. Many of these streets will be residential streets, with relatively low traffic volumes, though some two-lane streets will have significantly higher traffic volumes. On higher volume two-lane streets, with few passing opportunities, LSVs may reduce the capacity of the road. This is not likely to be a problem if the proportion of LSVs to total traffic is low, but is likely to be a problem if this proportion is high. The worst situation will arise if the split of LSVs to conventional cars is 50:50. The problem can be ameliorated to some extent if the road has some space at the edge of the roadway where LSVs can pull over to let faster vehicles pass.

2. Two-lane Conventional Highways

Permit LSV operation in mixed traffic on two-lane conventional highways with a maximum posted speed of 50 km/h, provided the projected future time horizon ADT does not exceed a threshold traffic volume for two-lane highways as determined by the road authority or the Level of Service C traffic volume as shown in Table 3.

3. Four-lane Undivided and Divided Arterials

Permit LSV operation in mixed traffic on four-lane streets with a maximum posted speed of 50 km/h, provided the projected future time horizon ADT does not exceed a threshold traffic volume for four-lane roads as determined by the road authority or the Level of Service C traffic volume as shown in Table 3. At low traffic volumes and/or low percentages of LSV traffic, the LSVs are unlikely to contribute significantly to congestion. As traffic volumes and the percentages of LSVs increase, the risk of congestion increases. At high traffic volumes and high percentages of LSVs, the risk of congestion is substantial. The advantage over two-lane roads is that faster vehicles can use the passing lane to overtake the LSVs. Where LSVs are permitted to operate on four-lane roads, it is recommended to restrict the LSVs to use of the right lane, except where left-turns need to be made.

A further point for consideration is as follows. The federal government, through Transport Canada's Motor Vehicle Safety Regulations, establishes technical requirements and restrictions for original equipment manufacturers' (OEMs') vehicles, that is the vehicles as manufactured. The provincial governments (and to some extent, municipal governments) by legislation or by-law regulate the licensing, requirements and operation of vehicles as they are used on the road. If vehicle modifications are permitted by the province, for example, the vehicle on the road may differ in some respects from the vehicle as manufactured. Some enterprising parties have developed modifications to LSVs that will enable their operation at higher speeds, such as 55 km/h rather than 40 km/h as defined in the federal standards. This would address the desires of many LSV drivers for higher speeds, but could expose such drivers to greater hazard in case of collision, since LSVs do not need to meet all of the safety standards imposed on higher speed vehicles. It will be up to the provinces to decide how best to regulate modifications to and operation of LSVs.

5. LSV Braking Characteristics and Effect on Traffic Flow

Somewhat curiously, the federal Motor Vehicle Safety Regulations do not contain any specific requirements for service brakes in LSVs, but do require that LSVs have a parking brake. The matter of service brakes is covered by provincial Highway Traffic Acts rather than by federal standards. The Ontario Highway Traffic Act, for example, addresses vehicle brakes in two places, Section 64 and Regulation 587.

Section 64 (1) states the following:

> Every motor vehicle, other than a motorcycle, when driven on a highway shall be equipped with at least two braking systems, each with a separate means of application and effective on at least two wheels, one of which shall be adequate to stop the vehicle as required by regulations made by the Ministry and the other of which shall be adequate to hold the vehicle stationary.

Regulation 587 (3) states the following:

> The brakes required by Section 64 of the Act and this Regulation shall be adequate to stop the vehicle...referred to in column 1 of the Table within a distance not greater than the distance set opposite the vehicle...in column 2 while being operated at a rate of speed of twenty miles per hour (32 km/h) on a dry, smooth, hard asphalt or other paved surface free from loose material and having not more than 1 per cent gradient.
>
> Under such conditions, Regulation 587 (3) requires a motor vehicle having a seating capacity for less than 10 persons to be able to stop within a distance of 25 feet (7.6 m).

The **Neighborhood Electric Vehicle Technical Specification** produced by NEV America in 2007 requires brakes, but says little about them, except to state that the braking effort for converted vehicles should be similar to OEM models of comparable size and weight.

Performance specification sheets for a range of LSVs show that the braking distances from 20 mph (32 km/h) range from about 18 to 26 feet (5.5 to 7.9 m), and they all meet or almost meet the Ontario requirement of a braking distance of 25 feet. (Note that Ontario HTA Regulation 587 permits some types of trucks a braking distance of 50 feet from 20 mph, double the braking distance required of most passenger vehicles.)

The average deceleration rate corresponding to the regulated braking performance may be calculated using one of the standard equations of motion:

$v^2 = u^2 + 2as$ (Equation 3)

where v = final velocity (feet/sec) = 0
u = initial velocity = 20 mph (29 fps).
a = average acceleration (feet/sec/sec or fpsps)
s = distance = 25 feet (7.6 m)

$a = -(u^2)/2s = -(29*29)/(2*25) = -841/50 = -16.8$ fpsps $= -16.8/32.2$ g $= -0.52$ g

A braking distance of 25 feet from 20 mph (7.6 m from 32 km/h) corresponds to an average deceleration rate of about 0.52 g, somewhat more than double normal braking rates. (See The Institute of Traffic Engineers **Transportation and Traffic Engineering Handbook**, 1976, Table 2.7).

Consequently, in normal traffic flow, most current LSVs exhibit satisfactory braking performance, since they meet provincial braking requirements for most passenger vehicles and since heavier vehicles are permitted longer braking distances. Braking performance of most current LSVs is not expected to adversely affect traffic flow.

6. Strategies for Mitigating Risks

The key issue is whether MTO and other road authorities wish fundamentally to discourage or encourage the use of LSVs in mixed traffic. The first decision is whether or not to permit the use of LSVs on public roads. The second decision, if it is decided to permit their use on public roads, is whether to discourage or encourage their use (by either design or indifference).

Some might feel that one approach to mitigating or minimizing risks would be to discourage the use of LSVs in mixed traffic. Just as one comic commented that the safest roads are those with no traffic, so another comic might suggest that the safest roads are those with no LSVs, or at least as few as possible. The fact that the LSV maximum speed is limited to 40 km/h (albeit for good safety reasons) may itself discourage the use of LSVs in mixed traffic. Another approach, while it might appear to encourage the use of LSVs, would be to permit the use of LSVs on low speed roads, but without giving any consideration to the connectivity of such road sections to permit LSV travel to multiple desired destinations. A municipality might then have a number of isolated or partly connected street sections where LSVs could be operated, but there would be no comprehensive network plan to facilitate the use of LSVs. This could have the effect of discouraging LSV use rather than encouraging it.

The other approach would be to encourage the use of LSVs in mixed traffic by taking an approach similar to that in Lincoln, California, and to introduce measures that will facilitate the use of LSVs because of the benefits that they provide. Claimed benefits for LSVs include the following (as listed in the City of Lincoln, California **NEV Transportation Plan**):

- LSVs are zero emission electric vehicles.
- LSVs improve air quality.
- The energy consumption of an LSV is less than 1/5 that of conventional automobiles, with a corresponding reduction in greenhouse gases.
- LSVs provide freedom and continued mobility for aging or impaired drivers.
- LSVs are affordable.
- LSVs encourage use of existing public transportation.
- Accommodating LSVs is more effective and less costly than dial-a-ride programs for unmet transit needs.
- LSV routes can double as bicycle routes if properly designed.

As noted in Section 4, the City of Lincoln developed a broad-based plan to encourage the use of LSVs by planning the city so as to accommodate them. The objective is city-wide NEV routes that would "enable any resident to travel from his/her home to Downtown Lincoln." An NEV-ready city must have the necessary infrastructure, including charging facilities, pavement markings, signage, parking, and education to safely accommodate LSV travel. To develop and achieve a route network amenable to LSVs, the city identified three classes of LSV routes, as outlined in Section 4: Class I routes (separate right-of-way for use of LSVs, pedestrians and bicycles, 3.65 m wide for two-way travel); Class II routes with a separate striped lane on each side of the road, 2.1 m wide), and Class III routes (shared use with mixed traffic on roads with a speed limit of 35 mph or less).

The Transport Canada study conducted by CEVEQ, referenced earlier in Section 4, made the following recommendations to governments at various levels, as guidelines for LSV use and for facilitating, promoting and regulating the use of LSVs:

8.1 Recommendations to Government Authorities

8.1.1 Federal Government

- Require that LSVs be able to maintain a minimum speed (32 km/h) in hilly conditions.
- Require that a positive wheel-lock (park system) be installed in LSVs to prevent the wheels from turning when the vehicle is stopped.
- Require that windshield wipers be installed on LSVs.
- Require that LSVs with doors (even removable, plastic doors) be equipped with adequate ventilation and defogging systems.
- Conduct studies to assess the impact of increasing the top speed of LSVs to 50 km/h.

8.1.2 Provincial Government

- Authorize the on-road use of LSVs in zones with 50 km/h or lower speed limits, except in areas where actual known speeds of traffic are higher than authorized speeds (e.g., major arterial roads). ** See authors' note below.*
- Include municipalities in each step leading up to the authorization of LSV use on municipal road networks.
- Prepare a guide for municipalities to help them facilitate the introduction of LSVs in municipal areas (general information on LSVs, introduction criteria and signage).
- Prohibit the use of LSVs in winter, except in cases where LSVs are adapted to winter conditions (defrosters, windshield washers, winter tires, heaters, battery insulation, etc.)
- Require the same driver's licence and minimum age for LSVs as for passenger vehicles.
- Conduct a national awareness campaign focussing on safety and environmental benefits.
- Assess the possibilities of introducing tax incentives, such as lower registration fees and taxes, and promoting the implementation of a public battery-recharging infrastructure.

8.1.3 Municipal Authorities

- Determine which streets are safe in accordance with a guide prepared by Transport Quebec before allowing the on-road use of LSVs in municipal areas.
- Allocate reserved parking spaces for environmentally friendly vehicles.
- Allow free parking for LSVs in all city pay-parking lots.
- Set up battery-recharging facilities in strategic locations (downtown areas, shopping malls, etc.).
- Inform the public of the presence of LSVs in urban areas by erecting billboards that have been pre-standardized by provincial authorities.

* *The authors do not agree with this recommendation as stated, for the following reason: actual speeds are higher than the posted speed limit on almost all roads, hence following this recommendation would exclude LSVs from almost all roads. We would prefer a recommendation that excludes LSVs on roads where actual known*

speeds are significantly higher than posted speed limits, allowing for some flexibility, or where the 85th percentile speed exceeds 65 km/h.

The Transport Canada study also includes recommendations to manufacturers, which are not included here.

In addition, the following measures are recommended by the authors of this report:

- The province develop standards for LSV-related signs and pavement markings, for use throughout the province.
- The Motor Vehicle Safety Regulations require a minimum acceleration rate of 0-32 km/h in 6.0 seconds, and 0-40 km/h in 8.0 seconds.
- Municipalities develop networks of streets that will accommodate LSVs, to facilitate a greater array of destinations accessible by LSVs, so that networks will have connectivity rather than simply be a collection of isolated road sections.
- The province and municipalities require LSVs to use the right lane on multi-lane roads, except for left turns.

7. Summary: Effect of Low Speed Vehicles on Traffic Flow

The effect of low speed vehicles (LSVs) on mixed traffic flow, on roads with a posted speed limit of 50 km/h or lower, has been examined with regard to LSV acceleration, maximum speed, and braking capabilities.

Although LSVs have somewhat lower acceleration capabilities than other light vehicles (e.g., cars and pickups) in mixed traffic, this lower acceleration performance is unlikely to have an adverse effect on vehicle flow or congestion, especially since LSV acceleration rates are about three times as high as those of heavy trucks.

LSV maximum speed characteristics (restricted by law to 40 km/h) can have a significant effect on road congestion, depending on the proportion of LSVs as a percent of total traffic volume, and the volume of traffic itself. As LSV percentage and/or total traffic volume increase, congestion increases. Municipalities should permit LSVs only where the projected future ADT is less than a predetermined threshold (such as Level of Service C, for example) for each type of road. Where key road sections in a desired road network would preclude LSV use because of anticipated congestion concerns, municipalities should consider filling in those gaps by use of separate rights-of-way (Class I routes) or separated, adjacent LSV/bicycle lanes (Class II routes).

LSV braking rates are comparable to those on conventional passenger vehicles, and are not expected to adversely affect traffic flow.

The province needs to decide whether it wishes to encourage or discourage the use of LSVs, as noted in Section 6. If the province wishes to encourage the use of LSVs in mixed traffic on low speed roads, then the measures outlined in Section 6 should be introduced and implemented. Such measures require coordinated efforts with the federal and municipal levels of government. A coordinated approach among federal, provincial and municipal governments, and with the manufacturers, will afford the greatest likelihood and degree of success.

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