TP 14285E

Pilot Project for Evaluating Motorized Personal Transportation Devices

Segways and Electric Scooters

Prepared for
Transportation Development Centre
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by
Centre for Electric Vehicle Experimentation in Quebec (CEVEQ)

May 2004

CEVEQ

Centre d'expérimentation des véhicules électriques du Québec

Centre for Electric Vehicle Experimentation in Québec

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by
Pierre Lavallée
Centre for Electric Vehicle Experimentation in Quebec

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16. Abstract

The Centre for Electric Vehicle Experimentation in Quebec (CEVEQ) submitted a proposal to the Quebec Department of Transport and Transport Canada to set up and carry out Phase 1 of the Fly-Trottel Project, a pilot project for evaluating two types of motorized personal transportation devices (MPTDs): the Segway and the electric scooter.

This report contains information on these two MPTDs, including a general literature review on MPTDs that focussed on pilot projects carried out in the U.S. and Europe, and legislation in various countries regarding user safety, legal framework and traffic conditions. The report also contains an analysis of existing safety regulations for Segways and scooters, the legal framework for using these vehicles, traffic rules, and incidents involving these MPTDs. Alongside these activities, CEVEQ, supported by groups of experts and a group of 50 test participants, performed ergonomic, technical, and operational evaluations of the MPTDs on a closed indoor test track and in the laboratory.

In light of the results of the technical and ergonomic evaluations performed in Phase 1 of the project, it is recommended that Phase 2 be carried out to evaluate electric scooters and Segways in actual operating conditions in order to evaluate their reliability and safety in an urban environment, their social acceptability, and their ability to replace cars for short trips in urban communities.

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16. Résumé

Le CEVEQ a proposé au ministère des Transports du Québec et à Transports Canada de mettre en place et de réaliser la phase 1 du projet Fly-Trottel, un projet pilote d'évaluation portant sur deux appareils de transport personnel motorisés (ATPM), le Segway et la trottinette électrique.

Ce rapport contient des informations sur les ATPM, comprenant une compilation générale de la littérature sur les ATPM, incluant les projets pilotes réalisés aux États-Unis et en Europe; la réglementation dans divers pays sous l'angle de la sécurité des utilisateurs, du contexte légal et des conditions de circulation. Ainsi, ce rapport fait une analyse des réglementations existantes en lien avec la sécurité, le contexte légal d'utilisation, les règles de circulation et les incidents survenus. Parallèlement, le CEVEQ, appuyé par des groupes d'experts et un groupe composé d'une cinquantaine d'utilisateurs, a procédé à une évaluation ergonomique, technique et opérationnelle des ATPM lors d'essais en circuit fermé aménagé ou en laboratoire.

À la suite de résultats des évaluations techniques et ergonomiques réalisées lors de la phase 1 du projet, il est recommandé de réaliser une deuxième phase de ce projet portant sur l'évaluation de la trottinette électrique et du Segway en conditions réelles d'utilisation, afin d'évaluer notamment la fiabilité et la sécurité de ces appareils lorsqu'ils sont utilisés en milieu urbain; l'acceptabilité sociale des trottinettes et des Segway; et leur capacité à remplacer l'automobile pour les courts déplacements en milieu urbain.

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We also wish to thank the people who participated in the survey of motorized personal transportation devices (MPTDs), specifically Segways and electric scooters, for the enthusiasm and motivation they exhibited during the evaluation.

Finally, we salute the professionalism of our partners: PMG Technologies Test and Research Centre, Systèmes Humains-Machines inc. (SHUMAC) and the Industrial Design Department of the University of Quebec in Montreal (UQAM).

All of these contributions and expertise have been invaluable in helping CEVEQ carry out Phase 1 of the Fly-Trottel Pilot Project.

Foreword

The specific objective underlying the progress made in the past three decades to control pollution and energy consumption was to reduce the impact of transportation on health and the environment. However, this progress has often been more than offset by increases in the number, use and power of motor vehicles of various kinds. Developments in transportation are now placing numerous obstacles in the path of countries interesting in setting up sustainable development policies in this area.

Sustainable development defined in the simplest terms is "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." Sustainable transportation, the concrete expression of sustainable development in the transportation industry, is transportation "that does not endanger public health or ecosystems and meets mobility requirements."

Summary

The Centre for Electric Vehicle Experimentation in Quebec (CEVEQ) submitted a proposal to the Quebec Department of Transport and Transport Canada to set up and carry out Phase 1 of the Fly-Trottel Project, a pilot project for evaluating two types of motorized personal transportation devices (MPTDs): the Segway and the electric scooter.

Project activities included the gathering of information on MPTD pilot projects, the drafting of a summary report of these studies, and an analysis of existing safety regulations, the legal framework for using these vehicles, traffic rules, and incidents involving these MPTDs. Alongside these activities, CEVEQ, supported by groups of experts, performed ergonomic, technical and operational evaluations of the MPTDs on a closed indoor test track and in the laboratory. In addition to these evaluations, a survey of the MPTD users was conducted. An evaluation in actual-use conditions, i.e., Fly-Trottel Project 2, may be carried out in a later phase. The project partners and the Quebec Automobile Insurance Corporation (SAAQ) will decide whether to carry out such an evaluation once the results of Phase 1 on device safety are known.

Background summary

The transportation of goods and people is growing exponentially. The adverse effects of mobility (dependence on fossil fuels, pollution in all its forms, greenhouse gases, congestion, etc.) are known and well documented, and most of the world's governments, including those of Canada and Quebec, admit that urgent measures must be taken and environmentally sustainable solutions must be found.

Discussions about various visions of the best solutions for these problems are taking place around the world. One of these visions involves the use of advanced technology based on the "hyper car" concept, an ultra-light, ultra-streamlined vehicle equipped with a hybrid electric propulsion system that consumes ten times less fuel. Another vision advocates public transit as the basis for all sustainable solutions. In this search for alternative methods, MPTDs could help promote a modal transfer away from the automobile for short-distance trips. Electric scooters and Segways are two, environmentally friendly, "in" modes of transportation that facilitate effortless travel and could provide suitable transportation in urban communities. Legislators concerned about safety issues and congested public thoroughfares, especially in major cities, are responding prudently to the arrival of these MPTDs, especially given the controversy arising from their sharing of public roads with other road users and pedestrians.

Regulatory situation

In 2003, 40 American states and the District of Columbia[1] introduced regulations allowing Segways to be used on sidewalks, bicycle paths and some roads. We also drew up a list of about 40 projects in the United States and around the world where Segways were demonstrated or used.

In the United States, electric scooters are still not regulated under federal legislation. However, numerous accidents related to scooter use in general have led to the introduction of laws and regulations governing their use. These laws vary from state to state, but most American states do not allow electric scooters to be used on public thoroughfares and sidewalks. According to the American Academy of Pediatrics,[2] only four states in the United States have laws governing electric scooter use.

1 www.segway.com
2 www.aap.org

In Canada, MPTDs, including electric scooters and Segways, are prohibited on public thoroughfares and sidewalks. Transport Canada, which is responsible for establishing safety standards for motor vehicles that might be used on roads, believes that Segways are not a motor vehicle for road use, but rather a transportation device. It is therefore up to the provinces to decide on the place to be given Segways on public thoroughfares. In 2001, Quebec's National Assembly prohibited all motorized scooters on public thoroughfares.

Segway evaluation results

The results of the technical evaluation carried out at the PMG Technologies Test and Research Centre demonstrated that under normal use, Segways are very stable, run quietly and smoothly, and give users a feeling of being in control. They are easy to manoeuvre, accelerate gently, run silently and can stop quickly in case of emergency. Users are informed immediately of any loss of pressure in a tire by the device's slight veering to the deflated tire side. The device easily goes up and down hills with gradients as steep as 36%. Turns with curve radii as low as 15 ft. can be negotiated at full speed without skidding and while maintaining full control of the device.

We learned from the ergonomic evaluation carried out by Systèmes Humains-Machines inc. (SHUMAC) that a wide range of users found Segways easy to use in normal situations as well as in situations involving obstacles. Segways compare favourably with other types of vehicles, particularly in terms of stability, an area where they seem superior to other vehicles such as bicycles or mopeds. The ergonomic evaluation also identified a certain number of weaknesses, including a marginally effective audible warning level, visual displays that were difficult to read in the sun, codes in shapes and colours that made interpretation of the information confusing, and an overly short shutdown time in case of breakdown. The evaluators also found in one specific and probably rare case—i.e., shutoff of the power supply while the device was going up a steep gradient—that the device was impossible to immobilize and keep stable.

The evaluation also identified users who should refrain from using Segways, particularly pregnant women, people with proprioceptive disorders[3] and people with inadequate vision for driving any other vehicle.

The results of the behavioural study, conducted on a target group of 49 people who had tested a Segway in a closed environment, indicated that the parameters to be taken into account were training[4] recognized by a government-certified organization, a set minimum user age of 14, and the wearing of safety helmets. Obtaining a driver's licence was not deemed mandatory. Among the necessary improvements we noted to make this device safer were those concerning the audible alarm volume level, visual display and shutdown time. The Segway was perceived to be a device designed to meet a large number of mobility requirements for a broad segment of the public. The survey results also indicated that Segways could possibly generate transfers to other forms of mobility, especially alternatives to automobiles.

[3] An impairment of a person's perceptions of own limbs, their connection to the body and their relationship to the environment (from *Coma Guide for Caregivers*, Delaware Health and Social Services, Division of Services for Aging and Adults with Physical Disabilities, p 18).

[4] Segway LLC recommends a four-hour period of training for the Segway HT, e Series (commercial model) and 30 minutes of training for the Segway HT, i Series and p Series (consumer models).

Electric scooter evaluation results

People participating in the study thought that 10 to 15 minutes of practice and explanations regarding operation was enough time to learn how to operate the scooters. The categories of people who should refrain from using electric scooters are more or less the same as for Segways, e.g., pregnant women, people with proprioceptive disorders, people with shifted centres of gravity and people carrying loads. Closed environment testing demonstrated that electric scooters were safe in normal use situations. Among the improvements to be made were the additions of a horn and headlights. The identified parameters for standardization were mandatory helmets and a minimum user age of 12. Electric scooters seem primarily intended for young people, particularly for recreation and for short trips close to home.

Recommendations

The results of the technical and ergonomic evaluations carried out in Phase 1 of the Fly-Trottel Project clearly demonstrated that Segways have safe handling ability. In addition, most users who participated in the study found that scooters and Segways were easy to use and safe for trips on the test tracks.

It is therefore recommended that Phase 2 of the Fly-Trottel Project, in which electric scooters and Segways will be evaluated in actual-use conditions, be carried out according to procedures established by the Project partners. Evaluations in actual-use conditions will be helpful in the search for a new regulatory framework by defining technical characteristics and conditions in which the MPTDs can be used. The following will be evaluated in Phase 2:

- Reliability and safety of these devices when used in urban areas
- Social acceptability of scooters and Segways in Quebec
- Ability of these devices to replace automobiles for short trips in urban areas

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1 Background

1.1 Introduction

The current car-based urban mobility model has negative repercussions such as illnesses due to air pollution, climate warming (greenhouse gases), road accidents, congestion and dependence on limited fuel sources. An estimated three million people in the world die each year because of pollution.[1] According to the Canadian government, 16,000 people die prematurely every year because of air pollution, including 1,900 in the Montreal area alone. Children are the main victims of pollution-related diseases. Forty percent of diseases caused by the environment affect children under five, whereas these children make up only 10% of the world's population.[2] The World Health Organization predicts that in 2010, automobiles will be responsible for 40% of the planet's greenhouse gas emissions.[3]

Between 1950 and 1990, the number of motor vehicles in the world multiplied nine times, increasing from 75 million to 675 million. According to the most conservative projections of the Organisation for Economic Co-operation and Development (OECD), there will be 1.62 billion vehicles in 2030 (Table 1). This spectacular increase in the number of vehicles, combined with a staggering increase in kilometres driven, will require drastic measures to limit the negative effects of transporting goods and people.

TABLE 1
Transportation Indicators for OECD and Other Countries, 1990 and 2030[4]

	Light Vehicles		%	Heavy Vehicles		%
	1990	2030		1990	2030	
OECD countries						
Number of vehicles (millions)	468	811	**73**	16	31	**94**
Kilometres travelled (billions)	7,057	12,448	**76**	687	1,377	**100**
Weight of fuel consumed (megatons)	563	520	**-8**	182	359	**97**
Other countries						
Number of vehicles (millions)	179	725	**305**	14	56	**300**
Kilometres travelled (billions)	2,380	9,953	**318**	647	2,512	**288**
Weight of fuel consumed (megatons)	167	394	**136**	142	552	**289**
All countries						
Number of vehicles (millions)	648	1,537	**137**	30	87	**190**
Kilometres travelled (billions)	9,437	22,400	**137**	1,334	3,889	**192**
Weight of fuel consumed (megatons)	730	914	**25**	324	911	**181**

Moreover, although Canada accounts for 0.5% of the world's population, it produces 1.8% of global greenhouse gas (GHG) emissions, which ranks Canada among the top producers in terms of emissions per inhabitant. Given these circumstances and in order to stop pollution and reduce its GHG, Canada made a commitment as part of the Kyoto Protocol to reduce its GHG emissions during the 2008–2012 period by 6% from 1990 levels. The transportation industry accounts for 28% of all of Canada's GHG emissions. In Quebec, the transportation industry accounts for 38% of these emissions.

Sustainable solutions for Canadian cities, as for cities around the world, are achieved through transitions toward environmentally sustainable modes of transportation, such as public transit. Sustainable urbanization also means

1 International Energy Agency. *Oil Market Report*, November 2003. www.oilmarketreport.org/
2 Unicef, 2002 Report. www.cyberpresse.ca/
3 World Health Organization. www.who.int/
4 OECD publication: *Motor Vehicle Pollution: Strategies Beyond 2010*, p 135. Light vehicles in this case include passenger cars, light-duty trucks and motorcycles.

space planning and management, such as higher-density living areas organized around major hubs served by buses and subways, and day-to-day services distributed closer to where people live. In this context, using a wide range of technical solutions to provide transportation, such as motorized personal transportation devices tailored to each city's specific circumstances, is considered an alternative or a response to widespread automobile use.

1.2 History

Nowadays, the sharing of thoroughfares by MPTDs, other road users and pedestrians is still a controversial topic in many countries. Some American states allow the use of MPTDs according to certain rules; others have simply banned them from public thoroughfares and sidewalks, while others currently have no regulatory provisions for MPTDs (see Chapter 3.2).

The term "motorized personal transportation device" (MPTD) is derived from American terms that have come into use, such as "electric personal mobility assistive device" and "personal motorized mobility device." Such terms became necessary when the Segway Human Transporter (HT), a personal transportation device, came onto the American market in 2001. In Canada, the Segway HT is not considered a motor vehicle intended for road use and therefore does not come under the authority of Transport Canada, the government agency responsible for setting vehicle safety standards. It is up to the Canadian provinces to legislate the extent to which Segways can be used on public thoroughfares.

Motorized scooters appeared on the North American consumer market in the early 1990s. They generated considerable controversy, particularly scooters driven by noisy, polluting gasoline motors. Canada has no specific regulatory framework covering scooters. Faced with growing numbers of motorized scooters and given the fact that they are not defined in the Highway Safety Code, the Quebec National Assembly banned all motorized scooters from public thoroughfares in 2001.

Since 1999, the Centre for Electric Vehicle Experimentation in Quebec (CEVEQ), together with Transport Canada, the Quebec Department of Transport (Transport Québec) and other stakeholders, has carried out several evaluations of electric bicycles and low-speed electric vehicles (LEVs) for regulatory purposes.

The Fly Project (Segways) and the Trottel Project (electric scooters) were developed by CEVEQ and submitted to government, municipal and industrial partners in the winter of 2003. The two projects were merged in the spring of 2003 under the shared name of Fly-Trottel Project. In July 2003, changes were made to the Fly-Trottel Project to include a comprehensive study of safety and operational aspects of the devices in a closed environment in Phase 1.

Phase 1 activities were launched in September 2003 under CEVEQ supervision and continued to the end of December. A Follow-up Committee consisting of representatives of Transport Canada, Transport Québec, Health Canada and CEVEQ participated in the validation work that needed to be done along the way.

1.3 Proponent

CEVEQ, founded in 1996, is the first centre in Quebec and Canada dedicated to the development of electric and hybrid vehicles and advanced modes of transportation. CEVEQ offers the following expertise to private firms and government or municipal organizations:

- Technical, operational and regulatory evaluations for electric vehicles (EVs) and hybrid vehicles (HVs)
- Demonstration project and technology showcase management
- Economic intelligence and technology monitoring
- Product development (electric propulsion)
- Publication of studies and reports
- Organization of forums and symposia
- Linking up of partners
- Dissemination of information on advanced modes transportation

In recent years, CEVEQ has carried out demonstration and evaluation projects to promote the implementation of concrete solutions for sustainable transportation, such as the Montreal 2000 Electric Vehicles Project, the Electric Bicycle Project, which resulted in federal and provincial (Quebec and British Columbia) regulations, and the Assessment of Low-Speed Electric Vehicles in Urban Communities pilot project, in co-operation with Transport Québec and Transport Canada. CEVEQ also organized the International Forum on Urban Mobility and Advanced Transportation (MUTA), which is held alternately in France and Quebec. The first MUTA forum was held in October 2002 in Quebec; the second forum was held in Poitiers, France, in 2003; and the third forum, MUTA 2004, will be held in Mont Tremblant and St. Jérôme, Quebec, from September 15 to 18, 2004.

1.4 Objectives

In a proposal submitted to Transport Québec and Transport Canada, CEVEQ offered to set up Phase 1 of the Fly-Trottel Project, which was a pilot project for evaluating motorized personal transportation devices (MPTDs).

The project had various objectives, which can be summarized as follows:

- Help find a regulatory framework for MPTDs;
- Identify standardization parameters and safety requirements;
- Evaluate training and safe use aspects during tests in a closed environment;
- Determine potential uses of the vehicles and limitations on their use by various groups of people;
- Promote the use of clean modes of transportation in urban communities.

1.5 Methodology

Phase 1 of the Fly-Trottel Project consisted of two major components:

1. Gather, analyse and summarize information concerning the introduction of Segways and electric scooters in the United States and Europe.

2. Perform ergonomic, technical (handling and performance) and operational evaluations of the MPTDs in an enclosed test track environment or in the laboratory. In addition to these evaluations, a survey of MPTD users was carried out.

Complementary evaluations of the Segways and electric scooters were carried out with the help of three groups of experts and a user sample of 49 people. CEVEQ, as Project Manager, prepared a summary of the various studies and drafted the final report.

- A literature review was carried out, including a general compilation of the literature on MPTDs, pilot projects carried out in the United States and Europe, and regulations in various countries pertaining to user safety, legal contexts and conditions for MPTD use. This part of the study was carried out by CEVEQ.

- A report was drafted that outlined the tests carried out with targeted users selected for their representativeness (age, sex and abilities). After receiving the training recommended and authorized by the Segway manufacturer and provided by CEVEQ, participants used the MPTDs on a prepared track in a closed environment. The Segway training ("orientation") lasted four hours, while the training/orientation for electric scooters lasted one hour. Each user was given an average of about 30 minutes in which to carry out practical testing with the devices and then asked to fill out a comprehensive questionnaire prepared by the ergonomist and CEVEQ.

- A technical report was drafted, describing the Segway's handling and performance evaluation under various riding conditions, particularly specific manoeuvres such as emergency braking, turns and driving on mixed road surface conditions. These tests were conducted in the laboratories and on the tracks of the PMG Technologies Test and Research Centre.

- An ergonomic report was prepared in order to provide an opinion concerning various aspects of the safe use of Segways based on well-established ergonomic principles. The study was carried out by Systèmes Humains-Machines inc. (SHUMAC) in three phases: (1) a study comparing Segways with other modes of personal transportation, (2) observations made during training and testing sessions in a controlled environment in St. Jérôme and (3) a review of the interface between users and the devices based on standards and guidelines specific to ergonomic studies.

- A complementary evaluation report was prepared by the Industrial Design Department of the Université du Québec à Montreal (UQAM) as part of a course entitled Transportation Vehicle and Equipment Design Methodology. Because this work was not classified as an expert report, it did not merit a chapter in this Final Report. However, some interesting observations are included in the section devoted to the findings of ergonomic studies and were used as additional information in the SHUMAC study.

2 Motorized Personal Transportation Devices (MPTDs)

2.1 Segway

Christened the Segway Human Transporter and initially known as “IT” and “Ginger”, the Segway was unveiled with great ceremony in December 2001 in the United States. It was described as “the first of its kind—a self-balancing, personal transportation device designed to go anywhere people do.”[5] About 6,000 of these MPTDs are in use around the world.

Dean Kamen, inventor of the Segway HT, at the International Forum on Urban Mobility and Advanced Transportation (MUTA 2002)

The idea for the Segway came from the iBot, a revolutionary wheelchair equipped with six wheels that allowed persons with disabilities to climb stair steps without the wheelchair losing balance. The machine was originally christened “Fred” by its inventor Dean Kamen, President of Segway LLC.

Segway LLC has three models in its product line to date:

- Segway HT, i 167 (i Series),
- Segway HT, e 167 (e Series) and
- Segway HT, p 133 (p Series).

The iBOT and its user climbing steps

Segway HT, e series

Segway HT, i series

Segways are activated by a coded key that is difficult to copy and records the user’s settings. Each Segway has three “intelligent” keys that allow users to adjust their driving mode to their experience and riding conditions. Beginner mode (maximum speed of 8 km/h and slow turns) allows users to gain confidence and become familiar with the vehicle. Sidewalk mode (maximum speed of 12 km/h and average-speed turns) is tailored to pedestrian environments. Open Environment mode (maximum speed of 20 km/h and sharp turns) allows users to travel in open environments.[6]

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5 www.segway.com

6 www.segway.com

Segway HT, p series

The Segway maintains its own balance and that of its passenger. It is equipped with a stationary T-shaped control shaft fitted into a platform mounted on two parallel wheels. Segways are driven standing up and handle according to human body dynamics: lean forward to move forward, stand straight up to stop, and lean backward to reverse. The device has no brakes or accelerator, but has a handgrip for making turns. It is the only vehicle able to turn in place, just like a person, because its wheels have the ability to turn in opposite directions. Segway LLC recommends four hours of training on the Segway HT, e Series (commercial model) and 30 minutes of training on the Segway HT, i Series and p Series (consumer models). This theoretical and practical training teaches the basic fundamentals of riding a Segway HT.

Using its microprocessors, the Segway continually analyses its performance. Five gyroscopes and two sensors work together to determine the Segway's position in relation to its centre of gravity. The onboard computers analyse their measurements and compensate in real time for surface irregularities in order to control the device's movement and ensure the rider's stability. The Segway has a maximum range of 25 km in optimal use conditions (no wind, flat terrain and constant speed) or 17 km in normal use conditions. The i Series and e Series Segways weigh 38 kg and can be folded up and stored in a car.

The p Series Segway, weighing 31 kg, is the lightest and most portable model in the product line. Its wheels are smaller than those of the other models, its platform is narrower, and it has a maximum speed of 16 km/h. This Segway was initially sold to consumers in test markets. Considered a short-distance transportation solution, this model has been available on the American market since mid-October 2003.

2.2 Electric scooters

The electric scooter is a two-wheeled, battery-operated personal transportation device. Similar to conventional scooters, it weighs about 15 kg, is close to 1 m in length and has an ignition key, accelerator and brake handles.[7] Some models have a seat; others are fitted with safety devices such as headlights, turn signals and headlight reflectors; some can be folded up; and some are equipped with three wheels.[8]

To start the scooter, all one has to do is push off energetically two or three times and activate the gas lever to engage the motor. It has a maximum speed of 20 km/h (may vary depending on several factors, such as rider's weight and evenness of terrain) and a maximum range up to 15 km.[9]

Zappy electric scooter

7 Scooter weight and performance may vary from one model to another.

8 Manufacturer BMW was expected to launch the SlideCarver in the spring of 2003. The firm promoted the high-tech three-wheeled scooter as the "high-tech scooter for summer 2003." The BMW invention is a product of automobile and motorcycle technology. www.worldofbmw.com/newsstories/0307233wheeler.htm

9 These specifications vary from model to model.

Scorpion S-I electric scooter

Motor scooters appeared on the North-American market in 1990; historically, the term “scooter” dates from 1917. It is derived from the word “scoot”, which means to go suddenly and swifty. Swiss photographer Patrick Rohner is purportedly the father of the motor scooter. Looking for a way to travel short distances, he built a board with wheels and attached a rope in front to steer. Later he replaced the rope with a metal shaft.

There is no mutually agreed definition of electric scooter aside from the fact that it is driven by an electric motor. The electric scooter concept is complicated by confusing terminology inherent to rapid technological change and by the various properties and performances of existing models and a lack of parameters and common technical specifications. Some regulations do not specifically mention electric scooters as such, while others make a general reference to electric scooters amid a mixed array of skateboards, in-line skates and motorized scooters (modified thermal and/or electrically powered).

2.3 MPTDs: A segment of the advanced ground transportation sector

Electric traction vehicles (subway trains, light-rail transit systems [LRTs] and electric buses, cars and bicycles), which by their nature are clean modes of urban transportation, are an appropriate response to air and noise pollution problems. There is a trend to develop new ultra-light modes of transportation, such as Segways, to meet short-distance travel needs in cities. As part of a greenhouse gas reduction strategy, MPTDs can be an alternative and a new dimension in urban transportation, along with extended public transit systems, and can replace automobiles for short-distance trips.

3 Literature Review

CEVEQ compiled literature on MPTDs by:

- Gathering together publications from government agencies, international co-operation agencies, universities, research centres, manufacturers, leasing companies, etc.
- Telephoning and setting up interviews with representatives of these firms, government and municipal authorities, consumer associations, etc. to discuss the information;
- Using the Internet to build an information bank.

In processing the information, emphasis was placed on the following: (1) results of experiments in countries that permit the use of Segways and electric scooters, (2) legal frameworks for introducing MPTDs, (3) user safety, (4) conditions for Segway and electric scooter use, and (5) accidents and injuries arising from MPTD use. The CEVEQ study (*Literature Review: Projects, Regulatory Frameworks and Safety Aspects*) includes a full report of the Centre's research, which is partly summarized in Chapter 3 of this report.

3.1 Pilot projects around the world

We compiled a list of nearly 40 projects in the United States and around the world where Segways had been demonstrated or used. Most of these projects are currently in progress or are confidential, which means that several studies were not available. However, we obtained some data, which are set out in Table 2. No pilot project or study involving electric scooters was identified. The following chapter will therefore deal more specifically with projects involving Segway HTs that are completed or in progress.

The objective of the Segway sales strategy, released in 2001, was to demonstrate the devices and to focus in particular on their potential commercial and industrial uses. Providing visibility for Segways, initial tests and projects were carried out in the work environments of several United States federal agencies, including the U.S. Postal Service and the U.S. National Park Service.

Several pilot demonstration programs are currently under way in various cities around the world. These projects focus on various ways that Segways can be used for recreation and tourism purposes, such as short-term rental services in downtown areas. Other tests were carried out in university and research centre environments in order to assess the possible inclusion of Segways among various modes of transportation or to understand user safety and performance aspects.

The following is a summary of a few pilot projects:

- In 2002, the United States Postal Service (USPS) purchased 40 Segways in order to determine the device's effectiveness in transporting and delivering mail. USPS found that the initial tests carried out in six cities were promising[10] and continued the tests throughout 2003 in order to fully assess the device's safety aspects and benefits in terms of time and money saved.

[10] *2002 Comprehensive Statement on Postal Operations*, United States Postal Service.

TABLE 2
Segway Test Sites and Project Characteristics

Organization/Area	Application	Launch Date	Evaluation Objectives	Country
Police Atlanta, Georgia; Boston, Massachusetts; Santa Monica, California; and Fond du Lac, Wisconsin	Police patrols	December 2002 and July 2003	• Police patrols: traffic, safety and traffic control • Tests	United States
Health Care Emergency Medical Services (EMS), Boston, Massachusetts MedExpress, Alexandria, Louisiana	Health and emergency care	April to July 2002 November 2002	• Assess safety performance • Assess performance in terms of patient access times	United States
Postal Services **United States Postal Service** Bronx, New York; Chandler, Arizona; Norman, Oklahoma; Memphis, Tennessee; and San Francisco, California **Canada Post**	Mail delivery	January 2002 Pre-launch	• Efficient mail delivery • Time and physical effort factors	United States Canada
Municipalities and Cities Atlanta, Berkeley, Seattle Paris, Dijon, Besançon, Nice, Marseille Bangkok Vancouver, Montreal	Urban communities	May 2002 and January 2003	• Short-distance trips • Train and bus stations • Economic viability • Municipal services • Airport equipment • Guided tours • Rentals	United States France Thailand Canada
Companies GE Plastics, New York State Electric and Gas Corporation (NYSEG), Georgia Power	Industrial and semi-industrial	2002 and 2003	• Mode of transportation • Inspections and patrols • Manoeuvrability • Water and electricity meter reading	United States
Parks and Recreational Centres National Park Service (Grand Canyon and Washington DC) Disney Cruise Lines Orlando	Recreation and tourism parks	September 2002	• Efficient mode of transportation • Patrols • Tours	United States
Universities Louisiana Tech University Center for Entrepreneurship and Information Technology (CenIT) Pittsburgh Technical Institute (PTI) University of Hartford University of Memphis, Worcester Polytechnic Institute (WPI), Catholic University of America (CUA), Georgia Institute of Technology REHABTech (Monash University)	Technical testing and various assessments	December 2002	• Use in and between classrooms • Event management • Maintenance and repairs • Campus patrols	United States Australia


U.S. Postal Service tests the Segway HT for transporting and delivering mail

The City of Seattle tested and assessed Segways in water meter reading operations. The tests were conducted from October to December 2002. During this period, nearly 200 daily routes in commercial and residential areas were travelled by meter readers on Segways.[11] The preliminary results appear to show that Segways reduce or eliminate the physical limitations (walking and carrying of weight) and their consequences (fatigue, illnesses, medical care and absences). The City of Seattle's annual costs for injuries per meter reader in the 1998–2002 period was $998. The City estimated that using Segways could generate a 20% reduction in injuries.

In June 2003, REHABTech, a centre specializing in rehabilitation (of persons with reduced mobility) affiliated with Monash University (Australia) conducted some basic tests of Segways involving an amputee and a person who had had polio who suffered acute fatigue. Within a short time, the patients were able to get on the Segways and use them confidently without a safety harness. The amputee commented: "I'll be confined to a wheelchair…If I use a Segway, I'll be more mobile for a longer time." The amputee took longer to get used to getting on and off the Segway: two to three minutes, compared with one minute for the polio survivor. The procedures consisted of watching the training video, followed by practical training with the help of the instructor, who held the crossbar while the patient stabilized the Segway. These operations were repeated until the patients were confident of having the device under control and not rocking to and fro. The most difficult operation was getting on and off the device. REHABTech believes the Segway HT, p Series, would be ideal and more practical for persons with reduced mobility because its platform is lower and easy to step onto.[12] REHABTech also believes that the Segway should be an ideal solution for many people with reduced mobility. The Centre will release a document with instructions on certain aspects to consider in the use of Segways by persons with reduced mobility.


Amputee tests the Segway at Monash University

Various Segway projects helped us identify some potential uses for Segways in commercial, industrial and urban settings. In all of these demonstration projects, Segways offered a variety of advantages, including reduced physical limitations, rapidity and greater mobility.

The following are some interesting applications we noted in various projects:

- Police patrols
- Assistance for maintenance services (reading of water or electricity meters)
- Mail transport and delivery
- Natural gas pipeline inspections
- Rentals in recreational and tourism areas
- Guided tours for tourists and local residents
- A solution for people with reduced mobility (trials by an amputee)

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11 *Water Meter Reading with Segways: Life Cycle Cost Analysis Report*, June 2003, City of Seattle.
12 Bill Contoyannis, Manager/Rehabilitation Engineer, REHABTech, Monash University.

- An extension of or access to public transit (intermodal)
- Transportation for managing and patrolling events

“Station Oxygène” Segway rental site (France)

In all of the applications we observed, none mentioned the use of Segways in the winter. However, Segway LLC representatives say that the Segway HT is designed to go anywhere a person can. It enables people to go almost everywhere. Its tires make it useable on various types of terrain and in rugged environments. Probably in response to numerous comments, Segway LLC is now selling tires with a better grip for use in snowy conditions.

3.2 Regulatory frameworks around the world

3.2.1 Segways

3.2.1.1 United States

The United States began regulating Segways in 2002, just after the product began to be marketed and a year after a media campaign promoting the Segway HT and its inventor Dean Kamen.

At the time this report was written, 40 states and the District of Columbia[13] had introduced regulations governing the use of Segway HTs on sidewalks, bicycle paths and some roads. The laws vary from state to state, but most define the Segway as an “electric personal assistive mobility device” or a “personal motorized mobility device.” Some states even decided to redefine the term pedestrian to include “a person using a Segway.”[14]

In fact, the first step toward approval of Segway HTs on sidewalks was adoption of national legislation in June 2002 that legalized their use on sidewalks under federal jurisdiction. This legislation (Senate Bill 2024) defined the Segway HT as a new vehicle class: an “electric personal assistive mobility device,” separating it from other motorized vehicles such as scooters. However, Senate Bill 2024, which defines the Segway as an electric transportation device with a stabilized platform between two parallel wheels, gives states and local authorities the power to pass legislation governing the use of Segways at the regional and local level. It approves the use of Segways on sidewalks under federal authority and on private property.

According to the Bill’s wording, the device “employs advances in technology and energy efficiency to fully and safely integrate the user with pedestrian transportation;”…“enables individuals to travel farther and carry more without use of traditional vehicles,” and “promotes gains in productivity; minimizes environmental impacts; and facilitates better use of public roadways.”

[13] www.segway.com/

[14] See Table 3 in the section entitled Pedestrian Legislation Applies.

Summary of principal United States regulations

The following was found in the literature review:

- In the following 34 states, Segways are authorized on sidewalks, public streets and bicycle paths: Alabama, Alaska, Arizona, California, Delaware, Florida, Georgia, Illinois, Indiana, Kansas, Maine, Maryland, Michigan, Minnesota, Mississippi, Missouri, Nebraska, New Hampshire, New Jersey, New Mexico, North Carolina, Ohio, Oregon, Oklahoma, Pennsylvania, Rhode Island, South Carolina, Tennessee, Texas, Utah, Virginia, Washington, West Virginia and Wisconsin.
- These MPTDs are specifically prohibited on the streets of three states: Connecticut, Iowa and Vermont.
- Segways are authorized for use solely on sidewalks and/or bicycle paths in the District of Columbia and in four states: Connecticut, Idaho, Nevada and South Dakota.
- An age limit is imposed on Segway users in the District of Columbia and in 11 states: Arizona, Connecticut, Georgia, Iowa, Missouri, Ohio, New Jersey, Rhode Island, Utah, Vermont and Virginia.
- Helmets are mandatory in nine states: Delaware, Florida, Georgia, Maryland, New Jersey, Ohio, Pennsylvania, Utah and Virginia. Depending on the state, they are mandatory for persons under age 12, 15, 16 or 18. In New Jersey, helmets are mandatory for all users.
- Pedestrian traffic rules apply to Segway users in 14 states: Arizona, California, Georgia, Idaho, Illinois, Kansas, Minnesota, Missouri, Nevada, New Mexico, North Carolina, South Dakota, Vermont and West Virginia. However, two states, New Jersey and Texas, require Segway users to comply with standards applying to bicycles when they travel on roadways and bicycle paths.[15] In one state, Oregon, the two requirements are combined: Segway users are required to comply with legislation governing pedestrians when on sidewalks and with regulations governing bicycles when on bicycle paths.
- At the same time this report was written, some states still did not have a definitive regulatory framework for Segway use. Either the regulatory process was still in progress or there was no formal prohibition of Segway use in these states: Arkansas, Colorado, Hawaii, Kentucky, Louisiana, Massachusetts, Montana, New York, North Dakota and Wyoming (see Table 3).
- There is currently no state requiring Segway users to have a licence, unlike motor vehicle users, who must have a licence before driving on a public thoroughfare.

No regulations make reference to Segway HT training, which the manufacturer strongly recommends.

The CEVEQ study also revealed that some cities, in accordance with national legislation that gives local authorities the option of enacting additional laws with regard to Segway HT use, have strictly prohibited their use on sidewalks.

This is the case in the City of San Francisco (population 776,733), which was the first American city to prohibit their use, throughout the city and county, on sidewalks and bicycle paths and in public transit stations and any other area intended for pedestrians and cyclists. Segway HTs are also banned from sidewalks in La Mirada (population 47,000), a suburb of Los Angeles, California; from some stations and sidewalks in the City of Washington; and in some Maryland and Virginia suburbs.

Pasadena, California (population 136,237), located only 15 minutes from Los Angeles, is also assessing the possibility of banning Segways in commercial areas.

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15 On its Web site www.hwysafety.org, the Insurance Institute for Highway Safety regularly publishes a status report on places in the U.S. where regulations with respect to Segways are changing.

New York City recently announced that it was considering extending the ban on the use, sale and lease of motorized scooters, including Segways, in private places. The law currently prohibits the use of such devices in public places. The planned measure could provide for a maximum fine of US$1,000 and a 15 day prison sentence for individuals who continue to sell or lease these devices, and US$500 and seizure in the case of persons who illegally use these devices.

In most of the cases, municipal acts and regulations are based not only on fears of possible collisions between the devices and pedestrians, but also on petitions and concerns raised by groups representing pedestrians, seniors, persons with disabilities, consumers or public safety experts. In fact, we found in the literature review that ordinances prohibiting Segways did not contain statistical information or references in regard to damages or injuries caused by Segways. Moreover, they contained even less data on the safety of sidewalk users or on Segway demonstrations and traffic integration tests to support decisions to ban the devices. Some prohibitions simply state that it is essential to promote and ensure pedestrian safety.

3.2.1.2 Segway regulatory framework in Europe

In Europe, EEC Directive 92/61 governs two-wheeled and three-wheeled vehicles. This directive applies solely to vehicles intended for road travel. Because Segways have two wheels and are designed especially for sidewalk use, they do not come under this Directive or any other European Union motor vehicle regulations.[16]

Segways have already been introduced in some European countries. In addition to France, Segways have been introduced into Hungary, Italy, Great Britain and Belgium. In the latter three countries, regulatory processes authorizing the use of Segways on sidewalks are still ongoing.[17]

In France, in accordance with the opinion expressed by the European Commission on July 12, 2002, Segways are not considered a vehicle and therefore remain subject to Highway Code rules for pedestrians (sections R. 412-34 to R. 412-43).[18] Consequently, Segways can be used in urban centres only on sidewalks and in pedestrian areas, provided the devices move at walking speed, i.e., a maximum of 6 km/h, in order to respect the flow of pedestrian spaces.

16 *The EC position on the application of Directive 92/61 EEC to the Segway HT*. European Commission Entreprise Directorate-General's letter to Segway LLC, July 2002.

17 Stephan DePenasse, International and Regulatory Affairs, Segway LLC.

18 Highway Traffic and Safety Directorate of the French government's Facilities, Transportation, Accommodation, Tourism and Marine Affairs Department.

TABLE 3
State Regulatory Requirements for Segway HT Use in the United States

State	Allowed on Sidewalks and Bicycle Paths	Allowed on Roadways	Helmet Mandatory	Age Limit	Laws Governing Pedestrians Apply
Alabama	Sidewalks and bicycle paths	Yes	–	–	–
Alaska	Sidewalks and bicycle paths	Yes	No	–	–
Arizona	Sidewalks	Yes, if there are no sidewalks	No	16	Yes
Arkansas	–	–	–	–	–
California	Sidewalks and bicycle paths	Yes	No	–	Yes
Colorado	–	–	–	–	–
Connecticut	Sidewalks	No	No	16	–
Delaware	Sidewalks and bicycle paths	Yes, on roads with speed limits of 48 km/h or less	If under age 16	–	–
District of Columbia	Sidewalks	–	No	16	–
Florida	Sidewalks and bicycle paths	Yes, on roads with speed limits of 40 km/h or less	If under age 16	–	–
Georgia	Sidewalks	Yes, on roads with speed limits of 55 km/h or less	If under age 16	16 on highways	Yes
Hawaii	–	–	–	–	–
Idaho	Sidewalks	–	No	–	Yes
Illinois	Sidewalks	Yes	No	–	Yes
Indiana	Bicycle paths	Yes	No	–	–
Iowa	Sidewalks and bicycle paths	No	No	16	–
Kansas	Sidewalks	Yes	No	?	Yes
Kentucky	–	–	–	–	–
Louisiana	–	–	–	–	–
Maine	Sidewalks and bicycle paths	Yes, on roads with speed limits of 55 km/h or less, if there are no bicycle paths or sidewalks	No	–	–
Maryland	Sidewalks	Yes, on roads with speed limits of 48 km/h or less, if there are no sidewalks	If under age 16	–	–
Massachusetts	–	–	–	–	–
Michigan	Sidewalks	Yes, on roads with speed limits of 40 km/h or less	No	–	–
Minnesota	Sidewalks and bicycle paths	Yes, on roads with speed limits of 55 km/h or less, if there are no sidewalks	No	–	Yes
Mississippi	Sidewalks and bicycle paths	Yes, anywhere bicycles are permitted	No	–	–
Missouri	Sidewalks and bicycle paths	Yes, on roads with speed limits of 70 km/h or less	No	16	Yes
Montana	–	–	–	–	–
Nebraska	Sidewalks and bicycle paths	Yes, except on expressways and interstate highways	No	–	–
Nevada	Sidewalks and bicycle paths	–	No	–	Yes
New Hampshire	Sidewalks	Yes	No	–	–
New Jersey	Sidewalks and bicycle paths	Yes	Yes	16	–
New Mexico	Sidewalks and bicycle paths	Yes	No	–	Yes
New York	–	–	–	–	–

State	Allowed on Sidewalks and Bicycle Paths	Allowed on Roadways	Helmet Mandatory	Age Limit	Laws Governing Pedestrians Apply
North Carolina	Sidewalks and bicycle paths	Yes, on roads with speed limits of 40 km/h or less	No	–	Yes
North Dakota	–	–	–	–	–
Ohio	Sidewalks, except if reserved for exclusive use of pedestrians or bicycles	Yes, on roads with speed limits of 80 km/h or less	If under age 18	14	–
Oklahoma	Sidewalks and bicycle paths	Yes, on municipal streets	No	16	Yes
Oregon	Sidewalks and bicycle paths	Yes, on roads with speed limits of 55 km/h or less	No	–	–
Pennsylvania	Sidewalks, except if prohibited by local jurisdiction	Yes, except on expressways	If under age 12	–	–
Rhode Island	Sidewalks and bicycle paths	Yes, except if bicycles are prohibited on the road	No	16	–
South Carolina	Sidewalks	Yes, if there are no sidewalks	No	–	–
South Dakota	Sidewalks	–	No	–	Yes
Tennessee	Sidewalks and bicycle paths	Yes	No	–	–
Texas	Sidewalks and bicycle paths	Yes, on roads with speed limits of 48 km/h or less and if there are no sidewalks	–	–	–
Utah	Sidewalks	Yes, on roads with speed limits of 55 km/h or less and with fewer than 4 lanes	If under age 18	16	–
Vermont	Sidewalks and bicycle paths	No	No	16	Yes
Virginia	Sidewalks, except if prohibited by local jurisdiction	Yes, on roads with speed limits of 40 km/h or less and if there are no sidewalks	If under age 15	14	–
Washington	Sidewalks and bicycle paths	Yes, but not on controlled highways	No	–	–
West Virginia	Sidewalks	Yes	No	–	Yes
Wisconsin	Sidewalks, except if prohibited by local jurisdiction	Yes; however, the municipality may prohibit them on certain highways or on roads with speed limits of 40 km/h or more	No	–	No
Wyoming	–	–	–	–	–

Source: Insurance Institute for Highway Safety, December 2003

3.2.1.3 Segway regulations in Canada

Under Canada's *Motor Vehicle Safety Act*, Transport Canada is responsible for setting safety standards for motor vehicles manufactured in or imported into Canada that may be used on roads. Since Segways are not motor vehicles intended for road use, they do not fall under Transport Canada's jurisdiction. It is therefore up to the provinces to decide the future of Segways on public roadways.

Under provincial motor vehicle acts and regulations, sidewalks are an integral part of the public roadway. The same acts and regulations therefore apply to vehicles that can be used on sidewalks. Without checking with the authorities in each province, it is assumed that Segways are considered motor vehicles. Since Segways do not meet the requirements (lights, brakes, etc.) of any vehicle class already defined in regulations, they are therefore in non-compliance and prohibited from use on roads or sidewalks, as is the case in Quebec, Ontario and British Columbia.

Discussions have been held with Quebec and Ontario government representatives to allow Segways to be tested on public thoroughfares (sidewalks and shoulders).

3.2.2 Electric scooters

3.2.2.1 Status of electric scooters in Canada

There is currently no regulatory framework for electric scooters defined in the *Motor Vehicle Safety Act*. Transport Canada considers most electric scooters to be restricted use motorcycles (RUMs).[19] Under the *Motor Vehicle Safety Act*, a restricted-use motorcycle is defined as "a vehicle, excluding a power-assisted bicycle, a competition vehicle and a vehicle imported temporarily for special purposes, but including an all-terrain vehicle designed primarily for recreational use, that (a) has steering handlebars, (b) is designed to travel on not more than four wheels in contact with the ground, (c) does not have as an integral part of the vehicle a structure to enclose the driver and passenger, other than that part of the vehicle forward of the driver's torso and the seat backrest, and (d) bears a label, permanently affixed in a conspicuous location, stating, in both official languages, that the vehicle is a restricted-use motorcycle or an all-terrain vehicle and is not intended for use on public highways."

Each province and territory has the right to establish regulations for the off-road use of these vehicles in addition to additional safety standards and licence and registration requirements.

On June 21, 2001, the Quebec National Assembly prohibited the use of motorized scooters on public roads. However, the use of motorless scooters is authorized in Quebec, although they must be equipped with a reflector or white reflective material in front and a reflector or red reflective material on the back and on each side, as close as possible to the rear.[20]

British Columbia's Motor Vehicle Act[21] considers electric scooters to be motor vehicles that do not meet provincial standards relative to safety equipment for road use. The Insurance Corporation of British Columbia specifies that electric scooters be prohibited from sidewalks.

3.2.2.2 United States regulatory framework

In the United States, electric scooters are not subject to federal legislation.[22] However, the upsurge in damages related to scooter use in general has led to the adoption of laws and the imposition of restrictions on their use. These laws vary from state to state. Most American states do not allow electric scooters to be used on public roadways and sidewalks.[23] In some cases, the laws require the use of safety equipment, such as helmets, or additional protection, such as knee pads, elbow pads and wrist guards.

According to the American Academy of Pediatrics, only four states in the U.S. have laws governing scooters. California and Oregon are the two states with regulations authorizing the use of electric scooters. In Washington State, electric scooters are considered illegal on streets and sidewalks. Nevertheless, Seattle municipal by-laws state that electric scooters can be used on bicycle paths and access routes such as lanes as long as the speed limit does

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19 Road Safety and Motor Vehicle Regulation Directorate, Transport Canada. See also the warning published by Health Canada at www.hc-sc.gc.ca/

20 Notice issued by the Société d'assurance automobile du Québec (SAAQ).

21 Insurance Corporation of British Columbia (ICBC). www.icbc.com/

22 www.electric-scooters-electric-scooters.com/guides_More-Scooter-Information.htm

23 Ibid.

not exceed 40 km/h. However, they are prohibited in Seattle's train and public transit stations and on public park pathways and sidewalks.

California law defines a "motorized scooter" as "any two-wheeled device that has handlebars […] and is powered by an electric motor that is capable of propelling the device with or without human propulsion." The following are some requirements for motorized scooters set out in the California Vehicle Code:[24]

- No driver's licence is required;
- Registration is not necessary;
- The minimum age limit is 16 years;
- Helmets must be worn;
- They cannot be driven on sidewalks, except to enter or exit an adjacent property;
- They are authorized on bicycle paths;
- The authorized maximum speed is 24 km/h;
- On roads without designated bicycle paths, the vehicles are allowed in zones where the speed limit is 40 km/h or less;
- Passengers are prohibited from riding on motorized scooters;
- No baggage or object may be carried that prevents the user from having at least one hand on the handlebars;
- Appropriate clothing and equipment must be worn when riding the vehicles at night.

3.2.2.3 Overview of regulations around the world

Some countries have adopted provisions regarding scooter use obviously to dispel uncertainty about the status of users of this new mode of transportation. These provisions are intended to change the mentalities and behaviour of various users in order to strike a balance among users of public thoroughfares. The various regulations focus on skateboards, in-line skates and, in a general way, scooters.

Belgium

The law requires scooter users above age 16 to use bicycle lanes, where they exist.[25] Where there are no bicycle paths, they must stay on the right-hand side of roads where speed limits are limited to 30 km/h. Where speed limits are restricted to 50 km/h, they must ride on the right-hand side of road, the sidewalk or the shoulder. On public roads outside urban areas, they must use sidewalks or shoulders, where practicable. Otherwise, on other public roads, they must stay on the right-hand side of the road. In urban areas without sidewalks or shoulders, the use of these devices is prohibited.

24 http://www.leginfo.ca.gov/
25 Royal decree of April 4, 2003, amending the royal decree of December 1, 1975, with respect to general regulations for the policing of road traffic.

France

In France, scooters powered by either electric or thermal motors for travel on public roads must be classed as a "vehicle" and "accepted"[26] or certified as such. If, during a road check, a rider cannot produce the vehicle's Community Certificate of Conformity, provided by the vehicle's manufacturer or manufacturer's representative in France, it means that the motorized scooter is not a vehicle and that its rider has committed a violation.[27]

However, under section R412-34 of the Highway Safety Code, hand-operated, two-wheel vehicles may be ridden on roads and riders must follow the rules for pedestrians.

Australia

In Australia, electric scooters are regulated by the Australian Road Rules. However, depending on the power of the motor, the regulations may vary from state to state owing to various interpretations of the specific class to which electric scooters belong.[28]

If a scooter has a motor with less than 200 W of power, it is considered to be a bicycle under Australian law and its use is authorized. Scooters with more than 200 W of power are considered motor vehicles; however, they do not comply with motor vehicle regulations and are therefore not authorized on roads or any other public thoroughfares.

Regulations in the various Australian states are similar to the Australian federal laws, except in the states of Western Australia and Northern Territory, which have no legislation for MPTDs. In Tasmania, it is illegal to ride a motor scooter, except on private property. In South Australia, motorized scooters must be registered because they are considered motor vehicles under the Motor Vehicle Act of South Australia. Their use at night is prohibited and riders must have a driver's licence and wear protective helmets. Scooters must be equipped with horns. In Queensland, riders must be aged 16 or older. If the scooter has a seat, the rider must have a driver's licence.

3.2.3 Accidents related to MPTD use

3.2.3.1 Segways

Because Segways have been introduced to the market relatively recently (2001–2002), we do not have statistics on accidents related to their use.

To date, no fatal accidents arising from Segway use have been identified or reported in the United States or elsewhere in the world, according to information gathered from various organizations, including the Center for Injury Research and Policy (CIRP),[29] the American Academy of Pediatrics (AAP)[30] and the Insurance Institute for Highway Safety (IIHS).[31]

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26 In European Union Directive 92/61/EEC, "acceptance" is defined as the action by which a member state finds a type of vehicle to be in compliance with both the technical requirements of specific directives and verifications of the accuracy of manufacturer's data.

27 www.securiteroutiere.gouv.fr

28 Road Transit Authority

29 The CIRP is dedicated to high-quality research at the international level and aims to establish programs and policies to control the incidence, severity and consequences of injuries.

30 The AAP, with approximately 57,000 members in the United States, Canada and Latin America, is committed to the attainment of optimal physical, mental and social health and well-being for all infants, children, adolescents and young adults.

31 For over 30 years, the IIHS, an independent, nonprofit, scientific and educational organization, has been in the forefront of efforts to reduce deaths, injuries, and property damage caused by motor vehicle accidents.

However, some incidents, including those leading to the recall of Segway HTs, should be highlighted. In fact, the U.S. Consumer Product Safety Commission (CPSC), which, together with Segway LLC, ordered the recall of all devices that had been sold, sent us one of the reports concerning the Segway incidents. CPSC says it has two other incident reports,[32] but cannot make them public because the incidents have not been confirmed by the complainant and have not yet been investigated.

The copy of the report we received includes an epidemiological description and Segway documentation. Without necessarily determining the cause of the incident, CPSC, through its investigation systems, wanted to specify exactly when the product became associated with injuries, illnesses of any kind or deaths. CPSC interviewed people who were involved in the incidents as well as witnesses to the incidents.

Incident summary

The victim of the incident that occurred on May 2, 2002, was a 43-year-old man who was a member of Ambassador Force, a group responsible for downtown security in Atlanta. The accident occurred while the man was patrolling on his Segway. He lost control of the device on the sidewalk and fell while trying to make a turn. The victim was taken to hospital with fractures to the knee and tibia, and underwent two operations for his injuries. The HTs were taken out of service, sent to the manufacturer for an assessment, and later put back into service. The man had taken and completed a Segway training course in April 2002 that was intended to teach the basics of riding a Segway. He was supposedly in good health and had never had mental or physical problems. He was 1.89 m tall and weighed 106 kg. He was not fatigued or under the influence of drugs or alcohol. The victim rode his Segway for about two hours per day. This case is considered the first accident involving a Segway.

Recall of Segway HTs (Human Transporters)

In late September 2003, Segway LLC and CPSC jointly announced a voluntary recall of all 6,000 Segways sold between March 2002 and September 2003 so that the software could be updated. The recall included all of the i Series models as well as e Series and p Series models with serial numbers between 022111000001 and 032361005500.

This recall occurred following the submission of three reports involving people who fell off their Segways, including one person who suffered severe head injuries.

Segway LLC explained that accidents could occur in “certain operating conditions, particularly when the batteries are close to the end of their range.” The Segway manufacturer also said that accidents could occur if riders accelerated suddenly, hit an obstacle, or kept on going after receiving the low-battery warning signal.

Segway LLC reminds users that, despite the upgrading of the software, the device operating instructions outlined in the Segway HT manuals are essential for safety.

It should also be mentioned that U.S. President George Bush nearly fell off a Segway in the summer of 2003 while on a visit to Kennebunkport, Maine.[33] The President managed to stay on his feet, although, to avoid falling, he had had to jump off the device, which fell forward in front of him. The first United States President to ride a Human Transporter had supposedly forgotten to turn the device on, thus preventing the gyroscopes from automatically balancing the device.

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32 Todd Stevenson, Director, Office of the Secretary. U.S. Consumer Product Safety Commission.

33 www.bbc.co.uk/, www.cnn.com and www.ustoday.com

Concerns about safety aspects related to the speed and handling of Segways have deflated the campaign to get people to ride Segways on sidewalks. These fears are raised primarily by groups representing pedestrians, children, seniors, people with disabilities, consumers and public health experts.

Several groups expressed their concerns about the possible risks of collision between Segways and pedestrians and called for intensive testing in urban areas and sufficient data compilation on safe MPTD use.

- In 2002, the American Academy of Pediatrics (AAP) asked Congress to consider the potential risks of injury resulting from the use of motorized scooters, including Segways, before considering any federal regulations authorizing their use on sidewalks. The organization maintains that children, seniors and persons with mental disabilities are the groups most at risk.
- In its letters to members of the Environment and Public Works Committee of the U.S. Senate, the Consumer Federation of America recommends that Congress study Segway use safety issues before this "vehicle" is allowed on sidewalks.
- The American Council of the Blind (ACB) deplores the lack of attention given to the safety of blind people and certain other types of pedestrians. The problem for this category of pedestrians is a complex one especially since they cannot see and must use their sense of hearing to judge traffic flow. The group says that because Segways are silent and almost noiseless, they could be a potential hazard, especially since they are not equipped with horns.

The pressure from groups representing pedestrians, children, seniors, persons with disabilities, consumers, blind people and public health experts about the presence of Segways on sidewalks, bicycle paths or any other pedestrian thoroughfare is based on the following concerns:

- Mandatory helmets: To avoid possible injury from falls, some organizations condemn the fact that helmets are not mandatory for Segway users or for a particular group of users (young people). Even on the Segway Internet site, there are photographs of some riders wearing helmets;
- Minimum age of users;
- Feelings of uneasiness and inconvenience: Faced with Segways on sidewalks and the risk of accidents, pedestrians could be tempted to abandon sidewalks to Segway users;
- How many Segways can there be on the sidewalk at one time without making pedestrians feel uneasy?
- Should Segways be registered?
- Speed limits, taking into account pedestrian traffic and rush hour periods;
- Can people whose driver's licence has been suspended or revoked be authorized to use Segways?
- Should insurance be required for Segways?[34]
- Risks and potential harm to "vulnerable" pedestrians (children, seniors, blind people and persons with reduced mobility): The problem for blind people is all the more complex because they cannot see and must use their sense of hearing to judge traffic flow. Segways could be a potential hazard because they do not have horns;
- Test Segways in a number of restricted areas in order to assess their impact in terms of accidents;
- Safety of Segway users (helmets, reflectors and age restrictions): 6,000 Segways were recalled recently following three reports of people falling off their Segways, including a person who suffered severe head injuries when the batteries were low. None of these reports has yet been made public. Segways are not equipped for night visibility, especially since the devices do not have headlights or reflectors. According to injury prevention science, equipping a device with safety features in the design stage is more effective than requiring users to provide their own equipment each time the need arises.[35]

[34] In the U.S., the Progressive Insurance Company was the first to provide insurance services for owners of Segway HTs. Progressive offers three types of insurance, including full coverage. There are currently no regulations requiring that Segways be insured before they are used on sidewalks. www.progressive.com

[35] Gary Smith, Director, Center for Injury Research and Policy. www.injurycenter.org/

- More expertise in areas such as traffic flow, pedestrian safety and environmental impact;
- Data on Segway brake performance in a collision;
- Statistics on Segway–pedestrian collision tests: There are currently no available data or test results with respect to typical accidents with vehicles, pedestrians, bicycles, stationary objects or other Segways. Because riders are raised slightly up off the ground, no report has been written on possible collisions with doorways or tree branches;
- Probability of Segway riders becoming involved in accidents with each other;
- Sidewalk space is already limited: Sidewalks are already the place of choice for a changing variety of wheeled devices, such as skateboards, while growing numbers of mopeds and bicycles can be found on pedestrian thoroughfares. Increasingly, it is mainly pedestrians who are being struck by users of the above-mentioned devices (new modes of transportation). Again, it is mainly seniors who are affected, in addition to children, whose movements are sometimes unpredictable;
- The purpose of sidewalks is to separate pedestrians from motorized vehicle traffic;
- Harmful health effects: Obesity rates are rising because more and more people are using cars instead of walking, bicycling or doing other physical activities associated with walking;[36]
- Sidewalks in some cities are often crowded and may not be appropriate for Segways;
- Clearer, less confusing regulations: Depending on the state or jurisdiction, Segways should be subject to specific requirements and restrictions.

3.2.3.2 Manual and motorized scooters, including electric scooters

Canada

In Canada,[37] injuries associated with scooters most often involve children between the ages of 8 and 13 (76.4%). Nearly two thirds (65.9%) of the injured are boys and almost half (47.2%) of all injuries occur between 4:00 pm and 7:59 pm.

Based on the first injury indicated for each case (out of up to three possible injuries), nearly one third of injured scooter users had fractured upper limbs (30.2%), while fractured lower arms accounted for 15.4% of all injuries. In emergency rooms, close to half of the injured (47.2%) received treatment requiring medical follow-up, and 4.6% of these were admitted to hospital.

Circumstances of accidents in Canada

Scooter-related injuries occurred most often in places other than roads (67.2%), and over one third of all injuries occurred close to home (34.4%). In most cases, loss of control of the scooter was the cause of injury (59.0%). The most frequent direct cause was contact with a surface (79.0%).

It should be noted that the injuries described above only involved motorless scooters. They do not account for all injuries incurred in Canada, but rather only those for which care was provided in the emergency rooms of 15 hospitals belonging to the Canadian Hospitals Injury Reporting and Prevention Program (CHIRPP) network. Injuries incurred by the following categories of people are underrepresented: older teenagers and adults receiving treatment

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36 In 2000, obesity was the cause of 400,000 deaths in the United States. These figures released by the Centers for Disease Control and Prevention (CDC) show a significant increase in recent years in the consequences of obesity on the health of Americans. In ten years, obesity has been the cause of 100,000 additional deaths in the United States. *Journal of the American Medical Association*, October 1999. http://www.walksf.org/

37 Data analysis carried out by the Injury Section (Health Canada). *Injuries Associated with Motorless Scooters (as of May 2001)*, taken from the Canadian Hospitals Injury Reporting and Prevention Program (CHIRPP) database. All ages, June 2001 (305 files).

in general hospitals, Aboriginals, and people living in rural areas. Fatal injuries are also underrepresented in the CHIRPP database because emergency room data do not include people who died before they could be taken to hospital or people who died after being admitted to hospital.

Quebec

Because electric scooters are banned from public and pedestrian thoroughfares in Quebec, there are no accident statistics. However, Claude Rousseau, President of Zap Québec and manager of an electric scooter rental outlet operating in the Old Port of Montreal for the past four years, told us that no accidents had occurred.

As for manual scooters in Quebec, three Quebec hospitals reported 227 accident victims (scooter-related) between May 2000 and December 2001.[38] The number of injured increased during that period from 51 victims in the last eight months of 2000 to 176 during the 12 months of 2001. Over half of the injured were male (61%) and the ratio of boys to girls was 1.6. Nearly half the injured were between the ages of 10 and 14 (47%), followed by children between the ages of 5 and 9 (41%), persons aged 15 and over (8%) and children under the age of 5 (4%).

Nearly half the injuries (47%) occurred on public roads, 8% on sidewalks, 15% at home, 4% in parks, and 3% at school. In 21% of cases, the place where the accident occurred was not specified. The main cause of accidents involving injury was loss of control of the scooter during use (86%). Collisions were reported in only 7% of cases, and most were collisions with a stationary object. Falls from scooters were responsible for only 3% of accidents, while other circumstances (scooter breakage or injury incurred in the course of storing a scooter) accounted for 2%.

TABLE 4
Locations of Scooter-Related Incidents – Canada

Location	Number (%) of Cases
Other than roadways	**205 (67.2)**
At person's home or other home, or nearby	105 (34.4)
Garden/backyard	35
Driveway	16
Sidewalk	12
Other place inside the home	12
Other place outside the home	8
Unspecified place in the home	22
Far from home	100 (32.8)
Sidewalk	52
Public park	20
School	14
Other place	14
Roadway (highway or public road)	**83 (27.2)**
Unknown location	**17 (5.6)**
Total	**305 (100.0)**

Source: CHIRPP

The most frequent injuries were fractures (40%), followed by bruises or scrapes (16%), sprains (16%), cuts (14%) and minor head injuries (6.4%). Most injuries were upper limb injuries (48%), followed by head, face and neck injuries

38 Bulletin épidémiologique hebdomadaire [weekly epidemiology newsletter] of the Institut de veille sanitaire [health monitoring institute], No. 38/2002, September 17, 2002.

(26%), lower limb injuries (20%) and torso injuries (4%). Only 12% of victims said they were wearing a helmet when the accident occurred and only one was wearing protective gear on elbows, knees and wrists. Girls and boys in equal numbers had been wearing helmets. Nearly all of the victims (88%) were treated and later given medical follow-up, if needed; 4% spent a short time in an emergency room under observation, and 7% were hospitalized.

United States

According to the U.S. Consumer Product Safety Commission (CPSC),[39] 2,870 cases of injury related to motorized scooter use were reported in the United States in the first nine months of 2001. In 2003, 2,760 cases were reported for the same period. In 2000, there were 4,390 cases and 1,330 cases in 1999. Young people over the age of 15 were involved in 39% of the cases. The most common injuries were arm, leg, face and head fractures and injuries. The CPSC says it has reports on three deaths related to motorized scooter use in 2001.

The CPSC also reports a staggering increase of 700% since 2000 in the number of injuries associated with scooter use. In all, 90% of the injured were children under 15. The organization says that if the young people had worn protective gear, they could have prevented or reduced the seriousness of over 60% of all the injuries.

In response to these numerous accidents, the CPSC submitted a list of recommendations focussing essentially on safety aspects, including the wearing of helmets, and restrictions on use to pedestrian or motor vehicle areas with low traffic volume and level terrain. The American Academy of Pediatrics (AAP) asked Congress to look at the potential risks of injury from motorized scooters before considering any federal regulations authorizing their use on sidewalks. The AAP is also asking legislators to consider restricting the age of users and making the wearing of helmets and other safety equipment mandatory.

According to the Austrian medical journal *Arzte Woche*, scooters, being very mobile, are often impossible to steer, especially on uneven ground or cobblestones, and the ability of their wheels to grip wet asphalt is inadequate. In addition to causing falls, scooters can also be hazardous if the ends of their handlebars are not carefully covered with rubber or a protective covering. The number of accidents related to motor scooter use has also risen significantly in Austria.

[39] Scooter Data. www.cpsc.gov

4 Evaluations

Two types of Segways and two electric scooter models were made available to participants in Phase 1 of the Fly-Trottel Project. The Segways were the Segway HT, i 167 (i Series) and the Segway HT, e 167 (e Series). Two Zappy electric scooters and one Scorpion S-I electric scooter were used for the electric scooter tests. The Segways that were used had had their software update following the voluntary recall of Segways sold between March 2002 and September 2003.

The objective of the study components, which consisted of technical evaluations, ergonomic evaluations and testing in controlled environments, was to answer a series of questions about the safety aspects, user profiles and potential applications of Segways and electric scooters, and possible transfers to alternative forms of mobility that the devices might generate.

The following is the series of questions, grouped into five major categories:

- **User profile**: Are the MPTDs being studied intended for a particular category of people (age group, gender, occupation, etc.)? What categories of people should refrain from riding these devices (seniors, pregnant women, etc.)?
- **Training**: Is training necessary in order to properly and safely use these MPTDs? How difficult is it to learn how to use these new personal transportation devices?
- **Safety**: Are the MPTDs being studied safe? What are their least safe and most safe aspects? What improvements could we make to make these devices safer? Can we identify standardization parameters (driver's licence, mandatory helmets, reflectors, etc.)?
- **Applications**: For what mobility purposes are these MPTDs best suited (recreation, commuting to work, trips of less than 3 kilometres, etc.)?
- **Transfers to alternative forms of mobility**: Are the MPTDs being studied in Phase 1 of the Fly-Trottel Project sufficiently attractive and efficient to encourage transfers to alternative forms of mobility, particularly where cars are concerned? Would they promote a reduction in the number of gasoline-powered vehicles on the roads and thus a reduction in urban congestion and its harmful effects?

4.1 Technical evaluations of Segways

Tests were carried out at PMG Technologies, the only public testing centre for motor vehicles in Canada and one of the most complete testing centres in North America. They were conducted indoors and outdoors on prepared surfaces from November 3 to 6, 2003.

The Segway tests focussed on the following five aspects in order to assess their performance:

- Maximum acceleration
- Top speed
- Emergency braking
- Gradients
- Turns

The following three parameters were selected for each aspect:

- Ambient temperature (laboratory temperature and outside temperature +5^{o}C)
- Test surfaces (even and mixed)
- Tire pressure (equal and unequal pressure)

The data gathered after the tests focussed on the following aspects:

- Top speed (forward/reverse)
- Maximum acceleration/deceleration
- Maximum upward gradient
- Emergency braking performance
- Performance on gradients with different slope angles (upward/downward)
- Behaviour and performance at low temperatures
- Turning performance (various turning radii)
- Performance with unequal tire pressure
- Performance on mixed surfaces

View of instrumented Segway HT and test rider

General test procedures

All of the tests were carried out by one rider who was tall and had used the device for about 20 hours prior to the tests. All of the tests were carried out in high-speed mode (red key) and only on a dry surface.

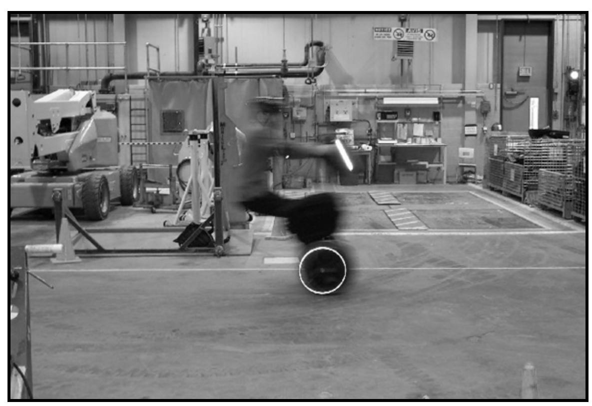
Technical evaluation summary

This section provides a summary of the technical evaluation carried out by PMG Technologies. The complete report may be obtained by contacting CEVEQ.

The test results demonstrated that in normal use situations, Segway HTs are stable, run quietly and smoothly, and give users the feeling of being in control of the vehicle.

Observations following the performance tests

The top forward drive speed (20.5 km/h) complied with specifications (20 km/h). The average acceleration speed (0 to 20 km/h) was 7.09 seconds. The average braking distance (20 to 0 km/h) was 5.21 m. The average top speed in reverse was 14.9 km/h.



View of rider and vehicle braking indoors

Side view of rider and Segway climbing a 30° hill

Generally speaking, cold temperatures, a deflated tire, uneven terrain or any combination of these conditions degraded the device's performance. A positive aspect of this finding was that a deflated tire reduced the braking distance by between 2% and 16%. When all unfavourable conditions were combined, the top speed decreased by 7% and the acceleration time increased by 69%. At equal tire pressure and on even terrain, a decrease of 15°C in ambient temperature caused a 4% decrease in speed, a 20% increase in the acceleration time and a 9% increase in the braking distance.

Performance during testing: acceleration, top speed and braking

The technical evaluations carried out by PMG Technologies demonstrated the following.

Close-up of Segway showing deflated right tire (on left)

- In all of the forward drive tests, the Segway HT remained stable and the rider felt in control;
- The evaluators found the device's braking capability "astonishing";
- When one of the tires was deflated, the device veered to one side and the rider had to continually correct the device's direction to keep it going straight ahead;
- The tests demonstrated that the device was not designed to be used in reverse at high speed;
- On gradients, the device remained stable and the rider remained in control. On the steepest gradient (36%), the device seemed to reach its limit in terms of torque, grip and comfort. The rider felt the device was no longer as safe;
- When making turns, the device was generally stable for circles more than 20 ft. in diameter;
- The tests seemed to demonstrate that cold temperatures[40] and turning in circles for a period of time reduced the efficiency of the gyroscopes.

Conclusion

In normal use situations, Segways are very stable, run quietly and smoothly, and give users the impression of being in control. They are easy to handle, accelerate gently, move quietly and can stop quickly in case of emergency. The rider is immediately informed of tire pressure loss by a slight veering of the device toward the deflated tire side.

The device easily goes up and down gradients as steep as 36%. Turns with curve radii as short as 15 ft. can be made at full speed without slipping and while keeping full control of the device, provided the rider shifts his or her weight in the direction of the turn.

40 External temperature during the tests was between 1°C and 8°C.

4.2 Ergonomic evaluation of Segways[41]

SHUMAC conducted the ergonomic evaluation of the Segways. The main objective was to provide an "opinion based on well-established ergonomics and focussing on various aspects of safe Segway use." The study sought to identify whether use of these MPTDs would pose serious problems.

The ergonomic evaluation focussed on the following three aspects:

- A study comparing Segways with other modes of transportation. This comparison dealt mainly with the levels of difficulty of using Segways, compared with other modes of transportation (walking, mopeds, bicycles and cars).
- Observations during the training and testing sessions helped identify some of the main problems facing users.
- The user interfaces of the devices were examined using various standards and guidelines specific to ergonomic studies. Special scrutiny was given to handlebars and indicators during this phase.

This chapter sets out the main conclusions of the SHUMAC study.

In summary, the ergonomic evaluation demonstrated the following:

- Because the literature review failed to locate a thorough evaluation of Segway ergonomics, the ergonomic study of the Segways carried out as part of this Project was a first;
- Generally speaking, the requirements for driving Segways do not seem more rigorous than those for other modes of personal transportation, such as bicycles, mopeds or cars;
- The device also appeared more stable than most other vehicles compared in the study. However, regaining control of the device after losing control could prove more difficult than for other types of vehicles;
- Some groups of users, especially pregnant women and seniors, may have particular problems;
- The audio response level of the devices is insufficient and some useful information is not indicated;
- The time between an alarm (e.g., a dead battery) and the device stopping seems too short;
- Users required a bit of training in how to get on and off the device because Segways tend to respond to any movement made with the handlebars;
- Breakdowns while going up steep gradients could pose a problem for users because it is impossible to immobilize the device and maintain platform stability. It is also difficult to get off the device on a sloping gradient.

Segway use

The ergonomic evaluation demonstrated that a wide variety of users find Segways easy to use in normal use situations as well as in situations involving obstacles. The devices also compare favourably with other types of vehicles, particularly in terms of stability, where they also seem superior to other vehicles such as bicycles or mopeds.

Segways seem very straightforward to use, except where changing direction is concerned. On a Segway, changes of direction are executed by the left hand, which can sometimes be a problem, particularly when a quick or unaccustomed response is required in unexpected situations.

The experts also found that when Segways are used in buildings and public places, their obstructiveness is minimal, and compared them to a person on crutches or a person pulling a suitcase on wheels.

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41 We know that Canada Post ergonomists are also working on the project; however, the data are not yet available.

Note that most users participating in the study felt that the mental effort required for operating a Segway varied from low to medium, which compares favourably with bicycles, mopeds and cars.

Evaluation by analogy or comparative analysis

A qualitative comparative study was carried out to position Segways in relation to other types of personal transportation. Table 5 shows the results of the comparison of various vehicles with Segways. A qualitative evaluation, comparing each mode of transportation with the Segway, was carried out for each category (eg, understanding of how the device works). The Fly-Trottel Project ergonomic experts used the following values in their qualitative evaluations:

++ Much better (or much more advantageous or much easier) than the Segway
+ Somewhat better (or somewhat more advantageous or somewhat easier) than the Segway
+/- About the same as the Segway
- Worse than (or less advantageous than or not as easy as) the Segway
-- Much worse (or much less advantageous or much more difficult) than the Segway
N/A The comparison was not applicable or not very relevant.

TABLE 5
Results of a Comparison of Various Vehicles with Segways

	Mode of Personal Transportation[42]					
	Walking	**Moped**	**Segway**	**Bicycle**	**Car**	**Comments**
Understanding of how device operates	N/A	+/-	+/-	+	-	Understanding of how the device operates is considered to be nearly the same in the case of mopeds and Segways
Training	N/A	-	+/-	-	--	Mopeds and bicycles are considered to require comparable amounts of training as Segways, but more training time than Segways. Cars require still more training because of their complexity.
Use in normal use situations	++	-	+/-	+/-	-	In normal use situations, walking is considered the most natural mobility method, followed by Segways and bicycles, and mopeds and cars.
Handling	++	-	+/-	+/-	--	Walking permits maximum flexibility, followed by Segways, which adjust very easily to various postures, followed closely by bicycles. Mopeds, because of their weight and speed, seem more difficult to handle, and cars even more so.
Sharing of space with pedestrians	++	--	+/-	-	--	Mopeds and cars usually do not share space with pedestrians. Sometimes bicycles can share space with pedestrians. Segways seem equivalent to an electric wheelchair.

42 All comparisons were made with Segways as the focus of comparison.

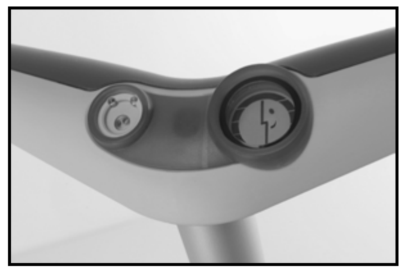
Results in terms of stability both within and at the limits of the operating envelope

The ergonomic evaluation tended to show that the Segway's, operating envelope – i.e., the usual operating parameters – was "larger" than that of a bicycle or moped, and even that of a car. In other words, Segways were designed to maintain the user's balance and stability as automatically as possible, thus creating a larger operating envelope than those of the other types of locomotion studied.

The ergonomic experts felt that "users would see a relatively sudden transition when Segways leave their normal operating envelopes. This leaves users with very few opportunities and very little time to regain control of a Segway that suddenly leaves the envelope." By design, Segways tend to isolate users from their immediate environment and provide them with a comfortable form of mobility. But in doing so, they also distance the user from surrounding objects.

Usability standards and evaluation

The ergonomic studies also helped to assess whether the dimensions and some of the visual and technical characteristics of Segways could effectively accommodate various types of users. The following specific aspects were evaluated:


Segway display icon

- **Handlebar height**: The handlebars are high enough to accommodate users of varying heights ranging from a short woman (a woman shorter than 2.5% of women in the American population) to a very tall man (a man taller than 97.5% of men in the American population).
- **Hand grip diameter**: Hand grips make it possible to carry the weight of a Segway, especially in "power assist" mode (a mode in which the Segway provides some of the power required to move the device up a stairway, for example).
- **Audio alarm level**: The audio alarms on Segways are only marginally effective.
- **Visual status indicator**: The display icon can be difficult to read in a sunny environment. There are also codes in several shapes and colours that are difficult to read. These observations were also corroborated in the work carried out by Université du Québec à Montréal (UQAM) transportation system design students. This work helped identify weaknesses in graphical information, which sometimes appeared confusing or overly complex.
- **Acceleration and deceleration**: The control lever appears very straightforward and does not seem to present problems.
- **Steering**: The left handgrip steers the device. This steering method is different than that usually used in other types of personal transportation vehicles. Users need to spend some time learning how to use it in order to get used to it.
- **Shutdown time**: The 15-second time period before the device shuts down in the event of a breakdown is too short. In specific, probably rare cases (breakdown while climbing a steep gradient), a breakdown of the Segway could be a problem for the user because (1) it is impossible to immobilize the device and maintain platform stability and (2) it is difficult to get off the device safely.

User characteristics that may give rise to particular problems

In addition to the supplier's recommendations, the ergonomic study identified other characteristics that should be taken into account, based on scientific knowledge.

- Because the Segway platform is positioned about 21 cm (8 in.) above the ground, a fall to the ground can have more serious consequences than a fall to the ground by a person who is walking owing to the additional potential force the extra height produces. This is especially true when one considers that Segways are generally expected to be moving.
- Maintaining one's balance varies according to one's age. The simple task of remaining standing on a stable surface has been the subject of much research and it is known that body balance is controlled at various levels of the nervous system. Because elderly people make greater demands on their nervous systems to keep their balance, the challenge they face in using this type of device is greater.
- We can also expect Segways to pose special challenges for people with shifted centres of gravity, e.g., people carrying loads or pregnant women.
- People with disorders possibly affecting the quality of proprioceptive information they receive (e.g., peripheral neuropathy) should refrain from using Segways.
- People with vestibular (inner-ear balance) disorders, such as labyrinthitis, should not use these devices.
- Adequate vision, as for driving any other vehicle, is required for this device.

Conclusion

Overall, the ergonomic evaluation demonstrated that a wide variety of users find Segways easy to use in ideal situations as well as in situations involving obstacles. The tests demonstrated that Segways compare favourably with other types of vehicles, particularly in terms of handling, where they also seem superior to other vehicles such as bicycles or mopeds.

To summarize, the following weaknesses were identified in the ergonomic evaluation:

- Audio alarm warnings were marginally effective;
- Visual display is difficult to read in sunny environments, and codes in shapes and colours make interpretation of information confusing;
- Shutdown time is too short in the case of a breakdown;
- In specific, probably rare cases (breakdown while climbing a steep gradient), the breakdown of a Segway could be a problem for the user because it is impossible to immobilize the device and keep the platform stable.

The following users who should refrain from using Segways were also identified in the ergonomic evaluation:

- Pregnant women
- People with proprioceptive disorders
- People with shifted centres of gravity or people carrying loads
- People with vestibular disorders
- Some seniors
- People with inadequate vision for driving other types of vehicles

4.3 User group tests

Selection criteria for recruiting participants were submitted to the Fly-Trottel Project Follow-up Committee. Participants had to be representative of various segments of society. After the selection, the participants were asked to attend a four-hour Segway training/orientation session and a one-hour training/orientation session for the electric scooters.

A total of 49 people participated in the Segway tests in a controlled environment, while a total of 40 people, or nine fewer than for the Segway tests, participated in the electric scooter tests in a controlled environment. Consequently, 18% of the participants did not participate in the electric scooter tests. The main reasons they cited were age (over age 65) and lack of interest in a device perceived as a toy for youngsters.

The characteristics of user group participants in the tests supervised by CEVEQ and the ergonomist were selected and submitted to the Fly-Trottel Project Follow-up Committee for approval and had to reflect various problems dealt with in the study.

4.3.1 Characteristics of users

Gender: 61% of the participants were men and 39% were women. Men were therefore overrepresented in the study, compared with the general population. A good ratio would have been 50% men and 50% women.

Age groups: Age groups were fairly well distributed. Of the participants, 14% were between the ages of 16 and 20; 24% were between the ages of 21 and 40; 37% were between the ages of 41 and 60; 6% were between the ages of 61 and 70; and 18% were over the age of 71. The age groups corresponded fairly well with age groups in the Quebec population and could be considered representative.

Occupation: The participants worked in a wide range of jobs; no fewer than 29 occupations were represented. This broad sample included office workers, managers, public servants, commercial representatives, technicians, engineers, urban planners and police officers. Among the most frequently cited occupations were retirees (24%) and students (14%).

Physical characteristics: The physical characteristics of the participants clearly varied. However, the data show no significant variations in the participants' size. Their height varied between 1.5 m and 1.95 m, with most measuring between 1.67 m and 1.80 m. Seven people were taller than 1.82 m and one person was 1.95 m. There was greater variation in the participants' weight, which varied between 48 kg and 118 kg: 14% of the participants weighed less than 57 kg; and another 14% weighed over 91 kg. One person said she weighed 118 kg. According to the overall data on physical characteristics, most Fly-Trottel Project participants were people of average height (between 1.5 m and 1.95 m) and average weight (average of 68 kg).

Physical fitness: Participants in general indicated they were in fairly good physical shape (86% of participants). Most said they played sports where co-ordination was important regularly (39% said more than twice a week) or occasionally (47%). Only 14% of participants said they never played sports where co-ordination was important. It should be noted that the question mentioned sports intended primarily for younger people, such as rollerblading, ice-skating, cycling, volleyball, hockey, tennis or soccer. The question did not specifically mention less strenuous physical activities, such as walking, swimming or tai chi, in which seniors are likely to participate more regularly.

Health problems: Very few people said they had health problems. Out of 49 participants, only 3 said they had balance problems, 2 said they had central or peripheral vision problems, 1 had limited manual dexterity, and 3 said they had disorders that might affect their performance. Most participants (59%) wore corrective glasses.

Travel habits: Participants used several modes of transportation for short trips under 3 km. Cars were by far the most frequently used mode of transportation (67% or 33 responses), followed by walking (40% or 20 responses), bicycles (22% or 11 responses) and the lowly public transit (6% or 3 responses). Because this section of the questionnaire was multiple-choice, participants could indicate more than one possible method of locomotion. This section posed the greatest risk of not corresponding to expected habits in urban communities. Because the tests were carried out only in the City of St. Jérôme, the participant sample was not representative of the overall Quebec population. For example, in terms of travel habits, it would be logical to find differences between those of St. Jérôme residents and those of another city.

4.3.2 Training

Participants chosen for the tests were given a training session by a CEVEQ trainer who had been officially certified by Segway LLC upon completion of a full Segway LLC training course. The various training modules consisted primarily of explaining the basic principles of the device to each participant, as well as limitations on use of the device, its variable-speed key system, its safety rules and systems (audible, vibrating and visual warning alarms and indicators) and encouragement to operate the devices responsibly in pedestrian environments.

After watching a 20-minute video on safety and being given an introduction to the product and a description of the device and its components, participants took turns going through an initial series of tests to learn how to get on and off the devices. Then they learned how to operate the device: how to go forward and backward and how to stop and turn. During these sessions, they also learned how to ride the devices in an environment full of obstacles and in a gradually narrowing and restricted passageway marked out with cones to simulate door frames and narrow corridors. At intervals, participants carried out unrestricted tests in a closed environment.

In the second series of tests, participants rode the devices in a closed environment and in operating conditions that included a sandbox, a pebbly path, a hump representing a steep slope, various uneven surfaces, and a 20º gradient ending in a landing with stairs afterwards. The participants practised getting on and off the Segway, then taking the device up and down stairs in power assist mode. In power assist mode, the device can be moved in places where it would be inappropriate to ride the device, such as stairs. The first half of the tests were carried out in black key mode (8 km/h) and the other half in red key mode (20 km/h).

4.3.3 Test track

An obstacle course reproducing the main terrain characteristics that users of MPTDs would encounter in actual-use conditions was built and installed in a 7,300 m^2 building. This track simulated some of the day-to-day traffic conditions on sidewalks and various surfaces. The track included the following:

- A test corridor with plastic cubes in the centre;
- A 20° gradient ending in steps;
- A operating environment consisting of:
  - a concrete surface,
  - a box full of sand,
  - a bumpy surface, and
  - a hump.
- Various other obstacles created with cones to simulate entrances and door frames, and with other device users.


A participant riding her Segway on a bumpy surface

Once the training was completed, participants had some free time in which to use and familiarize themselves with the MPTDs. Immediately following this, participants filled out a comprehensive questionnaire. The questionnaire answers were then entered in a database.

The objective of the CEVEQ experiment was to gain a better understanding of the potential problems various users might have while operating a Segway or electric scooter, as well as to gather their reactions to various problems they experienced and their viewpoints on safety and potential uses for these types of MPTDs.

4.4 Segway user evaluation report

4.4.1 Training and learning[43]

The ergonomic experts participating in the Project said that training—whether it was a full four hours of training or a 45-minute orientation session—played a fundamental role in the participants' safe use of the devices. This observation corresponded in every respect with the results of the user group survey.

Just under 60% of participants either had only vaguely heard of Segways or did not know anything at all about the device, while 14% had learned about Segways prior to participating in the tests in a closed environment. The user sample was therefore made up of people with some experience with Segways and people who knew very little about them.

Out of the 49 participants, only three thought the training sessions had not helped them to adequately familiarize themselves with the Segways. These participants also said they needed a few additional hours of training to familiarize themselves more with the MPTD. Three people said they needed about four additional hours of training, while one person said that between five and nine additional hours seemed appropriate.

Two of the people who said they would have preferred a longer period of training also said they had balance problems. Training in how to use a Segway should also take into account certain factors that limit how quickly people learn.

For the vast majority of participants (94%), the four hours of training provided by CEVEQ was quite appropriate.

Nonetheless, 14% of the participants said they were not quite ready to use a Segway to get around normally (in an open environment), even after four hours of training. This suggests that additional "field testing"or experience not directly related to the training is necessary for some people so that they feel confident about riding the MPTD in normal conditions.

43 Segway LLC recommends four hours of training for the Segway HT, e Series (commercial model), and 30 minutes of training for the Segway HT, i Series and p Series (consumer models).

Table 6 shows the results of the survey concerning various learning aspects and their level of difficulty. The results indicate that Segways are generally easy or moderately easy to learn how to use, especially where balance and putting the devices in motion are concerned. Handling aspects, such as steerability, reflex actions and getting around obstacles, seemed slightly more complex.

All participants said the information they were given in the training session was adequate and relevant.

TABLE 6
Evaluation of Level of Difficulty Involved in Learning How to Use a Segway

	Easy	Average	Difficult
Balance	69%	24%	4%
Acceleration	79%	19%	2%
Deceleration	69%	27%	2%
Steering	44%	48%	8%
Reflex actions	39%	49%	12%
Stops and starts	71%	24%	4%
Obstacles	35%	54%	8%

4.4.2 Safety

Initial apprehensions

In all, 44% of participants had apprehensions before riding the devices. Although these apprehensions seemed well founded, given the design and newness of the devices, they were dispelled during the tests because only two people said they had not lost their apprehensions during the tests. Consequently, if the Segways raised some fears initially, they were quickly dispelled.

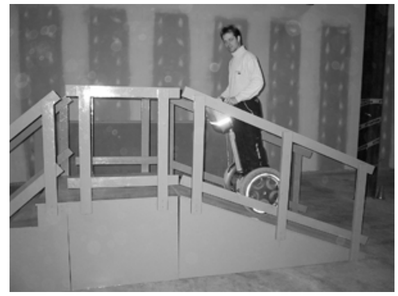
Because it is not initially obvious to users how the Segway operates (five gyroscopes working together to determine the device's position on its gravity axis and which maintain its balance and that of its passenger), we sought to determine whether users felt confident about this new type of device and found the following:

- 86% of users said that they did not have the impression when accelerating or decelerating that they would fall forward or backward;
- 95% of users thought the Segway was sufficiently stable when it came to a stop;
- 96% of users said they thought the Segways had a sufficient response time to properly respond to emergencies;
- All users (100%) thought they had good visibility when they stood at the device's steering controls.

Handling

The tests in an ideal environment helped determine whether users felt at ease during various operations. A special effort was made to identify actions that could be particularly hazardous with a Segway, including the following: getting on and off a Segway; stopping (stationary position); accelerating and decelerating; braking; turning; reversing; going up and down hills; getting around obstacles; travelling on various road surfaces; reading the instrument panel; lifting or setting down objects while standing on a Segway; getting through doors; and travelling in hallways.

The survey results clearly show that the vast majority of users (80%) found all of the actions easy to perform. However, this percentage fell to 68% when it came to making turns (right or left) or going up or down hills. In the case of negotiating hills, the percentage of people who thought they felt fairly at ease increased from 17% to 28%. In all cases, the number of people who found these actions difficult to perform remained marginal, i.e., less than 5% of users. The action that seemed most difficult to perform was getting around obstacles. In this case, 40% of users said they felt moderately at ease, 55% felt completely safe and only 4% said they found it difficult (2 people out of 49).



A participant going up a 20° hill

Breakdown of results

The test track was built in a closed environment and incorporated ideal conditions that were different from normal operating situations (rain, bad weather, lighting, uneven surfaces, traffic and unexpected situations).

The participants who said they had balance problems also said they generally found the Segways more difficult to handle than other users. This finding was not at all surprising because it corresponded to expectations. These people had a harder time with all types of MPTDs, including bicycles, mopeds and scooters.

There was no variation between the overall results and the results for people who wore corrective glasses and people who had vision problems. Their answers were identical in every respect with those of average users. In short, the people with vision problems did not mention having any particular problems in regard to safely using the Segways.

Participants with manual dexterity problems and those with health problems that might affect their performance also did not mention having any particular problems in regard to safely using the Segways. The results show that these people felt at ease and safe on the devices.

Surprisingly, the greatest number of answers saying that the Segways were difficult to handle came from the 41-to-60 age group—a group that is often used as the ideal average sample or population and usually exhibits no particular "distortion" from either a physical fitness or learning standpoint. There are several possible explanations:

- The sample was not sufficiently representative of this age group;
- They came from work environments with higher than average stress levels and therefore had higher expectations of the MPTD's performance.

We found no variation between the results for women and for men. Both groups had similar results with respect to Segway safety aspects. As many women as men in our user sample said they felt at ease and safe for the most part on the Segways.

The results also show that neither height nor weight were factors that had an impact on the compiled data. Physical fitness activities did not play a role in the results either. In other words, being in good physical shape was neither a prerequisite for nor a handicap in using a Segway.

However, in reply to the question about feeling in complete control of the device, 30% of participants said they had "never" felt completely in control of the Segway, compared with 63% who acknowledged they had "sometimes" felt in complete control and only 4% of participants who said they "often" felt in control of the MPTD. The novelty of the devices might explain these variations from the previous data. Users required a certain period of time to feel fully confident on a motorized personal transportation device, be it a Segway, bicycle, moped or car.


Close-up of Segway HT in the sandbox

It is therefore natural that, although the users found the Segways relatively easy to handle, they did not yet feel, at their level, completely in control of the devices. A longer testing and adjustment period is needed to better assess this aspect.

Nonetheless, 55% of participants felt confident "all the time" during their test experience and 43% "often" felt confident. Only one person out of 49 said that she "rarely" felt confident during her experience with the Segways.

Improvements to be made

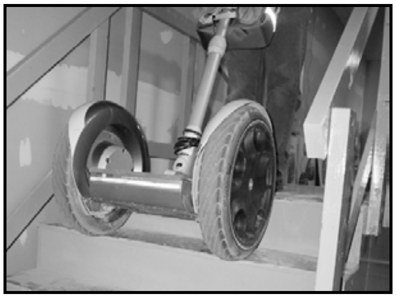
Of the participants, 18% said the Segways did not require improvements. The rest of the participants said the addition of the following accessories would be useful:

- A horn: 24 replies
- A headlight: 22 replies
- A speedometer: 18 replies
- A rear-view mirror: 16 replies

Safety standards

With regard to safety, 70% of participants said that certified training in safety standards provided by the government would be desirable and 57% said that riders should wear helmets. Only 22% thought that a driver's licence was necessary, and a large majority (65%) thought there should be an age limit for Segway users, i.e., above age 14.


Practising turning with the Segway



Negotiating stairs with the Segway

Evaluation of the device's performance

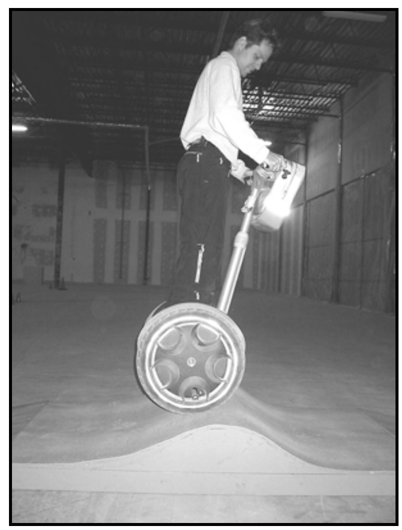
The performance evaluation from the users' perspective focussed on speed, responses of controls, power on hills, handling ability, comfort, braking and obstacles.

Nearly all participants thought the overall performance of the Segways for most of the above study aspects was good or satisfactory. However, there was one difference to be noted where speed on hills was concerned: a couple of people (2 out of 49) thought the devices' power was "deficient."

Trainer's observations and opinions

There were no accidents during the Segway HT and the electric scooter training and testing sessions. Initial apprehensions about the Segways (fear of tipping over, falling, etc.) were dispelled during the training and testing.

During the training, the trainer nonetheless identified problems that participants had in using the turn control because of the unusual relationship between the direction of the steering grip and that of the Segway. The method for controlling a Segway's direction of travel is, in fact, different from that usually used in other types of vehicles: movement of the control toward the left causes the device to turn left and toward the right makes the device turn right. The ergonomic study, which also made this observation, gave us additional information on this aspect.



Riding over a hump

However, these problems diminished throughout the training and testing. Note also that in Table 5 comparable training was considered necessary for mopeds and bicycles, which require more training time than Segways. Cars require even more training because of their complexity. Moreover, a large majority of participants in the performance study thought that the amount of mental effort required to operate a Segway was low to average, which compares favourably with bicycles, mopeds and cars.

4.4.3 Applications

Overall perceptions

All of the participants said they enjoyed their experience with the Segways.

The user groups seemed to have positive perceptions of the Segways during the tests. Choosing from several possible answers, 67% said the Segways were "a new mode of personal transportation that will meet specific travel requirements in urban communities," 43% said they even found Segways a "revolutionary method for getting around," 20% thought they "would be especially useful for persons with reduced mobility," and 10% thought they "were particularly suited to travel in closed environments." Only one person thought the Segways were "primarily a novelty."

Potential applications

Opinions on potential applications for Segways were equally shared among the following: commuting to work; recreational purposes; running errands; and getting around the neighbourhood. The answers suggested that Segways could be used for many types of travel.

Interest in testing Segways in various environments

Most participants said they were interested in further testing of the Segways in various actual-operating environments. The following were the environments in which they were most interested, in descending order:

- Bicycle paths (82%)
- Sidewalks (80%)
- Parks (69%)
- Inside shopping malls (65%)
- Inside buildings (61%)
- Within the boundaries of industrial or private property (53%)

These tests could be used to better validate the data on this MPTD's potential applications.

4.4.4 Profile of potential purchasers

When asked whether they would be interested in purchasing a Segway, men (53%) seemed more interested than women (33%) and young people more interested than seniors. In fact, the results showed that interest in Segways decreased with the age of the respondents. While 86% of users between the ages of 16 and 20 were interested in purchasing a Segway, the percentage dropped to 50% of people in the 21-to-40 age group, to 44% of people in the 41-to-60 age group, and to only 25% of users in the over-71 age group.

The percentage of users who did not want to purchase a Segway was 51%, while 45% were possibly interested in purchasing this type of MPTD.

4.4.5 Transfers to alternative forms of mobility

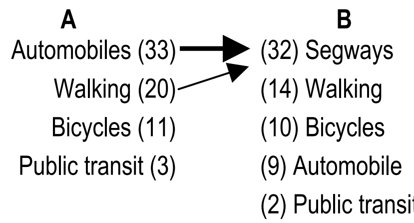
The user survey results show that Segways can potentially generate transfers to alternative forms of mobility. According to the data, if people had Segways, they would make greater use of them for their short-distance trips (less than 3 km). Figure 1 illustrates this transfer to alternative forms of mobility. It can clearly be seen that the most frequently used mode of transportation for short trips in the summer, fall and spring (Column A) would be very different if people had MPTDs such as Segways for making these trips (Column B).

This transfer to alternative forms of mobility mainly affects automobiles. While 33 people currently use their car regularly for short trips, this number would drop to 9 if they had access to Segways.

Walking is also subject to some transfers to alternative forms of mobility. According to the figure, Segways would replace walking for six trips. The data show that this transfer would mainly affect seniors and people with weight problems (over 90 kg).

Note that transfers to alternative forms of mobility seem marginal where bicycles and public transit are concerned. Segways may not have an impact on these two forms of mobility.

FIGURE 1:
Segways' Role in Generating Transfers to Alternative Forms of Mobility



4.5 Summary of Segway user evaluations

Is training necessary? Yes, because it plays a fundamental role in the safe use of Segways. Moreover, only one user out of 49 said that training was unnecessary.

What level of training is required for Segways? The data show that the level of difficulty involved in learning how to use Segways is generally easy or average. For a minority of users, learning how to use a Segway was slightly more complicated, particularly for certain handling aspects such as actions requiring quick reflexes.

Are Segways intended for a particular category of people (age group, gender, occupation, etc.)? Everything indicates that Segways have been designed to meet the mobility needs of a vast majority of people.

What categories of people should refrain from using Segways? Some seniors, pregnant women, people with proprioceptive disorders, people with shifted centres of gravity or carrying loads, and people with vestibular disorders.

Are Segways safe? The test results demonstrated that in ideal-use situations (enclosed track, even surfaces), Segways were stable and gave users the impression of being in control of the vehicle.

What improvements could be made to make these devices safer? The ergonomic evaluation showed that the Segway's audio alarm, visual display and shutdown time could be improved.

Can standardization parameters be identified? The parameters to be taken into account are recognized training provided by a government-certified organization, such as the Quebec Automobile Insurance Corporation (SAAQ), a set minimum user age of 14 and mandatory helmets. Having a driver's licence was not considered mandatory.

For what mobility purposes are Segways best suited? Segways are designed for a wide segment of the public and to meet multiple mobility requirements in urban communities and in open and closed environments.

Do Segways perform sufficiently well and are they attractive enough to generate transfers to alternative forms of mobility? The user survey results indicate that a substantial number of transfers could be generated to Segways as an alternative form of mobility, especially as an alternative to cars.

4.6 Electric scooter user evaluations

4.6.1 Training

The scooter training consisted of explaining to participants how the device operated (performance, acceleration, braking, etc.), and was followed by a period of unrestricted testing in a prepared enclosed track environment. Slightly more than 72% of participants had only vaguely heard of electric scooters or had no knowledge of the devices at all, while 5% had obtained information about them before participating in the tests in the enclosed track environment. A little over 20% had previously tested them. The user sample was therefore made up of people who generally had less experience with and less knowledge of electric scooters than Segways. These data seem a little surprising given that scooters have been in use for a much longer time than Segways. However, they have perhaps attracted slightly less attention from the media in recent years than Segways.

Out of 40 participants, only four thought that the training session that was provided—a mainly theoretical training session lasting 15 minutes—had not helped them become sufficiently familiar with electric scooters. These participants also said they would need a few additional hours of training to become more familiar with the MPTD. Two people said they would need about four hours of additional training, while one person said that more than 15 hours would be necessary.

Table 7 shows the survey results for various training aspects and their level of difficulty. The results show that overall the electric scooter training was relatively easy, as was the case with the Segways.

TABLE 7
Evaluation of Level of Difficulty Involved in Learning How to Use a Segway

	Easy	Average	Difficult
Balance	67%	25%	8%
Acceleration	77%	18%	5%
Deceleration	85%	10%	5%
Steering	72%	20%	6%
Reflexes	75%	20%	5%
Stops and starts	80%	13%	7%
Obstacles	60%	30%	10%

A participant on the Scorpion S-I

Compared with Segways, however, electric scooters seemed easier to learn how to use in terms of handling, reflex actions and getting around obstacles.

Like the Segway users, all users (100%) said that the information they were given during the training session was adequate and relevant.

Despite these encouraging results for the training, 75% of the participants (30 out of 40) thought a training session was not absolutely necessary for using an electric scooter.

4.6.2 Safety

Initial apprehensions

In all, 15% of participants had apprehensions before riding the electric scooters, which was relatively less than for the Segways (44%). However, the apprehensions were dispelled during the tests, given that only two people said their apprehensions had not lessened during testing. It can therefore be said that the electric scooters, probably because of their more familiar appearance, gave rise to fewer initial apprehensions than did the Segways.

Handling

The tests in an artificial environment helped determine whether users felt at ease during various operations. A special effort was made to identify manoeuvres that could be particularly hazardous with electric scooters. The manoeuvres assessed for electric scooters were identical in every respect with those assessed for Segways.

The survey results clearly show that the vast majority of users (73%) found all of the electric scooter manoeuvres easy to perform. However, this percentage dropped to 53% when users carried out manoeuvres to get around obstacles, drive on various types of surfaces and pick up and set down objects. Between 20% and 30% of participants felt relatively at ease while carrying out these manoeuvres. In all cases, it was a marginal percentage of people who found these manoeuvres difficult, i.e., less than 5%. Manoeuvres to get around obstacles seemed to be the most difficult, with 30% of participants saying they felt relatively at ease, 52% saying they felt completely safe and 8% saying they found them difficult (3 out of 40).

Practising turning with the electric scooter

Breakdown of results

The tests were carried out in ideal operating conditions, which were different from normal operating conditions.

Participants who had admitted to having balance problems said they generally found the handling of electric scooters as easy as did the other participants. Unlike Segway users, this user category did not seem to have problems in using the scooters. However, since the number of seniors (the segment of the population more likely to have balance problems) participating in the tests was lower than the number of seniors participating in the Segway tests, the results are likely to vary.

According to the data on participants with manual dexterity problems and participants with health problems that might affect their performance, between 5% and 7% of these participants had specific problems using the electric scooters safely, particularly when executing manoeuvres to get around obstacles.

There was no variation between the overall results and those for participants wearing corrective glasses and persons with vision problems. Their answers were identical in every respect to those of average users. In short, people with vision problems did not mention having any particular problems with respect to the safe use of electric scooters.

No variation was found between men and women in the results. Both groups had similar results for electric scooter safety aspects. As many women as men in our user sample admitted feeling at ease and safe for the most part on electric scooters.

As with the Segways, the results indicated that neither height nor weight were factors that had an impact on the compiled data. Moreover, physical fitness activities did not play a role in the results. In other words, being in good physical shape was neither a prerequisite for nor a handicap in using electric scooters.

Feeling of safety

In reply to the question about feeling completely in control of the device, only one person indicated that she "never" felt completely in control of the electric scooter, compared with 33% who said they "sometimes" felt in complete control and 65% who "often" felt in control of the MPTD. An explanation for this variation in feelings of safety between electric scooter and Segway users is that electric scooters are equipped with a handbrake and that steering is controlled directly from the handlebars (arm- and upper body-activated) and not by a handgrip (wrist-activated). This use of different parts of the body to steer the movements of the two MPTDs may explain the variations in feelings of safety between electric scooter and Segway users.

In all, 60% of users "always" felt confident while riding the electric scooters and 27% "often" felt confident. Five percent of users (2 out of 40) said they "sometimes" felt confident while riding the electric scooters and 5% said they "rarely" felt confident. The percentage of people who did not feel very confident on an electric scooter was therefore slightly higher than the percentage for Segways.

Improvements to be made

Forty-five percent of participants said the electric scooters did not need improvements, a fairly large difference compared with the Segway results (18%). The rest of the participants said that the addition of the following accessories would be useful:

- A horn: 14 replies
- A headlight: 12 replies
- A rear-view mirror: 7 replies
- A speedometer: 5 replies

Safety standards

In regard to safety standards, 70% of participants emphasized that helmets should be mandatory and that there should be a minimum age requirement, with 53% favouring a minimum age of 12 years and up and 28% favouring 14 years and up. Only 17% of participants thought that training approved by a government-certified organization, such as the Quebec Automobile Insurance Corporation (SAAQ), was necessary, while 15% felt that a driver's licence for this type of device was a necessity.

4.6.3 Applications

Overall perceptions

Ninety-three percent of participants said they had enjoyed their experience with the electric scooters, while 7%, or three of them, did not like this MPTD.

The electric scooters seemed to be perceived differently than the Segways. In fact, 42% of the participants (compared with 67% in the case of the Segways) indicated, from among several possible answers, that electric scooters were "a new mode of personal transportation that will meet specific mobility needs in urban communities" and 15% (compared with 43% in the case of the Segways) said that this was a "revolutionary way to get around." Ten percent thought they were "more particularly suited for getting around in enclosed environments" and no fewer than 13 people (32.5% of participants, compared with only one of 49 in the case of the Segways), who were mainly young people under age 20, thought the electric scooters were "primarily a novelty."

Potential applications

Opinions as to potential uses for electric scooters were fairly unanimous: 52.5% of participants (21 replies) considered them to be primarily for recreation and 37.5% (15 replies) thought they would be useful for short neighbourhood trips. They could also be somewhat useful for running errands (12 replies or 30%), but not very useful for commuting to work (20% or 8 replies). The electric scooter survey data indicate that this MPTD is more suited as a means of mobility for recreational activities and relaxation.

Interest in carrying out tests in various environments

Most participants said they were interested in carrying out more tests with the electric scooters in various actual use environments. The following are the environments in which they were most interested, in descending order:

- Bicycle paths (70%)
- Parks (70%)
- Sidewalks (50%)
- Public roads (47.5%)

These tests could be used to better standardize the data on potential uses for electric scooters.

4.6.4 Potential buyer profile

Unlike Segways, few people were interested in acquiring an electric scooter. Out of 40 participants, only 10 (25%) said they were considering possibly buying such a device. When the age of potential purchasers was taken into account, the results were quite surprising. According to the data, people in the 41-to-60 age group were the most interested in purchasing an electric scooter. All of the participants under age 20 (100%) were not interested in purchasing such a device. Interest was not much higher in the 21-to-40 age group, where only 3 people out of 11 expressed interest in purchasing this type of MPTD. The number of potential purchasers in the over-61 age group was fairly low (one person out of four), of course, considering this age category's low level of interest in participating in the scooter tests of Phase 1 of the Fly-Trottel Project.

To sum up, the overall electric scooter user profile would be a person between age 41 and 60. In all, 25% of the women participants and 25% of the men said they were interested in this mode of transportation. Electric scooters therefore seem to be of interest to both men and women.

4.7 Summary of electric scooter user evaluations

Is training necessary? No. A sufficient amount of time for learning how to operate an electric scooter would be 10 to 15 minutes.

What is the learning level required? According to the data, learning how to use electric scooters is relatively easy and simple.

Are electric scooters intended for a particular category of people (age group, gender, occupation, etc.)? Seniors expressed little interest in this MPTD and no one in the under-20 group was interested in purchasing it. Only people in the 41-to-60 age group expressed interest in electric scooters.

What categories of people should refrain from using electric scooters? The same categories of people who should refrain from using Segways, i.e., seniors, pregnant women, people with proprioceptive disorders, people with shifted centres of gravity or people carrying loads, and people with vestibular disorders.

Are electric scooters safe? The test results demonstrated that electric scooters were quite safe in an enclosed track environment.

What improvements could be made to make this device safer? The addition of a horn and headlights would be worthwhile improvements.

Can standardization parameters be identified? Make helmets mandatory and set a minimum user age of 12.

For what mobility purposes are electric scooters best suited? Electric scooters seem best suited for recreation and short neighbourhood trips close to home.

5 General Summary of Segways and Electric Scooters

Table 8 is a general summary of the results of the user surveys conducted by CEVEQ. It also serves as a basis for comparing the two types of MPTDs.

TABLE 8
General Summary of Segways and Electric Scooters

	Segway	Electric Scooter
General characteristics	The Segway is a device equipped with a T-shaped control shaft attached to a platform mounted on two parallel wheels. The device is ridden standing up and handles according to human body dynamics: leaning forward makes the device go forward, standing up makes it stop, and leaning backward makes it reverse (the device is equipped with a balancer and gyroscope system). The device has no brakes or accelerator, but has a steering grip to use for turning. It is the only vehicle able to turn in place, as a pedestrian does, because its wheels can turn in opposite directions.	An electric scooter is a battery-operated, two-wheeled personal transportation device. Similar to a conventional scooter, it weighs about 15 kg, is close to a metre in length and has an ignition key, hand accelerator and brakes. Some models have seats; others have safety features, such as headlights, turn signals and reflectors, and can be folded up or fitted with three wheels.
	Test Data	
Types of devices	Two models: Segway HT, i 167 (i series) and Segway HT, e 167 (e Series)	Two Zappy electric scooters (stand-up) and one Scorpion S-I electric scooter (with seat)
Track	Enclosed track in a controlled environment specially prepared for the project. Track included various obstacles (gradients and cones) and different types of surfaces.	Enclosed track in a controlled environment specially prepared for the project. Track included various obstacles and different types of surfaces.
Test population	Tests in a controlled environment in St. Jérôme; 61% of participants were men; test population was representative overall (age, weight, height); 49 participants.	Tests in a controlled environment in St. Jérôme; 40 participants (who also participated in the Segway tests); most seniors were not interested in the scooter tests.
	User Profile	
Potential buyers	51% of users. Generally men under the age of 40.	25% of users. Generally those in the 41-to-60 age group.
Potential users	All types of people using Segways for various short-distance mobility purposes (trips under 3 km)	Young people using scooters for recreational purposes and neighbourhood transportation
Type of training	Theoretical and practical	10 to 15 minutes of device operating theory
Mandatory training?	Yes, recognized training provided by a government-certified organization, such as the SAAQ.	No
Learning difficulty	Generally fairly easy, but steering, reflex actions and getting around obstacles slightly more difficult than for scooters.	Relatively easy; not particularly complex, except for getting around obstacles.

Safety

Apprehensions	Acute at first, but dispelled as tests carried out.	There were fewer initial apprhensions about electric scooters than for Segways, possibly because the device seemed more familiar.
Feeling of safety	Felt very safe	Felt very safe
Complexity of manoeuvres	80% of test participants thought all of the manoeuvres were easy. However, this percentage dropped to 68% when turning manoeuvres were undertaken (right and left) and when the devices had to negotiate hills.	75% of test participants thought that all of the manoeuvres were easy. However, this percentage dropped to 53% when manoueuvres to get around obstacles were undertaken, when the devices were driven on a variety of surfaces and when users picked up or set down objects.
Breakdown of results	• Participants who said they had balance problems also said they generally found it more difficult to handle Segways than did other users. • There was no variation between the overall results and those for participants with corrective glasses and participants with vision problems. • Participants with manual dexterity problems and participants with health problems that could affect their performance did not mention having any particular difficulty in using the Segways. • Surprisingly, the 41-to-60 age group had the highest number of responses saying that the Segways were difficult to handle.	• Participants who said they had balance problems said they generally found electric scooters as easy to handle as did other users. • According to the data on participants with manual dexterity problems and participants with health problems that could affect their performance, between 5% and 7% of them had particular difficulty with the safety aspects of electric scooters, especially in terms of performing manoeuvres to get around obstacles, steering and reflex actions.
Additional accessories	82% of participants said the Segway needed improvements: horn, headlights, rear-view mirror and speedometer.	55% of participants said the electric scooter needed improvements, particularly the addition of a horn and headlights.
Standardization parameters	Recognized training provided by a government-certified organization such as the SAAQ; a set age limit of 14; and mandatory helmets. Driver's licence not mandatory.	Mandatory helmets and age limit of 12.
Accidentology	No statistics. Because of the newness of the device, no reliable data has been compiled.	Statistics in many western countries show a significant increase in accidents related to scooter use (conventional or motor-driven) in the past two to three years.
Suitability to urban communities	94% of participants thought the Segways were safe for trips in urban areas.	75% of participants thought that electric scooters were safe for trips in urban areas.

Applications		
Overall perceptions	67% of test participants said Segways are "a new mode of personal transportation that will meet specific travel requirements in urban communities" and 43% said they even found Segways a "revolutionary method for getting around".	32.5% of test participants throught that electric scooters "are primarily a novelty."
Applications	Various mobility purposes: commuting to work, running errands, recreation, etc.	Recreation
Transfers to Alternative Forms of Mobility		
Potential transfers	From cars to Segways for trips of less than 3 km in the summer, spring and fall. Walking would be replaced by Segways in some cases.	Not assessed
Comments/summary	"A perfect mode of transportation for persons with disabilities. Also perfect for our shopping centres, mail delivery and other purposes." (Monique)	"A good thing for young people instead of gasoline-powered scooters." (Philippe)

To sum up, Segways are more complex to learn how to use than electric scooters and they require a minimum of training. They are also more expensive to buy. However, Segways are designed for a larger segment of the population and to meet a wider variety of mobility needs in urban communities and in closed or open environments. Segways would also generate transfers to alternative forms of mobility, particularly from automobiles to Segways.

Uses for electric scooters seem more limited, particularly to recreational uses. Their market is limited to recreation and tourism.

6 Conclusions

Given the many problems of congestion, pollution and urban mobility, new modes of transportation, such as motorized personal transportation devices (MPTDs), increasingly seem to be an alternative to widespread automobile use.

Within this perspective, Phase 1 of the MPTD evaluation project sought to identify standardization parameters and safety requirements by evaluating two types of MPTDs in a closed environment under ideal conditions. These were the Segway HT and the electric scooter, two devices that could meet mobility requirements in urban communities.

Where Segways are concerned, the results of the technical tests demonstrated that in normal use situations, Segway HTs were stable, operated quietly and smoothly, and gave users the feeling of being in control of the vehicle. The ergonomic evaluation also demonstrated that Segways are easy to use in normal use situations, including situations involving obstacles, for a broad cross section of users. The devices also compare favourably with other types of vehicles, particularly in terms of stability, where they seem superior to other vehicles such as bicycles and mopeds.

The performance studies carried out in a closed environment demonstrated that Segways are more complex to learn how to use than electric scooters and that training, as specified by the manufacturer, is necessary. However, Segways are designed for a broader segment of the population and are meant to meet a wider variety of mobility requirements in urban communities. Segways would also generate transfers to alternative forms of mobility and reduce car use for short distances, in particular.

The performance studies carried out in a closed environment also demonstrated that electric scooters are easy to use in normal use situations as well as to get around obstacles. The survey results clearly show that a large majority of test participants found all electric scooter movements easy to perform. However, this device is targeted more for young people and seems primarily intended for recreational purposes.

A vast majority of test participants thought that both types of MPTDs were safe for getting around in closed environments. The evaluation results suggest that Segway use is appropriate in closed environments, such as major industrial complexes, hospitals, shopping centres and airports. More in-depth studies should be carried out in Phase 2 of the Fly-Trottel Project to determine whether Segways and electric scooters should be used on public roadways. During Phase 2, the following could be assessed:

- Ability of these MPTDs to share sidewalks with pedestrians
- Impact of actual operating conditions in a dynamic rather than a static environment on the performance of Segways and electric scooters: crossing at intersections, various day and night lighting conditions, and adverse weather conditions (wind, rain and cold temperatures)

7 Recommendations

In light of the results of Phase 1 of the evaluation, it is recommended that:

- Phase 2 of the Fly-Trottel Project to evaluate electric scooters and Segways in actual operating conditions be carried out according to procedures to be determined by the Project partners;
- Evaluations under actual operating conditions be continued to help develop a new regulatory framework and to define new technical characteristics and conditions under which MPTDs may be used.

Phase 2 would also assess:

- The reliability and safety of these devices when used in urban communities;
- Social acceptance of scooters and Segways in Quebec; and
- The ability of these devices to replace cars for short trips in urban communities.

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