

**Improving Bay Area Rapid Transit (BART) district  
Connectivity and Access with the Segway Human  
Transporter and other Low Speed Mobility Devices**  
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Authors

Caroline J. Rodier, Susan A. Shaheen, Linda Novick

CALIFORNIA PATH PROGRAM  
INSTITUTE OF TRANSPORTATION STUDIES  
UNIVERSITY OF CALIFORNIA, BERKELEY

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Linda Novick**

**California PATH Research Report  
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The contents of this report reflect the views of the authors who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the State of California. This report does not constitute a standard, specification, or regulation.

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CALIFORNIA PATH PROGRAM  
INSTITUTE OF TRANSPORTATION STUDIES  
UNIVERSITY OF CALIFORNIA, BERKELEY

**IMPROVING BAY AREA RAPID TRANSIT (BART) DISTRICT  
CONNECTIVITY AND ACCESS  
WITH THE SEGWAY HUMAN TRANSPORTER AND  
OTHER LOW-SPEED MOBILITY DEVICES**

**Phase One Final Report**

**Caroline J. Rodier, Ph.D.**

Post-Doctoral Researcher  
California Partners for Advanced Transit and Highways (PATH) &  
1357 S.46th Street, Bldg. 452  
Richmond, CA 94804-4648  
(510) 231-9472 (O); 510 231-9565 (F)  
cjudier@path.berkeley.edu

**Susan A. Shaheen, Ph.D.**

Honda Distinguished Scholar in Transportation, University of California, Davis &  
Policy and Behavioral Research, Program Leader,  
California Partners for Advanced Transit and Highways (PATH) &  
1357 S.46th Street, Bldg. 452  
Richmond, CA 94804-4648  
(510) 231-9409 (O); 510 231-9565 (F)  
sashaheen@path.berkeley.edu; sashaheen@ucdavis.edu

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## EXECUTIVE SUMMARY

Access to transit stations is a significant barrier to transit use in many urban regions. Parking during peak hours is often limited, and many individuals are only willing to walk about a quarter mile to transit stations (Cervero, 2001). While there are some effective feeder services (e.g., shuttles) that help extend the range of transit access, these systems are limited because of fixed routes and schedules. A number of strategies have recently been implemented to improve transit access and transit use, including bicycles, electric bicycles, carsharing, and personal neighborhood electric vehicles (Shaheen, 1999; Shaheen et al., 2000; Shaheen, 2001; Shaheen and Wright, 2001; Shaheen and Meyn, 2002).

An innovative mobility device that may also improve access to transit stations is the Segway Human Transporter (Segway HT). The Segway HT, brainchild of Dean Kamen, was unveiled in 2001 to accolades over its technological achievement and skepticism about its safety. The Segway HT was designed for use in the pedestrian environment. It is a self-balancing, two-wheeled electric device on which the operator stands upright and steers using weight distribution and a hand control. The device weighs between 83 and 95 pounds and can attain a speed of 12.5 miles per hour (mph).

This report documents the results of the first phase of a two-part project: (1) research and feasibility analysis and (2) the field operational test and research of a shared-use Segway HT, electric bicycle, and bicycle rental model linked to a Bay Area Rapid Transit (BART) District station and surrounding employment centers. The feasibility analysis identified the Pleasant Hill BART station and surrounding community, in the East San Francisco Bay Area, as a viable field test location for the introduction of low-speed modes. The location met all criteria established by Partners for Advanced Transit and Highways (PATH) researchers and project partners (i.e., BART, Segway LLC, Giant Bikes, and All Aboard), including: (1) favorable location physical attributes (i.e., employment density and distribution, available pedestrian/bicycle infrastructure, and the absence of significant transit feeder service); (2) community support, in particular, the ability of the field test design to address the safety concerns of the elderly, disabled, and pedestrian advocates; (3) evidence of a large pool of employers who could benefit from the service; (4) a transit station vendor to distribute the devices; and (5) a multi-jurisdictional location to enhance the transferability of the results.

Despite some negative publicity surrounding Segway HT safety, interest in the device and preliminary evidence of its potential benefits remain substantial enough to include it in this research demonstration project. A comparative evaluation of three devices—Segway HT (new), electric bicycle (enhanced), and bicycle (traditional)—should contribute significantly to an understanding of the context in which the different low-speed devices may increase transit access most cost-effectively.

There are preliminary signs that the Segway HT can produce economic (e.g., time savings and reduced vehicle operation and maintenance costs) and environmental benefits

(i.e., reduced vehicle emissions) when it is carefully applied for selected purposes and locations, as the results of the authors' Segway HT pilot project survey (included in this study) suggest.

It appears that efforts to familiarize officials and stakeholders with the Segway HT have helped to curtail many threats to ban the Segway HT (because of safety issues related to sideway use) that have arisen in local jurisdictions. Only three local jurisdictions have an effective ban on the device, and only six states have not passed Segway HT-enabling legislation where it is necessary. Additional safety requirements in much of the state-level legislation may have been included to address stakeholders' safety concerns. At the very beginning of the feasibility analysis, steps were taken to involve local stakeholders and officials to identify and address any safety concerns.

In addition, the literature review on the safety of low-speed modes (included in this study) indicates that the risk of crashing is relatively small and often does not involve collisions with other low-speed modes or motor vehicles. Crashes that do occur are most frequently the result of poor surface conditions, user error, obscured driver vision, and low-speed mode design. Many of these causal factors can be minimized in the selection of field test routes, by training and requiring additional safety equipment. The survey of Segway HT pilot projects (included in this study) also emphasized the need for thorough training on all route terrain and recommended the use of additional safety equipment.

The results of community meetings and interviews during the feasibility analysis phase, the low-speed mode literature review, the regulatory and legislative history of the Segway HT, and the survey of the Segway HT pilot projects informed the safety requirements that are included in the field operational test design described below:

- Safe routes on sidewalks and trails;
- Extended device training for participants on all terrains included in the routes;
- Walking the Segway HT within the BART station;
- Safety equipment (i.e., helmets, lights/reflectors, and bells);
- Restrictions on participant age and health; and
- Following field test "rules of the road" as a condition of participation (i.e., top Segway HT speed eight mph and to yield right-of-way to all other pedestrians and low-speed mode users, including devices used by the disabled).

## References

- Cervero, R. Walk-and-Rider: Factors Influencing Pedestrian Access to Transit. *Journal of Public Transportation*, Vol. 3, No. 4, 2001, pp. 1-25.
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## CHAPTER 1: INTRODUCTION

Access to transit stations is a significant barrier to transit use in many urban regions. Station parking during peak hours is often limited, and most people are only willing to walk about one-quarter mile to transit stations (Cervero, 2001). While there are some effective feeder services (e.g., shuttles) that help extend the range of transit access, these systems are limited because of fixed routes and schedules. A number of strategies have recently been implemented to improve transit access and transit use, including bicycles, electric bicycles, carsharing, and personal neighborhood electric vehicles (Shaheen, 1999; Shaheen et al., 2000; Shaheen, 2001; Shaheen and Wright, 2001; Shaheen and Meyn, 2002).

A new mobility device that may also improve access to transit stations is the Segway Human Transporter (Segway HT). The Segway HT, brainchild of Dean Kamen, was unveiled in 2001 to accolades over its technological achievement and skepticism about its safety. The Segway HT was designed for use in the pedestrian environment. It is a self-balancing, two-wheeled electric device on which the operator stands upright and steers using weight distribution and a hand control. The device weighs between 83 and 95 pounds and can attain a speed of 12.5 miles per hour (mph).

This report documents the results of the first phase of a two-part project: (1) research and feasibility analysis and (2) the field operational test of a shared-use Segway HT, electric bicycle, and bicycle rental model linked to a Bay Area Rapid Transit (BART) District station and surrounding employment centers. The authors have identified the Pleasant Hill BART station and the surrounding area as a feasible field test location. Significant business development and a downtown area are within a two-mile radius of the BART station. The sidewalks are wide and underutilized and a trail system exists that links the station to local neighborhoods. There is limited bus and shuttle service to area businesses. Furthermore, employers are located near the downtown area so that the devices can also be used during the day for lunch, errands, or meetings. This research field test will provide an opportunity for researchers to test and evaluate low-speed alternative methods to improve transit station access, while expanding choice.

The second phase of the project focuses on the evaluation of the field operational test and compares the effectiveness of a new mode (the Segway HT), a technologically enhanced mode (the electric bicycle), and a traditional mode (a regular bicycle). A comparative evaluation of the three modes should contribute significantly to an understanding of the context in which different low-speed modes may increase transit access most cost-effectively. More specifically, the research evaluation will address the following questions:

- How effective is each mode with respect to increasing transit use and why?
- Which modes increase transit use most cost-effectively and why?

- Will the enhanced features of the Segway HT and electric bicycles relative to bicycles (e.g., greater travel distances, comfort, carrying capacity, and reduced physical exertion) outweigh possible user resistance to using these new modes?
- Does offering a range of “choice” increase the attractiveness of low-speed modes to improve transit access?

As part of the feasibility analysis, in Chapter 2, the authors review the literature on the safety of low-speed modes in pedestrian environments, including walking, bicycling, skating, skateboarding, scooter riding, and operating wheelchairs. Advocates for the elderly, disabled, and pedestrians have raised safety concerns about the use of the Segway HT on sidewalks, and three cities in California have banned the use of the device on sidewalks. The literature review provides insights into potential safety issues that may need to be addressed in the demonstration project. For each low-speed mode, the authors describe regulations, operational characteristics, crash rates, and factors that contribute to crashes. Conclusions are made about the relative risk of each mode, the most significant risk factors, and the implications of the literature review results for the field operational test.

In Chapter 3, the authors chronicle the regulatory and legislative history of the Segway HT at the federal, state, and local levels. The Segway HT was designed for operation in the pedestrian environment; however, with two electric motors and the ability to move people and cargo, the Segway HT could be classified as a motor vehicle and thus prohibited from sidewalk use. The regulatory and legislative responses to the Segway HT provide insights into potential concerns that need to be addressed in the field test.

Next, in Chapter 4, the authors present the results of a survey of selected pilot Segway HT implementation projects in the public and private sectors. The survey results provide insights into potential benefits and challenges of Segway HT use in a range of application environments.

In Chapter 5, the authors describe the feasibility analysis of the field operational test. Lessons learned from the literature review on the safety of low speed modes, the regulatory and legislative history of the Segway HT, and the survey of Segway HT pilots, described in the previous chapters, are incorporated into this analysis.

Finally, in Chapter 6, the authors draw general conclusions about the results of the feasibility analysis for the proposed field test.

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## **CHAPTER 2: WHAT THE LITERATURE SAYS ABOUT THE SAFETY OF LOW-SPEED MODES**

### **INTRODUCTION**

In this chapter, researchers review the literature on the safety of low-speed modes, including walking, bicycling, skating, skateboarding, scooter riding, and operating wheelchairs. The literature review provides insights into potential safety issues that may need to be addressed in the field operational test. For each low-speed mode, the authors describe regulations, operational characteristics, crash rates, and factors that contribute to crashes. Conclusions are made about the relative risk of each mode, the most significant risk factors, and the implications for the field test.

Literature on the safety of low-speed modes was reviewed from October 2002 to July 2003. Resources searched include: library databases (e.g., MELVYL, TRIS, and PATH), the Internet, and Transportation Research Board Annual Meeting proceedings. In addition, interviews with safety experts (e.g., Dr. David Ragland at the University of California, Berkeley) were also conducted to identify additional literature. Approximately 300 reports, journal articles, news articles, and web-based articles were examined during the literature review process.

### **PEDESTRIANS**

#### **Background**

Because of relatively slower travel speeds and greater difficulty carrying packages, walking tends to be less attractive than driving for many “purposeful” trips (Goldsmith, 1993). Only 5.4 percent of all trips (Hu and Young, 1999), 2.68 percent of all commute trips (U.S. Census Bureau, 2003), and 8.5 percent of all commute trips five miles or less are made by foot (Pedestrian and Bicycle Information Center, 2003). In addition, it is well known that walking access to transit drops dramatically with distance from transit stations: approximately 85 percent of transit access trips are made by foot within a quarter mile, ten percent within one mile, and two percent within two miles (Federal Transit Administration, 1996; cited in Zegeer et al., 2002).

#### **Characteristics**

The physical abilities of pedestrians are described in a 1999 Federal Highway Administration (FHWA) review on sidewalk design (Axelson, 1999). The report states that “the concept of the ‘standard pedestrian’ is a myth; in reality, travel speeds, endurance limits, physical strength, stature, and judgmental abilities of pedestrians vary tremendously” (Axelson, 1999, p.13). For example, the average walking speed for all pedestrians is 2.7 mph (U.S. Department of Transportation, 1988; cited in Axelson, 1999); for older pedestrians it is 1.9 mph (Staplin et al., 1998; cited in Axelson, 1999). In

addition, many pedestrians are able to change direction immediately, but older pedestrians or pedestrians burdened with objects may have more limited maneuverability (Axelson, 1999).

Pedestrians tend to walk in the center of the sidewalk to allow space between themselves and the edge of the sidewalks (e.g., streets, telephone poles, and/or swinging doors) (Axelson, 1999). This space, often referred to as “shy distance,” reduces the effective sidewalk space available to pedestrian traffic (Axelson, 1999). According to the Oregon Department of Transportation, pedestrians typically leave a distance of 24 inches on either side of the sidewalk to avoid buildings or obstructions, for example (Oregon Department of Transportation, 1995; cited in Axelson, 1999). Thus, the effective space available to pedestrian traffic for a ten-foot sidewalk would be reduced to six feet (Axelson, 1999).

## **Regulation**

Laws that govern pedestrian travel in California reflect concerns about potential conflicts between pedestrians and other vehicles (California Vehicle Code Sections, 21950, 21954-21956, 21960; cited in American Automobile Association, 2003). These laws require that pedestrians: (1) obey traffic rules and etiquette; (2) yield to oncoming vehicles if the vehicles pose a hazard to the pedestrian; (3) cross at marked crosswalks at an intersection; (4) walk on the left-hand edge of the road facing traffic if no sidewalk is available; and (5) not walk on certain roadways and freeways. These laws attempt to establish a clear separation between pedestrians and vehicles to avoid conflicts and maximize safety.

## **Crashes**

### *Locational Factors*

Several government studies evaluate pedestrian crash data and identify the frequency of conflict type (e.g., pedestrian only, pedestrian-bicycle, or pedestrian-motor vehicle) by location (e.g., sidewalk or roadway) (Hunter et al., 1996; Stutts and Hunter, 1997; Shankar, 2003).

A 1997 FHWA study evaluated emergency room data from 1995 to 1996 (one year) on *pedestrian<sup>1</sup> only*, *pedestrian-bicycle*, and *pedestrian-motor vehicle collisions* from eight

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<sup>1</sup> The study defines a pedestrian as any person engaging in an activity that does not involve a motorized or road vehicle (i.e., walking, running, playing, standing). This definition thus includes people with special equipment such as in-line skates, rollerblades, skateboards, wheelchairs, strollers, and bicycles. Out of the 1,345 cases reviewed, only 15.2 percent involved individuals using special equipment. The study also includes conflicts that occur on any public or private ground if a motor vehicle is involved; any location where there is vehicular traffic (i.e., parking lots, stores, businesses); and any “public transportation-related facilities not generally open to vehicular traffic” (i.e., sidewalks, multi-purpose trails) (Stutts and Hunter, 1997).

hospitals in California, New York, and North Carolina (Stutts and Hunter, 1997). Table 2-1 (below) summarizes the pedestrian injury events by type and location from the study. It can be seen that more pedestrian injury events occurred in non-roadway locations (48.1 percent) than roadway locations (43.4 percent). The sidewalk was the most common location for pedestrian injury events (27.5 percent of total injury events). Pedestrian-only events were most frequent on sidewalks (41.6 percent) due to icy winter conditions in New York. Pedestrian-motor vehicle conflicts occurred most often on roadways (84.1 percent). The number of pedestrian-bicycle conflicts is small compared to pedestrian-motor vehicle and pedestrian only crashes, and most pedestrian-bicycle injury events occurred on sidewalk (57.1 percent). However, pedestrian-motor vehicle crashes on roadways were most often fatal (14 of 15) or produced injuries that were serious enough to require hospital admissions (174 of 254) relative to other injury event type and location (Stutts et al, 1997).

**Table 2-1. Number of Pedestrian Injury Events by Type and Location.**

| Injury Event Location     | Ped-MV     | Ped-Bicycle | Ped Only   | Total       |
|---------------------------|------------|-------------|------------|-------------|
| <b>Roadway</b>            | <b>439</b> | <b>8</b>    | <b>188</b> | <b>635</b>  |
| <b>Non-Roadway</b>        | <b>57</b>  | <b>12</b>   | <b>635</b> | <b>704</b>  |
| Sidewalk                  | 7          | 12          | 383        | 402         |
| Driveway, Yard            | 15         | 0           | 53         | 68          |
| Parking Lot               | 33         | 0           | 166        | 199         |
| Off-road Trail, Park, etc | 2          | 0           | 33         | 35          |
| <b>Other/Unknown</b>      | <b>26</b>  | <b>1</b>    | <b>98</b>  | <b>125</b>  |
| <b>Total</b>              | <b>522</b> | <b>21</b>   | <b>921</b> | <b>1464</b> |

Source: Stutts and Hunter (1997)

A 1996 FHWA study analyzed 5,073 police reports from North Carolina, California, Florida, Maryland, Minnesota, and Utah in the year 1991 or 1992 on *pedestrian-motor vehicle crashes* (Hunter et al., 1996). Common crash locations were roadways with no special features, intersections, and mid-blocks. Intersection-related crashes were typically caused by a turning vehicle, obstructed view of pedestrian, and driver violations. Most crashes occurred in a roadway-related environment (81.1 percent) rather than a non-roadway environment—such as sidewalks, walkways, and paths (2.4 percent)—because this study focused on pedestrian-motor vehicle crashes. The authors also report that of pedestrian crashes included in the study, six percent were fatal, 27 percent sustained serious injuries, 34 percent sustained moderate injuries, 28 percent sustained minor injuries, and five percent sustained no injuries.

A 2003 National Highway Traffic Safety Administration (NHTSA) report, in which data from the Fatality Analysis Reporting System (FARS) from 1998 to 2001 on *pedestrian-motor vehicle crashes* were analyzed, found that out of 4,461 pedestrian fatalities in single vehicle crashes, 94.5 percent of fatalities occurred in roadways and only 3.6

percent occurred on non-roadways (Shankar, 2003). Of the roadway fatalities, 21.4 percent were located at intersections and 78.6 percent were located outside of intersections (i.e., on crosswalks, roadways without crosswalks, parking lanes, bicycle paths, and outside traffic-ways). Of the fatalities located outside of the intersections, most of these (55.4 percent) were on roadways with no crosswalk available, where drivers likely could not anticipate a crossing pedestrian.

### *Human Factors*

As described in the previous section, *pedestrian-motor vehicle crashes* appear to be most common at intersections and on roadways without crosswalks. The 1996 FHWA study indicates that pedestrians were most often exclusively at fault in pedestrian-motor vehicle crashes (43 percent), and drivers were less often solely at fault (35 percent) (Hunter et al., 1996). Pedestrian negligence typically included “running into the road, failure to yield, alcohol impairment, stepping from between parked vehicles, and walking or running against traffic” (Hunter et al., 1996, p.149).

It appears that younger individuals are more likely to be involved in pedestrian-motor vehicle crashes than older individuals. The 1996 FHWA report indicated that 29.8 percent of injured pedestrians were less than 15 years old, and 29.7 percent of pedestrians injured were between the ages of 25 and 44 (Hunter et al., 1996). In the 1997 FHWA study, it was found that 30.4 percent of injured pedestrians were less than 15 years old (Stutts and Hunter, 1997). These trends may be explained by higher walking rates among younger individuals and poorer judgment due to relative inexperience. The study also noted that pedestrians over 45 are more likely to be injured by icy conditions on non-roadways (e.g., sidewalks) (Stutts and Hunter, 1997).

## **BICYCLES**

### **Background**

Because of relatively slower travel speeds, difficulty carrying packages, safety concerns, and/or adverse weather conditions (Goldsmith, 1993), bicycling tends to be less attractive than driving and walking for most commute trips (U.S. Census Bureau, 2003; Hu and Young, 1999). In the 2000 U.S. Bureau of Transportation Census, only 0.44 percent of commuter trips were by bicycle, while 2.68 percent were by foot and 87.5 percent were by car (2003). Results of the 1995 Nationwide Personal Transportation Survey indicated that most people bicycle for social or recreational purposes (60 percent), but some also bicycle for personal or family business (22 percent) and to commute (eight percent) (Hu and Young, 1999).

### **Characteristics**

Bicycles typically require 3.3 feet of operating width, which includes 30 inches of occupied space and five inches of free space on either side (American Association of

State Highway and Transportation Officials, 1999). In California, sidewalks have a minimum width requirement of 4.9 feet (California Department of Transportation, 2001). If a bicyclist uses a sidewalk with a width of 4.9 feet, then only 1.6 feet of space would remain for other sidewalk users. Most bicyclists travel almost six times the speed of a typical pedestrian (Allen et al., 1998; U.S. Consumer Product Safety Commission, 2002a). Pedestrians can stop almost immediately, but bicycles traveling at 15 mph must take 15 feet to stop (U.S. Consumer Product Safety Commission, 2002a) or, if traveling at half that speed on dry concrete, 2.1 feet (Science Learning Network, 2003). The turning radius for a bicyclist, traveling at 15 mph with a lean angle of 15° is 56.3 feet and at half that speed, with a lean angle of 15°, 14.1 feet (American Association of State Highway and Transportation Officials, 1999). Pedestrians can turn in place. In sum, bicycles operate at faster speeds, need a greater distance to brake, and require more space to turn than pedestrians.

### **Regulation**

Due to their operational characteristics, bicycles are typically defined as motor vehicles, and thus must follow many of the same laws; for example, in California, “bicycle riders (cyclists) on public streets have the same rights and responsibilities as automobile drivers” (California Department of Motor Vehicles, 2000). More specifically, bicyclists are required to use left and right turn lanes and ride in the direction of traffic (California Department of Motor Vehicles, 2000). Riding on sidewalks is discouraged (California Department of Motor Vehicles, 2000), and several localities have explicitly prohibited it (e.g., San Francisco Traffic Code; American Legal Publishing Corporation, 2002a, 2002b).

The American Association of State Highway and Transportation Officials (AASHTO) guidelines also caution against riding on sidewalks: “sidewalks are typically designed for pedestrian speeds and maneuverability and are not safe for higher speed bicycle use” (AASHTO, 1999, p. 58). AASHTO also mentions that motor vehicles do not expect higher speed bicyclists to enter crosswalks from sidewalks and that a bicyclist’s sight is often blocked by obstructions such as buildings or shrubs (American Association of State Highway and Transportation Officials, 1999).

### **Crashes**

One 2002 study based on data from the National Electronic Injury Surveillance System (NEISS)<sup>2</sup> and the National Sporting Goods Association (NSGA)<sup>3</sup> estimated sports’ injury rates based on participation and found that bicycling has a higher injury rate (11.5 injuries out of 1,000 participants) than skateboarding (8.9 out of 1,000) and in-line

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<sup>2</sup> Kyle et al. (2002) report that the NEISS provides an estimate of the number of consumer product-related injuries nationwide through a sample of injuries from a number of hospital emergency departments throughout the United States. This study used NEISS data from 1987 to 1998.

<sup>3</sup> According to Kyle et al. (2002), the NSGA data were collected from 1987 to 1998 from a panel survey of 20,000 households.



skating (3.9 out of 1,000), but a lower injury rate compared to basketball (21.2 out of 1,000) or football (20.7 out of 1,000) over the course of one year (1998) (Kyle et al., 2002). Another study examined more recent data from the U.S. Consumer Product Safety Commission (CPSC) and the NSGA and found that, when injury rates are considered per 10,000 days of participation, bicycling has the second highest injury rate (2.05) behind skateboards (2.51), followed by in-line skating (1.71), and scooters (1.03) (U.S. Consumer Product Safety Commission, 2002b).

### *Locational Factors*

A number of studies evaluate bicycle crash data and identify frequency of conflict type (e.g., bicycle only, bicycle-bicycle, or bicycle-motor vehicle) by location (e.g., sidewalk or roadway) (Stutts and Hunter, 1997; Aultman-Hall and Adams, 1998; Wachtel and Lewiston, 1994; Tinsworth et al., 1993; Hunter et al., 1996).

The 1997 FHWA report that evaluated emergency room data on *bicycle<sup>4</sup>-only, bicycle-pedestrian, bicycle-bicycle, and bicycle-motor vehicle* crashes found that bicycle crashes are most common on the roadway (58.3 percent) and less common in the non-roadway environment (26.4 percent) (Stutts and Hunter, 1997). Table 2-2 (below) summarizes the bicycle injury event type and location from the study. The authors noted that these results can be explained by the fact that bicycles are most often relegated to roadways. Moreover, most bicycle crashes on the road are bicycle-only events (53.4 percent), and fewer are bicycle-motor vehicle conflicts (43.1 percent). In the non-roadway environment, bicycle-only injury events were most frequent (84.7 percent), and the sidewalk was the most common location of injury events. Compared to the total number of bicycle crashes and bicycle-only crashes, sidewalk conflicts between bicycles and pedestrians and other bicycles were insignificant. Bicycle-motor vehicle crashes on roadways were most often fatal (5 of 6) or produced injuries that were serious enough to require hospital admissions (68 of 120) relative to other injury event types and locations (Stutts and Hunter, 1997).

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<sup>4</sup> The definition of bicyclist in this report is “any person riding or being carried on a bicycle or other two- or three-wheeled vehicle operated solely by pedals,” which includes “bicycle, tricycle, big wheel, pedal scooter” (Stutts and Hunter, 1997).

**Table 2-2. Number of Bicycle Injury Events by Type and Location.**

| Injury Event Location     | Bicycle-MV | Bicycle-Bicycle | Bicycle-Ped | Bicycle Only | Total       |
|---------------------------|------------|-----------------|-------------|--------------|-------------|
| <b>Roadway</b>            | <b>280</b> | <b>15</b>       | <b>8</b>    | <b>347</b>   | <b>650</b>  |
| <b>Non-Roadway</b>        | <b>23</b>  | <b>10</b>       | <b>12</b>   | <b>249</b>   | <b>294</b>  |
| Sidewalk                  | 15         | 3               | 12          | 131          | 161         |
| Driveway, Yard            | 0          | 1               | 0           | 25           | 26          |
| Parking Lot               | 6          | 0               | 0           | 17           | 23          |
| Off-road Trail, Park, etc | 2          | 6               | 0           | 76           | 84          |
| <b>Other/Unknown</b>      | <b>17</b>  | <b>3</b>        | <b>1</b>    | <b>150</b>   | <b>171</b>  |
| <b>Total</b>              | <b>320</b> | <b>28</b>       | <b>21</b>   | <b>746</b>   | <b>1115</b> |

Source: Stutts and Hunter (1997)

One study of 2,963 *commuter bicyclists* in Ottawa and Toronto, Canada, also found that crash events occurred more frequently on roads than on sidewalks (Aultman-Hall and Adams, 1998). There were few sidewalk falls (9.9 percent of total falls in Ottawa and 9.3 percent in Toronto) and fewer sidewalk collisions (4.2 percent of total collisions in Ottawa and seven percent in Toronto). However, sidewalk crashes produced significantly more injuries and more major injuries than other locations. The authors noted that many of the sidewalk events documented in this study were not reported to the police and thus would not have been found in police crash databases. Sidewalk bicyclists, however, report more near misses with other bicyclists than bicyclists on the roads. The study also found that bicyclists use sidewalks on major roads, to cross bridges, take shortcuts, and on high-volume roads (Aultman-Hall and Adams, 1998).

Another study analyzed police records of *bicycle crashes* (from 1985 to 1989) and *bicycle counts* in Palo Alto, California, and found that bicyclists riding on the sidewalk or a bicycle path ran a greater risk of injury at intersections<sup>5</sup> than bicyclists riding on the road (2.4 percent of 2,005 roadway bicyclists injured whereas 4.2 percent of 971 sidewalk bicyclists injured) (Wachtel and Lewiston, 1994). Sidewalk bicycling incurred “greater risk than those on the roadway (on average 1.8 times greater), most likely because of blind conflicts at intersections” (p. 35). Bicycling against traffic on the sidewalk increased the risk of being injured (2.2 percent of 2,553 sidewalk bicyclists riding with traffic injured whereas 7.8 percent of 423 sidewalk bicyclists riding against traffic injured) (Wachtel and Lewiston, 1994). The authors also noted that “sidewalk bicycling appears to increase the incidence of wrong-way travel” (Wachtel and Lewiston, 1994, p. 35).

In another study, Consumer Product Safety Commission (CPSC) investigators conducted a phone investigation of *bicycle-related injuries* in the NEISS from January through

<sup>5</sup> Wachtel et al. (1994) defined an intersection as “any point where turning or crossing movements are possible for the bicyclist or the motorist,” which includes paths meeting a roadway or sidewalks or paths meeting driveways.

December 1991 (Tinsworth et al., 1993). The authors found that bicycle injuries occurred most often on neighborhood streets (41 percent on neighborhood streets, 12 percent on sidewalks/playgrounds, and 28 percent at “other” locations). Most of the crashes resulted from uneven or slippery surface conditions (42 percent), excessive speeds (22 percent), and/or a collision with a moving or non-moving object (28 percent) (Tinsworth et al., 1993).

The 1996 FHWA report also presents data on *bicycle-motor vehicle crashes* (3,000 cases). Common roadway locations for these crashes include intersections (50.4 percent) and driveways (19.1 percent) (Hunter et al., 1996). In both these locations, driver’s vision of bicyclists may be obscured. Most crashes occur on the roadways, particularly at crosswalks. Only 2.3 percent of all crashes are in non-roadway locations.

### *Human Factors*

Several governmental studies address the human factors that contribute to bicycle crashes (Hunter et al., 1996; Clarke and Tracy, 1995; Stutts and Hunter, 1997). The 1996 FHWA study reports that, for *bicyclist-motor vehicle crashes*, bicyclists were solely at fault 50 percent of the time, and drivers were exclusively at fault 28 percent of the time (Hunter et al., 1996). Bicyclist errors leading to these crashes typically included a failure to yield (20.7 percent) and riding against traffic (14.9 percent) (Hunter et al., 1996).

A 1995 FHWA report, which cites a study of *bicycle crashes (all types)* in Winnipeg, Canada, also described the frequency of bicyclist error that lead to crashes: failure to yield (15.1 percent), riding on the sidewalk or in the crosswalk (14.3 percent), and disobeying stop sign/red light (11.1 percent) (Thom and Clayton, 1992; cited in Clarke and Tracy, 1995).

Again, it appears that younger individuals are more likely to be involved in bicycle crashes than older individuals. The 1996 FHWA report found that 45.1 percent of *bicyclist-motor vehicle collisions* involved people less than fifteen years old, and 23.1 percent of collisions involved 25 to 44 year olds (Hunter et al., 1996). Another study reported that bicyclists less than 15 years old dominated the non-roadway, bicycle-only events (60.6 percent), and those 25 to 44 years of age dominated bicycle-motor vehicle events for both roadway and non-roadway locations (32.9 percent for roadway and 40.9 percent for non-roadway) (Stutts and Hunter, 1997). Again, these age-related trends may be explained by higher participation rates among the identified age groups and poorer judgment of younger individuals due to their relative inexperience.

## IN-LINE AND ROLLER SKATES

### Background

The popularity of skating has dramatically increased in recent years; the number of in-line skaters has grown from 3.1 million in 1989 to 29.1 million in 1997 (Osberg et al., 2000). In this section, in-line skating and roller skating are treated interchangeably unless otherwise noted. In-line skates are skates whose wheels are in one single line. Roller skates consist of four wheels distributed over two axles, two in the front and two in the back.

One author conducted an on-line survey<sup>6</sup> of frequency and purpose of skate travel (Osberg et al., 2000). Of the 339 people who participated in the survey, most responded that they skate to visit friends (39 percent responded “sometimes” and 26.9 percent responded “often”) or run errands (37.2 percent responded “sometimes,” and 18 percent responded “often”). Fewer respondents indicated that they skate to work (15.8 percent responded “sometimes,” and 8.1 percent responded “often”) (Osberg et al., 2000).

### Characteristics

Several studies describe the operational characteristics of in-line skaters. In one study, observations<sup>7</sup> and in-line skater measurements were taken at three separate locations (sidewalk, asphalt trail, and long asphalt road) in Florida with the assistance of video cameras (Birriel et al., 2001). The modal speed was approximately 10.5 mph, and the highest speed was greater than 19.5 mph. Schieber et al. (1994) cited similar speed ranges: 10 to 17 mph. These speeds are almost four to eight times as fast as walking speeds. The modal sweep width, or lateral distance the skater occupies, was four feet, and the largest sweep width was greater than seven feet. The modal stopping width was four feet, and the largest stopping width was 12 feet. The modal stopping distance was 20 feet, and the longest stopping distance was 95 feet (Birriel et al., 2001).

Another study cited “Guidelines for Establishing In-Line Skate Trails in Parks and Recreational Areas,” which found that “experienced skaters commonly reach cruising speeds of 10 to 17 mph” (International In-Line Skating Association, 1992; cited in Schieber et al., 1994).

Allingham and MacKay (1997, p. 13) in their “In-Line Skating Review, Phase 2” report state that a “‘skilled’ in-line skater traveling at a similar speed to a bicycle can stop in the same or shorter distance.” The required lateral width is 14.9 feet, plus a maneuvering allowance of 1.3 feet on each side of the skater. Thus, the skater requires 7.5 feet of operating width. Skaters can achieve speeds of over 15.5 mph and “the differences in

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<sup>6</sup> The survey was an option on the author’s skating website. Participants are those who happened to log on to the website and agreed to participate in the survey.

<sup>7</sup> Seven hundred forty-one observations were obtained for speed, 698 were obtained for sweep width, and 335 were obtained for stopping data (Birriel et al., 2001).

speeds between bicycles and other conveyances, including pedestrians, can result in a potential safety hazard on some facilities” (Allingham and MacKay, 1997, p. 15).

## **Regulation**

Due to the potential safety hazards posed by skating, some cities have imposed bans or regulations on skating (Osberg et al., 2000). Skating bans are usually imposed in congested areas; for example, the city of Pittsburgh prohibits roller skating on sidewalks in business districts (Osberg et al., 2000). Other areas, such as Dalles, Oregon, regulate skaters as they do bicyclists (Osberg et al., 2000). Some areas consider skates to be recreational equipment; for instance, regulations in Arlington, Virginia, provide that “no persons shall use roller skates, skateboards, [or] toys, on highways where play is prohibited” (Osberg et al., 2000, p. 7). The quality of path surfaces provided by cities can also restrict skating (Osberg et al., 2000). For example, cobblestones, rough pavement, brick, wood, steel, and gravel surfaces all make skating extremely difficult (Osberg et al., 2000; Allingham and MacKay, 1997).

## **Crashes**

The 2002 study based on data from the NEISS and the NSGA found that the injury rate for in-line skaters is 3.9 injuries for every 1,000 participants over the course of a year, which was less than half the bicycling injury rate (11.5 injuries for every 1,000 participants) (Kyle et al., 2002). Another study, based on more recent CPSC and the NSGA data, found that, when injury rates are considered per 10,000 days of participation, in-line skating injury rates (1.71) are only somewhat lower than bicycling injury rates (2.05) (U.S. Consumer Product Safety Commission, 2002b).

### *Locational Factors*

A number of available studies use crash data to provide information on skating injury rates by location (Orenstein, 1996; Osberg et al., 1998; Allingham and MacKay, 1997; Frankovich et al., 2001).

One study (Orenstein, 1996) analyzed skating crash data from the Fairfax Hospital in Washington, D.C. during the period from May 1992 to October 1993 (137 injuries, 63 of which were inline skaters and 36 of which were roller skaters). It was found that most in-line skating injuries occurred on the street (34.9 percent) or the sidewalk (27 percent) and that most roller skaters were injured in a park or skating rink (50 percent) or the sidewalk (27.8 percent) (Orenstein, 1996).

Another study (Osberg et al., 1998) evaluated in-line skating injury data from the National Pediatric Trauma Registry over a nine-year period (October 1988 to April 1997). It found that most in-line skaters sustain injuries on the road (54.7 percent); however, most of these injuries were due to falls (72.6 percent) rather than collisions with

motor vehicles (22.1 percent) or other causes (5.3 percent). This study did not provide specific information about sidewalk injuries.

One study analyzed skating injury data (893 cases in 1995) from the Canadian Hospital Injury Reporting and Prevention Program (CHIRPP) (Allingham and MacKay, 1997). The CHIRPP database consists of 15 emergency hospitals, of which 10 are pediatric hospitals and five are general hospitals. The authors found that in-line skating injuries occur most often on roads (36.5 percent) and footpaths/sidewalks (11 percent). Most of the crashes were caused by loss of control (67.5 percent), but a few resulted from motor vehicle collisions (3.5 percent), surface conditions (five percent), and collisions with either a stationary object or another person including cyclists (5.6 percent). In addition, this study found that 14.2 percent of the in-line skating injuries were to the head, neck, and face area, which are typically more serious (Allingham and MacKay, 1997).

Another study (Frankovich et al., 2001) analyzed in-line skating injury data from three emergency departments from three hospitals in Canada; the triage staff administered questionnaires to a total of 121 patients with in-line skating injuries from August 23, 1995, to November 19, 1996. Most of these injuries were sustained at parks (48.7 percent), and some were sustained on sidewalks (21.8 percent) and roadways (25.2 percent). The greatest contributing factors to injuries were loss of control (50 percent) and road hazards (30.5 percent). Other factors were less significant, for example, conflicts with other skaters (5.9 percent), cyclists (2.5 percent), motor vehicles (2.5 percent), and pedestrians (0.8 percent). This study found that five percent of in-line skating injuries were head injuries, 20 percent were contusions, and 40.2 were fractures (Frankovich et al., 2001).

### *Human Factors*

As described earlier, most skating injuries, regardless of the location, appear to be caused by loss of control due to skater error or poor surface conditions (Osberg et al., 1998; Allingham and MacKay, 1997; Frankovich et al., 2001). For example, Osberg and Stiles (2000) state that “the majority of skating injuries are due to forward falls on outstretched arms, without vehicle, bicycle, or other skater involvement” (Schieber and Branche-Dorsey, 1995; cited in Osberg and Stiles, 2000, p. 229).

Again, younger individuals appear more likely to be involved in skating crashes. Allingham and MacKay (1997) reported that 59.6 percent of skaters injured were between 10 and 14 years old, followed by five to nine year olds (20 percent), and then by 15 to 19 year olds (14.9 percent). It is important to note, however, that the CHIRPP database over-represents pediatric hospitals and thus may over-represent crash rates among children. Frankovich et al. (2001) found that 50 percent of injured skaters were between 18 and 35 years old and that 31 percent were younger than 18 (Frankovich et al., 2001).

## **SKATEBOARDS**

### **Background**

Skateboarding is typically considered a sport (e.g., street skating, stunts, and other tricks) (Williams, 2002). In the year 2000, it was estimated that 11.6 million people participated in skateboarding (Bach, 2001). By the year 2005, this number is expected to increase to 15 million (Williams, 2002). Skateboarding typically attracts teenage and 20-something males (Bach, 2001).

### **Regulation**

Although most use skateboards for sport, some also use them for travel. In particular, college students often skateboard from class to class. However, due to safety concerns, some cities and college campuses have restricted skateboarding. In the city of Davis, California, skateboards are prohibited on sidewalks in central traffic districts. At the California State University in Long Beach, skateboards are prohibited “on all streets, alleys, sidewalks, parking facilities, driveways, paths and grounds on the campus” (Engoy, 2000).

### **Crashes**

Skateboarding crash rates appear to be relatively high. The 2002 study based on data from the NEISS and the NSGA found that 8.9 out of 1,000 skateboarders are injured over the course of a year (1998) (Kyle et al., 2002). The NSGA and found that, when injury rates are considered per 10,000 days of participation, skateboarding has the highest injury rate (2.51), following by bicycling (2.05), in-line skating (1.71), and scooters (1.03) (U.S. Consumer Product Safety Commission, 2002b).

#### *Locational Factors*

There is very limited evidence available on the location of crashes and contributing factors. The Orenstein (1996) study, described above, found that skateboard injuries occurred frequently on roads (31.6 percent) and sidewalks (18.4 percent) and in other locations, such as indoor areas, parking lots, and driveways (36.8 percent). Another study found that skateboard injuries were eight times more likely to be severe or critical compared to skating injuries, and about three percent of skateboard injuries were serious enough to require hospital admissions (Osberg et al., 1998).

#### *Human Factors*

As with skating, loss of control appears to be the major cause of skateboarding crashes rather than conflicts with other roadway or non-roadway users. Orenstein’s (1996) analysis indicated that 51.3 percent of skateboarding injuries are due to excessive speeds, 17.9 percent to an obstruction, and 7.7 percent to motor vehicle collisions. There also

appears to be some concern about the design of skateboards; they do not have a steering mechanism and so users may lose control more easily (Engoy, 2000).

Younger people, again, appear to be more likely to injure themselves on skateboards because of their lack of experience and ability. One study found that the mean age of injured skateboarders in this study was approximately 13.8 years old (Orenstein, 1996). A 2002 statement by the Committee on Injury and Poison Prevention reports that, according to the U.S. CPSC, 51,000 skateboard injuries involving skateboarders less than 20 years old occurred in the year 1999. The report also states that younger children have a high risk of injury because of poor judgment, surrounding traffic (pedestrian or vehicular), and poor strength (Committee on Injury and Poison Prevention, 2002). Moreover, younger children's "center of gravity is higher than that of older children and adults, their neuromuscular system is not well developed, and they are not sufficiently able to protect themselves from injury" (Committee on Injury and Poison Prevention, 2002, p. 542).

## **SCOOTERS**

Scooters in this section refer to narrow, human-powered devices that riders stand on, as opposed to motorized scooters that are more like small motorcycles.

### **Background**

People of all ages use scooters for a variety of purposes, including recreation and commuting (Eisner, 2000). Since scooters can collapse into a handheld unit, they are convenient to use (Eisner, 2000). The manual scooter typically consists of a baseboard, vertical T-bar to be used as handlebars, and small wheels located at the front and back of the baseboard. This type of scooter is also referred to as a "kick scooter", "push scooter", or "non-motorized scooter."

### **Characteristics**

Manual scooters are typically narrow in width. Razor kick scooters, for example, have the following unfolded dimensions: length of 26 inches by width of 14 inches by height of 35 inches (California Speed-Sports, Inc., 2002). The width of the scooter – 14 inches – when compared to a sidewalk width of 4.9 feet is relatively small. The speed of manual scooters ranges from five to eight mph (Nova Cruz Product Inc., 2000; cited in Levine et al., 2001).

### **Regulation**

Scooter restrictions are similar to those of skating. For example, in Santa Rosa, California, one local ordinance prohibits scooters from sidewalks and streets in specified city areas (City of Santa Rosa City Council, 2001). The ordinance states that scooters, as well as other skating devices, pose a hazard to pedestrians and motorists because the user cannot change direction quickly, cannot maintain complete operational control of the



device at all times, and can be easily obstructed from the view of pedestrians and motorists (City of Santa Rosa City Council, 2001). Popular scooter brands use wheels that are extremely similar to, if not the same as, in-line skates (Fry, 2003). These wheels allow for higher velocities but, like skates, perform poorly on uneven surfaces (Fry, 2003). In addition, their use is restricted by regulation and available infrastructure.

## **Crashes**

Scooter injury rates (3.1 out of 1,000 participants over a year) are not high relative to in-line skating, skateboarding, and bicycling (U.S. Consumer Product Safety Commission, 2002b). When injury rates are considered per 10,000 days of participation, scooter riding has a lower injury rate (1.03) than skateboarding, bicycling, and in-line skating (U.S. Consumer Product Safety Commission, 2002b).

### *Locational Factors*

One study analyzed data from the CHIRPP and found that, as of May 2001, there were 305 cases of scooter injuries, and 27.2 percent of those injuries occurred on the roadway and 67.2 percent occurred on non-roadway location (Injury Section [Health Canada], 2001). Approximately, 21 percent of scooter injuries were located on the sidewalk, either near or away from the home. Almost 50 percent of the injuries resulted in hospital discharges, and 4.6 percent were serious enough to require hospital admissions (Injury Section [Health Canada], 2001). Another study (Levine et al., 2001) found that, out of 15 children treated for scooter related injuries at the Pediatric Emergency Service of Bellevue Hospital Center from July 2000 through September 2000, 40 percent were located in a park, and 40 percent of the crashes occurred on the sidewalk. The U.S. Consumer Product Safety Commission, after conducting a study using telephone interviews of injury victims (injury victims found from NEISS database) from December 2000 to June 2001, found that most injuries are due to falls (75 percent out of 61,340 scooter injuries). Most of these falls occurred when the wheels hit something small, such as a pebble or crack in the surface (27 percent) (U.S. Consumer Product Safety Commission, 2002b). Other contributing factors included falling when doing tricks (13 percent) and when trying to stop (nine percent) (U.S. Consumer Product Safety Commission, 2002b).

### *Human Factors*

The few available scooter studies indicate that conflicts are not a major cause of scooter injuries. One study found that most scooter injuries result from falls (87 percent), and only 6.7 percent resulted from motor vehicle conflicts (Levine et al., 2001). The study also found that the major cause of injuries was loss of control (59 percent), largely due to surface conditions (79 percent). Another study (Abbott et al., 2001) reports that the most frequent causes of injury were excessive speed, objects on pavement, and inability to brake (Abbott et al., 2001). This study also describes scooter design characteristics that can lead to loss of control, falls, and injuries:

1. When riding a scooter, the rider's weight is positioned forward near the front wheel. Leaning on the handlebars to make a turn increases the risk of tipping over forward.
2. Pushing the scooter requires one foot on the footrest and the "push" foot on the ground. Should the scooter lean too far away from the push foot towards the opposite side of the body, the foot on the footrest stays where it is and cannot stabilize or stop the scooter from tipping over.
3. The scooter's wheels are small and close together, compounding the scooter's instability if it hits even a small obstacle on the street (e.g., a pebble, stone, or crack in the pavement). (Abbott et al., 2001, p. 2-3)

Limited evidence is available on the typical age of injured scooter riders. One study found that eight to 13 year olds make up 76.4 percent of injured scooter users; however, pediatric hospitals were disproportionately represented in this database (Injury Section [Health Canada], 2001). The U.S. Consumer Product Safety Commission (2002b) found that most injuries occur in children between four and 15 years old, and only a small percentage of users aged 20 and older are injured.

## **WHEELCHAIRS**

### **Background**

Wheelchair users in the U.S., outside of nursing homes, have increased from 720,000 in 1980 to approximately 2.2 million in the year 2000 (Seeman, 2000). As the baby boomers reach retirement age, it is likely that the number of wheelchair users and their accessibility needs will grow at an even faster rate.

One important finding reported by many of the reviewed studies is that a large portion of people that need mobility devices cannot afford the device that best suits their needs or any device at all. For example, one 2000 report on mobility devices in the U.S. comments that

...about half of people or their families pay for devices solely on their own. The unmet need for devices is substantial, with the primary barrier being that people simply cannot afford to purchase them. (Kaye et al., 2000, p. 1)

A 1999 article on manual and electric wheelchairs reports that "about 2.5 million people... purchased their assistive devices without the assistance of the third party payer and that they had unmet assistive device needs that they could not afford" (Cooper, 1999, p. 27).

## **Characteristics**

Two studies describe the operational characteristics of wheelchairs. The 1999 FHWA design guideline for access states that wheelchairs (both manual and powered) have a width of approximately 2.5 feet and a turning radius that ranges from 2.1 feet to 4.2 feet (Axelson et al., 1999). Powered wheelchairs typically have a larger turning radius because they are longer than manual wheelchairs and thus require a five feet by five feet area to complete a 180° turn (Axelson et al., 1999). Both manual and powered wheelchairs usually travel faster than pedestrians, but are slower than pedestrians on uphill grades (Axelson et al., 1999). Another study of 15 electric powered wheelchairs (three of five different models) found that the wheelchairs attained a maximum speed that ranged from 4.1 to 7.1 mph and could travel a distance that ranged from 16 to 20.1 miles on one charged battery (Wolfe et al., 2000).

## **Regulation**

Many states consider wheelchair users to be pedestrians. For example, California law defines a pedestrian as someone “who is walking or using a human-powered device such as a wheelchair, skateboard, or roller skates” (American Automobile Association, 2003; Vehicle Code 467), and thus wheelchair users have the same rights and responsibilities as pedestrians.

The Americans with Disabilities Act (1990) requires that public areas and commercial businesses be accessible to disabled persons. For example, the act states that: “at least one accessible route within the boundary of the site shall be provided from public transportation stops, accessible parking, and accessible passenger loading zones, and public streets or sidewalks to the accessible building entrance they serve.” More specifically, design guidelines state that sidewalks must have slopes that accommodate wheelchair travel, cross-slopes, or slopes that are “measured perpendicular to the direction of travel” should not have more than a two percent grade and the rate of change of a grade should not exceed 13 percent (Axelson, 1999, p. 35).

## **Crashes**

### *Locational Factors*

A few studies describe the location related factors that contribute to wheelchair injuries (Calder and Kirby, 1990; Kaye et al., 2000; Cooper, 1999). Calder and Kirby (1990) searched the National Injury Information Clearinghouse database for wheelchair-related fatalities from 1973 to 1987 (the entire time span of the database at the time the study was conducted) and found 770 wheelchair-related fatalities (Calder and Kirby, 1990). The National Injury Information Clearinghouse receives death certificates from state health departments and codes those that involve a consumer-related product. The study found that most fatalities occurred in institutions, private residences, or hospitals (90 percent), and that only 0.3 percent of fatalities occurred on the sidewalk. A number of the

total cases involved a fall down stairs (6.6 percent of total cases); however, most of these cases were located in private areas such as institutions, homes, and hospitals (Calder and Kirby, 1990).

Kaye et al. (2000) evaluated the National Health Interview Survey<sup>8</sup> and found that, compared to those using canes, walkers, and crutches (or mobility devices), wheelchair users and scooter users were more likely to have accessibility problems outside of the home (33.2 percent of wheelchairs surveyed and 34.1 percent of scooters surveyed).

Another study analyzed data from the NEISS database from 1986 to 1990 and found that of 2,066 nonfatal wheelchair incidents, tips and falls contributed to 73.2 percent of the cases, and “a secondary factor, such as a ramp” contributed to 41.4 percent of the cases (Unmat and Kirby, 1994, p. 32; cited in Cooper, 1999).

### *Human Factors*

Several reports showed that falls and tips are the leading cause of wheelchair-related injuries and fatalities. One study found that, of 109 wheelchair users interviewed who sustained 253 incidents over the past five years, 42 percent of incidents were due to tips and falls (Gaal et al, 1997; cited in Cooper, 1999). Another article analyzed 577 mail surveys of manual wheelchair users in Nova Scotia, Canada, and found that 57.4 percent of the respondents “had completely tipped or fallen at least once,” and 66 percent of respondents reported having partially tipped (Kirby et al., 1994; cited in Cooper, 1999). Calder and Kirby (1990) also found that 77.4 percent of fatalities in their study involved a fall or tip.

Older individuals appear to sustain wheelchair injuries more often than younger individuals because they use the device more frequently. Calder et al. (1990) found that 81 to 90 year olds appear to have the most fatal wheelchair-related crashes (38.6 percent). Kaye et al. (2000) showed that, out of 6,821 people that use assistive devices, 14 percent of them are 65 years old and older.

### **Additional Issues**

It appears that wheelchairs themselves are an important cause of injury to wheelchair users. Due to poor training and equipment, wheelchair users develop injuries such as rotator cuff damage (damage to the shoulder muscles), carpal tunnel syndrome, and wrist problems (Seeman, 2000). Technologically more advanced wheelchairs and scooters that minimize the risk of incurring such injuries are available; however, the cost of these devices is more than insurance companies are typically willing to pay. Thus, wheelchair users must either risk the possibility of injury or personally pay for a better unit.

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<sup>8</sup> This survey is “a national representative household survey conducted annually by the Census Bureau for the National Center for Health Statistics” that gathered data on the disabled community. The 2000 report also states that “respondents to the 1994 and 1995 NHIS also took part in two supplemental surveys, known collectively as the National Health Interview Survey on Disability (NHIS-D)” (Kaye et al., 2000, p.5).

One concern that wheelchair users have is the lack of wheelchair awareness and reform. Advancements such as electric wheelchairs and scooters are available; however, awareness and usage of these devices are comparatively low (Seeman, 2000). Doctors are not typically trained to provide wheelchair users with advanced wheelchairs (Seeman, 2000). Insurance companies opt for inexpensive wheelchairs that may cause injuries to the wheelchair user in the long run because inexpensive wheelchairs are too heavy and ill-fitting (Seeman, 2000). It appears that wheelchair users are not properly trained to operate their wheelchairs, which is another cause of injuries (Seeman, 2000).

## CONCLUSIONS

All low-speed modes discussed in this report are used for “purposeful” travel to varying degrees; however, pedestrian, bicycle, and wheelchair modes are used more commonly as such than skates, skateboards, and scooters. Skates and skateboards are most frequently employed for recreational and sporting purposes. Scooters have only recently become popular, and thus little information is available on their pattern of use; however, the information that is available indicates that many children use them for recreational purposes.

Operational characteristics across the low-speed modes are described in Table 2-3 (below). All the wheeled low-speed modes travel at significantly higher speeds than pedestrians. Bicycles and skates appear to travel at the greatest speeds and have the greatest space requirements for braking distance and/or turning radius. The space requirements for wheelchair turning are also significant.

**Table 2-3. Low-Speed Mode Operational Characteristics.**

| <b>Low-Speed Mode</b> | <b>Speed</b>                 | <b>Width</b>   | <b>Braking Distance</b> | <b>Turning Radius</b> |
|-----------------------|------------------------------|----------------|-------------------------|-----------------------|
| <b>Pedestrians</b>    | 2.7 mph                      | Not applicable | Not applicable          | Not applicable        |
| <b>Bicycles</b>       | 15 mph                       | 3.3 feet       | 15 feet                 | 56.3 feet             |
| <b>Skates</b>         | 10.5 mph                     | 4 feet         | 20 feet                 | Not available         |
| <b>Skateboards</b>    | Not available                | Not available  | Not available           | Not available         |
| <b>Scooters</b>       | 5 to 8 mph                   | 14 inches      | Not available           | Not available         |
| <b>Wheelchairs</b>    | 4.1 to 7.1 mph<br>(electric) | 2.5 feet       | Not available           | 2.1 to 4.2 feet       |

The relative safety risks and more significant risk factors by low-speed mode are presented in Table 2-4 (below). To summarize, it can be seen that the risk of being injured while using a low-speed mode is relatively small (injury rate per 10,000 days of participation). Skateboarders have the greatest injury rate (2.15 percent), followed by bicyclists (2.05 percent), by skaters (1.71 percent), and by scooter riders (1.03 percent). Approximately, 0.1 percent of wheelchair riders are killed in crashes. Crash rates are not available for pedestrians.

Second, it appears that most low-speed mode crashes do not involve collisions with other low-speed modes or motor vehicles (when data are available). However, available data suggest that those types of crashes most often result in fatal or serious injuries to pedestrians and bicyclists. Most crashes involve the low-speed mode only (63 to 80 percent). For pedestrians, 63 percent of crashes involve pedestrians-only, 36 percent involve motor vehicles, and one percent involves bicycles. For bicycles, 67 percent involve bicycles-only, 29 percent involve motor vehicles, 3 percent involve other bicycles, and two percent involve pedestrians. For skates, 80.5 percent of crashes involve skaters-only, 5.9 percent involve other skaters, 3.5 percent involve motor vehicles, 2.5 percent involve bicycles, and 0.8 percent involves pedestrians. Data were not available for skateboards, scooters, and wheelchairs.

Third, not surprisingly, crash rates in the non-road and road environment appear to be related to the frequency with which the low-speed mode uses the environment. Typically, the location of use follows from regulation of the mode. For example, regulations discourage bicyclists from using the sidewalks. Most pedestrian crashes occur in the non-road environment (48 percent), and most of these crashes occur on the sidewalk. When pedestrian crashes do occur on the road environment (43.4 percent), it is most commonly where sidewalk pedestrian travel meets the road (e.g., intersections). Bicyclists are most often injured in the road environment (58.3 percent), on intersections and driveways, and less often in the non-road environment (26.4 percent). Most of the crashes in the non-road environment are bicycle-only crashes on sidewalks. In-line skaters are most often injured on roads (34.9 percent) and sidewalks (27 percent). Roller skaters are most frequently injured in parks/rinks (50 percent) and on sidewalks (27.8 percent). Skateboard crashes occur most often in indoor areas, parking lots, and driveways (36.8 percent), sidewalks (18.4 percent), and roads (1.6 percent). Scooter crashes are most common in the non-road environment (67 percent) on sidewalks (21 percent) and on roads (27.2 percent). Wheelchair crashes rarely occur on sidewalks (0.3 percent); most occur indoors (e.g., hospitals or institutions).

Fourth, the most common risk factors for low-speed mode crashes are surface conditions, user error (e.g., excessive speeds or wrong-way travel), motor vehicle driver error, obscured driver vision, and device design characteristics (e.g., inability to brake).

Finally, the young are most commonly injured in low-speed mode crashes, with the exception of wheelchairs. It appears that younger people use low-speed modes more often. In addition, the young are frequently less experienced and have poorer judgment

and may make more errors when operating devices. The design of skateboards and scooters appears to make use by children more dangerous.

This literature review on the safety of low-speed modes has important implications for the proposed field test that links shared-use Segway HTs, electric bicycles, and bicycles to the Pleasant Hill BART station and employment centers in the East San Francisco Bay Area. First, the literature review suggests that user error is a major cause of low-speed mode crashes, and thus extensive training will be required of program participants to ensure that user error is minimized. For example, issues of particular concern that will be addressed are transitioning from paths to roadways at crosswalks and intersections, going against traffic, and driveway dangers. Second, the literature review indicates that poor surface conditions are a significant contributing factor for low-speed crashes, and thus the paths included in the demonstration will be carefully selected to maximize surface condition quality. Paths can also be selected to avoid obstructions to driver vision of low-speed mode users. Training will also include practice and instruction on the best ways to handle more challenging surface conditions. Finally, the project will restrict the participant age (under 18 and over 65).

**Table 2-4. Relative Safety Risks and Risk Factors by Low-Speed Modes.**

| <b>Low-Speed Mode</b> | <b>Injury Rates</b>                                     | <b>Regulated Location</b> | <b>Frequency of Crashes Type</b>  | <b>Frequency of Crash by Location</b>  | <b>Common Risk Factors</b>   | <b>Commonly Injured Age Group</b> |
|-----------------------|---|---------------------------|---|--|--|-----------------------------------|
| <b>Pedestrians</b>    | Not Available   | Sidewalks                 | Only: 63%<br>Vehicle: 36%<br>Bicycle: 1%                                    | Nonroad: 48%<br>-sidewalk<br>Road: 43.4%<br>-intersection<br>-no crosswalk   | Only: surface conditions<br>Vehicle: pedestrian & driver negligence                    | Young                             |
| <b>Bicycles</b>       | 2.05 per 10,000 days of participation                   | Sidewalks use discouraged | Only: 67%<br>Vehicle: 29%<br>Bicycle: 3%<br>Ped: 2%                         | Road: 58.3%<br>-intersection (sidewalk bicyclers)<br>-driveway<br>Nonroad: 26.4%<br>-most are bicycle only on sidewalk | Only: surface conditions<br>Vehicle: wrong way bicycle travel & obscured driver vision | Young                             |
| <b>Skates</b>         | 1.71 per 10,000 days of participation (in-line skating) | Some bans on sidewalks    | Only: 80.5%<br>Skaters: 5.9%<br>Vehicle: 3.5%<br>Bicycle: 2.5%<br>Ped: 0.8% | In-Line:<br>-road: 34.9%<br>-sidewalk: 27.0%<br>Roller:<br>-park/rink: 50%<br>-sidewalk: 27.8%                         | Surface conditions<br>Collisions   | Young                             |
| <b>Skateboards</b>    | 2.51 per 10,000 days of participation                   | Some bans on sidewalks    | Not available   | Other (indoor areas, parking lots, and driveways): 36.8%<br>Sidewalks: 18.4%<br>Roads: 1.6%                            | Excessive speeds: 51.3%<br>Obstructions: 17.9%<br>Collisions with MV: 7.7%             | Young                             |
| <b>Scooters</b>       | 1.03 per 10,000 days of participation                   | Some bans on sidewalks    | Not available   | Non-road: 67%<br>-most on sidewalks: 21%<br>Road: 27.2%  | Surface conditions<br>Excessive speeds<br>Inability to break<br>Vehicle conflict       | Young                             |
| <b>Wheelchairs</b>    | 7.6 fatalities per 100,000 users per year               | Sidewalks                 | Not available   | Sidewalk: 0.3%<br>Most occur inside  | Tips and falls<br>Ramps  | Elderly                           |



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## CHAPTER 3: REGULATORY AND LEGISLATIVE HISTORY

### INTRODUCTION

The Segway HT was unveiled in 2001, to accolades over its technological achievement and skepticism about its safety and overall benefits. The device was designed for operation in the pedestrian environment. However, because of its two electric motors, the Segway HT could have been classified as a motor vehicle and prohibited from use on sidewalks. This chapter chronicles the regulatory and legislative history of the Segway HT at the federal, state, and local levels.

### FEDERAL REGULATIONS AND LEGISLATION

In 2001, Segway LLC initiated lobbying efforts to secure approval for the use of the Segway HT in the pedestrian environment. These efforts contributed to the National Highway Traffic Safety Administration (NHTSA) determination that the Segway HT should not be classified, regulated, or licensed as a motor vehicle. The Consumer Product Safety Commission (CSPC) also ruled that the Segway HT should be regulated as a consumer product. NHTSA and CSPC worked together to develop and define a new classification for the Segway HT—an “electric personal assistive mobility device” (EPAMD). This term is defined as follows:

“Electric personal assistive mobility device” means a self-balancing, non-tandem wheeled device that: (1) was to transport only one person with personal baggage; (2) is powered solely by an electric propulsion system; and (3) has a top motor-power speed not in excess of 20 miles per hour (Library of Congress, 2003).

The term EPAMD and its definition were later used in federal and state legislation and local ordinances.

Following the EPAMD classification, the former senator from Segway LLC’s home state of New Hampshire, Bob Smith, introduced a federal bill (S. 2024) to enable the use of the Segway HT in pedestrian environments. The bill contained three key components:

1. The term “electric personal assistive mobility device” and its definition (provided above);
2. A set of operating guidelines that allowed the use of the device on “bicycle trails and pedestrian walkways constructed or maintained by Federal-aid highway funds;” and

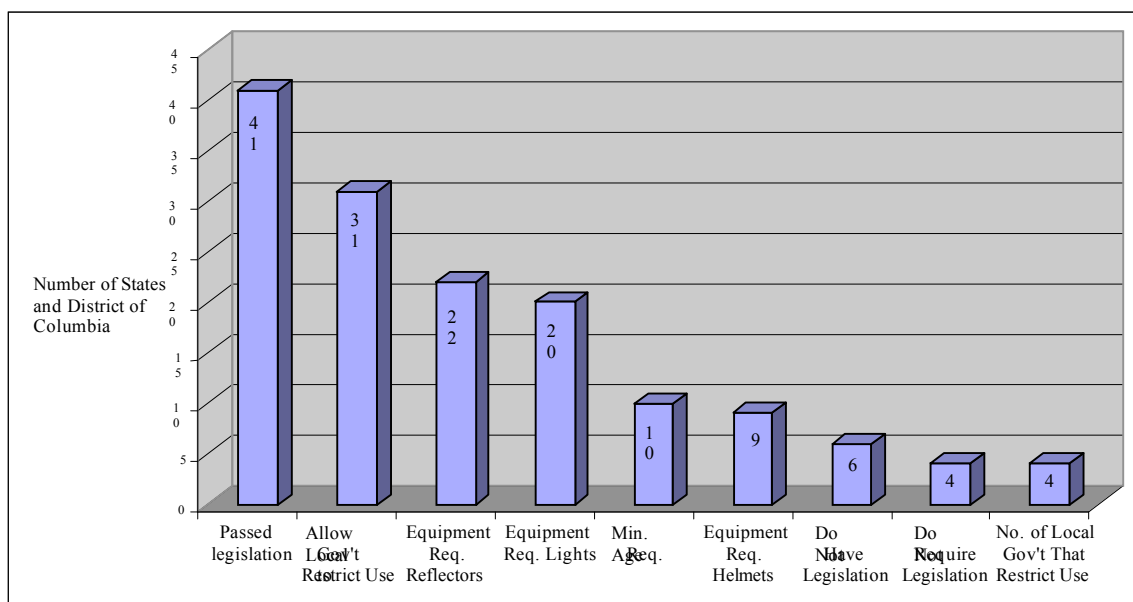
3. A description of controlling authorities (i.e., “State or local authorities”, which established appropriate use of the Segway HT device (Library of Congress, 2003).

The bill was officially introduced on March 15, 2002, read twice, and referred to the Committee on Environment and Public Works. The last action on the bill was an amendment to the title on June 17, 2002. Segway LLC abandoned its federal lobbying efforts, after several months, to concentrate on state and local enabling legislation. The proposed federal bill’s three-part structure (EPAMD definition, operating guidelines, and controlling authorities), however, did serve as a template for future state legislation.

## STATE LEGISLATION

At the state level, legislation to allow the use of the Segway HT in the pedestrian environment progressed rapidly. In December 2001, New Jersey passed EPAMD-enabling legislation, and soon after, in February of 2002, similar legislation was also passed in New Hampshire. By October 2003, 40 states and the District of Columbia had passed enabling legislation. Four states (Arkansas, Kentucky, Louisiana, and Montana) did not require EPAMD legislation because they had no prohibition against powered conveyances on their sidewalks (note that legislation corresponding to each of the states mentioned in this section is referenced at the end of this chapter). The remaining six states (Colorado, Connecticut, New York, Massachusetts, North Dakota, and Wyoming) have not yet passed legislation (Segway LLC, 2003). Figure 3-1 (below) summarizes key statistics about Segway HT-enabling legislation.

**Figure 3-1. Summary of EPAMD Legislation.**





The state legislation shares the basic features of the proposed federal bill, but many states expanded upon the proposed three-part structure to clarify its exemption from motor vehicle status and to permit its use on pedestrian infrastructure, as illustrated in the following additional language (*italics have been added, indicating change from federal legislation*):

- “. . . device *that can turn in place . . .*” (California Motor Vehicle Code);
- “. . . with an electric propulsion system *of (750 watts) one horse power average power . . .*” (New Jersey, New Mexico, Utah, West Virginia, Missouri, Indiana, Washington, Florida, Iowa, Oklahoma, Nebraska, Vermont, Tennessee, South Carolina, Michigan, Ohio, California, Georgia);
- “. . . whose maximum speed *on a paved level surface. . .*” (New Mexico, West Virginia, Missouri, Indiana, Washington, Florida, Iowa, Oklahoma, Nebraska, Tennessee, South Carolina, Michigan, Ohio, California, Georgia); and
- “. . . while ridden by an operator *who weighs 170 pounds . . .*” (New Jersey, New Mexico, West Virginia, Missouri, Indiana, Washington, Florida, Iowa, Oklahoma, Nebraska, Tennessee, South Carolina, Ohio, Georgia).

In addition, the operating guidelines were expanded or made more specific in the legislation passed by many states. Much of this language addressed the “use” environment and safety concerns. For example, many states:

- Expanded the “usable infrastructure” from “bicycle paths and pedestrian walkways” of the federal bill to include streets, roads, and highways;
- Exempted Segway HT owners from obtaining operating licenses and registering the device (Washington, D.C., Florida, Iowa, Oklahoma, Wisconsin, Rhode Island, Delaware, Pennsylvania, and Arkansas);
- Provided Segway HT users with the rights and duties of pedestrians (North Carolina, Idaho, Washington, Kansas, Vermont, Maryland, Rhode Island, Minnesota, Washington, D.C., and Connecticut);
- Gave Segway HT users the rights and duties of bicyclists and operators of motor vehicles, depending on the allowed operating infrastructure (New Jersey, New Mexico, Utah, and Wisconsin);
- Required Segway HT users to yield the right-of-way of pedestrians, to give an audible signal when passing pedestrians, and to use lower speeds on sidewalks (North Carolina, New Hampshire, New Mexico, Virginia, Washington, Florida, Iowa, Oklahoma, Wisconsin, Nebraska, Maine, Tennessee, South Carolina, Rhode Island, Delaware, Michigan, Minnesota, Washington, D.C., and Hawaii);

- Included minimum age requirements of Segway HT users (Utah, Virginia, Missouri, Arizona, Iowa, Vermont, Rhode Island, Pennsylvania, Hawaii, and Oregon);
- Required additional equipment, such as lights and reflectors, when operating the Segway HT between dusk and dawn (New Hampshire, New Mexico, Virginia, Missouri, Iowa, Oklahoma, Wisconsin, Nebraska, Maine, Vermont, Tennessee, South Carolina, Delaware, Pennsylvania, Michigan, Minnesota, Ohio, California, Georgia, Connecticut, Hawaii, and Oregon); and
- Required Segway HT users to wear helmets (teenagers and younger in Utah, Pennsylvania, Georgia, and Florida, and all ages in New Jersey).

## LOCAL LEGISLATION

As discussed above, most states passed enabling Segway HT legislation, and some did not require such legislation, but 31 states allowed local jurisdictions to restrict Segway HT use. California's legislation is typical of this language:

. . . for the purpose of assuring the safety of pedestrians, including seniors, persons with disabilities, and others using sidewalks, bicycle paths, pathways, trails, bicycle lanes, streets, roads, and highways, a city, county, or city and county may, by ordinance, regulate the time, place, and manner of the operation of electric personal assistive mobility devices. . . and their use as a pedestrian. . . (California).

California's legislation also allows state agencies to "limit the time, place, and manner of use on state property," which includes university campuses and state buildings. A few other states (New Hampshire, New Mexico, Maine, and Michigan) allow state departments (e.g., Departments of Transportation or Natural Resources) and/or oversight committees to limit the use of the device.

New York State restricts the use of the Segway HT in cities with a population of one million or more (e.g., New York City). Thus, in New York City, the public is not allowed to use the Segway HT on streets or sidewalks. However, some press reports suggest that it is unclear whether city officials are actually enforcing the ban by ticketing Segway HT users. The New York City Police Department is currently testing the Segway HT as part of a pilot program.

Despite widely publicized discussions in many local jurisdictions, there have been few actions limiting the use of the Segway HT. It appears that 24 local jurisdictions have discussed restricting Segway HT use, but only three have actually restricted use. Three cities in California have implemented bans; San Francisco and La Mirada have citywide sidewalk bans, and Healdsburg has banned the device on four square blocks in the downtown center (Sprague, 2003; McMahan, 2003). San Francisco has also banned the Segway HT from public transit stations and vehicles. A ban was enacted in the D.C.

metro transit system area (Washington, D.C., Maryland, and Virginia), but it is temporarily not being enforced. Elsewhere, communities continue to discuss the possibility of restrictions and many are taking a “wait and see” approach. For example, the city council of San Mateo, California, has directed staff to monitor Segway HT use in the surrounding metropolitan region and revisit the possibility of an ordinance if the need arises (Fraley, 2003).

Safety concerns raised by advocates for the elderly, disabled, and pedestrians appear to be the driving force behind most of the local bans. The weight (83 to 95 pounds), maximum speed (12.5 mph), and quiet operation of the Segway HTs on sidewalks with limited space are the primary sources of concern for the disabled and elderly. Their physical limitations may make it difficult for them to hear, see, or move out of the way of a relatively quiet, fast, and heavy moving device on the sidewalks (Walk San Francisco, 2003a; Walk San Francisco, 2003b). Pedestrians appear to be more concerned about the use of these devices on congested or narrow sidewalks and paths.

Segway LLC has countered activists’ concerns with claims that the Segway HT is safe, easy to use, and environmentally beneficial (i.e., reduced roadway and parking congestion and improved air quality). To make their case, Segway LLC and Segway HT owners have often provided demonstration rides to citizen and local officials. In Davis, California, after three owners demonstrated the Segway HT use on downtown sidewalks, the Safety Advisory Commission “did not feel that there were safety issues with the Segway,” and the city council stopped a motion to ban it (City of Davis City Council, 2003). San Mateo, California, had considered implementing a ban similar to that of San Francisco, but after learning of the city of Seattle’s cost savings after incorporating the Segway HT into its municipal fleet, it is now applying for grants to do the same (Fraley, 2003). Authorities in Capitola, California, have also adopted the “wait and see” approach after a demonstration ride (Turner, 2003).

## CONCLUSION

The Segway HT was designed for operation in pedestrian environments; however, because of its two electric motors and ability to move people and cargo, it could have been classified as a motor vehicle and thus prohibited from use on sidewalks. This chapter chronicles the regulatory and legislative history of the Segway HT at the federal, state, and local levels. The key developments are as follows:

- NHTSA determination that the Segway HT should not be classified, regulated, or licensed as a motor vehicle.
- CSPC ruled that the Segway HT should be regulated as a consumer product.
- NHTSA and CSPC classified and defined the Segway HT as an “electric personal assistive mobility device” or EPAMD.

- The federal bill (S. 2024) to enable the use of the Segway HT in the pedestrian environment was never passed, but its three-part structure (EPAMD definition, operating guidelines, and controlling authorities) did serve as a template for further state legislation.
- By October 2003, 40 states and the District of Columbia had passed enabling Segway legislation, four states did not require the legislation because they had no prohibition against powered conveyances on their sidewalks, and six states have not yet passed enabling legislation.
- Many states have added requirements in their legislation to increase the safety of Segway HT use (likely in response to stakeholder concerns), including the use of safety equipment (lights, reflectors, and helmets), age restrictions, and clarification of rights and responsibilities.
- Legislation in 31 states allows local governments to restrict the use of Segway HTs. Despite the safety concerns of elderly, disabled, and pedestrian advocates, only three jurisdictions (to date) currently enforce bans Segway HTs use. It appears that a greater familiarity with the device can ease citizen concerns.

The last two developments are of particular relevance to the design of the field test. The demonstration design should consider the use of safety equipment to minimize user risk, incorporate age restrictions, and include clear rules of use in the instructional handbook. During the feasibility analysis, researchers carefully introduced stakeholders to the Segway HT (both with demonstrations and information), identified their potential concerns, and addressed those concerns in the design of the field test (described in more detail in Chapter 5).

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## CHAPTER 4: LESSONS LEARNED FROM PILOT PROJECTS

### INTRODUCTION

Since the Segway HT was unveiled in 2001, 6,000 units have been sold internationally and in all 50 states. The markets for Segway HTs include both individual consumers and the public and private employment sectors. Key consumer markets include individuals who require mobility assistance but do not meet the strict definition of impairment, urban or short-distance commuters, recreational users, and individuals who choose the product because it reflects a lifestyle choice. Public and private sectors include manufacturing and distribution, law enforcement and emergency services, postal and delivery services, municipal transportation, park and recreation, transit and employment centers, universities, and leisure. In this chapter, the authors present results of a survey of selected pilot Segway HT implementation projects in the public and private sectors. Lessons learned from these pilots are relevant to the field operational test described in this report and are incorporated into its design.

### METHODOLOGY

Segway LLC representatives provided PATH researchers with numerous Segway HT pilot project contacts from both the public and private sectors. PATH researchers conducted a telephone survey of 13 pilots from August to October 2003. See Appendix A for the telephone survey.

### RESULTS

This section presents key results from the Segway HT pilot project survey. A summary of results is also provided in Table 4-1 (below). Detailed summaries of the pilot project interviews are presented in Appendix B.

In the **manufacturing and distribution** sector, two power companies were surveyed. Both companies implemented a shared use (one to two employees per Segway HT) pilot program to test the productivity benefits related to meter reading and/or gas leak survey work. Both companies implemented an in-house training program. One company required employees to use a helmet when operating the device. Neither company uses the devices in the rain or snow. One company reported benefits of improved company image and operation and maintenance cost savings (relative to trucks). However, this company notes that considerable planning is required to identify suitable routes for Segway HT use. For this company, apartment complexes and smaller neighborhoods provide the best routes.

In the **law enforcement and emergency services** sector, three agencies were contacted. In general, these agencies report that the primary benefits of the Segway HT are:

- Faster access to locations that are not easily reached by traditional vehicles (i.e., trucks, cars, or even golf carts);
- Greater patrol coverage area because of faster travel speeds on the device;
- Improved visibility of the public by officers and of officers by the public due to the height gained by riding the device; and
- Improved public relations due to greater visibility and public interest in the device (e.g., individuals like to have pictures taken with officers on the Segway HT).

All three agencies considered Segway HT training to be very important. Two agencies experienced difficulties on more challenging terrain but have addressed these issues with more training. One agency reports that the greatest challenges encountered are short battery life (particularly on grass) and transporting the device because of its heavy weight (and thus they have developed their own carrier).

In the **postal and delivery** sector, the U.S. Postal Service was interviewed. The Postal Service has initiated a pilot project that uses the device for operations and city-postal delivery in selected areas of the county. It has an in-house training program, but program managers could not comment on safety issues or other challenges that users have encountered because the study is ongoing. Thus far, they have found that the device works well in inclement weather, makes employees' jobs easier, and reduces vehicle-operating costs.

In the **municipal transportation sector**, three agencies were contacted. Two agencies use the device for transportation in the downtown Atlanta area, and one agency uses the device to read water meters in Seattle.

The agencies that use the device for *downtown travel* have found the greatest benefits to be time savings and convenience (i.e., avoiding parking hassles and congestion). The greatest challenges are short battery life and restricted access to buildings because of security (i.e., Segway HTs were not allowed into building). Both use the device in the rain (one regularly and one on a more limited basis). One of these agencies suggests the use of lights for night and early morning riding.

The agency that uses the device for *water meter reading* has found a number of benefits to use, including:

- Energy efficiency;
- Reduced environmental impacts (from the use of clean vehicles);
- Significantly improved worker efficiency; and
- Some indication of reduced worker stress (the agency plans to study this).

Some of the challenges include the preconditioning of batteries and the modification of fleet vehicles to carry the Segway HT. In sum, it is reported that the device can improve

efficiency and reduce negative environmental impacts, but “it will not replace pick-up trucks.”

In the **parks and recreation** sector, the National Park Service (Grand Canyon) was interviewed. The Park Service used the device for a one-week trial for ranger campground patrol, to read water meters, and for commuting purposes. A number of benefits were identified, including 40 percent faster meter reading, improved visibility of patrol personnel, and greater travel range for interpretive rangers (i.e., they could talk to more people and answer more questions). A number of challenges were also identified; on the largely unpaved terrain of the park the device got only four miles per charge, and the meter reader found that riding the device was hard on his back. In general, the Park Service found that the device could not replace cars because it could not be used in the winter at the park. They also reported that training was very important.

In the **transit and employment** sector, the Los Angeles Metropolitan Transportation Association (MTA) was interviewed. It uses the device for security, short trips, service, crowd control at special events, and public relations. MTA has an in-house training program that includes a safety video, closed-track use, and field use. MTA reports that training is very important. It has found that officers more than 6’4” tall can hit their heads on parking garage doors that are seven feet high, which limits the use of the device to some degree. They do not use the device much in inclement weather. MTA reports a number of benefits, including efficiency (e.g., officers can cover a greater area because of faster travel speeds), ease of use, mobility, officer visibility, and improved public relations. They also report a perception of reduced knee injuries because of reduced walking with heavy belts. They report that the greatest challenge is limited battery life.

In the **educational or university** sector, Worcester Polytechnic Institute was interviewed. They report using the device for a number of purposes including campus police patrol, admissions office tours, and travel by the University President. Training took place at Segway LLC headquarters. The University uses the device less in inclement weather. It reports that benefits include time savings and generating interest in new technology.

In the **leisure** sector, Disney Cruise Line was interviewed. It offers the device for guest use on both the Disney Magic and Disney Wonder ships and in Castaway Cay (an island). The cruise line also uses the device for work-related functions including moving greeters and officers between areas of their 1,000 acre private island. Officers also use it to make rounds and observe operations. Disney continues to evaluate the program to determine its value to guests and crew. The company reports that the greatest benefits are enhanced guest experience and a fun publicity opportunity; the greatest challenges are space to ride on the ships and the labor required to train guests.

| Application                                     | Organization   | Date             | Users/<br>HT | Purpose   | Success   | Training  | Safety<br>Issues                                       | Weather                    | Challenges   | Suggestions                            |
|---|--|------------------|--------------|---|---|---|--|----------------------------|--|--|
| <b>Manufacturing &amp; Distribution</b>         | <b>New York State Electric &amp; Gas</b><br>Various cities, NY | 7/02 to present  | 2+           | Meter reading<br>Gas leak survey work   | Still conducting productivity tests.  | In-house  | Still conducting safety tests                          | No                         | No response  | None                                   |
|   | <b>Georgia Power</b><br>Various cities, GA                     | 02 to present    | 1-2          | Meter reading   | Transport costs<br>Image  | In-house<br>½ day                                   | Careful use<br>Helmets                                 | No                         | Locating best routes                                 | Match job with tool                    |
| <b>Law Enforcement &amp; Emergency Services</b> | <b>UC Police Department</b><br>Berkeley, CA                    | 03? To Present   | 5            | Law enforcement<br>Security<br>Emergency services                                       | Greater visibility of officers (> height)<br>Public relations               | In-house<br>30-40 minutes<br>video + manual         | Turning<br>Stairs<br>Curbs                             | No                         | Safety & Environmental interaction                   | Training is important                  |
|   | <b>MedExpress</b><br>LA  | Present          | 1+           | Emergency service in areas with no vehicle access                                       | Quick access patients in crowded situations<br>Public Relations             | In-house<br>(4-5 hours)                             | Traction issues on wet ground                          | No                         | Battery life; transport                              | Training is important                  |
|   | <b>Toledo Port Authority</b><br>Toledo, OH                     | 8/02 to present  | 1            | Patrol terminals & immediate surrounding areas  | Time savings<br>Faster emergency response times                             | Segway HQ   | None   | Don't know                 | None   | Training is important                  |
| <b>Postal &amp; Delivery Services</b>           | United States Postal Service<br>Various US cities              | 1/02 to Present  | 2            | Deliver mail on certain routes  | Jobs easier<br>Transport costs  | In-house  | No response  | Rain<br>Snow               | No response  | None                                   |
| <b>Municipal Transportation</b>                 | <b>Ambassador Program</b><br>Atlanta, GA                       | 4/02 to present  | 1-2          | Patrol 200 square block assisting visitors, businesses & police.                        | Productivity<br>Time savings<br>Transport costs                             | In-house (4 days)<br>Field (2 weeks)                | Rider error when hit a rut                             | Rain<br>Snow               | Battery life   | Take breaks when riding;<br>Use lights |
|   | <b>Atlanta Regional Commission</b><br>Atlanta, GA              | 06/02 to 12/02   | 1+           | Municipal transport<br>Attend meetings<br>Run errands                                   | Convenience<br>Avoid parking hassles & traffic                              | In-house<br>(1 day)                                 | None   | Rain<br>(use less)         | Building security can limit entry                    | None                                   |
|   | <b>Seattle Fleets and Facilities Department</b><br>Seattle, WA | 10/02 to present | 1-2          | Read water meters   | Energy efficiency<br>Environmental impacts                                  | In-house<br>(6-8 hours)                             | Wear high visibility vests<br>Helmets optional         | Rain<br>(often)            | Training, legislative, environment interaction       | A good tool, but won't replace trucks. |
| <b>Parks &amp; Recreation Services</b>          | <b>National Park Service</b><br>Grand Canyon, AZ               | 6/02 (1 week)    | 1            | Patrol campgrounds<br>Read water meters<br>Answer questions<br>Give programs<br>Commute | Productivity<br>40% faster meter reading<br>More visitor contact            | On site by Segway<br>LLC personnel<br>(1 or 2 days) | None   | No                         | Battery life short on unpaved terrain (4 mi./charge) | Training is important                  |
| <b>Transit &amp; Employment Centers</b>         | <b>MTA</b><br>Los Angeles, CA                                  | Present          | 3            | Security<br>Short trips<br>Crowd control<br>Public relations                            | Efficiency<br>Ease of mobility<br>Greater visibility of officers (> height) | In-house<br>½ day                                   | 6'4" tall or > can't use; hit heads on 7' garage doors | No                         | Battery life   | Training is important                  |
| <b>University</b>                               | <b>Worcester Polytechnic Institute,</b><br>Worcester, MA       | Present          | 4            | Patrol campus<br>Admission tours  | Time savings<br>Convenience<br>Spark technology interest                    | Segway HQ   | None.  | Rain<br>Snow<br>(less use) | Fear of new things                                   | Great in the college environment       |
| <b>Leisure</b>                                  | <b>Disney Cruise Line</b><br>Port Canaveral, FL                | 7/02 to present  | Many         | Rides for guests<br>Marketing<br>Move personnel   | Good publicity<br>Guests really enjoy it                                    | 5-10 minute instruction for rides                   | No   | No                         | Space to ride<br>Training labor                      | None                                   |

Table 4-1. Summary of Key Results from Segway HT Pilot Surveys.

## CONCLUSIONS

The results of this survey of Segway HT pilot projects in the public and private employment sectors yielded a number of general “lessons learned.” Key challenges reported by the pilot projects include:

- The importance of training for safe use of the Segway HT in a range of environments;
- The need for additional safety equipment to avoid accidents and/or minimize injury (e.g., helmets, lights, and vests);
- The relatively short battery life of the Segway HT, particularly on unpaved terrain;
- The weight of the Segway HT, which may make transporting it difficult (e.g., in trucks used for emergency response);
- Building security and/or lack of secure parking, which may restrict use of the Segway HT for downtown travel; and
- The rider’s height (greater than 6’4”), which may restrict Segway HT users’ access to garages that are seven feet tall or less (this appears to be most problematic for law enforcement patrol in urban areas).

Key advantages reported by pilot projects include:

- Travel time savings, improved access, and avoided parking hassles in congested downtown areas;
- Reduced vehicle operation and maintenance costs;
- Increased access (e.g., emergency services) to locations that are not accessible by trucks, cars, or even golf cart;
- Greater efficiency (i.e., faster meter reading, deliveries, or patrols);
- Environmental benefits (i.e., from the use of clean fuel vehicle);
- Improved public relations; and
- Anecdotal evidence that workers’ use of the Segway HT may reduce stress (physical and psychological) in certain situations.

In general, it appears that the Segway HT may yield economic and environmental benefits when it is carefully applied for selected purposes and locations.

## CHAPTER 5: FEASIBILITY ANALYSIS

### Introduction

This chapter presents the culmination of the first phase of the field operational test: the feasibility analysis of the Segway HT, electric bicycles, and bicycles as connectivity devices in a shared-use rental program linked to suburban transit and work sites. The feasibility analysis incorporated lessons learned from the literature review on the safety of low-speed modes, the regulatory and legislative history of the Segway HT, and the survey of Segway HT pilots, as described in previous chapters. The feasibility of launching a field test at the Pleasant Hill BART station in the East San Francisco Bay Area was determined based on station and surrounding community characteristics including:

- Favorable physical attributes of the location, including, density and distribution of employment, sidewalk space, other paths, and the absence of significant transit feeder service;
- Community support, in particular, the ability of the field test to address the safety concerns of local elderly, disabled, and pedestrian advocates;
- Numerous employers who could benefit from the service and support the concept;
- A transit station vendor who could distribute the devices; and
- Multi-jurisdictional location to enhance the transferability of the results.

### Suburban Transit Location Analysis

The Pleasant Hill BART station (see Figure 5-1 below) was identified as a feasible location in which to launch the field test. Pleasant Hill is located in the East San Francisco Bay Area. The residential population is approximately 27,000. There is significant business development surrounding the BART station, and the downtown area is approximately two miles from the BART station. Many sidewalks are wide and lightly used.





**Figure 5-1. Pleasant Hill BART Station and Surroundings**

This station is located in Contra Costa County and is surrounded by the communities of Pleasant Hill, Concord, and Walnut Creek, which allows for the investigation of the devices in different jurisdictions. There is limited bus and shuttle service in the area, and the devices could serve as an efficient feeder service from BART to the offices.

Employers in the Pleasant Hill Area are located near retail and commercial businesses, providing a mixed-use location to test Segway HT use during the day. In Pleasant Hill, there are also opportunities to expand to the residential population, who could use the Segway HT as a commuter device on evenings and weekends in a subsequent field test phase. Finally, a trail system exists that connects the BART station to local neighborhoods and employment centers, which can be used for traveling to and from the station.

A 1998 BART study documents some of the ridership trends at the Pleasant Hill BART station. The survey found that 86 percent of those traveling during the morning peak period were commuting to work. In addition, approximately 20 percent of the riders surveyed rode BART less than 5 or more days a week. These results suggest that there is an opportunity to increase the frequency of BART travel among current BART commuters. To access the BART station, 15 percent of respondents walked, eight percent took transit, two percent bicycled, 74 percent drove their car, and less than one percent used some other mode. The field test would also target new BART users and the 74 percent who drive their cars to the station.

The survey demographic data (BART, 1998) for station users suggest that most respondents were between the ages of 18 and 44. The age distribution of morning peak travelers surveyed was as follows: less than one percent under 18, five percent 18 to 24, 48 percent 25 to 44, 43 percent 45 to 64, three percent 65 and over. Relatively young travelers may be more likely to use the new or alternative devices introduced in this field test.

The survey demographic data (BART, 1998) for the station also suggest that household income for the BART travelers is relatively high. Results of shared-use vehicle studies suggest that early adopters of new technology tend to have a higher income than the general population. The household income distribution of the morning peak travelers were as follows: eight percent at \$30,000 or less, 28 percent at \$30,001 to \$60,000, 37 percent at \$60,001 to \$100,000, and 28 percent over \$100,000.

The rental vendor for the devices at the Pleasant Hill BART station is Black BART. Under an agreement with BART, this for-profit organization operates a concession called All Aboard, which sells coffee, sandwiches, reading material, and sundries. The business is staffed during the day, especially during commute hours. There is space available at this location to display, store, and re-charge the devices. This vendor allows for the implementation of the rental model in the field test as well as the possibility of continuation after its completion.

Two other BART stations, Dublin/Pleasanton and Walnut Creek, were also identified as promising potential locations for the field test. These sites also faced transit connectivity challenges and possessed an adequate number of employers within the travel range of the devices. However, both sites were rejected because vendors were not available at these stations.

### **Expert Interviews and Stakeholder Meetings**

A series of expert interviews and stakeholder meetings were held over the course of the first phase of the field test. The objectives of these interviews and meetings were to: (1) determine general support for the field test at the Pleasant Hill site, (2) identify potential stakeholder issues that needed to be addressed, and (3) gather necessary information to optimize the field test design (e.g., best routes and likely employers). Many of the stakeholders were introduced to the Segway HT and given the opportunity to operate it. The following is a description of the key expert interviews and stakeholder meetings.

**Elected Officials.** The first step in the feasibility analysis was an initial meeting with Supervisor DeSaulnier (Contra Costa County). This meeting was held to gauge support for the field test at the proposed location. Later Supervisor DeSaulnier and research staff met with representatives of each city that might be affected by the field test at potential BART stations. These meetings produced general support for the field test and for the use of sidewalks in all jurisdictions, with the exception of Walnut Creek. The Mayor of Walnut Creek requested that downtown Walnut Creek be excluded from field test routes because of sidewalk congestion.

**County Public Works Department.** Representatives from the County Public Works Department were also contacted. These meetings produced: (1) support for the field operational test, (2) support for the use of county sidewalks in the field test, and (3) an offer to assist researchers in contacting and presenting the project to city public work departments in the relevant jurisdictions.

**Community Development/Planning Departments.** Representatives from Community Development and Planning Departments in the relevant jurisdictions were also interviewed. The results of these interviews included: (1) support for the field test and (2) an agreement to help identify safe routes for the demonstration (i.e., areas to avoid because of poor sidewalk conditions, lack of sidewalk connectivity, high traffic, and hazardous intersections).

**Police Departments.** Representatives from the various police departments in the relevant jurisdictions were contacted. The police department representatives expressed support for the field test. They welcomed involvement in the project, expressed support for increased safety requirements of field test participants (e.g., helmets, lights, reflectors, and bells), and agreed to assist researchers with the identification of routes (i.e., areas where greater caution may be needed).

**Advisory Task Force.** A more formal facilitated meeting was held with representatives from the jurisdictions' departments of public works, community development/planning, and police. The objectives of this meeting included: (1) a discussion of inter-department and inter-jurisdictional issues affecting the field test and (2) the establishment of an advisory task force for the project. The outcomes included: (1) an expression of general support for the project, (2) a good discussion of practical issues that needed to be addressed (i.e., safe routes, use of bicycle helmets, other safety devices, and training), (3) an agreement to act as an advisory group (via email), and (4) an agreement to meet one more time before the launch of the field test. Researchers also agreed to loan a Segway HT to each jurisdiction for a one-week period to help the departments to identify safe routes and procedures.

**Bicycle/Pedestrian Groups.** Researchers conducted a number of phone interviews with representatives from community bicycle and pedestrian groups. These groups expressed general support for the field test and were particularly interested in the bicycle and/or electric bicycle modes. They agreed help researchers by helping to identify safe routes for bicycles and electric bicycles.

**Health Professionals.** Representatives from the non-profit Prevention Institute and the County Health Department were contacted. Both groups supported the project and agreed to act as project advisors, as needed. In particular, the groups expressed strong support for the inclusion of bicycles in the study because of the health benefits of increased physical activity. They were also very interested in future research findings from this project on Segway HT use (e.g., demographics of users and purposes of use).

**Accessibility/Disability Groups.** The Segway HTs in this field test would share sidewalks and access ramps with individuals with disabilities. Thus, the support of these groups was deemed critical. As discussed in previous chapters, these groups have been instrumental in Segway HT bans in three communities.

PATH researchers also met with the BART accessibility/disability task force. This group felt that the program was worthwhile because it encouraged people to take BART. However, they suggested that the Segway HT be walked (and not be ridden) in the BART station (and on BART property) because of crowded conditions in the station (particularly, during peak commute hours). Thus, the Segway HT will be ridden on sidewalks surrounding the station (governed by the County) and walked within the BART station (BART property).

In addition, researchers met with members of the Independent Living Center in Contra Costa County. This group expressed support for the field test. They liked the program because it would encourage transit use and felt that the Segway HT could be useful to members of the disabled community. They did make some suggestions for additional safety precautions that will be incorporated into the field test design: (1) adding a bell to the Segway HT so that people using the sidewalk or trail would understand that someone is passing, (2) instructing participants to say “on your left” if passing a blind person, and (3) instructing participants to give the right-of-way to disabled persons. With respect to the last precaution, our training will require participants to yield the right-of-way to all pedestrians, users of low-speed modes, and disabled persons.

**The East Bay Regional Park District.** The Contra Costa Trail System provides excellent connectivity between the Pleasant Hill BART station and employment locations within one to four miles of the station. The Pleasant Hill BART station’s location is adjacent to the trail. Many businesses and shopping areas, including the Shadelands Office Park and John Muir Medical Center area, can both be accessed directly by the trail, in addition to other businesses and shopping areas in the project area.

The trail system in Contra Costa currently does not allow motorized vehicles. To increase efficiency and safety of the program, researchers worked with the East Bay Regional Park District to allow the Segway HT and electric bicycles to access the trail as part of the field test. The Operations Committee voted (two to one) to allow use of the trail for the demonstration. The county concurred with the decision (the county controls portions of the land).

### **Focus Groups**

Focus groups will be conducted as part of the year-two implementation phase. Because of considerable stakeholder sensitivity surrounding the project, researchers deemed it necessary to focus more resources on stakeholder meetings and interviews rather than on focus groups. In addition, a longer time period was required in which to conduct the focus groups because the field test was expanded to include bicycles and electric bicycles.

### **Shared-Use Rental Model**

The results of the expert interviews and stakeholder meetings indicated support for an employer-based shared-use rental model, both for the commute and day use (i.e., business

and personal trip making throughout the work day). However, there was not much support for evening and weekend use, particularly on the trails.

The current design of the field test includes two primary user groups: workbased commuters and day user employees. Each morning, a specific group of trained employees will take BART to the station, check out a reserved device from the rental vendor, and ride the device to work. Once at the office, the device will be available to a larger group of employees for off-site meetings, errands, or lunch appointments. At the end of the day, the commuter will ride the device back to the transit station, where it will be stored and recharged.

At each employment site, a reservation system for using the Segway HT, electric bicycle, and bicycle will be developed in conjunction with participating employers. A safe and secure storage system will be deployed in conjunction with a rental agent at BART (i.e., All Aboard), each employment site, and local municipalities. The devices will be visible and secure during commute hours. The units will be stored and recharged overnight in a covered facility. The Segway HT devices will display signs indicating that the device cannot be operated without a smart access key to discourage theft. In addition, locks will be provided for the Segway HT, electric bikes, and bikes.

### **Project Partners and Contract Development**

The key project partners for this project include the following:

- **California Department of Transportation (Caltrans)** contributes funds, comments on research design, assists with project management, and helps to develop goals and objectives.
- **Innovative Mobility Research (at California PATH) (IMR)** is responsible for the research design and evaluation, research operations, communication and coordination among all partners, operation of the field test, and publications.
- **Bay Area Rapid Transit (BART) District** provides the transit link for the field test and the permission to distribute the Segway HTs, electric bicycles, and bicycles at the Pleasant Hill BART station.
- **All Aboard** concession, in association with BART, at the Pleasant Hill BART station has agreed to distribute and store the devices.
- **Segway LLC** has contributed 15 Segway HT units with equipment (e.g., locks, lights, horns). They have also agreed to assist with development of the training program and securing insurance.
- **Giant Bicycle, Inc.** has contributed five electric bicycles and five bicycles outfitted with bells, lights, mirrors, and locks to the field test. They will also provide twenty-five bicycle helmets and contacts for training and maintenance.

The formal agreements among all parties are designed to facilitate an ongoing operation, if the field test proves successful. Therefore, there will be an overall agreement between BART and Caltrans. This letter of agreement will include the field test design as well as agreement to use BART property for the project (including the vendor location and

ability to store devices on-site). It will not contain any legal or liability requirements. BART will incorporate this project into their current contract with Black BART, the “All Aboard” vendor. And the vendor will develop agreements with Segway LLC and Giant Bicycle. Liability issues related to the storage and vending of the devices will remain among these parties and not involve UC Berkeley or Caltrans. This will facilitate the transition to a pilot program (e.g., operated by All Aboard), if the project proves viable. On the research side, Caltrans has a contract with California PATH to conduct the research, and PATH has an agreement with both Segway LLC and Giant Bicycle to provide the devices for the program. Segway LLC and Giant Bicycle have stated in writing that they are providing the devices to the University for the purposes of the field test. They will work with the University on issues of liability coverage.

To conduct research with actual participants, the project underwent a Human Subjects Review at the University, which covered liability and safety issues related to participants. This project passed this review and received permission to go forward.

### **Marketing Strategies for Employers and Employees**

Recruitment of enthusiastic and committed employers and employees will be a vital component of the implementation. Once participating businesses are selected, employees will be recruited at each employment site with employer assistance. Researchers will develop a project description and conduct meetings to recruit participants. Employers will send emails to their employees, distribute flyers in company newsletters or other appropriate locations, and organize meetings for presentations by researchers to recruit participants.

A number of criteria will be used to identify potential employers for inclusion in the demonstration project:

- Employer location should be within four miles of the Pleasanton BART station.
- Employers should have employees who could potentially commute via BART.
- The employer should have an employee pool large enough to support Segway HT, electric bicycles, and bicycle day and commuter use (e.g., ten or more).
- Employees should have an interest in using the devices for their work and leisure trips.

The stakeholder interviews and meetings helped researchers identify key contacts for locating potential field test employers. These contacts included Contra Costa Commute Alternatives Networks (whose mission is to reduce single-occupant vehicle travel in Contra Costa County), Chambers of Commerce, and community leaders.

In particular, the Contra Costa Commute Alternatives Network indicated that there is employer/employee interest in this type of program based on their experience in the county. They agreed to commit some funding, bicycle racks, and mailing lists for the project. They provided researchers with an initial list of contacts for employers who appeared to be good candidates for the field test. They also organized a mailing to alert area employees, interested in commute alternatives, to the project.

Researchers are currently working closely with two businesses and one large business park with multiple businesses to secure participation in the field test. Businesses with campus settings or with multiple offices are particularly interested in using the devices during the day to facilitate office travel as well as for travel to the downtown for lunch and errands. In addition, businesses with a prior commitment to transportation programs (e.g., commuter checks) and younger workforces with flexible work hours appear to be more interested in the field test.

Because businesses in the field test area draw from a large geographic region, targeting potential BART riders may be challenging, particularly if employee's homebased connections to BART stations are not good. In addition, the current economic climate is such that employers are offering fewer employee services. The focus of the project may be on working with employers and employees to optimize their BART experience through the use of innovative devices that are available, not only during commute hours, but throughout the day.

As a result of the recall of the Segway HT (initiated by Segway LLC), some employers have expressed concern about the safety of the Segway HT. Segway LLC has upgraded the software on all units to resolve a problem of device balance when batteries run low. Researchers have initiated discussions to address these concerns and to explain how the problem has been corrected. Working with Segway LLC and Giant Bicycle to obtain liability coverage will be an important issue with respect to securing employer participation.

### **User Training Program**

Each individual enrolled in the field test will be trained in accordance with methods recommended and approved by Segway LLC, Giant Bicycle, and the project partners. All project participants will be required to complete training. Before individuals can travel by Segway HT, electric bicycle, and/or bicycle, they must be comfortable reserving, riding, and securing it at their employment site, in the community, and at BART.

Researchers have developed a user handbook that includes basic operating instructions, safety procedures, and emergency contact information. A copy of the itinerary and handbook will be shared with Caltrans before the onset of the program. The user handbook will be distributed to all field test participants.

Segway LLC will provide official training on the Segway HT for all of the employees participating in the program. This will include a video, information about the design and operation of the Segway HT, and an obstacle course including elements participants may occasionally encounter on the field test routes (e.g., water, curbs, traffic). The initial training program will last a minimum of two hours. Researchers will provide follow-up assistance as each participant starts the program.

Giant Bicycle will assist in arranging training for all employees participating in the field test. Training will be mandatory for all employees using the electric bicycles and bicycles. It will include instructions on the operation of the devices, “rules of the road,” and demonstration program rules.

As discussed above, safe routes for the field test will be identified in consultation with City and County public works, planning, and police departments and as well as bicycle and pedestrian professionals. The routes for Segway HT will include trails and sidewalks. The routes for the bikes will include trails and streets. The user handbook will include maps of the safe routes.

### **Evaluation Criteria**

The second phase evaluation of the field test will include four key criteria: (1) pre- and post-field test focus groups of Segway HT, electric bicycle, and bicycle users; (2) detailed “before and after” questionnaires and travel diaries; (3) a bystander survey; and (4) a rental model assessment to provide input into continued viability of the project and marketing. Data will be analyzed to assess modal shifts (e.g., reduced auto use and increased BART use), effects on parking, safety and perception of safety (i.e., device users and bystanders), health effects, and overall community perceptions. Lessons learned from this field test will be reported at the conclusion of the research and may be used to inform the design of third phase of the field test that could include full-size electric vehicles and stationary fuel cell stack (to power the electric devices).

The Pleasant Hill BART station site is also the planned test location of a hydrogen fuel cell stack to produce electricity, which could also be used by the vendor to charge electric bikes, the Segway HTs, and shared-use electric vehicles. This provides a fortuitous opportunity to experiment and study the concept of a “Hydrogen Highway” in California (as unveiled by the Governor on April 20, 2004). Thus, this project will help address the “last mile” problem associated with commuter use of transit systems and the need for clean and efficient electrical power generation in California.

Information about willingness-to-pay for the Segway HT, electric bicycles, and bicycles as short-range mobility devices will assist in determining the appropriate rental cost structure for the demonstration and insights about its use beyond the demonstration phase. Additional issues to be explored include: suitability of the training program; continued consumer use of the Segway HT, electric bicycles, and bicycles; willingness to pay for services; and the duration of program participation. Data on Segway HT, electric bicycles, and bicycle response (e.g., how they are used, how often they are used, and



comfort zones) and on-street reaction (i.e., interactions with non-users, cars, and pedestrians) to the devices will also be collected and analyzed.

As mentioned above, surveys of Segway HT, electric bicycles, and bicycle users will be conducted “before and after” the demonstration. Specific information about demographics, commute, physical activity, and mobility patterns before-and-after Segway HT, electric bicycle, and bicycle introduction; overall consumer and community response; bystander perceptions; and a rental model assessment (e.g., costs, training, and marketing) will be incorporated into the final analysis.

The inclusion of three different low-speed modes in the field test provides an opportunity for researchers to test and evaluate the alternative methods to improve transit station access, while expanding choice. PATH researchers will compare the effectiveness of a new mode (the Segway HT), a technologically enhanced mode (the electric bicycle), and a traditional mode (a regular bicycle). A comparative evaluation of the three modes will contribute significantly to an understanding of the context in which the different low-speed modes may increase transit access most cost-effectively. More specifically, the research evaluation will address the following questions:

- How effective is each mode with respect to increasing transit use and why?
- Which modes increase transit use most cost-effectively and why?
- Will the enhanced features of the Segway HT and electric bicycles relative to bicycles (e.g., greater travel distances, comfort, and carrying capacity) outweigh possible user resistance to using these new modes?
- Does offering a range of “choice” increase the attractiveness of low-speed modes to improve transit access?
- What are the relative health benefits of each mode when considering overall activity and travel patterns?

## **Conclusion**

The results of the feasibility analysis documented in this chapter indicate that the launch of the proposed demonstration at the Pleasant Hill BART station in the East San Francisco Bay Area is feasible. The location met all criteria including: (1) favorable physical attributes of the location (i.e., employment density and distribution, available pedestrian/bicycle infrastructure, and the absence of significant transit feeder service); (2) community support, in particular, the ability of the field test design to address the safety concerns of the elderly, disabled, and pedestrian advocates; (3) evidence of a large pool of employers who could benefit from the service; (4) a vendor at the transit station who could distribute the devices; and (5) a multi-jurisdictional location to enhance the transferability of the results.

Despite some negative publicity surrounding the safety of the Segway HT, interest in the device and preliminary evidence of its potential benefits remains significant enough to include it in this field operational test. The design has incorporated a number of safety requirements that address the concerns of local stakeholders. These include:

- The use of identified safe routes on sidewalks, streets, and trails;
- Walking the Segway HT in the BART station;
- The use of additional safety features (i.e., helmets, lights/reflectors, and bells);
- Participant age and health restrictions; and
- Following demonstration “rules of the road” as a condition of participation (i.e., top Segway HT speed eight mph and to yield right-of-way to all other pedestrians and users of low-speed modes including devices used by the disabled).

The expansion of the project to include electric bicycles and bicycles, not only expands traveler access, but also increases the odds that a cost-effective device will be identified that would allow transition of the demonstration to a pilot program, which could occur after the completion of the research phase.

**Reference**

BART (1998). Station Profile Survey.

## CHAPTER 6: CONCLUSION

The results of the research and feasibility analysis documented in this report identified the Pleasant Hill BART station and surrounding community, in the East San Francisco Bay Area, as a viable location for the introduction of shared Segway HTs, electric bicycles, and bicycles to suburban transit and employment centers. As discussed in Chapter 5, the location met all criteria including: (1) favorable physical attributes of the location (i.e., employment density and distribution, available pedestrian/bicycle infrastructure, and the absence of significant transit feeder service); (2) community support, in particular, the ability of the field test design to address the safety concerns of the elderly, disabled, and pedestrian advocates; (3) evidence of a large pool of employers who could benefit from the service; (4) a vendor at the transit station who could distribute the devices; and (5) a multi-jurisdictional location to enhance the transferability of the study.

Despite some negative publicity surrounding the safety of the Segway HT, interest in the device and preliminary evidence of its potential benefits remains significant enough to include it in this field operational test. A comparative evaluation of the three devices, Segway HT (new), electric bicycle (technologically enhanced), and bicycle (traditional), should contribute significantly to an understanding of the context in which the different low-speed devices may increase transit access most cost-efficiently. In addition, including these three devices in the field test, not only expands traveler access, but also increases the odds that a cost-effective device will be identified that would allow a transition to a pilot program after the conclusion of the field test.

There are preliminary signs that the Segway HT can produce economic (e.g., time savings and reduced vehicle operation and maintenance costs) and environmental benefits (i.e., reduced vehicle emissions) when it is carefully applied for selected purposes and locations, as the results of the survey of pilot Segway HT projects, described in Chapter 4, suggest.

It appears that efforts to familiarize officials and stakeholders with the Segway HT have helped stem, to date, most of the threats to ban it (because of safety issues on sidewalks) that have occurred in numerous local jurisdictions, as described in Chapter 3. Only three local jurisdictions have enforced a ban the device, and only six states have not passed Segway HT-enabling legislation where it is necessary. Additional safety requirements in much of the state-level legislation (i.e., relative to the initial federal-level legislation) may have been included to address stakeholders' safety concerns. As described in Chapter 5, at the very beginning of the feasibility analysis, steps were taken to involve local stakeholders and officials in the field test design to identify and address any safety concerns.

In addition, the results of the literature review on the safety of low-speed modes, described in Chapter 2, indicate that the risk of crashing is relatively small and often does not involve collisions with other low-speed modes or motor vehicles. The crashes that do

occur are most frequently the result of poor surface condition, user error, obscured driver vision, and the design of the low-speed mode. Many of these causal factors can be minimized in the selection of field test routes, by training, and by requiring additional safety equipment. The survey of Segway HT pilot projects in Chapter 4 also emphasized the need for thorough training on all route terrains and suggested additional safety equipment.

The results of the community meetings and interviews, the literature review on low-speed modes, the regulatory and legislative history of the Segway HT, and the survey of the Segway HT pilot projects informed the safety requirements that have been included in the field test design (described below):

- Safe routes on sidewalks, streets, and trails;
- Extended device training for participants on all terrains included in the routes;
- Walking the Segway HT in the BART station;
- Safety equipment (i.e., helmets, lights/reflectors, and bells);
- Restrictions on participant age and health; and
- Following demonstration “rules of the road” as a condition of participation (i.e., top Segway HT speed eight mph and to yield right of way to all other pedestrians and users of low-speed modes including devices used by the disabled).

**APPENDICES**

## APPENDIX A: SEGWAY HT PILOT PROJECT TELEPHONE SURVEY

Hello, my name is \_\_\_\_\_ and I am an assistant researcher at the University of California at Berkeley doing research on the Segway HT. We are preparing to launch our own field test in the next year.

Company/Organization: \_\_\_\_\_

Dates Used: \_\_\_\_\_

Pilot: Ongoing or over?

1. For what purposes have you applied the HT?

- Manufacturing & Distribution
- Law Enforcement/Security/Emergency Personnel
- Postal/Delivery
- Municipal Transport
- Parks/Recreation
- Transit/Employment Centers
- Leisure
- Other \_\_\_\_\_

2. Have you purchased the HT for use? Or are you conducting productivity tests to determine whether you will purchase units?

- Purchase for use
- Productivity tests to determine purchase
- Other \_\_\_\_\_

3. How are the HTs assigned to users?

Are they assigned separately to individuals?

And/or

Are they shared by a number of individuals (i.e., shared-use format)?

If so: # of users:

Time period shared:

What were the greatest challenges of this format?

Were adjustments made to the use format?

If so, what were they? Why were these adjustments made?

4. Have you instituted a training program for the HT?

If so, can you describe program (i.e., elements, duration, etc.).

How successful do you think the program has been?

What, if anything, have you or would you do to modify the program?

5. Have you encountered any safety issues with the HT?

If so, what, if anything, have you done to address these safety issues?

*If steps were taken to resolve safety issues...*

How successfully have these strategies been?

6. Have you used the HT in inclement (i.e., raining and snowing) weather?

If yes, did use of the HT drop during inclement weather?

If yes, do you know by how much?

7. What are the greatest benefits from your company/organization's use of the HT?

Please rank and explain.

- Productivity
- Time savings
- Transportation fuel costs
- Other \_\_\_\_\_

8. What are the greatest challenges to its use? Please rank and explain.

- Mechanical/electrical difficulties
- Segway-environment interaction
- Legislative (Infrastructure)
- Safety
- Training
- Other \_\_\_\_\_

9. Are there any recorded effects on the users (e.g., weight gain, change to disposition, etc.)?

9. Based on your experience with the HT, do you have any suggestions for other users?



## APPENDIX B: SUMMARY OF SEGWAY HT PILOT PROJECT INTERVIEWS

### Manufacturing and Distribution

#### New York State Electric and Gas (summer 2002 to present)

- Uses Segway Human Transporter (HT) for meter reading and gas leak surveys.
- Purchased for productivity and safety testing.
- Approximately two employees to one HT.
- Instituted an in-house training program.
- Reports no HT accidents yet.
- Has not used HT in rain or snow (no snow tires).
- Reports a range of reactions (both positive and negative) to HT.

#### Georgia Power (2002 to present)

- Uses HTs for meter reading.
- Purchased HTs for productivity and safety testing.
- Has one to two employees using one HT a day.
- Instituted an in-house HT training program developed with the Atlanta Regional Commission and the Ambassador Force that includes a series of different obstacles and lasts about half a day.
- Requires training and helmets for HT users.
- Has not used HT in rain or snow.
- Believes that benefits include: (1) improved company image by using cutting edge technology and (2) operation and maintenance cost saving (i.e., the HT is less expensive to run than trucks).
- Believes that the greatest challenge is developing routes that are suited to the HT (e.g., apartment complexes and smaller neighborhoods).
- Has tried e-bikes and e-trucks but they did not suit the requirements of the job.

### Law Enforcement & Emergency Services

#### Toledo Port Authority (August 2002 to present)

- Uses the HT for law enforcement (i.e., patrolling the terminal and areas immediately surrounding the terminal).
- Has one police officer per HT.
- Had Segway LLC personal train users.
- Reports that the HT allows for quicker and more efficient movement (i.e., a car and golf-cart are too large to be used in their terminal and thus the HT allows more efficient policy response to emergencies).
- Believes that training is important.

#### University of California Police Department (July 2003 to present)

- Uses HT for law enforcement, security, and emergency services.
- Interested in assessing the HT patrol potential relative to other fleet vehicles.
- Has five officers per one HT.

- Instituted an informal in-house training program (30-40 minutes) that consists of a video, an owner's manual, and user experience.
- Would like to improve their training program by extending the training time to three to four hours and having new users practice tight turns, different types of terrain, and quick starts and stops.
- Has experienced some difficulties with turns, stairs, and curbs and has tried to address these issues in their training program.
- Has not used the HT in inclement weather, but has used on surfaces that are wet (from sprinklers) and experienced no problems.
- Reports that the greatest benefits are: (1) improved visibility (officers can see eight inches over people and can cover more area) and (2) improved public relations (more positive interactions between pedestrians and officers when they approach to inquire about this novel device).
- Reports the following challenges in order of importance: (1) safety, (2) environmental interaction (campus terrain), (3) training, (4) mechanical/electrical difficulties (comfort with mechanics), and (5) legislative.
- Finds that training is important to handle more challenging rider circumstances.

#### MedExpress

- Uses the HT for emergency services for special events such as the Christmas Festival and Mardi Gras.
- The HT can reach patients that could not be quickly reached by an ambulance, for example, if someone goes down because of chest pains in a large crowd, a medic on an HT can weave through the crowd to reach to patient (an ambulance would have much greater difficulty).
- Has an in-house training program (four to five hours) that is run by two people who attended a training class at Segway LLC in New Hampshire.
- Training is essential to their staff because when they use the HT they are typically "on adrenaline" dealing with a tense situation.
- Finds that the training program can be easily adjusted to meet their needs.
- Have encountered some safety problems with wet ground and now train staff to avoid this.
- Does not use HT in the rain or in extreme heat.
- Believes that the greatest benefits are: (1) quick access to people in crowded environments and (2) great public relations ("Loaned an HT to the policy department to use in a downtown district and in one day 30 people wanted their picture taken with officers on HTs").
- Believes that the greatest challenges are: (1) battery life is too short (does not go 17 miles on a single charge) and batteries run out even faster on grass and (2) the weight of the HT (100 pounds) makes transporting it very difficult (MedExpress has developed their own Segway Carrier and Segway Cover to facilitate transporting the HT).
- Has also developed a self-contained and self powered sired with LED lights because the HT is silent.

## **Postal & Delivery Services**

### United States Postal Service (January 2002 to present)

- Uses the HT for operations and city-postal delivery.
- Purchased HTs for productivity tests.
- Assigns HTs to delivery routes (i.e., the regular carrier uses the HT and on her day off the replacement carrier uses it).
- Developed an in-house training program with Segway LLC (i.e., adapted the Segway training program to suit their specific needs and experiences).
- Could not yet comment about safety issues that they have encountered (study ongoing).
- Finds that the HT works well in inclement weather.
- Believes that the greatest benefits are making employees' jobs easier and savings in vehicle costs.
- Could not yet comment about the challenges they have encountered (study ongoing).
- Some employees were upset when the HT was taken away from them after the first six weeks of the pilot.

## **Municipal Transportation**

### Atlanta Ambassador Force (April 2003 to present)

- Uses the HT to travel a 200 square block area of Atlanta assisting visitors and businesses and working with the police.
- Have purchased HTs for used by supervisors (shared).
- Assigns HTs to two different shifts (morning/afternoon and evening/night).
- Implemented four days of in-house training and two weeks of field trains with Segway LLC representatives.
- Sent an employee to be trained at Segway LLC so that she could become a trainer.
- Encountered a safety problem when a supervisor hit a rut while riding the HT and crushed his knee (cause of the accident was determined to be user error).
- Uses the HT regularly during rainy weather.
- Reports that the greatest benefits are productivity, time savings, transportation fuel cost savings, and greater mobility.
- Reports that the greatest challenges are short battery life and frequent need to recharge.
- Recommends that riders do not ride for eight straight hours without a break.
- Suggests the use of lights on the HT for night and early morning riding.

### Atlanta Regional Commission (June 2002 to December 2002)

- Uses HT for municipal transportation (e.g., go to meetings and run errands).
- Have purchased HT for use by an agency motorpool of employees who have been trained on the use of the HT.
- Have implemented a one-day training program that is similar to the Segway LLC program (reduced from two days).
- Used the HT on a very limited basis in rainy weather.

- Report that the greatest benefits are time savings and convenience (i.e., avoid parking hassles and downtown traffic).
- Found that the greatest challenge to its use was building security that restricted entry of the HT.

#### Seattle Fleets and Facilities Department (September 2002 to March 2003)

- Uses the HT to read water meters.
- Have purchased HTs for use by meter readers (one to two ratio).
- Developed an in-house training program (six to eight hours) based on the Segway LLC program that makes use of their own obstacle course and a modified manual (half the time is spent on the manual and half riding the HT).
- Reports that the use of HT for water reading has significantly improved efficiency.
- Would have dealt with labor issues at the very beginning of the program.
- Encountered some concern from workers who were worried that efficiency gains may result in the elimination of some jobs rather than just improve their jobs.
- Requires riders to wear high visibility vests and made use of helmets optional.
- Uses the HT regularly in rainy weather and have found that it keeps the user quite dry.
- Reports that the greatest benefits are energy efficiency, environmental impacts (use of a clean vehicle), and improved worker efficiency.
- Reports that the greatest challenges are legislative and infrastructure, training, and environmental interaction.
- Also found that their vehicles needed to be modified to carry the HT and preconditioning of batteries is required.
- Report that users appear to be more relaxed, have more energy, and are less stressed (looking at longer term effects of the HT on reducing stress-related injuries).
- Believes that the HT is a tool that can improve efficiency and reduce negative environmental impacts but it will not replace pickup trucks.

### **Parks & Recreation**

#### National Park Service, Grand Canyon (June 2002)

- Used HTs for a one-week trial by a ranger to patrol campgrounds, by a water meter reader, by rangers who answer people's questions and give evening programs, and as a commute option to travel around the Grand Canyon village.
- Assigned HTs individually during the trial.
- Had Segway LLC personnel put on a one to two day training program that covered basic operations and safety.
- Found that they could not use the HT in the winter.
- Report the following benefits: 40 percent faster meter reading, greater visibility of patrol person, and the greater travel range for the interpretive ranger (i.e., could talk to more people and answer more questions).

- Report the following challenges: on the largely unpaved terrain of the park the HT got only four miles per charge, the meter reader found that riding the HT was hard on his back, and cars could not be replaced by HTs because the HT could not be used in the winter at the park.
- Found that training was very important.

## **Transit & Employment Centers**

### Los Angeles Metropolitan Transportation Association (MTA) (present)

- Uses the HT for security, short trips, service, crowd control at special events, and public relations.
- Assigns HTs (in a three persons to one HT ratio) to the Sheriff's Department, security (at night), and commuters (during commute hours).
- Finds that currently demand for the HT is greater than their supply.
- Have an in-house training program that includes a safety video, safe use, closed-track use, and field use.
- Found that officers more than 6'4" tall can hit their heads on parking garage doors that are seven feet high and thus limits the use of the HT to some degree.
- Report that they don't use the HT much in inclement weather.
- Report the following benefits: efficiency (e.g., officers can patrol faster), ease of use, mobility, officer visibility and public relations (public can see officers more because they are taller on the HT).
- Report that the greatest challenge is the limited battery life.
- Reports a perception of reduced knee injuries because of reduced walking with heavy belts.
- Found that training is very important.

## **Universities**

### Worcester Polytechnic Institute (present)

- Uses for a number of purposes: campus police patrol, admissions office tours, and travel by the University President (four to one ratio).
- Sent employees to Segway LLC for training.
- Uses it in snow and rain but use drops then.
- Reports that the benefits are time savings and generating interest in new technology (Dean Kamen is an alumnus and the HT inspires people).
- Finds campus to be a good environment for the HT.

**Leisure**Disney Cruise Line (July 2002 to present)

- Began offering HTs for guest use in the summer of 2002 on both the Disney Magic and Disney Wonder ships and in Castaway Cay (an island).
- Continue to evaluate the program to determine its value to guests and crew.
- Also uses HTs for work related functions including moving greeters and officers between areas of their 1,000 acre private island and officers use it to make rounds and observe operations.
- Have 30-50 guest riders per week.
- Have guest riders take five to ten minutes of instruction.
- Have not encountered any safety problems.
- Have not used during inclement weather.
- Reports that greatest benefits are enhanced guest experience and a fun publicity opportunity.
- Reports that the greatest challenges are space to ride on the ships and the labor required for guest training.