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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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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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ABSTRACT

To evaluate the potential for low-speed modes to improve transit access, a field test has been designed that will offer shared-use Segway Human Transporters (HT), electric bicycles, and bicycles linked to a Bay Area Rapid Transit (BART) District station and surrounding employment centers. Because of safety concerns, research was conducted to better understand the risks associated with these modes and potential risk factors. First, a review of the safety literature indicates that user error is the major cause of low-speed mode crashes and significant risk factors are poor surface conditions and obstructions to drivers' vision. As a result, an extensive training program and carefully selected routes have been included in the field test. Second, the regulatory and legislative history of the HT is chronicled to understand how concerns about its interaction with pedestrians have produced legislation that includes specific safety requirements. The low-speed modes used in this project will be equipped with safety devices and participants will be required to wear helmets. Third, the results of a survey of thirteen HT implementation projects provide insight into potential advantages and challenges to the HT field test. Fourth, results of interviews and meetings with field test stakeholders are presented with a discussion of their influence on the field test design. For example, participants will be required to walk the low speed modes at BART to avoid potential conflicts during crowded station conditions. Finally, conclusions and future steps in the project are discussed.

INTRODUCTION

Access to transit stations is a significant barrier to transit use in many urban regions. Parking during peak hours is often limited, and most people are only willing to walk about a quarter mile to transit stations (Cervero, 2001). Traditional transit feeder services, such as shuttles, can help extend the range of transit access, but may be limited by fixed routes and schedules. Recently, a number of innovative strategies have been implemented to improve transit access and transit use, including electric bicycles, carsharing, and personal neighborhood electric vehicles (Shaheen, 1999; Shaheen et al., 2000; Shaheen, 2001; Shaheen and Wright, 2001; Shaheen and Meyn, 2002).

Another innovative device that may improve access to transit stations is the Segway Human Transporter (HT). The HT, brainchild of Dean Kamen, was unveiled in 2001 to accolades over its technological achievement and skepticism about its safety. The 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 mph.

To evaluate the potential for low-speed modes to improve transit access, researchers have designed a two-phase field test that will offer shared-use HTs, electric bicycles, and bicycles linked to a Bay Area Rapid Transit (BART) District station and surrounding employment centers. The authors have identified the Pleasant Hill BART station, in the East San Francisco Bay Area, as the 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 employers and neighborhoods. There is limited bus and shuttle service to area businesses. Employers are located near to the downtown area so that the devices can also be used during the day for lunch, errands, or meetings.

FIGURE 1: Pleasant Hill BART Station and Surroundings

Innovative Mobility Research has teamed with the California Department of Transportation (Caltrans), the Bay Area Rapid Transit District (BART), Segway LLC, and Giant Bicycle Corporation to launch this field test. Caltrans has contributed funds, and assists with project management, and BART provides the transit link and permission to distribute low-speed modes from the Pleasant Hill Station. Segway LLC and Giant Bicycle have contributed the HT's, electric and traditional bicycles, and required safety equipment, as well as training, maintenance and insurance.

This paper is organized into four sections. First, the authors review the literature on the safety of low-speed modes to identify major risk factors. Second, the authors present the regulatory and legislative history of the HT in the U.S. to understand the underlying safety issues that have influenced its evolution. Third, the results of thirteen previous HT field tests are presented to gather lessons learned during small scale implementation. Fourth, the results of stakeholder interviews and meetings are presented with a discussion of how they influenced the design of the project. Finally, conclusions and future steps in the project are discussed.

LITERATURE REVIEW: SAFETY OF LOW SPEED MODES

This section summarizes the key findings of an extensive literature review on the safety of low-speed modes that operate in the pedestrian environment, including walking, bicycling, skating, skateboarding, riding scooters, and operating wheelchairs (reported previously in 1). The results provide insights into potential safety issues that need to be addressed in the field test.

Conclusions are made about the relative risk of each mode, the most significant risk factors, and the implications for the field test.

All low-speed modes discussed in this paper are used for "purposeful" travel to varying degrees; however, pedestrian, bicycle, and wheelchair modes are used more commonly than skates, skateboards, and scooters. Skates and skateboards are most frequently employed for recreational and sporting purposes (Williams, 2002). Scooters have only recently become popular; however, the limited information that is available indicates that many children use them for recreational purposes (Eisner, 2000).

Operational characteristics across the low-speed modes are described in Table 1. 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 (Allen, et al, 1998; U.S. Consumer Product Safety Commission, 2002a; American Association of State Highway and Transportation Officials, 1999). The space requirements for wheelchair turning are also significant (Axelson et al, 1999).

Table 1. Summary of Operational Characteristics Across Low-Speed Modes

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

The relative safety risks and common risk factors by low-speed mode are presented in Table 2. First, the risk of being injured while using a low-speed mode appears to be 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) (U.S. Consumer Product Safety Commission, 2002b). 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 is available; Stutts et al., 1997). However, available data suggests that collisions most often result in more fatal or serious injuries to pedestrians and bicyclists. Most crashes involve the low-speed mode only (63 to 80 percent).

Third, 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) (Hunter et al., 1996; Osberg et al., 1998; Allingham and MacKay, 1997; Frankovich et al, 2001; Engoy, 2000; Abbott et al., 2001;).

Finally, the young are most commonly injured in low-speed mode crashes, with the exception of wheelchairs (Hunter et al., 1996; Allingham and MacKay, 1997; Frankovich et al., 2001; U.S. Consumer Product Safety Commission, 2002b). It appears that younger people use low speeds modes more often (Orenstein, 1996). In addition, the young may be less experienced, have poorer judgment, and thus may make more errors when operating the devices (Committee on Injury and Poison Prevention, 2002). The design of skateboards and scooters also appears to make use by children more dangerous (Stutts and Hunter, 1997).

The results of the literature review on the safety of low-speed modes have important implications for the proposed field test. First, since user error was determined to be a major cause of crashes for low-speed modes, extensive training will be required of participants. Issues of particular concern that will be addressed during training are transitioning from paths to roadways at crosswalks and intersections, wrong way travel, and dangers of driveways. Second, the results of the literature review indicate that poor surface conditions were a significant contributing factor for low-speed crashes, and thus the paths included in the field test will be carefully selected to maximize surface condition quality. Paths will be selected to avoid obstructions to driver vision of low-speed mode users. In addition, training will include practice and instruction on the best ways to handle more challenging surface conditions. Third, the project will restrict the age of participants (under 18 and over 65 excluded).

Table 2: Summary of Key Results from the Literature Review on the Safety of Low Speed Modes

Low-Speed Mode	Injury Rates	Regulated Location	Frequency of Crashes Type	Frequency of Crash by Location	Common Risk Factors	Commonly Injured Age Group
Pedestrians	Not Available	Sidewalks	Only: 63% MV: 36% Bicycle: 1%	Nonroad: 48% -sidewalk Road: 43.4% -intersection -no crosswalk	Only: surface conditions MV: pedestrian & driver negligence	Young
Bicycles	2.05 per 10,000 days of participation	Sidewalks use discouraged	Only: 67% MV: 29% Bicycle: 3% Ped: 2%	Road: 58.3% -intersection (sidewalk bicyclers) -driveway Nonroad: 26.4% -most are bicycle only on sidewalk	Only: surface conditions MV: wrong way bicycle travel & obscured driver vision	Young
Skates	1.71 per 10,000 days of participation (in-line skating)	Some bans on sidewalks	Only: 80.5% Skaters: 5.9% MV: 3.5% Bicycle: 2.5% Ped: 0.8%	In-Line: -road: 34.9% -sidewalk: 27.0% Roller: -park/rink: 50% -sidewalk: 27.8%	Surface conditions Collisions	Young
Skateboards	2.51 per 10,000 days of participation	Some bans on sidewalks	Not available	Other (indoor areas, parking lots, and driveways): 36.8% Sidewalks: 18.4% Roads: 1.6%	Excessive speeds: 51.3% Obstructions: 17.9% Collisions with MV: 7.7%	Young
Scooters	1.03 per 10,000 days of participation	Some bans on sidewalks	Not available	Non-road: 67% -most on sidewalks: 21% Road: 27.2%	Surface conditions Excessive speeds Inability to break MV conflict	Young
Wheelchairs	7.6 fatal per 100,000 users per year (Caulder and Kirby, 1990)	Sidewalks	Not available	Sidewalk: 0.3% Most occur inside	Tips and falls Ramps	Elderly

REGULATORY AND LEGISLATIVE HISTORY OF THE HT

The HT was designed for operation in the pedestrian environment; however, with two electric motors and the ability to move people and cargo, the HT could be classified as a motor vehicle and thus prohibited from use on sidewalks, the most ubiquitous form of pedestrian infrastructure. This section chronicles the regulatory and legislative history of the HT at the federal, state, and local levels. The history is reviewed in order to identify potential concerns and solutions that stakeholders and legislators have identified.

Federal Regulations and Legislation

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

> The term "electric personal assistive mobility device" means a self-balancing, non-tandem wheeled device that (A) it was to transport only one person with personal baggage; (B) is powered solely by an electric propulsion system and; (C) has a top motor-powered speed not in excess of 20 miles per hour. (Library of Congress, 2003)

Next, federal bill S. 2024 was introduced to enable the use of the HT in the pedestrian environment. The bill contained three key components:

1. the term "electric personal assistive mobility device" and its definition;
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 the controlling authorities, which qualified the use of the device by stating "when State or local regulations permit." (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. At this point, legislative efforts began to be focused at the state and local level. The proposed federal bill's three-part structure (EPAMD definition, operating guidelines, and controlling authorities) however, did serve as a template for further state legislation.

State Legislation

At the state-level, legislation to allow the use of the HT in the pedestrian environment progressed rapidly. In December 2001, New Jersey passed EPAMD-enabling legislation, and in February of 2002, New Hampshire passed similar legislation. By October 2003, forty states and the District of Columbia had passed enabling legislation. Five states (Alaska, Kentucky, Colorado, Louisiana, and Minnesota) did not require EPAMD legislation because they had no prohibition against powered conveyances on their sidewalks. The remaining five states (Connecticut, New York, Montana, North Dakota, and Wyoming) have not yet passed legislation (Segway LLC, 2003). See **http://www.segway.com/general/regulatory.html** to access state HT legislation.

The state legislation shares the basic features of the proposed federal bill, but many states expanded the three-part structure to clarify the HT's exemption from motor vehicle status and to permit its use on pedestrian infrastructure. The operating guidelines were also expanded or made more specific in the legislation passed by many of the states. Much of this language addressed the use environment and safety concerns. For example, many states:

1. Expanded the "usable infrastructure" from "bicycle paths and pedestrian walkways" of the federal bill to include streets, roads, and highways;

2. Granted users the rights and duties of pedestrians (Connecticut, New York, Montana, North Dakota, and Wyoming);

3. Gave 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);

4. Required users to yield the right of way of pedestrians, to give an audible signal when passing pedestrians, and 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);

5. Included minimum age requirements of HT users (Utah, Virginia, Missouri, Arizona, Iowa, Vermont, Rhode Island, Pennsylvania, Hawaii, and Oregon);

6. Required additional equipment such as lights and reflectors when operating the 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

7. Required HT users to wear helmets (teenagers and younger in Utah, Pennsylvania, Georgia, and Florida, and all ages in New Jersey).

Local Legislation

Of the forty states and the District of Columbia that passed enabling legislation, thirty-one allowed local jurisdictions to restrict use of the HT. California's legislation enabled a city and county by ordinance to "regulate the time, place, and manner of the operation of electric personal assistive mobility devices" in order to protect the safety of the elderly, disabled, and bystanders (California).

New York restricts the use of the HT in cities with a population of one million or more (e.g., New York City). However, some press reports suggest that city officials may not be enforcing the ban. The New York City Police Department is currently testing the HT as part of a field test program.

Despite widely publicized discussions in many jurisdictions, there have been few actions limiting the use of the HT. While twenty-four local jurisdictions have discussed restricting HT use, only four have actually restricted use: in California, 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; McMahon, 2003). San Francisco has also banned the HT from public transit stations and vehicles. A ban was enacted in the D.C. metro transit system area (District of Columbia, Maryland, and Virginia), but it is temporarily not being enforced.

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 HTs on sidewalks with limited space are the primary sources of concern. The disabled and elderly feel particularly vulnerable because 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 by asserting that the HT is safe, easy to use, and environmentally beneficial. To make their case, Segway LLC and HT owners have often provided demonstration rides to citizens and local officials. In Davis, California, after three owners demonstrated the HT's 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, CA chose not to implement a contemplated ban upon learning of Seattle's cost savings after incorporating the HT into its municipal fleet. San Mateo is now pursuing funds to supplement its municipal fleet with HTs. (Fraley, 2003) Authorities in Capitola, CA, have also adopted the "wait and see" approach after a demonstration ride (Turner, 2003).

The state-specific legislative provisions to increase the safety of HT use, and to permit local jurisdictions to restrict its use, are of particular relevance to the design of the research field test. The field test design will consider the use of safety equipment to minimize user risk, incorporate age restrictions, and include clear rules of use in the instructional handbook. It is also interesting to note that while thirty-one states allow local governments to restrict the use of the HT, to date only three jurisdictions ban its use on sidewalks. It appears that most local governments have not found the HT's impact on the sidewalks sufficient to warrant restricting its use. During the feasibility analysis, researchers carefully introduced stakeholders to the HT (both with demonstrations and information), identified their potential concerns, and addressed those concerns in the design of the field test.

LESSONS LEARNED FROM PREVIOUS HT FIELD TESTS

Since the HT was unveiled in 2001, 6,000 units have been sold internationally and in all 50 states. The markets for HTs include individual consumers and 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, and recreational users. This section presents the key findings of a survey of selected HT implementation projects in the public and private sectors. Public and private sectors surveyed 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. Lessons learned from these field tests will be incorporated into the design of the Pleasant Hill BART field test. Between August and October 2003, UC researchers conducted telephone surveys of thirteen field tests provided by Segway LLC. Table 3 summarizes the survey results.

The results of this study of HT field tests yielded a number of general “lessons learned.” Key challenges reported by the field tests include:

1. The importance of training for safe use of the HT in a range of environments;

2. The need for additional safety equipment to avoid accidents and/or minimize injury (e.g., helmets, lights, and vests);

3. The relatively short battery life of the HT, particularly on unpaved terrain;

4. The weight of the HT, which may make transporting it difficult (e.g., in trucks used for emergency responses);

5. Building security and/or lack of secure parking, which may restrict use of the HT for downtown travel; and

6. The rider’s height (greater than 6’4”), which may restrict HT users’ access to garages that are 7’ tall or less (this appears to be most problematic for law enforcement patrol in urban areas).

Key advantages reported by the field tests include:

1. Travel time savings, improved access, and avoided parking hassles in congested downtown areas;

2. Reduced vehicle operation and maintenance costs;

3. Increased access (e.g., emergency services) to locations that are not accessible by trucks, cars, or even golf cart;

4. Greater efficiency (i.e., faster meter reading, deliveries, or patrols);
5. Environmental benefits (i.e., from the use of clean fuel vehicle);
6. Improved public relations; and
7. Anecdotal evidence that workers' use of the HT may reduce stress (physical and psychological) in certain situations.

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

EXPERT INTERVIEWS AND STAKEHOLDER MEETINGS

In order to anticipate and address stakeholder concerns, a series of expert interviews and stakeholder meetings were held during the initial phase of the project. During these interviews and meetings, many of the stakeholders were introduced to the HT and provided the opportunity to operate it.

The Community Development/Planning Departments helped researchers to identify the safest routes for participants to operate the low speed modes. For example, these departments identified areas to avoid because of poor sidewalk conditions, lack of sidewalk connectivity, high traffic, and hazardous intersections. Bicycle/pedestrian groups also agreed to help identify safe routes for the bicycles and electric bicycles.

The police departments asked researcher to include a number of additional safety measures as part of the design of the field test. These included the use of helmet by participants and equipping the low-speed vehicles with lights, reflectors, and bells. The police departments also agreed to assist researchers with the identification of routes to avoid or where greater caution may be needed.

The BART accessibility/disability task force requested that the HT be walked and not ridden in the BART station or on BART property in order to avoid potential collisions during peak commute hours when stations are very crowded.

Members of the Independent Living Center in Contra Costa County also made some suggestions for safety precautions including equipping the low-speed modes with bells, instructing participants to say "on your left" if passing a blind person, and requiring participants to give the right of way to disabled persons. Training will require participants to give the right of way to all pedestrians, users of low-speed modes, and disabled persons.

RENTAL MODEL

To fully investigate the range of uses in employment settings, the HT, electric bicycles, and bicycles will be tested in a variety of applications throughout the day. There will be two primary user groups in this study (and rental model): commuters at the work-end and employees during the day. 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 trained 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 is stored and recharged. Additional groups, such as residents who live near the BART station, could be added during the field test demonstration, if appropriate. If local residents were added, they would have access to the device on evenings and weekends.

At each employment site, a reservation system for using the 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 Segway LLC, a rental agent at BART, 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. In addition, the devices will display signage indicating that they cannot be operated without a smart access key to discourage theft.

Additionally, within the past year there was a recall of the HT (initiated by Segway LLC) and some 1, some employers have also expressed concern about the safety of the 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.

CONCLUSIONS

The field test at the Pleasant Hill BART station and surrounding community, in the East San Francisco Bay Area, is planned to introduce shared HTs, electric bicycles, and bicycles to suburban transit and employment centers. A comparative evaluation of the three devices, HT (new), electric bicycle (technologically enhanced), and bicycle (traditional), should contribute to an understanding of the context in which the different low-speed devices may increase transit access most cost-efficiently. As the survey of the HT field tests suggests, there are preliminary signs that the 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.

Safety concerns about the interaction of the low-speed devices and pedestrians during the initial phase of the project prompted a literature review on the safety of low-speed modes. The results of the review indicated 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 risk factors have been minimized in planned field test by careful selection of routes, by training, and by requiring additional safety equipment.

It appears that efforts to familiarize officials and stakeholders with the HT have helped stem, to date, most of the threats to ban the HT (because of safety issues) that have occurred in numerous local jurisdictions. Only three local jurisdictions have banned the device and only five states have not passed HT-enabling legislation where it is necessary. Safety requirements in much of the state-level legislation may have been included to address to stakeholders' safety concerns. From the beginning of the project, researchers took steps to involve local stakeholders and officials in the field test design to identify and address any safety concerns.

The next phase of this project includes implementation and evaluation. The evaluation will consist of four main components: (1) pre- and post-field test focus groups of 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 viability and marketing. Data will be analyzed to assess modal shifts (e.g., reduced auto use and increased BART use), parking impacts, safety (i.e., 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 a subsequent field test in an urban location.

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