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Transportation
**Federal Railroad
Administration**

Passenger Train Emergency Systems: Single-Level Commuter Rail Car Egress Experiments

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13. ABSTRACT (Maximum 200 words)

The Federal Railroad Administration (FRA) is investigating how to improve rule provisions addressing the safe, timely, and effective evacuation of intercity and commuter rail passengers in various emergency scenarios. A variety of evacuation concepts, strategies, and techniques for applicability to passenger rail cars operating in the United States are being investigated. Under the sponsorship of the FRA, three experimental series of egress trials were conducted to obtain human factors data related to the amount of time necessary for individuals to exit from a passenger rail car. Controlled variables included exiting from the car using one or two side doors to a high platform or an end door to an adjacent car outside the rail car, and lighting conditions. This interim report describes the results of all three series of egress experiment trials.

To FRA knowledge, the main commuter rail car experiment was the first time that U.S. passenger rail car egress time trials were conducted with regular commuter rail passengers as test participants. Evacuation times varied significantly by number of passenger rail car exits used and the exit route taken. The collected exit-time data are intended for use in establishing passenger rail car egress time estimates/norms and evaluating various aspects of car design that may promote or impede prompt occupant egress. The experimental data will also be used as input to the development of a passenger rail car emergency egress simulation computer model to predict emergency evacuation time for a variety of passenger rail car configurations.

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ENGLISH TO METRIC

LENGTH (APPROXIMATE)

1 inch (in)	=	2.5 centimeters (cm)
1 foot (ft)	=	30 centimeters (cm)
1 yard (yd)	=	0.9 meter (m)
1 mile (mi)	=	1.6 kilometers (km)

AREA (APPROXIMATE)

1 square inch (sq in, in^2)	=	6.5 square centimeters (cm^2)
1 square foot (sq ft, ft^2)	=	0.09 square meter (m^2)
1 square yard (sq yd, yd^2)	=	0.8 square meter (m^2)
1 square mile (sq mi, mi^2)	=	2.6 square kilometers (km^2)
1 acre = 0.4 hectare (he)	=	4,000 square meters (m^2)

MASS - WEIGHT (APPROXIMATE)

1 ounce (oz)	=	28 grams (gm)
1 pound (lb)	=	0.45 kilogram (kg)
1 short ton = 2,000 pounds (lb)	=	0.9 tonne (t)

VOLUME (APPROXIMATE)

1 teaspoon (tsp)	=	5 milliliters (ml)
1 tablespoon (tbsp)	=	15 milliliters (ml)
1 fluid ounce (fl oz)	=	30 milliliters (ml)
1 cup (c)	=	0.24 liter (l)
1 pint (pt)	=	0.47 liter (l)
1 quart (qt)	=	0.96 liter (l)
1 gallon (gal)	=	3.8 liters (l)
1 cubic foot (cu ft, ft^3)	=	0.03 cubic meter (m^3)
1 cubic yard (cu yd, yd^3)	=	0.76 cubic meter (m^3)

TEMPERATURE (EXACT)

[(x-32)(5/9)] °F	=	y °C

METRIC TO ENGLISH

LENGTH (APPROXIMATE)

1 millimeter (mm)	=	0.04 inch (in)
1 centimeter (cm)	=	0.4 inch (in)
1 meter (m)	=	3.3 feet (ft)
1 meter (m)	=	1.1 yards (yd)
1 kilometer (km)	=	0.6 mile (mi)

AREA (APPROXIMATE)

1 square centimeter (cm^2)	=	0.16 square inch (sq in, in^2)
1 square meter (m^2)	=	1.2 square yards (sq yd, yd^2)
1 square kilometer (km^2)	=	0.4 square mile (sq mi, mi^2)
10,000 square meters (m^2)	=	1 hectare (ha) = 2.5 acres

MASS - WEIGHT (APPROXIMATE)

1 gram (gm)	=	0.036 ounce (oz)
1 kilogram (kg)	=	2.2 pounds (lb)
1 tonne (t)	=	1,000 kilograms (kg)
	=	1.1 short tons

VOLUME (APPROXIMATE)

1 milliliter (ml)	=	0.03 fluid ounce (fl oz)
1 liter (l)	=	2.1 pints (pt)
1 liter (l)	=	1.06 quarts (qt)
1 liter (l)	=	0.26 gallon (gal)
1 cubic meter (m^3)	=	36 cubic feet (cu ft, ft^3)
1 cubic meter (m^3)	=	1.3 cubic yards (cu yd, yd^3)

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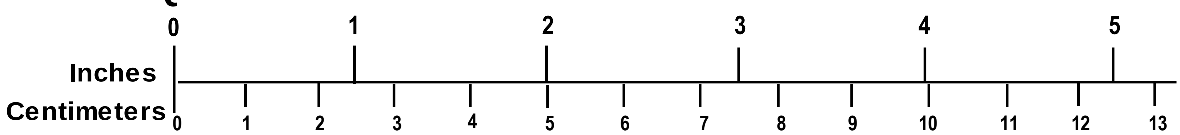
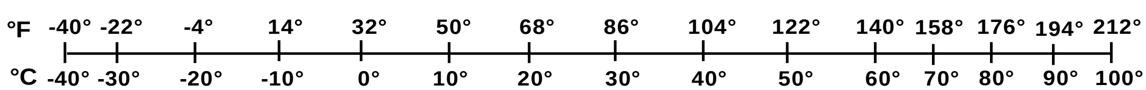


QUICK FAHRENHEIT - CELSIUS TEMPERATURE CONVERSION



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Preface

The Federal Railroad Administration (FRA), Office of Railroad, Policy, and Development, U.S. Department of Transportation (USDOT), is investigating how to enhance passenger rail equipment regulations contained in Title 49, Code of Federal Regulations (49 CFR), Parts 223, 238, and 239. These regulations are intended to address the safe, timely, and effective evacuation of intercity and commuter rail passengers in various emergency scenarios. A variety of evacuation concepts, strategies, and techniques for applicability to passenger rail cars operating in the United States are being investigated and evaluated.

Two parameters are necessary for determining whether safe evacuation from a passenger rail car can be achieved. One of the parameters is the actual time required for passengers to complete an emergency evacuation. The other parameter is the minimum available emergency evacuation time, defined as the time afforded by the materials/designs of the rail car before the interior of the car becomes untenable because of fire, smoke, or other hazardous conditions. Therefore, the safety criterion is that the minimum available evacuation egress time is longer than its actual emergency evacuation time. This safety criterion is essential in the progression from prescriptive safety standards toward performance-based standards for passenger train safety. Thus, it is paramount to determine the minimum emergency evacuation time of any car design.

This report describes the results of three experiments completed by staff of the John A. Volpe National Transportation Systems Center, in cooperation with the Massachusetts Bay Transportation Authority (MBTA), to obtain human factors data related to the length of time necessary for passengers to exit a single-level commuter rail car.

The main experiment on August 25, 2005, at North Station, Boston, MA, involved a series of egress trials by individuals into an adjacent car or onto the high-level station platform using one or two doors, under normal and emergency lighting conditions. Two additional experiments, consisting of a series of more limited egress trials for individuals to exit from the commuter rail car side doors using the stairway to the right of way and to a low platform, were conducted at the MBTA Commuter Rail Maintenance Facility, Somerville, MA, on April 19 and May 31, 2006.

To FRA's knowledge, the main commuter rail car experiment was the first time that U.S. passenger rail car egress time trials were conducted with regular commuter rail passengers as test participants.

The exit-time data were collected to assist in establishing estimates and norms for passenger rail car egress times and to evaluate various aspects of car design that may impede prompt emergency egress. The experimental data will also be used as input to the development of a passenger rail car egress computer model to predict emergency evacuation times for a variety of passenger rail car configurations.

Acknowledgments

Funding and direction of the passenger rail emergency preparedness research program has been provided by Kevin Kesler, Chief, Equipment and Operating Practices Division (EOP), Office of Railroad Policy and Development, Federal Railroad Administration (FRA), U.S. Department of Transportation (USDOT). Eloy Martinez, Manager, FRA Occupant Protection Program, reviewed and provided technical comments on the final draft of the interim report. Brenda Moscoso, FRA Railroad Safety Advisory Committee Emergency Preparedness Task Force Leader; and Daniel Knote, FRA Emergency Preparedness Leader, and Robert Scarola, all of the FRA Office of Safety, also provided extensive review and comments on the final draft report. In addition, Stephen Popkin, Director, Human Factors Center of Innovation, John McGuiggin, Chief, and Suzanne Horton, Systems Engineering and Safety Division, all of the John A. Volpe Transportation Systems Center (Volpe Center), Research and Innovative Technology Administration/USDOT, provided review of and comments for the final draft report.

The authors of this interim report also appreciate the important contributions of Claire Orth, former Chief, Equipment and Operating Practices Division; and N. Thomas Tsai, former FRA Manager, Occupant Protection Program; who provided direction of the commuter rail car egress experiment program plan and technical review of the initial draft report.

Stephanie Markos, Systems Engineering and Safety Division, Volpe Center, provided overall egress experiment technical direction and management, oversight of specific tasks, and technical review of all work products produced as a result of the commuter rail car egress experiments described in this report. John K. Pollard, Behavioral Safety Research and Demonstration Division, Volpe Center, collaborated with Ms. Markos in development of the overall egress experiment program plan, including trial design, scripts, and data recording; conduct of the specific experiments; data analysis; and preparation of this interim report. Last, Professors Galea and Muir and Ms. Mills provided review of the experimental data and the Volpe Center preliminary report describing the 2005 experimental results, as well as the final draft of this report which describes the results of both the 2005 and 2006 egress experiments.

Cassandra Oxley, MacroSystems Technology, Inc., prepared this report for publication; and Ms. Rodriguez, Volpe Center, and Barbara Siccone, formerly of Chenega Advanced Solutions and Engineering (CASE), provided formatting and typing support.

The success of the three series of commuter rail car egress experiments described in this report was due to the important contributions of the following individuals:

August 25, 2005 Egress Experiment Trials, Massachusetts Bay Transportation Authority North Station, Boston, MA

Volpe Center staff included Ms. Markos who provided overall management and task assignment, Mr. Pollard who designed and installed the video and audio recording equipment system, and Raquel Rodriguez who managed the administrative tasks related to participant recruitment and check-in/checkout, assisted by Mariana Vasquez.

During the egress experiment trials, Volpe Center staff included Christopher Cabrall, who operated the video recording equipment; and Rene Buchanan, Donna Burke, Tara DiDomenico, Caroline Donohoe, Danielle Eon; Catherine Guthy, Matthew Isaacs, Ms. Rodriguez, and Ms. Vasquez, who provided various administrative assistance and served as observers and marshals. In addition, Mr. Tsai, formerly of FRA, and David Mao, Office of Safety, FRA, served as observers.

The egress experiment trials were conducted with the cooperation of the Massachusetts Bay Transportation Authority. Volpe Center Staff greatly appreciate the special assistance provided by MBTA staff including Anna Barry, former Director of Railroad Operations; Robert Stoetzel, Chief Transportation Officer; Thomas Foster and Craig Diaz, Transportation Supervisors; all of Railroad Operations; James McGary, Steven Mudge, Chief Mechanical Officer, and interns Junior Aquea and Alex Griffin; and Lt. Salvatore Venturelli, Transit Police.

In addition, MBTA management also provided the use of two single-level commuter rail cars, power to operate the lights and video equipment, platform track space at North Station, Boston, MA, as well as extensive logistical assistance and cooperation prior to and during the experiment.

Last, Dennis Bonney, Bruce Curado, Richard Currier, Linda Dillon, and Roberta Ward, Massachusetts Bay Commuter Rail, Inc. (MBCR), provided operating and maintenance assistance.

The authors recognize the efforts of the 84 MBTA regular commuter rail passengers who participated in the 12 main experiment egress trials and the 2 people who participated in the two mobility-impaired egress trials.

Professor Edwin Galea, University of Greenwich; Professor Helen Muir, Cranfield University; and Ann Mills, Railway Safety and Standards Board, all of the United Kingdom, furnished important knowledgeable review of the experimental trial protocols including the scripts; and Professor Galea and Ms. Mills also served as observers during the actual experiments. Professors Galea and Muir; Rebecca McKowan, Research Officer, Cranfield University; and Ms. Mills provided technical review of the extensive experimental data and the Volpe Center preliminary report describing the experimental results.

Robert Gaumer, formerly of CASE, provided a variety of logistical support prior to, during, and after the egress experiment trials.

Richard Gopen, Multimedia Services/MicroLan Systems, Inc., provided photographic documentation during the egress trials and completed postproduction work for the video and audio data.

April 19, 2006, and May 31, 2006, Egress Experiment Side Door Stairway Trials, MBTA Commuter Rail Maintenance Facility, Somerville, MA

Ms. Rodriguez and John Zolock, formerly of the Volpe Center, provided administrative and other logistical assistance and also served as observers for both the April 19 and May 31 series of egress trials. Ms. Vasquez, Volpe Center, provided additional administrative support for the May 31 trials.

Mr. Mudge, MBTA; Robert Smith, MBCR; and Owen Finnegan, Edwards and Kelsey Corporation provided important logistical assistance at the MBTA Commuter Rail Maintenance

Facility for the April 19 series of trials. Mr. Mudge and William Shannon, MBTA, as well as Mr. Finnegan, provided important logistical assistance for the May 31 series of trials.

Mr. Gopen, Multimedia Services/MicroLan Systems, Inc., designed the video and audio recording system, provided photographic documentation during the egress experiments, and completed postproduction work with the video and audio data.

The authors appreciate the willingness of the numerous Volpe Center Federal employees who volunteered to participate in both series of egress experiments.

Contents

Figures

Tables

1. Introduction

One goal of the Federal Railroad Administration (FRA), U.S. Department of Transportation (USDOT), is to ensure that passenger rail equipment is designed, built, and operated with a high level of safety. FRA regulations in Title 49, Code of Federal Regulations (49 CFR), Parts 238, and 239, address the safety of intercity passenger and commuter train occupants in various emergency scenarios, such as collisions, derailments, and/or fire (1, 2). Accordingly, one FRA objective is to reduce casualties by requiring that passenger rail system operators provide a minimum level of emergency preparedness and response capability through the development of emergency preparedness plans and procedures; crew training; passenger awareness programs; and the installation of certain passenger rail car emergency equipment features and systems for the use of passengers and crew and responders in emergency situations.

In the majority of passenger train emergencies, it is not necessary to evacuate passengers since they are usually safer remaining aboard the train. However, the National Transportation Board (NTSB) determined that during some serious passenger train accidents, occupants could not readily identify, reach, or operate some emergency exits, and emergency response personnel was unable to identify or operate all rail car emergency access points (3, 4, 5, 6, 7, 8, 9, 10, 11). These difficulties resulted in delays in passenger train crew and passenger evacuation, as well as casualties, including fatalities and serious injuries.

FRA is investigating how to enhance current passenger rail equipment regulations related to emergency preparedness. Accordingly, FRA is sponsoring research to evaluate a variety of evacuation concepts, strategies, and techniques for application to passenger rail cars operated in the United States. Specific issues related to the safe, timely, and effective emergency evacuation that are being reviewed and evaluated include the number, location, and operation of emergency exits; emergency exit marking and instructions; emergency lighting; evacuation conditions; and passenger self-rescue (escape). FRA is interested in determining the feasibility of applying performance-based emergency evacuation time requirements, such as those of the Federal Aviation Administration (FAA), that specify evacuation times (e.g., 90 seconds [s] from an aircraft) to passenger rail cars (12).

This interim report describes a series of commuter rail passenger egress experiments that were conducted by the John A. Volpe National Transportation Systems Center (Volpe Center), Research and Innovative Technology Administration (RITA), USDOT, in cooperation with the Massachusetts Bay Transportation Authority (MBTA).

1.1 Purpose

Occupant egress time data from the three experiments described in this interim report (and any future experiments) are intended to assist in establishing baseline passenger egress times and evaluating various aspects of passenger rail car design that may enhance or hinder prompt egress.

The data will also be used as inputs to an egress computer model that is able to predict emergency evacuation times from different rail car configurations under a variety of emergency conditions. FRA has provided funding to the University of Greenwich (United Kingdom) to adapt existing EXODUS® computer egress model software for application to U.S. passenger rail car emergency egress time prediction.

The information obtained from the conduct of the passenger train egress experiments described in this interim report and the development of the passenger rail car computer egress model will provide an important tool to assist FRA in determining what, if any, revisions should be made to FRA regulations related to the number, type, size, and distribution of emergency exits, as well as other design features, such as emergency lighting. In addition, the computer egress model is intended for use by passenger railroad system operators and rail car designers to evaluate rail car emergency evacuation design features and emergency procedures.

1.2 Objective

The objective of the egress experiments described in this report was to obtain highly detailed observational data related to the length of time necessary for individuals to exit from a single-level commuter rail car to another car or to various exterior locations, using one or two exit doors, under both normal and emergency lighting conditions.

1.3 Scope

A series of three human factors egress experiments were designed and conducted by the Volpe Center.

The main experiment, consisting primarily of a series of 12 egress time trials, was conducted on August 25, 2005, using commuter rail cars, in cooperation with the MBTA, at North Station, Boston, MA. The experiment collected egress data related to the length of time necessary for participants to exit from a single-level commuter rail coach car into an adjacent car or onto the station high platform, using one or two doors, under both normal and emergency lighting conditions.

Two other experiments were also conducted on the same date at the North Station location to obtain data relating to mobility-impaired participant egress time.

In addition, two followup smaller-scale experiments consisting of a series of group and individual egress time trials were conducted on April 19 and May 31, 2006, at the MBTA Commuter Rail Maintenance Facility, Somerville, MA, to obtain egress time data for individuals using commuter rail car side door stairways to exit from the car to the right-of-way (ROW) and to a pavement simulating a low platform.

The remaining sections of this introduction provide additional context for the three series of egress experiment trials by presenting: 1) brief background information relating to egress time prediction in relation to emergency evacuation; 2) review of regulations/requirements issued by FRA and other DOT agencies, as well as other organizations, relating to emergency egress; and 3) listing of important variables that affect passenger rail car emergency evacuation.

1.4 Background

One of the two critical parameters for evaluating the impact of passenger rail car design features on emergency egress time is the amount of time necessary for occupants to exit from a particular rail car configuration. The other critical parameter is the available emergency evacuation time, defined as the time afforded by the materials/designs of the rail car before the interior of the car becomes untenable* as a result of fire, smoke, or other hazardous conditions. Therefore, the emergency egress safety criterion for a passenger rail car is that its minimum available evacuation egress time is longer than its necessary evacuation time. For example, if the growth of a rail car interior fire produces untenable conditions after 45 s, the evacuation time necessary for passengers and crew to exit from the car must be less than 45 s. (See additional discussion relating to minimum and available evacuation time in Reference 13]). This safety criterion becomes essential, especially as FRA transitions to performance-based regulations for passenger train safety from prescriptive safety standards. To evaluate the safety effectiveness of any passenger rail car design in terms of emergency evacuation, it is desirable to determine the minimum necessary and minimum available time for passenger and crew egress. (Because of the complexity of the variables involved, determining the amount of evacuation time available to passengers and crew before untenable conditions develop is beyond the scope of this report but is being addressed by other FRA-sponsored research.)

With the exception of the FAA 90-second requirement discussed in the next section, USDOT agencies do not currently include a requirement for specific evacuation time periods for passengers and crew from public transportation vehicles. This is because numerous variables, such as the vehicle configuration, number of passengers, and the operating environment, affect the length of time necessary for passengers and crew to leave a public transportation vehicle in an emergency evacuation. Current emergency evacuation-related requirements are discussed in the next section.

1.5 Public Transportation Vehicle Egress Requirements

The majority of USDOT transportation modal agencies address evacuation time by requiring a minimum number, type, and size of emergency exits at specified locations, which are identified by emergency lighting and/or emergency signs, and can be reached and operated by passengers and crew. Although FRA, FAA, and U.S. Coast Guard (USCG) all recognize the importance of operating crewmembers who are properly trained in emergency preparedness planning and procedures, the remainder of this section focuses on public transportation vehicle design requirements.

1.5.1 FRA

FRA regulations contained in Title 49, Code of Federal Regulations (CFR), Parts 238 and 239, provide specific prescriptive (versus performance-based) emergency egress requirements relating to passenger rail equipment that specify the type, number, size, location, and marking and operating instructions for doors intended for passenger egress and emergency window exits, as well as doors and windows intended for use by emergency responders for rescue access.

Certain provisions apply to new equipment (i.e., size of doors and emergency window exits and rescue access windows) while other provisions apply to all equipment (e.g., number of emergency window exits and rescue access windows, the marking of such exits and rescue access points, and the posting of instructions for their operation). In addition, FRA regulations also contain specific emergency lighting requirements for new equipment.

* Untenable means not capable of being occupied by people.

FRA regulations specify that each new passenger rail car must have at least two exterior side doors that are clearly marked for use as emergency exits and rescue access. In addition, each new and existing car must be equipped with a minimum of four clearly marked emergency-window exits and two rescue access windows.

The majority of passenger train emergencies are resolved quickly without the need to evacuate passengers who are usually safer if they remain on the train. If a train is unable to move, the generally accepted practice is to transfer passengers from the incident car(s) to unaffected cars or a rescue train or to move the disabled train to the nearest station. Moreover, if uninjured themselves, train crewmembers are responsible for evacuating uninjured passengers (and under certain conditions injured passengers) from the train to another train or to a point of safety.

Empirical data for estimating the amount of time needed to evacuate a passenger rail car was not available for consideration when FRA originally developed its current FRA regulations for passenger rail car emergency exits and emergency lighting and signs. However, the regulations do reflect the FRA belief that emergency lighting (currently required only for new cars) and clearly marked emergency exits that are rapid and easy to operate must both be available to passengers and train crew and that rescue access points be available to emergency responders to facilitate passenger and crew evacuation from trains when necessary in an emergency.

1.5.2 FAA

FAA regulations specify extensive prescriptive requirements for the type, size, number, location, and operation of aircraft emergency exits, which vary according to the number of passenger seats (14). FAA also requires that aircraft have emergency exit marking; minimum levels of emergency lighting; and depending on their capacity, floor emergency path exit marking. In addition, FAA requires that large aircraft, which carry more than 44 people, pass a 90-second performance criterion for passenger evacuation, as follows:

- Using a distribution of passengers meeting certain gender and age demographic criteria (40% female; 35% over 50 years of age; and 15% both female and over 50 years of age);
- Under conditions of darkness;
- Using only emergency lighting and emergency exit signs and floor proximity emergency exit path system;
- With half the exits disabled; and
- Under the direction of flight attendants (15).

Airlines and aircraft manufacturers are permitted to demonstrate compliance with the FAA evacuation requirement by either: 1) conducting an actual evacuation or 2) through testing and analysis that provide data equivalent to that provided by the actual evacuation demonstration. The “90-second” rule is based on the FAA-estimated elapsed time that results in untenable conditions because of fire. It should be noted that FAA regulations are based on the premise that, in most cases, passengers and crew must evacuate the aircraft as soon as possible because of the fire hazards resulting from large quantities of burning jet fuel.

Concerns have been raised regarding the safety of the FAA-required aircraft full-scale emergency evacuation demonstrations, after almost 400 injuries occurred between 1972 and

1991 during such tests. These concerns were discussed in a 1993 Report to Congress (16). That report also reviewed the capability of computer models available at that time to provide an alternative means to satisfy FAA requirements. (Subsection 1.6.2 and Chapter 4 briefly discuss computer egress simulation models.)

1.5.3 National Highway Traffic Safety Administration

National Highway Traffic Safety Administration (NHTSA) vehicle design regulations specify the type, number, size, location, and identification of emergency exits installed on large buses and school buses (17). Emergency lighting is not currently required for buses.

1.5.4 USCG/Safety of Life at Sea/International Maritime Organization

USCG emergency-preparedness-related regulations vary depending on the size of passenger ship and type of service (18). In all cases, at least two means of emergency egress must be provided along with emergency lighting and exit marking. Structural fire endurance requirements typically require a 1-hour rating; that hour is considered to be sufficient time to permit the evacuation of passengers to safety. However, USCG regulations do not require that shipping companies demonstrate that passengers can be evacuated in a minimum time period.

U.S. flag and other ships in international operations are expected to follow the Safety of Life at Sea requirements, which also contain prescriptive requirements for emergency exits and emergency lighting that are similar to or exceed the USCG requirements (19). The International Maritime Organization has developed a guideline for evacuation time analysis that consists of simple and more complex calculation methods that can be used to predict whether evacuation of passengers and crew to a point of safety from a ship of a particular design can be achieved within 1 hour (20).

1.6 Passenger Rail Car Egress Time Prediction

As noted earlier, predicting the time necessary for passengers and crew to evacuate from a passenger rail car or other public transportation vehicle is difficult. The only current means to validate occupant egress time prediction is to conduct actual simulated emergency evacuations or egress experiments from the car (or vehicle). However, such demonstrations have significant cost as well as safety and health issues. The safety issues include slipping, tripping, and /or falling by the participants. One of the challenges of conducting a valid test of egress behavior and safety features using members of the public is how to create a realistic test without putting individuals at significant risk of injury. Accordingly, the use of simulation models for egress behavior could reduce the number of actual evacuation tests that need to be performed to determine egress times for various passenger rail car designs.

1.6.1 Passenger Rail Car Egress Variables

Many variables that affect the time necessary for passengers to exit from a passenger train in an emergency must be considered and can be categorized as follows:

- Passenger Characteristics
  - Age/Gender
  - Weight (body mass)
  - Agility/Strength

  - Mobility impairments (including injuries, and disabilities)
  - Number of people in rail car
  - Seat location
  - Frequency of rail travel /familiarity with car
- Rail Car Geometry and Configuration
  - Car type
  - Number of levels (single/multi-level)
  - Number and arrangement of seats
  - Aisle and stairway arrangement
  - Door/window location, size, and operation
- Operating Environment
  - Location of emergency
    - Best case
    - Worst case
  - Time of day and lighting conditions
  - Weather conditions
  - Platform or ROW conditions
  - Car condition (damage) and orientation of cars
  - Station
    - High-platform
    - Low-platform
  - ROW (ballast, tunnel, bridge embankment)
- Training – Plan, Procedures, and Equipment
  - Passengers
  - Train crew
  - Emergency response
- Assistance in Exiting
  - Direction and assistance from train crew
  - Assistance from other passengers
  - Assistance from emergency response personnel

These variables are discussed in greater detail in References 21 and 22.

A computer simulation egress model could include all of the variables listed above, as well as the experimental egress trial results described in Chapter 4. The egress experiments described in this report were intended to obtain data only for selected rail car, passenger, and operating environment variables that could be controlled, as described in Chapters 2 and 3. Accordingly, although the effect of passenger injuries, different weather conditions, passenger rail car orientation, assistance in exiting, etc., all have an important impact on egress time, those factors were beyond the egress experiment scope and therefore were not considered or included.

1.6.2 Egress Computer Models

An FRA-sponsored study reviewed and evaluated a variety of computer egress models for their potential ability to evaluate the impact of passenger rail car design features, such as the type, number, size, and distribution of emergency exits and emergency lighting, on minimum necessary egress time (21). The use of a validated egress simulation computer model for passenger rail cars would decrease the need to conduct experiments using human test participants to predict the minimum necessary evacuation time for each different car design for various emergency scenarios, thus eliminating or minimizing safety and health risks from those experiments. In addition, using a computer egress model may permit many more passenger rail car emergency egress designs to be evaluated in a far shorter time period and at less cost than lengthy and complicated hand-recorded data and subsequent calculations.

To obtain data that can be used in a passenger rail car computer egress model, data for selected variables were obtained during the Volpe Center-conducted egress experiments that are described in the remainder of this report.

Chapter 2 presents an overview of the commuter rail car high-platform experiment egress trial protocol and analysis of data. Chapter 3 presents an overview of the protocols of the two followup egress experiment trials conducted for people exiting from a single-level car using the side door stairway steps to the ROW (planking and ballast using a step box) and to a "low-platform" pavement, and an analysis of those data. Chapter 4 provides a summary of the major findings, implications, as well as recommendations for the conduct of further egress experiments.

Appendices A through H contain additional information relating to the main high-platform egress experiment conducted in 2005.

Appendices I through Q contain information for the two followup side door stairway step egress experiments conducted in 2006.

2. High-Platform Egress Experiment Trials

This chapter provides an overview of the high-platform experiment egress trials conducted on August 25, 2005, with the cooperation of the MBTA at North Station, Boston, MA. These 12 egress trials utilized individuals who exited a single-level commuter rail car by either using one or more side doors onto either a high platform or by using an end door to exit to an adjacent car, under two different lighting conditions.

The measurement of passenger rail car occupant travel speed and egress flow rates were the objectives of the Volpe Center-conducted egress trials described in this chapter (as well as in Chapter 3). Although experiments to measure the time required to open the rail car end and/or side doors would be desirable, such experiments are inherently more complex, time-consuming, and expensive. This is because door-opening involves learning how to perform an action that the participant may not have done previously, whereas egress through an open door (from the rail car) is a more familiar action. Figuring out how to open the door in both powered and unpowered conditions may take much longer than actually performing the action, so each individual can operate each type of door mechanism only once. To make good use of individuals participating in such an experiment, it would be necessary to assemble a collection of passenger rail cars with all types of door-opening mechanisms of interest, which is logistically difficult and was beyond the scope of the experiments described herein.

Experimental egress rate measurements may be conducted on either a competitive or a noncompetitive basis. In a competitive experiment, individuals are given some type of financial incentive to exit from an area faster than other people, whereas other individuals receive no such incentives in noncompetitive experiments. In some competitive aircraft evacuation experiments, incentives resulted in individuals behaving so aggressively that some became jammed in the exits and sustained injuries. Although a rationale can be made that competitive experiments represent what could occur during an actual life-threatening passenger train emergency, the competitive framework was not used for the commuter rail egress-rate experiments because of the great variance it introduces in egress behavior and the risk of participant injury.

Participants were recruited from regular commuter rail passengers. The different elements of the experiment, including the variables which could be controlled, influencing participant movement from his/her seat from the original commuter rail car into either the adjacent commuter car or onto the high platform from the original car, are described in the remainder of this chapter.

2.1 Type and Number of Egress Trials

To establish a baseline rail car egress time, highly detailed observational data were collected and recorded during the 12 egress trials of the main high-platform experiment for the amount of time necessary for participants to exit a single-level commuter rail (coach) car: 1) onto the station high-level platform using one or two doors and 2) into an adjacent car; under both normal and emergency lighting conditions. The order of the main experiment egress trials (which were randomly repeated, see Table 1) was arranged to provide a varied but controlled distribution of the independent variables for the type of exit used and lighting condition as well as reduce the likelihood that participants would apply the experience of what they learned from the preceding trial. Each participant was also assigned to a different seat for each of the 12 egress trials (see Section 2.4).

Table 1. High-Platform Main Experiment Egress Trials

TRIAL #	DESTINATION	LIGHTS
1	Platform – 1 door	Emergency
2	Adjacent car	Normal
3	Platform – 2 doors	Emergency
4	Platform – 2 doors	Normal
5	Platform – 1 door	Normal
6	Adjacent car	Emergency
7	Platform – 1 door	Emergency
8	Adjacent car	Normal
9	Platform – 2 doors	Emergency
10	Platform – 2 doors	Normal
11	Platform – 1 door	Normal
12	Adjacent car	Emergency

In addition to the 84 people who participated in the high-platform main experiment egress trials, 2 people with serious mobility impairments participated in very brief, more limited separate trials to measure their commuter rail car egress time and platform walking speeds, as well as identify any factors that may have affected the time necessary for them to leave the rail car. Those trials are summarized and briefly discussed in Section 2.9. Note: These two individuals did not participate in any of the main experiment egress trials, because their inclusion would have introduced a high level of variance into the results and obscured the effects of other variables.

2.2 Commuter Rail Car/High-Platform Station Arrangement

MBTA provided two single-level "MBB" commuter rail cars built in 1987 for Volpe Center staff use during the experiment egress trials, power to operate the lights and audio and video equipment, and high-platform track space at North Station, Boston, MA. Figure 1 shows the schematic arrangement of the two commuter rail cars and the platform used for the high-platform egress experiments. This figure serves as a reference point for this section and the more extensive data descriptions in Sections 2.4 through 2.6.

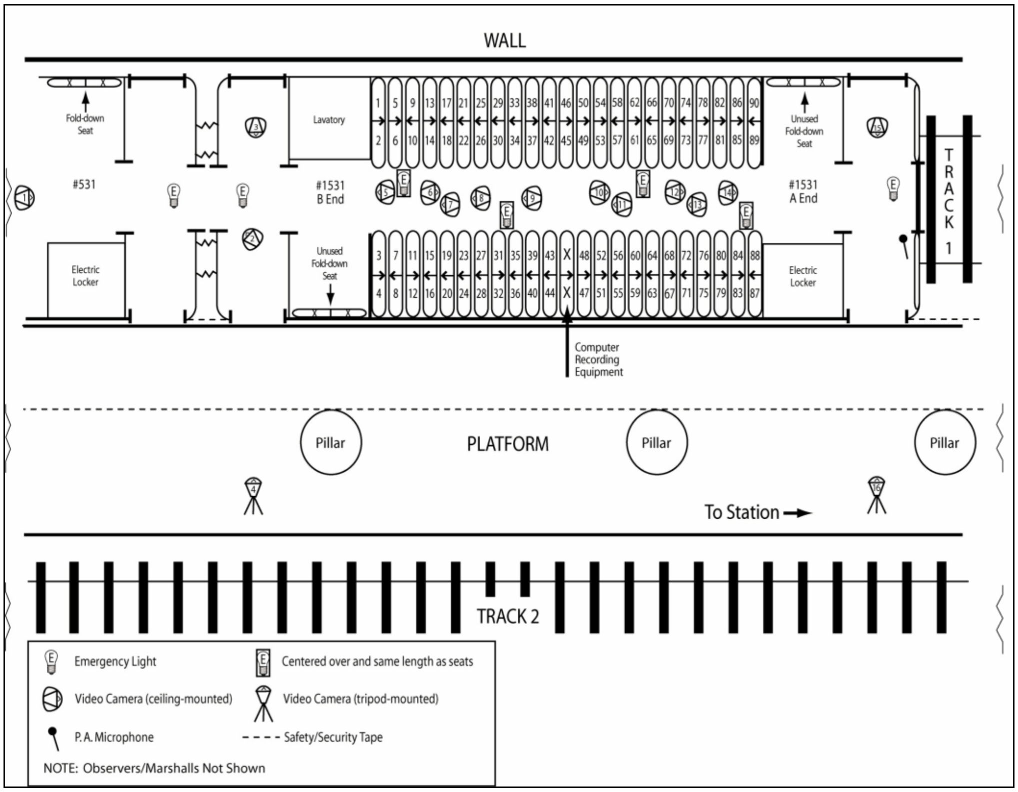


Figure 1. Main Egress Experiment Schematic: Car Interior and High-Platform Arrangement—North Station, Boston, MA

The two-car consist, containing a cab/coach car and a coach car, was located on Track 1, adjacent to a station platform. Half of the station platform was blocked off from Track 2 as a safety precaution and to prevent interference with video cameras. (The other rail cars connected to the train consist were not used for the experiment.) The station door to Tracks 1 and 2 was secured by the MBTA Transit Police to isolate the train from other commuter rail passenger traffic and to prevent interference with the experiment. All platforms at North Station are "high platform," meaning that passengers exited from Car #1531 (and Car #531) onto the high-platform without the need to step down the car side door stairway used at certain stations to reach the "low platform."

Figure 2 shows the exterior of the two-car train consist used during the 12 high-platform main egress trials. The commuter rail equipment included MBB Car #1531 and Car #531. (Note that the exterior of all side car windows were covered with opaque paper to darken the car interior seating area during the trials held under emergency lighting-only conditions [see Section 2.4].)

(a) Car #1531 – "A" end (b) Car #531 (left) and Car #1531 – "B" end (right)

Figure 2. MBTA "MBB" Commuter Rail Cars: Track 1 and Station Platform

Figure **3** shows interior and exterior views of the vestibule side doors located at the "A" and "B" end of Car #1531.

As previously noted at the beginning of this chapter, participants were not required to open any of the end and side doors before leaving Car #1531. The vestibule end and side door opening dimensions were identical on each end of the car.

(a) "A" end exterior and interior (b) "B" end exterior and interior

Figure 3. Car #1531: Interior and Exterior Side Doors to Platform

Figure 4 shows the open end door and vestibule located at the "B" end of Car #1531 and the open doorway diaphragm area between Car #1531 and Car #531. (Note: Car #531, which had the same type of two-by-two seating arrangement, was used only for the passage of participants from Car #1531 during the main experiment "exit-to-adjacent-car" egress trials. Photos are shown from the perspective of people leaving Car #1531 to enter the adjacent car.)

(a) “B” end door and vestibule area (b) “B” end diaphragm area

Figure 4. Car #1531: Interior End Door and Intercar Diaphragm (looking from Car 531)

Figure 5 shows the interior of Car #1531 used to seat the passenger participants during all 12 main experiment egress trials. Car #1531 has a seating capacity of 96 people with 24 rows of two-by-two bench-style seating. Half of the 90 seats used to seat the participants faced each end of the car. Seating was a combination of transverse seating and “facing seats.” (The distance between the edge of the transverse seat bottom cushion and the adjacent seat back was 18 inches (in; 47.5 centimeters [cm] and the distance [gap] between the facing seats was 12 in [30 cm] [as shown in Figure 5].)

Figure 5. Car #1531: Interior Transverse (left) and Facing Seats (right)

As also shown in Figure 5, paper numbers were taped to the back of each of the 90 seats in Car #1531 used by the participants. (See Section 2.5 for more information relating to seat assignment.)

The measured width of the interior aisle of Car #1531 at the armrest level was 30 in (76.2 cm).

The fold-down bench seats (not shown), located at each end of the car (designed as an accommodation for persons using wheelchairs), were not used for seating in the trials. In addition, one set of two seats in the middle of Car #1531, on the platform side, was used by Volpe Center staff for the video recording system).

2.3 Lighting

During half of the 12 main experiment egress trials, the normal interior car lighting system was turned off, and the interior of the passenger seating area of Car #1531 was illuminated only by four emergency-lighting ceiling fixtures (one of the four ceiling light fixtures located between Seats 61 and 65 was noticeably dimmer than the others, because of a defective battery). As previously noted, the exterior of the car windows was covered with opaque paper to prevent the entry of exterior platform light into the seating compartment. The fluorescent emergency-light fixtures located in the rail car vestibule ceilings, in combination with station lighting coming through the open side doors, provided 3- to 5-foot-candle (fc) (32–54 lux) illumination levels on the vestibule floors, as measured on the floor by Volpe Center staff, using an *Extech® 401036* light meter. In addition, normally bright platform lighting (greater than 10 fc [108 lux]) outside Car #1531 (and #531) was also present during all egress trials.

2.4 Participant (Passenger) Characteristic Distribution

Two major issues that require consideration when conducting human egress experiments are the safety of participants and associated privacy concerns. Federal regulations generally require that all human participants be briefed on the purpose of the experiment and that they read and sign "informed consent" documents explaining the experiment, as well as authorizations to make information protected by the Privacy Act available to the researchers. All personal data (e.g., height, weight, etc.) is protected information. Although the experimental protocol, participant briefing, and consent forms must usually be reviewed and approved by an "Institutional Review Board" prior to the conduct of such experiments, Volpe Center legal staff reviewed the experiment plan and script and determined that they met the Office of Management and Budget exception for "public behavior," because the participants would not be asked to perform actions different from those they normally perform in the course of their daily routine.

Posters were placed in North Station, Boston, MA, where the 12 egress trials were conducted (see Appendix A) to recruit 104 potential participants from the population of regular commuter rail passengers.

To qualify, individuals were required to possess a commuter-rail pass for the month of August 2005 or a "12-ride" book. Initially, the intent was to select participants from those who applied in accordance with the FAA-required evacuation test demographic guidelines:

- 40% female,
- 35% over 50 years of age, and
- 15% female and over 50 years of age.

However, the target distribution for the egress experiment was modified to consist of:

- Equal numbers of male and female participants
- Equal numbers of participants in each of the following age groups:

– 18–29 years,
– 30–50 years, and
– Over 50 years.

The target distribution for the main high-platform egress experiment was modified to include a higher proportion of women compared with that required by FAA for aircraft evacuations, but a slightly lower proportion of older people, to more accurately reflect the commuter rail population. However, the actual distribution of the 84 people who volunteered to participate in the main experiment was slightly different from the target, with a few more female and middle-aged participants than planned. Because this experiment demanded very little of the subjects in terms of physical fitness, the differences between planned and actual demographics are not expected to have affected egress rates. In addition to gender and age, the participants were asked to provide height and weight data (see Table 2). Detailed participant characteristic distribution data for these 84 people is contained in Appendix B.

Trial 1 involved only 81 people because of three late arrivals. However, 84 people participated during each of the other 11 egress trials. This total number included two people with slight mobility impairments: one person who had a broken arm and another who used a cane.

As noted previously, 2 other people with significant mobility impairments, other than the 84 people recruited for the main egress experiment, participated in two brief, separate, more limited egress trials (see Section 2.9).

Table 2. Main Experiment: Participant Characteristics

VARIABLE	NUMBER	PERCENTAGE*
GENDER		
Female	44	52
Male	40	48
Total	84	
AGE GROUP		
30 and under	26	31
31–50	32	38
Over 50	26	30
Total	84	
HEIGHT		
Under 5 ft	1	1
5 ft to 5 ft 6 in	33	39
5 ft 6 in to 6 ft	39	45
6 ft and over	11	13
Total	84	

WEIGHT (lbs)		
Under 100	1	1
100–149	25	30
150–199	46	55
200–249	10	12
250 and above	2	2
Total	84	

* Totals do not add to 100% because of rounding.

All 86 participants were compensated with their choice of gift certificates from various local stores. To avoid obscuring the effects of the variables of interest and for safety reasons, the egress trials were noncompetitive; no incentives were provided to the 84 participants during the main experiment high-platform trials to exit the commuter rail car by reaching the end and/or side doors before other participants.

All 86 participants in both the main high-platform egress trials and the other more limited mobility-impaired egress trials were told to exit the cars for their respective trials in an orderly manner, as quickly as possible, but without pushing, as if they were late for an appointment or work. (See Sections 2.6 and 2.9 for further information on the egress trial procedure.)

2.5 Data Collection

The following types of data were collected prior to or during the conduct of the main egress experiment:

- Physical dimensions of Car #1531, including seats, aisles, and end and side doors;
- Characteristics of each seat – identifier, location, proximity to various exits, and direction;
- Normal and emergency lighting illumination levels;
- Characteristics of each participant – identifier, age, gender, weight, and height;
- Sixteen video camera and 10 audio recording locations for each trial;
- Participant questionnaires; and
- Observer comments.

In addition, the Egress Experiment Team participated in a debriefing meeting during which preliminary results were shared and feedback was solicited for identifying "lessons learned."

2.5.1 Car Dimensions

Measurements of important commuter rail car physical dimensions including the seats, aisle and end and side doors are listed in Table 3.

2.5.2 Platform Data

The total width of the station high platform between Tracks 1 and 2 is 15 ft (4.6 meters [m]). However, to ensure participant safety, yellow security tape was installed around and between the platform canopy support columns to block off an approximately 4 ft (1.2 m) wide portion of the platform next to Track 2, making the platform width available to participants after they left Car #1531 by the side doors approximately 10 ft (3 m) wide. In addition, after Trial 1, participants who used the "B" end side door to exit the car were directed to go toward the center of the car on the Track 1 platform. The normal station platform ceiling lights were operational, providing bright light (approximately 10 fc [108 lux]) outside the car and on the platform surface.

Figure 6 shows the platform gap size between the "A" and "B" end side doors of Car #1531 and the high-level platform edge. The "A" end gap was 4 in (10 cm), and the "B" end gap was 3.5 in (8.9 cm).

Table 3. MBTA "MBB" Commuter Rail Car #1531 Dimensions

CAR/COMPONENT		INCHES (in) and FEET (ft)/ CENTIMETERS (cm) and METERS (m)*
EXTERIOR	Length between side doors	892 in (74 ft 3 in)/2266 cm (22.6 m)
	Total car length (including vestibules and diaphragms.)	1025 in (85 ft 4 in)/2603 cm (26 m)
VESTIBULES	Car width between end doors	113 in (9 ft 5 in)/287cm (2.9 m)
	Width between side doors	46 in (3 ft 10 in)/117cm (1.2 m)
DIAPHRAGHM	Length	25 in (1 ft 1 in)/63 cm (0.63 m)
INTERIOR PASSENGER COMPARTMENT		
Walls	Width between walls	115 in (9 ft 7 in)/292 cm (2.9 m)
Aisle	Length between end doors	885 in (73 ft 9 in)/2248 cm (22.5 m)
	Width at armrest level	30 in (2 ft 6 in)/76 cm (0.76 m)
All Seats	Cushion depth (front edge to back)	18 in (1 ft 6 in)/46 cm (0.46 m)
	Cushion length	36 in (3 ft)/91 cm (0.91m)
	Width between armrests	37.5 in (3 ft 1 in)/95 cm (0.95 m)
Transverse Seats	Width between front of cushion to back of next seat	18 in (1ft 6 in)/46 cm (0.46 m)
	Clear opening	12 in (1 ft)/30 cm (0.30 m)
	Pitch	33 in (2 ft 9 in)/84 cm (0.84 m)
	Front of armrest of first seat to end door "A" and "B" end	93 in (7f t 5 in)/236 cm (2.4 m)
	Door to seat back "A" and "B" ends	65 in (5 ft 5 in)/165 cm (1.6 m)
Facing Seats	Clear opening between seat edge	14.5 in (1 ft.2.5 in)/45 cm (0.45 m)
End Door (to Vestibule)	Frame opening, gasket-to-gasket	37.5 in (3 ft 1.5 in)/95 cm (0.95 m)
	Clear opening	33 in (2 ft 9 in)/84 cm (0.84 m)
	Height	78 in (7 ft 6 in)/198 cm (2 m)
	Car/Platform Gap: "A" and B" ends	4 in (8.9 m) and 3.5 in/9 cm
Vestibule Area Side Door to Platform	Frame Opening, outside	46.75 in (3 ft 10.75 ft)/119 cm (1.2 m)
	Frame Opening, gasket-to-gasket	39 in (3 ft 3 in)/99 cm (1 m)
	Height	78 in (7ft 6 in)/198 cm (2 m)

* SI units rounded

Figure 6. Car #1531: Side Door/Platform – "A" and "B" End of Car

2.5.3 Illumination Data

Volpe Center staff measured floor-level illuminance with an *Extech® 401036* light meter. The MBB cars used for this experiment were illuminated by double rows of the normal lighting system consisting of fluorescent fixtures that provided illuminance levels of 20–30 fc (215–324 lux) at the floor. Under emergency lighting conditions, the car floor-level illuminance values present are listed in Table 4.

While the main high-platform egress trials were conducted with the commuter rail car windows covered with opaque paper to block out external light from the seating area, the vestibule floors were illuminated by the platform lights. Platform lights were operating normally providing bright light outside the car and on the surface of the platform—at least 10 fc (108 lux).

Table 4. Illumination Levels – Emergency Light Fixture Locations

LOCATION	FLOOR-LEVEL ILLUMINANCE (FOOT-CANDLES)
Adjacent vestibule (Door B)	3.5
Between cameras 5 & 6	1.5
Between cameras 8 & 9	1.5
Between cameras 11 & 12	0.1 (defective battery in fixture)
Near camera 14	2.0
Opposite vestibule (Door A)	5.0

2.5.4 Participant Data

One hundred four people were selected from the more than 120 people who called to volunteer to participate in the experiment. When prospective participants contacted Volpe Center administrative staff, data regarding their gender, age, weight, and height (see Section 2.4) were recorded. Eight-four people actually participated in the 12 main high-platform experiment egress trials, and 2 other people participated in two other limited-mobility trials.

To reduce the impact of learning effects from the repetitive nature of the actions performed by persons during the trials, a random seat-assignment plan was generated (see Appendix C). When the 84 main experiment participants arrived at North Station to register, they were each assigned a numbered vest (see Figure 7) worn front and back, as well as an individual “checklist,” indicating the numbers of the different seats assigned to them for each of the 12 main experiment egress trials.

Figure 7. Main Experiment: Registrations/Participants with Vest Number Assignments

Seat assignments were randomly generated, and the order of egress trials was arranged to reduce bias from possible learning effects and to vary the data output results without having a completely new set of participants exit Car #1531 car during each of the 12 main experiment egress trials. Since participants were: 1) recruited from a pool of people who regularly ride the commuter train service, 2) were not required to open any side or end doors (see Section 2.5.4 and Chapter 3), and 3) exited the train directly into the adjacent car or onto the high platform, which are actions similar to those taken by the majority of commuter rail (as well as intercity rail) passengers each time they normally enter or leave a train (i.e., nonexperiment conditions), Volpe Center staff believe that the potential learning effects were minimal. In the two side-door trials, participants were instructed to exit as quickly as possible but were not given specific advice as to which door to use. Subsections 2.5.5 through 2.5.7 contain more information relating to participant data collection during the main experiment egress trials.

2.5.5 Video and Audio Data and Data Conversion

To acquire the detailed video record of each participant’s movements during each of the 12 main experiment high-platform trials, 13 miniature surveillance cameras (*Supercircuits®* CD4) were installed on the ceiling in the seating compartment of Car #1531 (see Figure 8) and on the interior vestibule ceilings, just outside the two end door locations of that car. One additional miniature camera was located on the ceiling, just inside the seating compartment of Car #531.

Eight small microphones were also installed on the interior ceiling of the seating compartment. The majority of the video cameras and microphones were mounted on the ceiling PA loudspeaker outer cover plate with magnetic mounts.

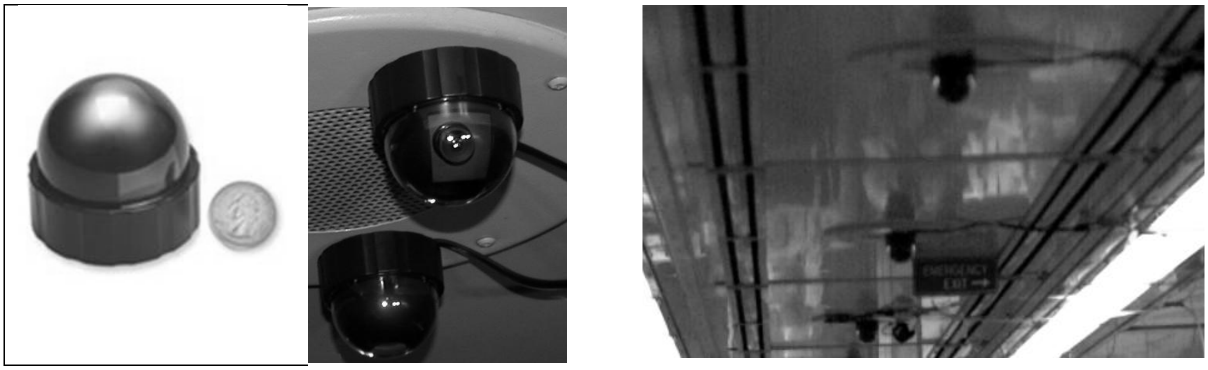


Figure 8. Miniature Video Cameras and Microphones Mounted on Seating Compartment Ceiling

In addition, two tripod-mounted video cameras (*Supercircuits*® PC-33C with a 6-mm lens), equipped with integral microphones were located on the platform facing the side doors, approximately 11 ft (3.3 m) away from the exterior of each door of Car #1531 (see Figure **9**).

Figure 9. Car #1531: Exterior Video Cameras – "B" End Side Door

The signals of all video cameras and microphones were recorded directly to a single computer hard drive using a *GeoVision*® GV-1000 video-capture card, *GeoVision*® GVA-16 audio-capture card, and *GeoVision*® software, version 6.1. This software time stamps each video frame in hours/minutes/seconds/hundredths (hh:mm:ss.sss) format (see Figure 10). The video and audio recording process was started and stopped for each trial so that the records were stored in separate directories with separate files for each camera and microphone.

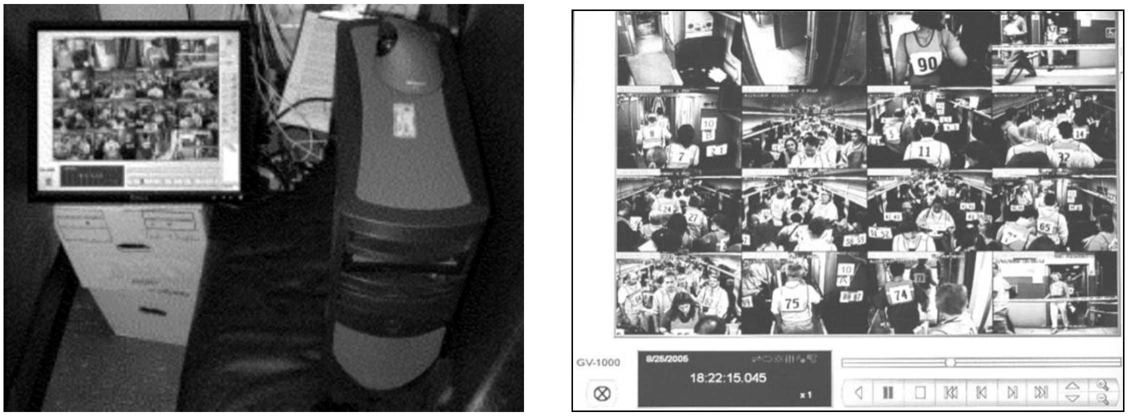
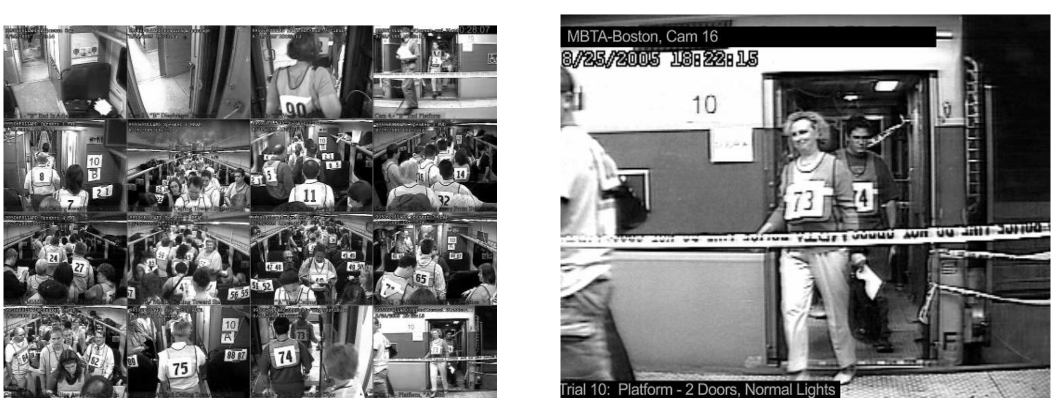


Figure 10. Video Data Recording Screen and Hard Drive/Screen – Closeup

For data analysis, the *GeoVision®* software was configured to record at a resolution of 320 × 240 pixels, and at the maximum allowable frame rate of 30 frames per second (fps). Because of limitations in computer processor speed, the actual number of frames recorded per second averaged in the low 20s. Audio was captured at a sampling rate of 11 kilohertz. The gaps created by the missing frames would have been of little consequence as long as the *GeoVision®* software was used for data review and analysis, because every frame was time stamped and the gaps were no longer than 67 milliseconds (ms).

However, viewing of video data in formats other than *GeoVision®* required recreation of missing frames so that timing by frame count instead of time stamp would be accurate**.** Compression was also applied to reduce the bit rate to approximately 4,000 kilobits per second so that less powerful computers could be used for data analysis. All videos were time-corrected (via a time-stretching algorithm) to run at 30 fps and synchronized with a single selected audio track (microphone near Camera 15). A digital clock counter, accurate to 1/100 s, was superimposed in the upper right corner of each video, which displays the elapsed time in h:mm:ss.sss. For each trial, the composite videos show all 16 camera views at their original 320 × 240 pixel size, laid out on a 4 × 4 matrix grid (1280 × 960 pixel total viewing size). Figure 11(a) shows the "all-cameras" video screen view for Trial 10, converted to Windows Media Video® (.wmv) format with new time clock added and labeling of each camera view.



(a) All camera view (b) Camera 16

Figure 11. Video Screen Views – Converted Video Media Format

In addition, to facilitate the data analysis, individual screen views of the 16 cameras for each of the 12 trials were generated. Each of these single videos was doubled in viewing size (to 640 × 480 pixels) to increase resolution of details. Figure 11(b) shows a closeup of the Camera 16 view from the same trial.

2.5.6 Questionnaires

All participants also completed a very simple and brief checklist questionnaire after each trial (see Appendix D). The questionnaire consisted of six questions intended to identify the exit location selected by the individual for the two door-to-platform egress trials and the reasons why; what effect the type of lighting (normal or emergency) had on the person's ability to exit; and questions related to other factors relating to interactions with other participants that may have made it difficult to leave the assigned seat and exit the car.

2.5.7 Observers

Four teams, each composed of two observers (see Appendix E), took notes (see Appendix F) during each of the 12 trials regarding participant behavior that could affect egress rates. The observer teams were located on the platform opposite the side door locations of Car #1531 (see Figure 12) or, in the case of the trials involving egress into the adjacent car, just inside the end door of Car #531.

Note: Other egress experiment team staff serving as marshals directed participants away from the vestibule side doors and along the platform after they exited Car #1531 to maintain a constant egress flow rate through the side door(s) (See Appendix E). The marshals also directed the participants to re-enter that car when each egress trial was completed and assisted participants in locating their new seat assignment for the next trial.

Figure 12. One Side Door to Platform Egress Trial: Observers

2.6 Main High-Platform Trial Procedure

Following registration, vest assignment, and seat assignment, participants were instructed to take their assigned seats in Car #1531 for the first main high-platform egress trial. After the participants were all seated, they were given a short briefing on the general purpose of the experiment and safety issues. Appendix G contains the full text of the script used by Volpe Center staff to provide directions to the participants for each of the 12 high-platform egress trials.

All participants were told to exit the cars for their respective trials in an orderly manner, as quickly as possible but without pushing, as if they were late for an appointment or work.

As noted previously, Section 2.9 contains information and discussion related to the brief mobility-impaired participant egress trials.

At the beginning of each of the main high-platform egress trials, participants were told whether they were to exit from Car #1531 through: 1) the open end door marked “A” into the adjacent car, or 2) either one or both end and vestibule side doors marked “A” or “B” onto the platform. In every trial, participants were encouraged to “walk as though late for work” but not to push or crowd. After the first trial, participants were requested to leave backpacks and other large bags on the overhead baggage rack. However, several participants continued to carry those belongings with them each time they left the car.

People were not told which egress trials would occur under emergency lighting conditions. The start time of each trial was marked with both a whistle blow and the drop of a large blue flag, which participants were prompted to expect. These signals are clearly visible and audible in the video recordings.

Each egress trial ended when the last person to exit the car had both feet on the platform outside the side doors or inside the adjacent car (across the diaphragm). A minute or two after the last person was out of Car #1531, the marshals directed the participants to re-enter that car and take their assigned seats for the next trial according to the assignment sheets previously issued to participants. Signs with the current trial number were posted in several conspicuous locations inside and outside the car to minimize possible confusion on the part of participants as to which trial was next and to identify each trial for the later data analysts. Participants completed the questionnaire for each trial before the start of the next trial. After the 12th trial, participants returned to Car #1531 to complete the final questionnaire and gather their belongings. Finally, participants were then directed to the checkout table to turn in their questionnaires and vests and to sign an acknowledgement of receipt of their gift certificates.

2.7 Data Analysis and Discussion

An analysis of the video data was conducted by Volpe Center staff using the original *GeoVision®* files. An *Excel®* spreadsheet was used to complete a worksheet containing data for each of the following items for each of the main egress trials:

- Trial number;
- Exit route;
- Lighting condition;
- Start time (indicated by flag drop and sound of whistle);
- Time at which the first person exited via End Door “A” into the adjacent car or from Side Doors “A” and/or “B” on to the platform, as applicable to the trial (time when both feet of participant reached destination; i.e., adjacent car or platform);

- Time at which the last person exited via End Door “A” into the adjacent or from Side Door “A,” and/or “Door B, on to the platform, as applicable to the trial” (time when both feet of participant reached destination; i.e., platform or adjacent car); and

- Count of people using each exit route.

The raw data extracted from the video files (see Table 5) for each of the 12 main experiment high-platform egress trials were used to calculate the following:

- Egress time – the total time from the moment when the signal to exit was given until the last person stepped onto the platform or adjacent car;

- Egress flow rate – the number of people per unit of time flowing through an exit; and

- Walking speed – distance traveled per unit of time (observed in this experiment while subjects walked through the vestibule to the adjacent car).

Table 5. High-Platform Main Experiment: Video Elapsed Egress Time Data

TRIAL #	EXIT	LIGHTS	START TIME	FIRST OUT SIDE DOOR A	FIRST OUT SIDE DOOR B	FIRST OUT ADJ CAR	LAST OUT SIDE DOOR A	LAST OUT SIDE DOOR B	LAST OUT ADJ CAR	COUNT SIDE DOOR A	COUNT SIDE DOOR B	COUNT ADJ CAR	COMMENTS
1	P1	E	17:33:47		17:33:54			17:35:28			81		4 people were late and thus not included in 1st trial
2	A	N	17:42:25			17:42:31			17:44:06			84	error, lights off for 2 s at beginning
3	P2	E	17:48:24	17:48:31	17:48:28		17:49:30	17:49:14		42	42		bar up, #82 exited thru adj car
4	P2	N	17:53:11	17:53:17	17:53:17		17:54:06	17:54:02		43	41		wrong trial # at A end inside; marshal blocking platform B camera
5	P1	N	17:57:49		17:57:54			17:59:32			84		long hair and backpacks cover vest numbers
6	A	E	18:03:18			18:03:23			18:04:59			84	circuit breaker (cb) door left open by electrician, 13th person closed it
7	P1	E	18:08:49		18:08:53			18:10:24			84		
8	A	N	18:13:20			18:13:24			18:15:01			84	
9	P2	E	18:17:54	18:18:00	18:17:59		18:18:48	18:18:49		43	41		
10	P2	N	18:21:59	18:22:05	18:22:05		18:22:53	18:22:53		41	43		
11	P1	N	18:25:59		18:26:04			18:27:39			84		
12	A	E	18:31:55			18:32:00			18:33:33			84	cb door closed just prior to 1st participant approach extra time for final instructions & thank you's

KEY: A = adjacent car; P1 = platform one-door; P2 = platform two door; N = Normal lighting; E = Emergency lighting

- Time is measured when participant has both feet over the inter-car diaphragm floor

Time: h:mm:ss

The egress rate was calculated by dividing average walking speed by the average interpersonal distance. Total egress time was calculated by multiplying the egress rate by the total number of persons who exited.

Computer simulation egress models require disaggregated walking speed data. Egress rate and total egress time data from experimental observations can be used for model calibration and validation.

The data in Table 5 were used to calculate elapsed egress times for the "first person out" and "last person out" of the participants using each of the three exit routes from Car #1531. Egress flow rates were calculated by dividing participant counts by the elapsed time (between "first person out" and "last out") for each route.

As Table 6 shows, the egress times and flow rates were remarkably consistent across trials (i.e., there was little evidence of learning or fatigue effects). The behavior of the participants appeared to reflect their familiarity with exiting from Car #1531, no matter which route they were told to take. (Note that for the egress trials involving both side doors, the participants were not told which door to use, only to use what they considered to be the nearest door.) The overall difference in exiting times between normal and emergency lighting conditions was not statistically significant because, as noted previously, both car vestibules and the station platform were well lit.

The average egress flow rate was 0.9 people per second (pps) from Car #1531. The greatest deviation from the average flow rate occurred during Trial 3, because of congestion on the platform that reduced the speed of participants to 0.7 pps leaving through Side Door "A."

The average elapsed time from the start of the egress trial (flag drop and whistle sound) for the first person to exit in each trial ranged from 4 to 7 s, with an average of 5.4 s. The total egress time for 84 participants, using a single exit route during the egress trials (either one side door to the high platform or end door into the adjacent car), averaged approximately 100 s, whereas trials using an exit route to the high platform using two side doors averaged approximately 58 s.

The walking speed of participants could be estimated from the video captured by Camera 4, which showed their transit through the vestibule—a distance of 3.7 ft (1.1 m) during egress through the adjacent car. These transit times ranged from approximately 0.7–0.9 s, implying walking speeds of 4–5 ft/s (1–1.5 m/s). These values are slightly higher than the design specification for normal walking speed of pedestrians at signalized street crossings of 4 ft/s (1.2 m/s) (23). The Canadian Government specifies a range of 3.7–4.6 ft/s (1.1–1.4 m/s) for the normal walking speed of pedestrians at signalized street crossings (24). Therefore, the egress experiment calculated walking speed estimates are within the range of those in the cited references.

Table 6. High-Platform Main Experiment:– Elapsed Egress Time Data – Calculated Egress Times

TRIAL #	EXIT	LIGHTS	RESEATING TIME	SIDE DOOR A *	SIDE DOOR B *	ADJ CAR	SIDE DOOR A	SIDE DOOR B	ADJ CAR	SIDE DOOR A FLOW RATE	SIDE DOOR B FLOW RATE	ADJ CAR FLOW RATE	SUM OF NORMAL LIGHTING FLOW RATES	SUM OF EM LIGHTING FLOW RATES
1	P1	E			0:00:07			0:01:41			0.85			0.85
2	A	N	0:06:57			0:00:06			0:01:41			0.88	0.88	
3	P2	E	0:04:18	0:00:07	0:00:04		0:01:06	0:00:50		0.71	0.91			1.62
4	P2	N	0:03:41	0:00:06	0:00:06		0:00:55	0:00:51		0.88	0.91		1.79	
5	P1	N	0:03:47		0:00:05			0:01:43			0.86		0.86	
6	A	E	0:03:46			0:00:05			0:01:41			0.88		0.88
7	P1	E	0:03:50		0:00:04			0:01:35			0.92			0.92
8	A	N	0:02:56			0:00:04			0:01:41			0.87	0.87	
9	P2	E	0:02:53	0:00:06	0:00:05		0:00:54	0:00:55		0.90	0.82			1.72
10	P2	N	0:03:10	0:00:06	0:00:06		0:00:54	0:00:54		0.85	0.90		1.75	
11	P1	N	0:03:06		0:00:05			0:01:40			0.88		0.88	
12	A	E	0:04:16			0:00:05			0:01:38					0.90
												COLUMN TOTAL	7.03	6.89
												COLUMN AVG	0.88	0.86

KEY: A = adjacent car; P1 = platform one-door; P2 = platform two-door; N = normal lighting; E = emergency lighting

* Time is measured when participant has both feet over the inter-car diaphragm floor

Time: hh.mm.ss

Egress time results from the video data indicated that individual egress flow rates from Car #1531 were unaffected by the type of egress route used (through end door into the adjacent car or from one or two side doors to the platform) or the lighting condition (normal or emergency).

In the benign setting of the main high-platform egress trials, no panic or congestion issues existed, allowing the use of a simple egress flow-rate equation to estimate passenger car total egress time in relation to seating configurations and load factors:

$$T_{total} = T_{fo} + (N/FR)$$

where T_{total} = total egress time (s)

T_{fo} = time for first person out (averaging approximately 7 s in these trials)

FR = flow rate (averaging approximately 0.9 pps in these trials)

N = number of participants

On the basis of this equation and the assumption that single-level commuter rail cars contain not more than approximately 130 seats, it is reasonable to predict that under similarly favorable circumstances:

- Evacuation of a full load of seated occupants from a single-level (coach) car onto a high platform through two side doors can be completed in less than 90 s (1.5 minutes [min]).
- Evacuation of a full load of seated passengers into an adjacent car through an end door or from a single side door onto a high platform from could be completed in approximately 150 s (2.5 min).

It is emphasized that the commuter rail car main high-platform egress experiment trials were conducted under the most favorable conditions to establish a baseline for computer model calibration and for comparisons with potential subsequent egress trials conducted under conditions that would more closely approximate an emergency.

The main high-platform egress experiments used a single-level car with two-by-two seating with only 84 of its 92 seats used for each egress trial to either the high platform or to the adjacent car. None of the 84 participants, with the possible exception of one person who used a cane, was perceived to be limited in walking speed.

Although comparable egress experimental data are not available, a body of data from actual egress flow rate measurements from various North American transit operations exists (25, 26). However, these times are normally expressed as egress flow times (seconds per person), which is the reciprocal of egress flow rate. Measured average egress flow times for alighting (i.e., exiting) passengers range from 1.4 to approximately 2 s/person. This range is naturally higher than the average of 1 s (the reciprocal of 0.9 pps measured in the main high-platform experiment, because when exiting under normal circumstances, some individuals leave gaps in the flow, thus increasing the overall egress time).

However, the participants in the main high-platform experiment egress trials were instructed to leave at a brisk pace, and most did not carry packages or other items; therefore, large gaps between people did not occur.

Had the main high-platform experiment egress trials been conducted with participants more representative of the actual mix of individuals who use intercity trains, a greater number of people with significant mobility impairments would have been included, particularly those older people who may have less agility. Walking speeds of such people have been estimated to average below 1.3 ft/s (0.4 m/s) (27)—less than half the speed noted as a result of the commuter rail car high-platform experiment egress trials described in this report. Therefore, it may be necessary to increase the total necessary intercity passenger car evacuation time by a factor of two or more, depending on the numbers of such people and the behavior of the unimpaired passengers.

In addition, exiting from a passenger train to a high-platform station is the “best-case” scenario. The exiting time for passengers evacuating from a commuter or intercity train to another location, without the benefit of being able to step directly onto a high-platform, could be significantly longer. Chapter 3 describes the results of two followup experiments that Volpe Center staff conducted to evaluate passenger egress time from a commuter car when the side stairway is used to exit to either the ROW or to a low-platform pavement.

Section 2.9 briefly describes the other two high-platform egress trials that involved mobility-impaired participants and their results.

2.8 Other Data

2.8.1 Observer Summary

Observations included the following:

- Several participants removed their backpacks or other items from the overhead luggage rack and carried them during each trial. However, because of the density near the car end doors, this did not appear to slow the flow rate.
- Certain occurrences, such as tripping or brief partial blocking of an open equipment door, did not significantly slow the flow rate.
- Vest numbers of some participants were not visible at times because of backpacks or long hair. (However, because of the numerous cameras and their various angles, it was possible to identify each participant during each trial during the data analysis).

2.8.2 Participant Questionnaire Summary

The questionnaires completed by each participant for each egress trial were reviewed to identify pertinent information (see Appendix H for data tabulation):

- In trials under emergency lighting conditions, approximately 50% of the participants indicated that conditions did not cause them difficulties. The remainder indicated that they walked more slowly to avoid the risk of bumping into someone or tripping. Under normal lightning, approximately 10% of the participants reported these concerns.

- When participants were directed to use a specific exit, approximately 75% indicated that the instructions were the reason for their choice, with "following the crowd" accounting for the remainder. In the "two side door" egress trials, approximately one-half of the participants said they chose the nearer exit. Approximately 20% said they were "following instructions," although the instructions did not provide any guidance other than exiting promptly but without pushing.

- Because the car was filled almost to capacity, most participants could not leave their seats immediately. Most had to wait until people who were already in the aisle near them began moving. Subject behavior was deferential (i.e., all subjects waited their turn to exit).

- Between 20 and 25 percent of the participants stated that they could walk as fast as they pleased once they got out of their seats. Most were slowed by those ahead, but pushing reports were rare—usually one in each egress trial.

- Nearly all participants reported that they exited normally from the car (i.e., without any concerns or holding onto railings). Two persons consistently stated that they used the hand rails when exiting, regardless of the lighting condition. Four participants said they slowed when stepping through the vestibule under emergency lighting, whereas only one or two slowed under normal lighting.

2.9 Mobility-Impaired Participant Egress Trials

During recruitment of the commuter rail passenger participants for the main high-platform egress experiment trials, two people who volunteered were identified as having significant mobility impairments. Because of several reasons relating to safety and time constraints, Volpe Center staff conducted two separate limited egress trials, with those two people as participants, to exit to the same high platform used for the main egress experiment, but using Car #531 (adjacent to Car #1531). Car #531 was also an MBB car with two-by-two seating. Although Car #531 was equipped with fewer seats than Car #1531, the aisle and end door used was the same width. Previous research has shown that aisle width is the principal determinant of egress rate, rather than seating configuration (28).

2.9.1 Participant Number 1

The female participant was in her early thirties and 8 months pregnant. She was asked to do two trials. In the first trial, the individual sat in one of the four facing seats at one end of Car #531. When the signal was given by the experiment team member, the person was asked to quickly walk along the length of the car (approximately 66 ft [20 m]) from her seat to and through the open vestibule end door and then use the open side door to exit the car. The elapsed time from the time the person started walking down the aisle until she reached the door was 15 s with a travel speed of approximately 4.8 ft (1.5 m)/s.

During the second trial, the individual was asked to walk outside Car #531 along the platform from the side door at one end of the car along the platform to the side door at the other end of the car. The elapsed time for the person to walk the distance of 60 ft (18 m) was 12 s, with a travel speed of about 5.2 ft (1.6 m)/s.

2.9.2 Participant Number 2

The second participant was a male approximately 40 years of age who walked with a severe limp and used a cane. In the first trial, the individual sat on one of the four facing seats at one end of Car #531. When the signal was given by the experiment research team leader, the person was asked to quickly walk along the length of the car (approximately 66 ft [20 m]) from his seat to and through the open vestibule end door and then use the open side door to exit the car. The elapsed time from the time the person started walking down the aisle until he reached the door was 15.3 s with a travel speed of approximately 2.9 ft (0.9 m)/s.

During the second trial, the participant was asked to walk outside Car #531 along the platform from the side door at one end of the car along the platform to the side door at the other end of the car. The elapsed time for the person to walk the distance of 60 ft (18 m) was 19.8 s with a travel speed of approximately 3 ft (0.9 m)/s.

2.9.3 Summary

Measurement of the walking speeds of mobility-impaired individuals was not an objective of this study. However, because such data are very limited, the two volunteers with conditions that might have slowed their walking speeds were measured. This walking speed data could be useful as an input database for a computer simulation egress model.

2.10 Summary – August 2005 Experiments

On the basis of the data obtained for the 2005 main high-platform egress experiment trials, the time necessary for 84 occupants to exit from a single-level commuter rail car with two-by-two seating and 92-person capacity (with no standees) averaged 58 s, when using two side doors to exit onto a high platform, and 1 min and 40 s, when using either a single side door to exit onto a high platform or an end door to exit into an adjacent car. From the start of a trial, as many as 7 s elapsed until the first participant was out of the car; thereafter, the average egress flow rate was approximately 0.9 pps.

With these values, total egress times for higher-capacity single-level passenger rail commuter cars with the same end and side door configuration are extrapolated for the same conditions, as follows:

- Single door (to high platform or to adjacent car)
  - 100 passengers: 122 s (2 min, 2 s)
  - 130 passengers: 156 s (2 min, 36 s)
- Two side doors (to high platform)
  - 100 passengers: 64 s (1 min, 4 s)
  - 130 passengers: 81 s (1 min, 21 s)

Egress times did not increase under emergency lighting conditions, given the benign conditions of the experiments (well-lit car end door and vestibule areas and station platform). Results of the main egress platform experiment indicated consistent egress times by participants for all trials, with minimal learning effects because of repetition and no apparent fatigue effect. No significant difference was observed between egress trials conducted under normal lighting conditions and those conducted under emergency lighting-only conditions, because the level of emergency lighting was sufficient for the participants to see and exit the car.

The results from the passenger rail car main high-platform egress trials demonstrate that passengers of normal agility can evacuate a fully loaded (no standees) single-level car to a high platform or an adjacent car in less than 2.5 min under both normal and emergency-lighting conditions. This time is short enough to allow all occupants to escape from most plausible fire scenarios (e.g., electrical or trash fires), if detected in a timely manner.

Measurement of the walking speeds of mobility-impaired individuals was not an objective of this study. However, because such data are very limited, the two volunteers with conditions that might have slowed their walking speeds were measured. This walking speed data could be useful as an input database for a simulation computer egress model.

3. Egress Experiments – Side Door Stairway Steps

To obtain egress time data from a commuter rail car using the side door stairway steps to reach the ROW (e.g., ballast, ground) between stations and to a low-platform (pavement) station, two followup egress experiments were conducted in cooperation with the MBTA at the Commuter Rail Maintenance Facility, Somerville, MA, on April 19 and May 31, 2006. This side stairway egress data, in conjunction with the data collected and analyzed from the main high-platform egress experiment described in Chapter 2, is intended for use in estimating passenger rail car occupant egress times.

3.1 General

Each of the two commuter rail car experiments using side doors with steps included a total of 10 egress trials. Five group trials and five individual trials were conducted in the early afternoon on each date, all under daylight conditions.

3.1.1 Participants

In contrast to regular commuter rail passengers (who participated in the August 2005 egress experiments), Volpe Center staff volunteers were recruited as participants in the 2006 experiments. However, for both experiment dates, the participants were asked how frequently they used commuter trains and the type of station they used: a high platform or low platform. Participants were not required to possess a commuter rail pass to participate in these two egress experiments, although several were regular riders. The same type of information was obtained for each Volpe Center participant regarding gender, age, weight, and height, as had been previously collected for the previous 2005 experiment participants (see Subsections 3.2 and 3.3.1). Each participant was provided with one of the same type of vests, as used in the 2005 experiment, and assigned different seat numbers for each of the egress trials.

3.1.2 Video/Audio Data Collection

For both egress experiments, three tripod-mounted minidigital video camcorders were used to record the exit time for each person. Microphones were positioned to capture Volpe staff instructions and starting cues (i.e., the whistle). Camera 1 was set up inside the vestibule and as close as possible to the ceiling and tilted down toward the side exit door and stairway steps to provide a wide-angle view of participants exiting the car. Two other cameras were located external to the train and set up to record at distances away from the exit side door. Camera 2 was facing and nearly perpendicular to the side door, approximately 5 ft (1.5 m) off the ground and 35 ft (10.7 m) from the door. Camera 3 faced the exit side door at an approximately 45-degree angle to the door, approximately 5 ft (1.5 m) off the ground and 45 ft (13.7 m) from the door. (See the specific car schematics and figures for each experiment.) The vestibule camcorder recorded audio from its internal microphone, whereas the external cameras were fed from wireless microphones worn by the Lead Experimenter who provided directions to participants. For each egress trial, the video/audio data were recorded continuously, starting prior to the beginning of the first of the individual trials and running until a few minutes after the last of the group trials was completed, a total of approximately 52 min. (See Sections 3.2.2 and 3.3.3 for additional information.)

3.2 Egress Using Commuter Rail Side Door/Stairway Steps to ROW/Ground

3.2.1 Participants and Car Configuration

Fifteen Volpe Center employees participated in each of the 10 egress trials. Appendix I contains age, height, weight, and gender information for each of the 15 participants who were roughly balanced according to gender and age. One mobility-impaired individual and three other people were perceived to be less agile than the majority of other participants.

The commuter rail car used for the series of egress trials in April 2006 was a single-level coach Car #237, with three-by-two seating, built by Bombardier in 1978–79 and rebuilt in 1996. Figure 13 shows a schematic of Car #237. (For safety reasons, a new Kawasaki bilevel car

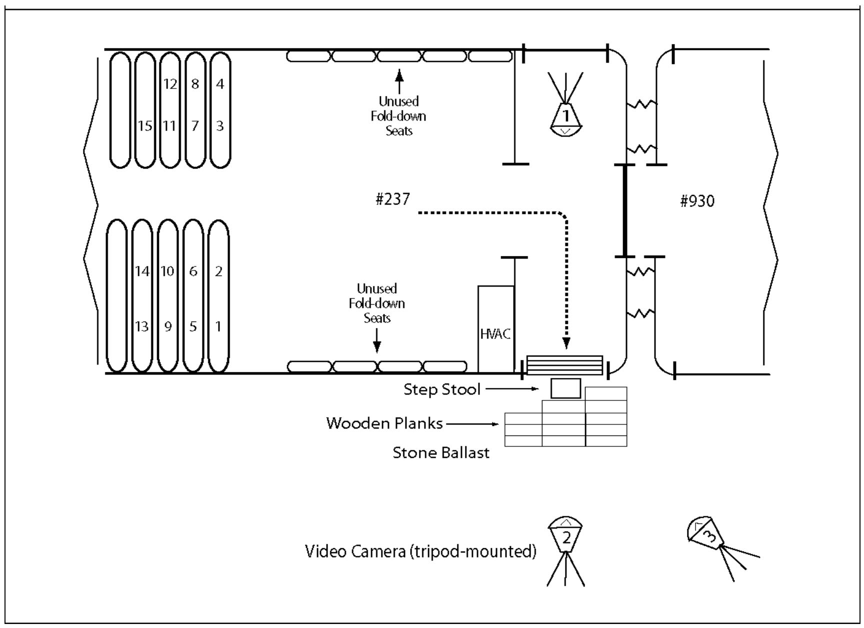


Figure 13. Car #237: Side Door Side Stairway Steps (via Step Stool) to ROW

(Car #930) was coupled to the Bombardier car to provide a temporary holding area for participants to return to after each of the 10 trials, before the start of the next trial.)

Figure 14 illustrates the location of the interior car vestibule video camera and the two external video cameras.

Figure 14. Car #237: Side Door Stairway – Interior and Exterior Video Cameras

The side door stairway consisted of four steps, each with a riser height of 8 5/8 in (22.9 cm). The total stairway step distance measured from the side door sill threshold to the bottom step was 33 in (84 cm). Since the difference in height between the bottom step of the side door stairs of Car #237 and the ballast/ground surface was 25 in (64 cm), a step stool was used for people to step down onto to reduce the step down distance from that bottom step to 16 in (41 cm). In addition, 2-inch (5 cm)-thick wooden planking covered the immediate ballast surface area around the step stool as a safety precaution. Figure 15 shows interior views of the car side door stairway, as well as an exterior view of the side door stairway planking and ballast.

Participants were seated, all facing forward, in numbered seats in the first four rows of Car #237 (see Figure 16). The distance from the first row to the interior vestibule end door used to exit the car was 8 ft (2.4 m).

(a) Interior views (b) Exterior view

Figure 15. Car #237: Side Door Stairway Steps

Figure 16. Car #237: Interior – Seat Numbers and Participants

3.2.2 Egress Trial Procedure

As noted earlier, 10 trials were conducted. The procedure used to direct participant actions for both side door experiments was similar to the August 2005 experiment. The individual and group egress trial scripts are contained in Appendix J.

In the five individual trials, participant numbers were called one at a time with enough time between calls to allow each person to step down from Car #237 and reach the ground before the next person's number was called out. (Seats were not assigned for any of the individual trials.)

For the five group trials, participants moved to different assigned seats after each trial (see Appendix K). The group trials were conducted using a faster pace than the individual trials with only as much time between trials as was necessary for people to enter the car and to be reseated.

Participants were directed to leave the car via the front (closest) vestibule end door and the side door stairway steps, after hearing a verbal and whistle cue, as detailed in the two scripts (see Appendix I).

Figure 17 shows the interior vestibule end door of Car #237, taped open to provide the same 33-inch (83.8 cm)-width as the MBB end door used in the 2005 egress experiment. Figure 17 also shows participants leaving Car #237 via the car end door and entering the vestibule during one of the egress trials.

After reaching the vestibule and turning right, the participants descended four steps. Following their exit from Car #237 (i.e., stepping down from the car steps onto the step box and then the wooden planking), participants were directed to immediately board the adjacent Car #930 by using the side door stair steps for that car. After the conclusion of each trial, all participants proceeded directly from the adjacent car (Car #930) back to Car #237. (Note: Following the conclusion of the first two individual trials, the wooden planking was rearranged to place more of the planking originally located on the right side (leaving the car) to the left side closer to the car to provide additional walking surface for participants to use after stepping off the step box.)

Figure 17. Car #237: View of End Door, and Individual at Side Door/Steps, Descending

3.2.3 Video/Audio Format

For the purpose of data review and analysis, all video camcorder and audio recordings were synchronized in postproduction, based on audio tones recorded simultaneously on all three camcorders at the beginning of each of the 10 trials. The three video recordings were placed in parallel and cut into segments covering each of the 10 trials (beginning 2–3 s before each trial, and ending when the last participant took one to two steps beyond the final step from Car #237 to the planking and ballast).

Each video clip was then cropped and titled, both as individual views and as synchronized composites, showing all three views of each egress trial on a single screen. Clock counters accurate to 1/100th of a second were added. The final video clips were also converted to an alternate video viewing media format, 720 × 540 pixel images compressed to a 4,121-kilobits per second rate. Figure 18 shows a still image of the composite view (three views) and a still image of an individual view for Group Trial 3 after format conversion.

Figure 18. Car #237: Side Door Stairway – Example Video Composite and Single Screen

3.2.4 Observers

Two Volpe Center staff members were located approximately 20 ft (6 m) away from Car #237, directly in front of the exterior of the side door stairway. Those observers completed the observer note sheets contained in Appendix L. In addition, observations were recorded by the two Volpe Center staff egress experiment coleaders as well as by Volpe Center audiovisual technical staff.

3.2.5 Data Analysis and Discussion

Video

The video recordings of each of the individual egress trials were reviewed to identify exceptionally fast or slow participant egress times. The descent times (i.e., the elapsed time from the last moment both of the person's feet were on the top step until the first moment both feet were on the planking and ballast) of each participant were measured. (Note: Some people stepped directly down from the stairway steps onto the ballast, instead of first onto the planking, either partially or entirely.)

In addition, the five group egress trial video recordings were analyzed to capture the following data items:

- Start time (indicated by sound of whistle);
- Time at which the first person to exit Car #237 reached the ROW (instant when both feet touched planking and ballast);
- Time at which the last person to exit Car #237 reached the ROW (instant when both feet touched planking and ballast); and
- Count of participants (passenger count).

From these data, egress flow rates were calculated by dividing the participant count (15 people) by the elapsed time from first person to exit Car #237 to last person to exit.

The egress flow rate estimates were used to develop an estimated total egress time for a fully loaded car (no standees). The total estimated egress time for 92 passengers was calculated to be 279 s (4 min, 39 s).

Data from the group trials, shown in

Table 7, show consistency in egress times and flow rates. The average elapsed egress time was 53 s. The egress flow rates average approximately 0.3 pps. No indications were observed to show learning or fatigue effects. These data show that the egress flow rates for passengers from a rail car to the ground, using the side door stairway steps, even with a step stool, are likely to be less than half of those for egress to high-level platforms, which average approximately 0.9 pps. It is also important to note that the proportion of a larger or smaller number of mobility-impaired occupants will likely increase the difference in passenger egress times.

The video recordings from the individual egress trials showed major differences between individuals in the time required to descend the side door stairs. Very agile participants completed the descent in just over 2 s and did not hold onto the handrail. Agile people usually used one or both of the railings. Less agile people needed to turn sideways and hold on to at least one of the hand rails or turn around completely and hold onto the railings with both hands as shown in Figure 19. The actions of the lowest agility participants increased the total time required to descend from the top step to the ground by 10–12 s. The implication is that if a passenger rail car were loaded with a high proportion of seated persons of low agility, evacuation to the ground, even using a step stool, will take five to six times longer than evacuating the same group to a high-level platform. Because passengers may become injured during a severe accident such as a passenger train collision/derailment or fire, this is an important consideration.

Table 7. Side Door Stairway Steps to ROW (Step Stool Planking and Ballast) – Egress Data

TRIAL#	START TIME	FIRST OUT (s)	LAST OUT (s)	COUNT	FLOW TIME (s)	FLOW RATE (pps)	AVG FLOW RATE (pps)
1	0:00	7.67	50.75	15	43.08	0.35	
2	0:00	10.94	57.62	15	46.68	0.32	
3	0:00	11.73	56.58	15	44.85	0.33	
4	0:00	7.89	51.00	15	43.11	0.35	
5	0:00	5.96	49.01	15	43.05	0.35	
							0.34

(a) Typical agility (b) Lowest agility

Figure 19. Participant Agility – Using Step Box

Participant Data

Although the participants were not requested to complete a detailed questionnaire for each trial of this experiment, information derived from “signup” data that they initially provided and later comments (see Appendix H) is highlighted on the next page:

- Slightly more than half of participants were regular commuter rail riders.
- Three participants had body-mass-index values above 30 (obese) with concomitant difficulty in descending the stairs to the step box.
- One participant had a major mobility impairment because of cerebral palsy.
- Several participants stated that they learned to make better use of the hand rails to descend the stairway steps and to the step box as the trials progressed.

Observer Data

The observers noted the time gap of several seconds between some of the slower participants, which was also shown in the video recordings. During all of the egress trials, due to multiple persons on the stairway at one time, the assigned observers could not accurately record the specific time it took for each participant to step from the top of the stairway down to the step stool and planking. However, this was not an issue since the video recording data were used to calculate the egress flow rate for each trial.

3.2.6 Summary

The egress flow rate for the 15 participants averaged 0.3 pps. Flow rates for passenger egress from a rail car to the ROW ballast, using the side door stairway steps, even with a step stool, are likely to be less than half of those for egress to high-level platforms, which averaged about 0.9 pps during the main high-platform egress trials described in Chapter 2 of this study.

Actions of the lower agility participants increased the total time required to descend from the top step to the ground by 10–12 s. It is also important to note that the proportion of a larger or smaller number of mobility-impaired occupants may significantly impact the difference in the egress flow rate and total passenger egress times.

3.3 Egress Using Side Door Stairway Steps to Low-Platform Pavement

3.3.1 Participants and Car Configuration

The second egress experiment also consisted of 10 trials. Seventeen Volpe Center participants took part in the five individual and five group trials. One person who participated in the August 2005 trials also participated in the May 2006 trials. In addition, a participant (who had also participated in the April 2006 trials) was noticeably less agile than other people. Several people of the other 16 participants were perceived to be very agile. Appendix M contains age, height and weight, and gender information for the 17 participants.

A single-level MBB car with the same interior configuration as that used at North Station in 2005 was used. Figure 20 shows the schematic of MBB Car #515. (Car #515 was coupled to another commuter rail car, which was not used by egress experiment participants.)

Figure 21 illustrates the location of the interior vestibule video camera and two exterior video cameras.

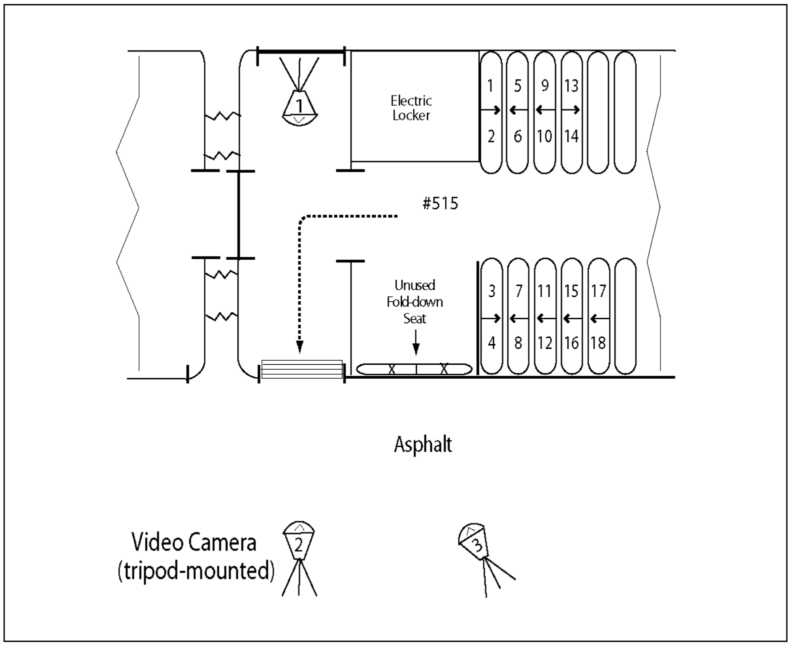


Figure 20. Car #515: Door Side Stairway Steps to Low-Platform Pavement

Figure 21. Car #515: Door Side Stairway – Interior and Exterior Video Cameras

Participants were seated in numbered seats in the first four rows, closest to the end of Car #515 that would be used to exit. (The experiment plan was for 18 participants; however, one volunteer was unexpectedly unable to participate.) Some seats were transverse, and some seats faced each other and did not face the end exit door. The distance from the first rows to the open-end door used by participants was approximately 8 ft (2.4 m).

Figure 22 shows the interior seat arrangement of Car #515, as well as the seated participants wearing vests, both identified by identification numbers.

Figure 22. Car #515: Interior – Seat Numbers and Participants

Figure 23 shows participants seated from the perspective of the rear of Car #515, looking forward to the end door used for exiting at the beginning of one of the individual trials.

Figure 23. Car #515: Interior View from Rear of Car during Egress Trial

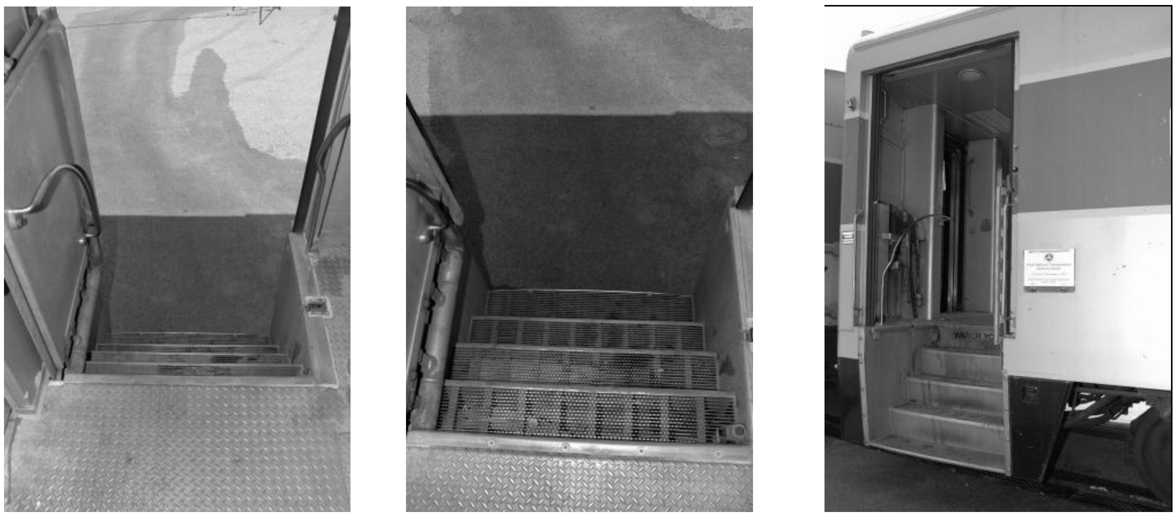
The side door stairway had four steps, each with a riser height of 8 5/8 in (22.9 cm). The total stairway step distance measured from the door sill threshold to the bottom step was 33 in (83.8 cm). The height between the bottom step of the side door stairs of Car #515 and the pavement (e.g., low platform) was 15 in (38 cm), which is less than the 16 in (40.6 cm) from the bottom step to the step stool described in Section 3.2. Figure 24 shows the interior and exterior views of the side exit door stairway.

3.3.2 Egress Trial Procedure

As noted earlier, 10 egress trials were conducted. The detailed scripts used are contained in Appendix N. In the five individual trials, participant numbers were called one at a time with enough time between calls to allow each person to reach the pavement before the next participant was called. For the group trials, the participants moved to different randomly assigned seats following each trial (see Appendix O). The group trials were conducted with only as much time between trials as necessary for participants to be reseated and complete the questionnaire for the previous trial.

During all egress trials, participants were directed to leave Car #515 via the open front (closest) end door and side door stairway steps, after heeding a verbal and whistle cue (see Appendix N). Participants then descended four steps directly onto the pavement.

After exiting from Car #515 (i.e., stepping onto the pavement) participants were directed to move to the right of the car. Following the conclusion of each trial (all people off the car), the participants proceeded back into Car #515 using the same stairs they had used to exit the car.



(a) Interior views (b) Exterior view

Figure 24. Car #515: Side Door Stairway Steps and Pavement (Low Platform)

3.3.3 Video/Audio Format

The same video and audio conversion process, as described in Subsection 3.2.4, was completed to enable Volpe Center staff to analyze the video data. Figure 25 shows still photos of the composite view (three views) and an individual view for Group Trial 4.

Figure 25. Car #515: Side Door Stairway – Example Video: Group Trial 4

Three Volpe Center staff members were located approximately 20 ft (6.1 m) away from Car #237 directly in front of the exterior of the side door stairway. Those observers completed the same type of observer note sheets contained in Appendix L for the April 2006 experiment. In addition, observations were recorded by the two Volpe Center staff egress experiment coleaders, one of whom stayed on the car and the other who moved on and off the car, as well as the Volpe audiovisual technical staff.

3.3.4 Questionnaires

Participants were asked to complete a questionnaire containing a set of four brief questions (see Appendix P).

3.3.5 Data Analysis and Discussion

Video

The video recordings of the individual trials were reviewed to identify exceptionally fast or slow participant egress times.

As for the previous stairway step trials, the video recordings of the five group trials were analyzed:

- Start time (indicated by sound of whistle);
- Time at which the first person to exit Car #515 reached the ground (instant when both feet touched pavement);
- Time at which the last person to exit Car #515 reached the ground (instant when both feet touched pavement); and
- Count of participants (passenger count).

Data from the group trials (see Table 8) show consistency in egress times and flow rates. The average elapsed egress times for the five trials were 30.5 s. As described in Subsection 3.2.5, passenger rail car egress flow rates were calculated by dividing the participant count (17) by the elapsed time from the first person to exit the car to the last person to exit the car. The average elapsed egress times for the five trials were 53 s.

Table 8. Side Door Stairway Steps to Low-Platform Pavement – Egress Data

TRIAL #	START TIME	FIRST OUT (s)	LAST OUT (s)	COUNT	FLOW TIME (s)	FLOW RATE (pps)	AVG FLOW RATE (pps)
1	0:00:00	5.94	29.36	17	23.42	0.72	
2	0:00:00	5.43	30.79	17	25.36	0.67	
3	0:00:00	5.68	31.80	17	26.12	0.65	
4	0:00:00	7.31	32.43	17	25.12	0.68	
5	0:00:00	5.57	28.93	17	23.36	0.73	
							0.69

Egress proceeded much more rapidly in these egress trials than in the April 2006 experiment. The egress flow rate doubled (0.7 versus 0.3 pps). The average flow time (the time for the entire group to pass through the side doorway to the pavement) was 25 s, compared with 44 s in April 2006, even though there were two more people in the April group. No indications were observed to show learning or fatigue effects.

The egress flow rate estimates were used to develop a total egress time for a fully loaded commuter rail-loaded car (no standees). The total time for egress from the commuter rail car for 92 passengers was calculated to be 139 s (2 min, 19 s), compared with 279 s (4 min, 39 s), for the same number of passengers, had they descended to the ground using a step stool (April 2006) instead of to the low-platform pavement. Egress via steps is substantially slower than egress to a high platform or adjacent car, where the average egress time for 92 people would be 110 s (1 min, 50 s), as estimated from the August 2005 experiments.

Factors that account for the higher flow rate and faster egress times in the May 2006 experiment egress trials than for the April 2006 experiment include:

- Higher agility of participants;
- Shorter drop from the bottom step of the stairway to the ground (in this case, pavement);
- A shorter distance to step out from the stairway; and
- A much larger and flatter surface to step onto.

In addition, the May 2006 experiment trials had only one participant of very low agility, while the April 2006 experiment trials had four such people. Figure 26 shows participants with typical and lowest agility exiting from Car #515 during Group Trial 2.

(a) Typical agility (b) Lower agility

Figure 26. Participant Agility

The large, even, and level asphalt pavement "landing area" permitted participants to make a less-cautious descent than during the April 2006 side stairway experiment when they had stepped from the stairway step to the smaller 18 in (45.7 cm) surface of the step stool (slightly unsteady on the ballast) and then to the planking. Instead, in this experiment, individuals stepped straight down from the steps to the pavement (and did not have to step out to reach the stool). Accordingly, some participants walked down the stairway without touching the handrails, whereas others made only light contact with them. One tall, young male participant jumped from the second highest step several times. In these trials, the one female with the lowest-agility, who had also participated in the April 2006 trials, came down the stairs facing forward, decreasing her descent time by half.

Participant Data

Participants completed a very brief questionnaire after each of the group egress trials. The following information from the questionnaires, initial participant signup data, and additional later participant comments (Appendix M) are highlighted below:

- Two participants had very high body mass index; none had other mobility impairments.
- Only 6 of the 17 participants were regular commuter rail riders; 6 were occasional riders.
- Most participants commented that the group behavior was orderly and polite with little or no pushing. Most could not walk as fast as they preferred because there were slower individuals ahead descending the stairs.

The questionnaire summary data is tabulated in Appendix Q.

Observers

As they did during the April 2006 experiment, the two observers noted a time gap of several seconds between some of the slower participants during the group trials, which was also shown in the video recordings. Because the egress flow rate by the participants was double that during the first experiment, and multiple people again were on the stairway at one time, observers were unable to accurately record the specific time it took for each participant to step from the top of the stairway to the pavement. However, the video recording data were used to calculate the egress flow rate.

3.3.6 Summary

Egress time and flow rates were measured for a group of 17 subjects using the side steps of a typical commuter rail car to descend to a low-platform pavement.

The average elapsed time for the five egress trials was 30.5 s.

Egress proceeded much more rapidly in these egress trials than in the April 2006 experiment. The egress flow rate was doubled (0.7 versus 0.3 pps). The average flow time was 25 s, compared with 44.2 s in April 2006, even though there were two more people in the April group.

The total egress time from the commuter rail car for 92 passengers was calculated to be 139 s (2 min, 19 s), compared with 279 s (4 min, 39 s) for the same number of passengers, had they descended to the ground using a step stool instead of to a low platform. Egress via steps is substantially slower than egress to a high platform or adjacent car, where the average egress time for 92 people would be 110 s (1 min, 50 s), as estimated from the August 2005 experiments.

Factors that account for the higher egress flow rate and faster egress time in the May 2006 experiment egress trials than for the April 2006 experiment include higher agility of participants and the easier exit path using the side stairway to step down to the large, flat pavement surface.

3.4 Summary Comparison of April and May 2006 Experiments

Egress by the participants from the commuter rail car proceeded much more rapidly in the May 2006 experiment than in the April 2006 experiment. The average flow rate doubled (0.7 versus 0.3 pps) between the two experiments. The average egress flow time (the time for the entire group to pass through the side doorway) was 25 s in the second experiment, compared with 44 s in the first, even though there were two more participants in the second. The elapsed time to first person out was as high as 12 s in the first experiment but only 7 s in the second experiment.

The use of the side door stairways as part of the exit path route slowed participant flow rates substantially, compared with exiting on to a high platform. Although some agile people descended in less than 2 s without using the handrails, less agile participants typically held both handrails and proceeded very slowly down steps, thus preventing other individuals from passing and thus slowing down all people behind them. This result is in contrast to travel along wide aisles that allow agile individuals to overtake those with mobility limitations (however, people did not pass each other in these two experiments). At the rates observed for descent from the side door stairway to a step stool placed on ballast with 27 percent of individuals classed as low agility, the time to exit from a high-occupancy single-level coach of seated passengers through side doors was estimated to exceed 6 min. If these people had to step down the full distance to the ballast, these egress times would have been substantially longer, and there could have been a higher risk of personal injury.

The height of the drop from the bottom step to the ballast or platform, as well as various physical aspects of the landing area (large size, firmness, level surface, etc.), exerted strong influences on the flow rate that were not fully investigated. However, such factors were observed to have the greatest effect on the behavior of people with low agility.

4. Summary of Analysis and Findings

The Volpe Center conducted a series of passenger rail car egress experiments in cooperation with the MBTA in 2005 and 2006. The 2005 experiments described in this interim report are believed to be the first experiments using U.S. passenger rail cars and regular passengers recruited from the general public ridership. The 2006 experiments were conducted using participants recruited from regular commuter rail passengers, as well as Volpe Center staff. As a result of the experiments, a significant amount of observational and quantitative data were collected and analyzed. The data are intended for use in developing a computer egress model that can be used to estimate passenger evacuation time.

4.1 Passenger Rail Car Egress Time

4.1.1 Main High-Platform Egress Experiment

On the basis of the data obtained from the 2005 main high-platform egress experiment trials, the time necessary for 84 occupants to exit from a single-level commuter rail car with two-by-two seating and 92-person capacity (with no standees) averaged 58 s when using two side doors to exit onto a high platform and 100 s (1 min, 40 s) when using either a single side door to exit onto a high platform or an end door to exit into an adjacent car. From the start of an egress trial, as many as 7 s elapsed until the first participant was out of the car; thereafter, the average flow rate was approximately 0.9 pps. Using these values, total egress times for higher-capacity single-level passenger rail commuter cars with the same end and side door configuration were extrapolated for the same conditions, as shown in Table 9.

Table 9. High-Platform High-Capacity Car Passenger Egress Time Estimates

	TYPE AND NUMBER OF DOORS	NUMBER OF PASSENGERS	EGRESS TIME
HIGH PLATFORM	Single door to platform or to adjacent car	100	122 s (2 min, 2 s)
		130	156 s (2 min, 36 s)
	Two doors to platform	100	64 s (1 min, 4 s)
		130	(81 s (1 min, 21 s)

Results of the high-platform experiment indicated consistent egress times by participants for all trials, with minimal learning effects because of repetition and no apparent fatigue effect. No significant difference was observed between egress trials conducted under normal lighting conditions and those conducted under emergency lighting-only conditions, because of the high density in the aisles which slowed the egress rate, as well as the high level of emergency lighting (well-lit car end door and vestibule areas and station platform), which enabled the participants to see and exit from the car without hesitation when they reached the end and side doors.

The results from the passenger rail car high-platform egress trials demonstrate that passengers of normal agility should be able to exit from a fully loaded (no standees) single-level car to a high platform or an adjacent car in less than 2.5 min under both normal and emergency-lighting conditions. This time is short enough to allow all occupants to escape from most plausible fire scenarios (e.g., electrical or trash fires) if detected in a timely manner (13).

4.1.2 Side Door Stairway Step Egress Experiments

As a followup to the 2005 high-platform egress experiment, two additional experiments during which individuals used side door stairway steps to exit a single-level commuter rail car were conducted in April and May of 2006.

Compared with the 2005 high-platform experiment, the number of participants was smaller for each of the two experiments, and several people were not regular commuter rail riders. However, the selected participants were again intended to represent a demographic range in terms of gender, age, height, and weight.

In the April 2006 egress experiment, it was necessary for participants to exit the commuter rail car using a step box after stepping down from the last step of the side door stairway; the ground surface consisted of wooden planking and ballast. The distance from the bottom step of the car to the top of the step box was 16 in (41 cm), with an additional drop of 9 in (23 cm) to the planking.

In the May 2006 egress experiment, participants exited the commuter rail car by stepping off the last step of the side doorway directly onto flat pavement, simulating the height of a low-platform station. The distance from the bottom step to the pavement was 15 in (38 cm).

Although the car interior aisle width was narrower in the May 2006 egress experiment, the opening widths of the end and side doors used to exit the car during both the April and May experiments were the same as had been used in the main high-platform egress experiment. Accordingly, aisle width was not a factor in either of the two experiments because participants were not trying to pass one another on their way to the end door.

Egress by the participants from the commuter rail car proceeded much more rapidly in the May 2006 experiment than in the April 2006 experiment. The average elapsed egress times for the five trials were 53 s for the April 2006 experiment and 30.5 s for the May 2006 experiment. The average egress flow rate doubled (0.7 versus 0.3 pps) between the two experiments. The average egress flow time (the time for the entire group of 17 persons to pass through the side doorway) was 25 s in the May 2006 experiment, compared with 44 s in the April 2006 experiment, even though there were two more participants in the latter experiment.

Table 10 shows estimated egress times extrapolated for passengers to exit from higher capacity cars to the ROW and to a low platform. The stairway experiments showed that the required time estimated for 100 passengers to egress to the ROW via a single side door stairway would take approximately 3 min longer than egress to an adjacent car or a high platform. However, if a low platform were used instead, the additional time would be only approximately 31 s.

Table 10. ROW/Low-Platform High-Capacity Passenger Egress Time Estimates

EXIT LOCATION	NUMBER OF DOORS	NUMBER OF PASSENGERS	EGRESS TIME
ROW (step stool to planking)	Single side door	100	306 s (5 min, 6 s)
		130	394 s (6 min, 4 s)
	Two side doors	100	159 s (2 min, 39 s)
		130	203 s (3 min, 23 s)
Pavement	Single side door	100	152 s (2 min, 32 s)
		130	195 s (3 min, 15 s)
	Two side doors	100	79 s (1 min, 19 s)
		130	101 s (1 min, 41 s)

The use of the side door stairway steps as part of the exit path route slowed participant flow rates substantially, compared with exiting onto a high platform. This was due to different agility; some passenger used handrails and moved more slowly. This result is in contrast to travel along wide aisles that allow agile individuals to overtake those with mobility limitations. At the rates observed for descent from the side door stairway to a step stool placed on ballast with 27 percent of individuals classed as low agility, the time to exit from a high-occupancy single-level coach of seated passengers through side doors was estimated to exceed 6 min. If these people had to step down the full distance to the ballast, these egress times would have been substantially longer, and there could have been a higher risk of personal injury.

The height of the drop from the bottom step to the ballast or platform, as well as various physical aspects of the landing area (large size, firmness, level surface, etc.) seemed to exert strong influences on the flow rate that were not fully investigated. However, such factors were observed to have the greatest effect on the behavior of people with low agility.

4.1.3 Mobility-Impaired Egress Experiment

Measurement of the walking speeds of mobility-impaired individuals was not an objective of this study. Although these data are very limited, the two volunteers with conditions that might have slowed their ability to exit the rail car were observed. These two volunteers consisted of two individuals:

- Female in her early thirties who was 8 months pregnant.
- Male approximately 40 years of age who walked with a severe limp and used a cane.

Both people were asked to sit at one end of the car.

During the first trial, when a signal was given, the individuals were separately asked to walk the length of the car from their seats to and through the open vestibule end door and then use the open side door to exit the car.

The respective elapsed times from the time the two participants started walking down the aisle until they reached the door was 15 and 15.3 s, with travel speeds of approximately 4.8 ft (1.5 m) and 2.9 ft (0.9 m)/pps.

During the second trial, when a signal was given, the individuals were separately asked to walk outside Car #531along the platform from the side door at one end of the car along the platform to the side door at the other end of the car. The respective elapsed time from the time the participants separately walked the distance of 60 ft (18 m) was 12 and 20 s, with travel speeds of approximately 5.2 ft (1.6 m)/pps and 3 ft (0.9 m)/pps.

4.2 Comparison to Other Passenger Train Egress Times

4.2.1 Other Passenger Train Egress Experiments

In 1991, Cranfield University (United Kingdom) conducted an evacuation experiment using an intercity coach with 76 seats (29). In the trials with 100 percent loading (75 seated participants), egress to a high platform through the two side doors was completed in 53 s in the noncompetitive trials and 39 s in the competitive trials. These times imply egress rates of 0.7 and 1 pps/door, respectively (similar to the results obtained from the experiments described in this interim report. The participants were mostly students, who were paid about $15 for attendance, with an additional $7 if they were among the first half of the subject pool to egress from the rail car in the competitive trials.

In 1999, the University of Greenwich (UG) measured egress rates from an overturned intercity coach. The 30 participants (average age of 28 years) in the egress trial without smoke exited at rates of 0.15 and 0.13 pps, respectively, for the two exits. In a subsequent trial with 32 participants and the overturned coach filled with theatrical smoke, the egress flow rate declined to 0.08 pps through a single end door.

While the UG experiment results may be more indicative of actual emergency evacuation situations than those described in this report, the actual emergency evacuation time by passengers is affected by many variables, such as type of emergency, the location of the train, the weather, assistance by train crew, other passengers, or emergency response personnel.

4.2.2 Egress Time Estimates Using Models

Hydraulic Models

When required to estimate egress times, passenger rail car builders and operators have historically opted to use hydraulic models because they are readily available and cost little to apply—they are "rough" calculations. Hydraulic egress models estimate occupant flow rates as a function of such parameters as density, effective aisle width, pitch of stairs, etc. Individual movement is controlled by the occupant density and the width of openings—doorways, stairs, and corridors. The coefficients in these egress models are based on observations of occupant evacuations from buildings (e.g., the number of persons per minute per unit of passage width). Some of the typical assumptions used with hydraulic models are:

- Everyone will start to evacuate at the same instant.
- Occupant flow will not involve any interruptions caused by decisions of the individuals involved.
- All or most of the people involved are free of disabilities that would significantly impede their ability to keep up with the movement of a group.

Similar to a fluid passing through a pipe, the entire population is assumed to move with the same speed, and the overall flow rate is determined by the most restrictive point ahead of the flow. When occupant density in a flow element (e.g., a corridor) is low, the speed will be the maximum individual person walking (travel) speed. As density increases, there is a critical value above which the travel speed will start to decrease as movement is retarded. The models work sufficiently well enough that their use has been accepted by the National Fire Protection Agency (NFPA) and other organizations concerned with building life safety codes.

Hydraulic egress models applied to passenger rail car egress can estimate passenger flow rates as a function of such parameters as passenger density, number of doors, effective aisle width, pitch of stairs, etc. However, the application of these hydraulic models directly to passenger rail car evacuations is problematic because: 1) different models estimate quite different flow rates for given openings and 2) the widths of aisles and pitches of passenger rail car stairways are outside the ranges observed in building evacuations.

For building evacuation, the flow rate through a given opening is estimated as directly proportional to its effective width. (Effective width is actual width minus the "boundary effect," an "adjustment" factor of 4–18 in [10–46 cm]). However, this linear relationship between width and flow rate does not hold for widths less than 43 in (1.1 m) (see Reference 30). In buildings, room and corridor widths are large enough that individuals who wish to overtake slower ones can easily do so, but passing other persons becomes progressively more difficult as widths diminish below 43 in (1.1 m). Flow rates per unit of width in passenger rail car aisles are certainly lower than for buildings, but there has not been agreement on just how much less.

As a result, different analysts using the building egress models about passenger rail car evacuation time have come to substantially different conclusions for similar scenarios. For example, in the 1998 high-speed train evacuation time assessment prepared for Amtrak (31), the methodology for transit stations, as described in NFPA 130 *Standard for Fixed Guideway Transit and Passenger Rail Systems* (32), was used. (This standard is revised every 2–3 years.)

With the 1997 edition procedure, the Acela trainset analysis estimated the egress flow rate was 0.8 pps for any doorway. The flow estimation formula in the 2000 edition was changed to 2.27 ppm (person per minute (ppm) per inch of corridor or doorway width, which would imply an egress flow rate of 1.3 pps for the 35-inch (90 cm)-wide doors of the Acela train set. The 2010 *NFPA 130* standard revised the flow coefficient downward to 2.08 ppm per inch, which would imply an egress rate of 1.2 pps for a 35-inch-wide exit. However, the *NFPA 130* calculation method ignores boundary layer effects at doors, although it recognizes them in corridors. The *NFPA 130* standard requires that corridors must be at least 68 in (173 cm) wide and doors must be at least 36 in (91cm) wide. In any case, the use of the NFPA 130 station egress calculation method in the context of passenger rail car evacuation time estimates is problematic because the narrower passenger rail car door and aisle configuration is significantly different from a building corridor.

An analysis prepared for Maryland Area Regional Commuter (MARC) rail cars (33) included an estimate of egress flow rates, based on the Society of Fire Protection Engineers methodology (30). Egress flow rates are estimated by a formula including density and boundary layer factors, in addition to average walking speed in feet per minute. However, the analysis authors calculated density as the total number of passengers divided by the floor area of the car. However, "density" is actually the reciprocal of the number of square feet of floor area for each person in the moving stream of exiting passengers. The MARC analysis calculations used the entire floor area of the car, including all of the area occupied by seats, instead of the usable floor area. Estimates were prepared for various MARC rail car configurations, using both side doors to the ground and end doors to adjacent cars, resulting in calculated egress rates ranging from 0.32 to 0.88 pps. However, the majority of egress flow rate estimates to adjacent cars were lower than those actually observed in the Volpe Center 2005 experiments, whereas egress-to-ground estimated rates were higher those observed in the 2006 experiments.

In the only other known example of an egress rate calculation for a U.S. passenger rail car, a 1980 analysis estimated that for a Bay Area Rapid Transit rail transit car located in a tunnel, the passenger egress rate onto the walkway and through the tunnel would be the limiting factor, not the door, and therefore all aspects of car geometry were ignored (34).

In summary, hydraulic models provide a quick method for generating estimates of egress times, and the methods can be referenced to publications of recognized fire-safety organizations. However, it must be recognized that when applied to passenger rail cars, these hydraulic models are used for aisles much narrower than for buildings and step heights much higher than those in buildings. Accordingly, depending on which model the analyst chooses, what assumptions are made about the boundary-layer effect, and how the effective floor area is measured, the occupant flow rate estimates can vary by a factor of 3. To validate these conflicting models for more accurate use in U.S. passenger rail car egress time estimation, actual empirical data from passenger rail car egress experiments are necessary. This egress data collection was the purpose of the Volpe Center-conducted egress experiments described in this interim report.

4.2.3 Egress Simulation Computer Models

Individual-movement models attempt to model the egress of individuals as they assess the situation and make decisions based on their personal characteristics and any other limitations imposed. Decisionmaking is typically controlled by the interaction between the individual's characteristics, conditions and events experienced, and the rules built into the model. Many of these models give the user the flexibility to input characteristics for each person or groups of people individually. With an individual entry method, the model user is able to enter details about each person in the structure. Details such as maximum walking speed, age, gender, aggressiveness, and knowledge of the structure can then influence the evacuation time of that individual and the group. Many of the characteristics that can be entered about individuals are driven by how much access the user has to data collected from observations of people movement. The way these models are constructed may also make it easier to include some of the unique aspects of rail car evacuation scenarios.

Individual-movement models control travel speed in a different fashion than the hydraulic models. Instead of having a global speed controlled by density, all people have their own individual maximum walking speed. If there are no hindrances (e.g., injuries), individuals will move with this speed until they encounter an obstacle such as a slower-moving person. At this point, the speed of the person behind is "capped" by the person in front, unless the space is wide enough for two abreast. Depending on the decisionmaking rules used, persons may overtake if possible, choose another route if available, or continue in queue. Some models add a degree of randomness to these decisions. Individual-movement models are more suited to incorporate decision-making than hydraulic models because the decision of individuals is more naturally translated into their movement.

The inclusion of decisionmaking in the calculation of egress time is important because it gives the computer model the capability to simulate a wider range of emergency scenarios. It can account for the fact that passengers are faced with different decisions depending on the scenario. The same population will egress differently if the train is stalled on a bridge over water than if there is a fire inside a train in a tunnel. The influence of trained rail personnel can more readily be incorporated if the user can define individuals in the group to have particular attributes, which leads them to make different decisions and take different actions than the rest of the occupants.

Some computer models simulate the effect of fire conditions on the occupants as they evacuate. It is recognized that hazardous conditions in one part of the enclosure may overcome some occupants, while others in another area are still able to exit. In other models, the intent is that the model user takes the calculated evacuation time and compares it with independent hazard development calculations to see whether occupants are able to escape in the minimum time necessary to escape the hazardous (e.g., untenable) conditions. If the evacuees are expected to have to traverse the area directly affected by the hazardous fire, smoke, and toxic products, the delays caused by the interaction with the hazardous conditions also need to be included.

4.3 Further Research

Individual agility and physical obstacles have a significant impact on the amount of time necessary for people to exit from a passenger rail car. This suggests that future egress experiments conducted under conditions intended to simulate real emergencies should use "within-subject" designs so that differences in individual abilities do not affect the results of the experiment, especially when the number of participants is limited.

FRA is currently funding the development of a passenger rail car egress computer model by the University of Greenwich, under the direction of the Volpe Center. Calibration of this model requires a large quantity of detailed data regarding the timing of all movements of each individual occupant from the rail car. Accordingly, the data obtained from the video recordings and other related information generated during these experiments described in this interim report will provide an important data input to the egress model development. These data provide a key means when combined with the known physical characteristics of each type of individual, the physical characteristics of the passenger rail car, and the operating environment at the time the data were recorded to validate the rail car egress model evacuation time estimates.

Additional experiments with passenger rail cars under other accident scenario conditions (cars tilted, etc.) would also provide important data inputs to the FRA passenger rail car egress model.

Under FRA sponsorship and with the partnership of the Washington Metropolitan Area Transit Authority (WMATA) and the New Jersey Transit, an Emergency Evacuation Simulator (Rollover Rig) for passenger cars was constructed at the WMATA Training Facility, located in Landover, MD, as shown in Figure 27. The FRA Simulator can "roll" a rail car "over" in 10-degree increments up to 180 degrees in place, to simulate rail car positions after derailments or other rail accidents. The Rollover Rig provides a safe environment for emergency responders to practice internal and external evacuation of a derailed rail car.

The Volpe Center conducted two egress demonstrations using the Rollover Rig with the cooperation of the FRA and APTA in late 2006 and early 2007. The objectives were to show the participants the effect of car angle and different levels of emergency lighting, types of signs, etc. on egress time.

The Volpe Center has developed an experimental plan intended to use the Rollover Rig to formally measure egress time by participants when the car is tilted at selected angles.

Figure 27. FRA Rollover Rig Exterior and Interior – 45 Degrees

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Appendix A. Main Experiment – Recruitment Poster

I WANT YOU

TO EARN $50.00

FOR TWO HOURS OF YOUR TIME

The U.S. Department of Transportation, the Federal Railroad Administration, and the Massachusetts Bay Transportation Authority are jointly sponsoring a passenger-behavior study. The study's purpose is to measure the time needed to leave commuter rail cars.

110 regular commuter-railroad riders are needed for the tests, which are scheduled for Thursday, August 25, 2005, at North Station. Tests will begin at 5:00 PM and end by 7:00 PM.

To qualify, you must be a regular rider and you must show a commuter-rail pass for the month of August 2005 or a 12-ride book, when you arrive to participate in the tests. What you will be required to do is to walk off the car, either onto the platform, or into an adjacent car. Video recordings of the 12 trials will be made.

For your participation, you will receive a $50.00 gift certificate from your choice of 5 major retailers.

To sign up, call Mariana Vasquez at 617-494-2144,
9:00 AM – 4:30 PM, Monday-Friday.
SIGN-UP DEADLINE: August 18, 4:30 PM.

Appendix B. Main Experiment: Participant Distribution Data – Males

MALES	AGE	HEIGHT	WEIGHT
41	Under 30 – 8	Under 5 ft – None	
		5 ft to 5 ft 5 – None	
		5 ft 6 in to 6 ft – 5	Under 100 – None
			100 –149 – 2
			150 –199 – 3
			200 – 249 – None
			Over 250 – None
		Over 6 ft – 3	Under 100 – None
			100-149 – None
			150-199 – 2
			200-249 – 1
			250 +- – None
	31– 50 – 19	Under 5 ft – None	
		5 ft to 5 ft 5 in – 2	Under 100 – None
			100-149 – None
			150-199 – 2
			200-249 – None
			250 + – None
		5 ft 6 in to 6 ft – 11	Under 100 – None
			100-149 – 1
			150-199 – 8
			200-249 – 2
			250 + – None
		Over 6 ft – 6	Under 100 – None
			100-149 – None
			150-199 – 3
			200-249 – 2
			250 + – 1
	Over 50 – 14	Under 5‘	
		5 ft – 5 ft 5 in – 3	Under 100 – None
			100 –149 – None
			150– 199 – 3
			200-249 – None
			250 + – None
		5 ft 6 in 6 ft – 10	Under 100 – None
			100 –149 – None
			150– 199 – 7
			200-249 – 2
			250 + – 1
		Over 6 ft – 1	Under 100 – None
			100 –149 – None
			150– 199 – 1
			200-249 – None
			250 + – None

Main Experiment: Participant Distribution Data – Females

FEMALES	AGE	HEIGHT	WEIGHT
43	Under 30 – 16	Under 5 ft – None	
		5 ft to 5 ft 5 in – 10	Under 100 – 1
			100-149 – 7
			150-199 – 2
			200-249 – None
			250 + – None
		5 ft 6 in to 6 ft – 6	Under 100 – None
			100-149 – 3
			150-199 – 3
			200-249 – None
			250 +- – None
		Over 6 ft – None	
	31– 50 – 15	Under 5 ft – 2	Under 100 – None
			100-149 – None
			150-199 – 2
			200-249 – None
			250+ – None
		5 ft to 5 ft 6 in – 13	Under 100 – None
			100-149 – 8
			150-199 – 4
			200-249 – 1
			250 + – None
		5 ft 6 in to 6 ft – None	
		Over 6 ft – None	
	Over 50 – 12	Under 5 ft – None	
		5 ft to 5 ft 5 in – 8	Under 100 – None
			100 –149 – 3
			150– 199 – 4
			200-249 – 1
			250 + – None
		5 ft 6 in to 6 ft – 3	Under 100 – None
			100 –149 – None
			150– 199 – 3
			200-249 – None
			250 + – None
		Over 6 ft – 1	Under 100 – None
			100 –149 – None
			150– 199 – None
			200-249 – 1
			250 + – None

Appendix C. Main Experiment - Participant Seat Assignment

VEST #	TRIAL 1	TRIAL 2	TRIAL 3	TRIAL 4	TRIAL 5	TRIAL 6	TRIAL 7	TRIAL 8	TRIAL 9	TRIAL 10	TRIAL 11	TRIAL 12
1	44	63	22	83	10	55	73	35	92	8	68	1
2	45	64	23	84	11	56	74	36	91	9	67	2
3	46	65	24	85	12	57	75	37	90	10	66	3
4	47	66	25	86	13	58	76	38	89	11	65	4
5	48	67	26	87	14	59	77	39	88	12	64	5
6	49	68	27	88	15	60	78	40	87	13	63	6
7	50	69	28	~~89~~	16	61	79	41	86	14	62	7
8	51	70	29	~~90~~	17	62	80	42	85	15	61	8
9	52	71	30	91	18	63	81	43	84	16	60	9
10	53	72	31	92	19	64	82	44	83	17	59	10
11	54	73	32	1	20	65	83	45	82	18	58	11
12	55	74	33	2	21	66	84	46	81	19	57	12
13	56	75	34	3	22	67	85	47	80	20	56	13
14	57	76	35	4	23	68	86	48	79	21	55	14
15	58	77	36	5	24	69	87	49	78	22	54	15
16	59	78	37	6	25	70	88	50	77	23	53	16
17	60	79	38	7	26	71	89	51	76	24	52	17
~~18~~	~~61~~	~~80~~	~~39~~	~~8~~	~~27~~	~~72~~	~~90~~	~~52~~	~~75~~	~~25~~	~~51~~	~~18~~
~~19~~	~~62~~	~~81~~	~~40~~	~~9~~	~~28~~	~~73~~	~~91~~	~~53~~	~~74~~	~~26~~	~~50~~	~~19~~
~~20~~	~~63~~	~~82~~	~~41~~	~~10~~	~~29~~	~~74~~	~~92~~	~~54~~	~~73~~	~~27~~	~~49~~	~~20~~
~~21~~	~~64~~	~~83~~	~~42~~	~~11~~	~~30~~	~~75~~	~~1~~	~~55~~	~~72~~	~~28~~	~~48~~	~~21~~
22	65	84	43	12	31	76	2	56	71	29	47	22
23	66	85	44	13	32	77	3	57	70	30	46	23
24	67	86	45	14	33	78	4	58	69	31	45	24
25	68	87	46	15	34	79	5	59	68	32	44	25
26	69	88	47	16	35	80	6	60	67	33	43	26
27	70	89	48	17	36	81	7	61	66	34	42	27
28	71	90	49	18	37	82	8	62	65	35	41	28
29	72	~~91~~	50	19	38	83	9	63	64	36	40	29
30	73	~~92~~	51	20	39	84	10	64	63	37	39	30
31	74	1	52	21	40	85	11	65	62	38	38	31
32	75	2	53	22	41	86	12	66	61	39	37	32
33	76	3	54	23	42	87	13	67	60	40	36	33

NOTE: 6 of the 92 vests were not assigned (as noted by strike out).   Therefore, some seats were not used by those "missing" participants. In addition, Seats 91 and 92 were not used, so participants assigned to those seats for trials randomly sat in seats that the six nonassigned vest participants would have used. Participants did not always sit in the assigned seats due to preference of avoiding four facing seats.

VEST #	TRIAL 1	TRIAL 2	TRIAL 3	TRIAL 4	TRIAL 5	TRIAL 6	TRIAL 7	TRIAL 8	TRIAL 9	TRIAL 10	TRIAL 11	TRIAL 12
34	77	4	55	24	43	88	14	68	59	41	35	34
35	78	5	56	25	44	89	15	69	58	42	34	35
36	79	6	57	26	45	90	16	70	57	43	32	36
37	80	7	58	27	46	~~91~~	17	71	56	44	31	37
38	81	8	59	28	47	~~92~~	18	72	55	45	30	38
39	82	9	60	29	48	1	19	73	54	46	29	39
40	83	10	61	30	49	2	20	74	53	47	28	40
41	~~84~~	11	62	31	50	3	21	75	52	48	27	41
42	~~85~~	12	63	32	51	4	22	76	51	49	25	42
43	~~86~~	13	64	33	52	5	23	77	50	50	24	43
~~44~~	~~87~~	~~14~~	~~65~~	~~34~~	~~53~~	~~6~~	~~24~~	~~78~~	~~49~~	~~51~~	~~23~~	~~44~~
45	88	15	66	35	54	7	25	79	48	52	22	45
46	89	16	67	36	55	8	26	80	47	53	21	46
47	90	17	68	37	56	9	27	81	46	54	20	47
~~48~~	~~91~~	~~18~~	~~69~~	~~38~~	~~57~~	~~10~~	~~28~~	~~82~~	~~45~~	~~55~~	~~19~~	~~48~~
~~49~~	~~92~~	~~19~~	~~70~~	~~39~~	~~58~~	~~11~~	~~29~~	~~83~~	~~44~~	~~56~~	~~18~~	~~49~~
50	1	20	71	40	59	12	30	84	43	57	17	50
51	2	21	72	41	60	13	31	85	42	58	16	51
52	3	22	73	42	61	14	32	86	41	59	15	52
53	4	23	74	43	62	15	33	87	40	60	14	53
54	5	24	75	44	63	16	34	88	39	61	13	54
55	6	25	76	45	64	17	35	89	38	62	12	55
56	7	26	77	46	65	18	36	90	37	63	11	56
57	8	27	78	47	66	19	37	~~91~~	36	64	10	57
58	9	28	79	48	67	20	38	~~92~~	35	65	9	58
59	10	29	80	49	68	21	39	1	34	66	8	59
60	11	30	81	50	69	22	40	2	33	67	7	60
61	12	31	82	51	70	23	41	3	32	68	6	61
62	13	32	83	52	71	24	42	4	31	69	5	62
63	14	33	84	53	72	25	43	5	30	70	4	63
64	15	34	85	54	73	26	44	6	29	71	3	64
65	16	35	86	55	74	27	45	7	28	72	2	65
66	17	36	87	56	75	28	46	8	27	73	1	66
67	18	37	88	57	76	29	47	9	26	74	92	67
68	19	38	89	58	77	30	48	10	25	75	91	68
69	20	39	90	59	78	31	49	11	24	76	90	69
70	21	40	10 ~~91~~	60	79	32	50	12	23	77	89	70
71	22	41	~~92~~	61	80	33	51	13	22	78	88	71
72	23	42	1	62	81	34	52	14	21	79	87	72

VEST #	TRIAL 1	TRIAL 2	TRIAL 3	TRIAL 4	TRIAL 5	TRIAL 6	TRIAL 7	TRIAL 8	TRIAL 9	TRIAL 10	TRIAL 11	TRIAL 12
73	24	43	2	63	82	35	53	15	20	80	86	73
74	25	44	3	64	83	36	54	16	19	81	85	74
75	26	45	4	65	84	37	55	17	18	82	84	75
76	27	46	5	66	85	38	56	18	17	83	83	76
77	28	47	6	67	86	39	57	19	16	84	82	77
78	29	48	7	68	87	40	58	20	15	85	81	78
79	30	49	8	69	88	41	59	21	14	86	80	79
80	31	50	9	70	89	42	60	22	13	87	79	80
~~81~~	~~32~~	~~51~~	~~10~~	~~71~~	~~90~~	~~43~~	~~61~~	~~23~~	~~12~~	~~88~~	~~78~~	~~81~~
82	33	52	11	72	91	44	62	24	11	89	76	82
83	34	53	12	73	92	45	63	25	10	90	75	83
84	35	54	13	74	1	46	64	26	9	91	74	84
85	36	55	14	75	2	47	65	27	8	92	73	85
86	37	56	15	76	3	48	66	28	7	1	72	86
87	38	57	16	77	4	49	67	29	6	2	71	87
88	39	58	17	78	5	50	68	30	5	3	70	88
89	40	59	18	79	6	51	69	31	4	4	69	89
90	41	60	19	80	7	52	70	32	3	5	68	90
91	42	61	20	81	8	53	71	33	2	6	65	91
92	43	62	21	82	9	54	72	34	1	7	64	92

Appendix D. Main Experiment – Participant Questionnaire Form

VEST NUMBER _______ TRIAL 1* QUESTIONS /RESPONSE**	√
1. I was seated facing the exit that I used to leave the car	
A True	
B False	
2. The lighting level:	
A made it hard to locate the exit	
B caused me to walk slower	
C made me feel that I may trip over	
D made me feel that I would bump into someone	
E did not cause me any difficulties	
3. I selected which exit to use because:	
A I was following instructions	
B it was nearest	
C it had the shortest line of people	
D I followed the crowd	
4. In leaving my seat:	
A I had no difficulties in getting into the aisle	
B I was slowed down by the person sitting next to me	
C I had to wait for a gap in the line before getting into the aisle	
D people let me into the line, even though there was a long line	
E I had to push my way into the aisle	
5. When I was in the aisle/line moving towards the exit:	
A I could walk at the speed I wanted to	
B I had to walk slowly since the line was moving slowly	
C I sometimes stopped to let people into the line	
D I tried to pass people but couldn't due to the crowd	
E I didn't try to pass people because it was unnecessary/impolite	
F people behind me were pushing me	
G I was moving slowly because I felt tired	
6. On exiting the car, I stepped out:	
A normally	
B slowly because I thought I may fall	
C holding onto the grab railing to assist me/support myself	

* Separate form completed by each participant for each egress trial, after each of 12 trials.

** Participants were told to check as many responses as they believed applicable.

Appendix E. Main Experiment: Observer/Marshal Duties

OBSERVER TEAM 1 (OBT1): DATA RECORDER (DR) STOPWATCH (SWO)

Single Door Trials: 1, 5, 7, 11

- Stand outside to left of door to be used, close to the car. Make sure that you have a clear view of the door and the approach to the door, but out of the way of exiting participants.
- SWO starts stop watch when starts, as indicated by the radio signal from Volpe staff announcer.
- SWO notes the time that the first person exits the car. This is marked by both feet of participant being placed on the platform.
- DR notes down time and any other observations on data sheet.
- SWO notes the time that the last person exits car. This is marked by both feet of participant being placed on the platform. The trial end will be announced by Volpe staff.
- DR notes down trial time on data sheet.

***Adjacent Door Trials*: 2, 6, 8, 12**

- Standing in adjacent car, in first or second seat row near the entrance that participants will use, on the right side of the car.
- SWO starts stop watch when the trial commences, as indicated by the radio signal from Volpe staff announcer
- SWO notes time that the first person enters the adjacent car. This is marked by both feet of participant having crossed the threshold to the next car.
- DR notes down time and any other observations on the data sheet.
- SWO notes time that the last person enters the adjacent car. This is marked by both feet of participant having crossed the threshold to the next car. The trial end will be announced by Volpe staff.
- DR notes down the trial time on the data sheet.

Two Door Trials: 3, 4, 9, 10

- Standing outside Door A, to the left of door, close to the car. Make sure that you have a clear view of the door and the approach to the door, but out of the way of exiting participants.
- SWO starts stop watch when the trial starts as indicated by the radio signal from Volpe staff announcer.
- SWO notes the time that the first person exits the car. This is marked by both feet of participant being placed on the platform.
- DR notes down the time and any other observations on the data sheet.
- SWO notes the time that the last person exits the car. This is marked by both feet of participant being placed on the platform. The trial end will be announced by Volpe staff.
- DR notes down the trial time on the data sheet.

OBSERVER TEAM 2 (OBT2): DATA RECORDER (DR) STOPWATCH (SWO)

Single Door Trials: 1, 5, 7, 11

- Stand outside to left of door to be used, beside OBT1. Make sure that you have a clear view of the door and the approach to the door, but out of the way of exiting participants.
- SWO starts stop watch when the trial commences as indicated by the radio signal from Volpe staff announcer
- SWO notes the time that the first person exits the car. This is marked by both feet of participant being placed on the platform.
- DR notes down the time and any other observations on the data sheet.
- SWO notes the time that the last person exits the car. This is marked by both feet of participant being placed on the platform. The trial end will be announced by Volpe staff.
- DR notes down the trial time on the data sheet.

Adjacent Door Trials: 2, 6, 8, 12

- Stand in adjacent car, in first or second seat row near the entrance that participants will use, on the left side of the car.
- SWO starts stop watch when the trial commences as indicated by the radio signal from JK.
- SWO notes the time that the first person enters the adjacent car. This is marked by both feet of participant having crossed the threshold.
- DR notes down the time and any other observations on the data sheet
- SWO notes the time that the last person enters the adjacent car. This is marked by both feet of participant having crossed the threshold. The trial end will be announced by Volpe staff.
- DR notes down the trial end time on the data sheet.

Two Door Trials: 3, 4, 9, 10

- Stand outside door A, to the right of door, close to the car. Make sure that you have a clear view of the door and the approach to the door, but out of the way of exiting participants.
- SWO starts stop watch when the trial commences as indicated by the radio signal from Volpe staff announcer.
- SWO notes the time that the first person exits the car. This is marked by both feet of participant being placed on the platform.
- DR notes down the time and any other observations on the data sheet.
- SWO notes the time that the last person exits the car. This is marked by both feet of participant being placed on the platform. The trial end will be announced by Volpe staff.
- DR notes down the trial end time on the data sheet.

OBSERVER TEAM 3: DATA RECORDER (DR) STOPWATCH (SWO)

Single Door Trials: 1, 5, 7, 11

- Stand outside to right of door to be used, close to the car. Make sure that you have a clear view of the door and the approach to the door, but out of the way of exiting participants.
- SWO starts stop watch when the trial commences as indicated by the radio signal from Volpe staff announcer.
- SWO notes the time that the first person exits the car. This is marked by both feet of participant being placed on the platform.
- DR notes down the time and any other observations on the data sheet.
- SWO notes the time that the last person exits the car. This is marked by both feet of participant being placed on the platform. The trial end will be announced by Volpe staff.
- DR notes down the trial end time on the data sheet.

Two Door Trials: 3, 4, 9, 10

- Stand outside Door B, to the left of door, close to the car. Make sure that they have a clear view of the door and the approach to the door, but out of the way of exiting participants.
- SWO starts stop watch when the trial commences as indicated by the radio signal from by Volpe staff announcer.
- SWO notes the time that the first person exits the car. This is marked by both feet of participant being placed on the platform.
- DR notes down the time and any other observations on the data sheet.
- SWO notes the time that the last person exits the car. This is marked by both feet of participant being placed on the platform. The trial end will be announced by Volpe staff.
- DR notes down the trial end time on the data sheet.

OBSERVER TEAM 4: DATA RECORDER (DR) STOPWATCH (SWO)

Single Door Trials: 1, 5, 7, 11

- Stand outside door to right of door, beside OBT3. Make sure that you have a clear view of the door and the approach to the door, but out of the way of exiting participants.
- SWO starts stop watch when the trial commences as indicated by the radio signal from Volpe staff announcer.
- SWO notes the time that the first person exits the car. This is marked by both feet of participant being placed on the platform.
- DR notes down the time and any other observations on the data sheet.
- SWO notes the time that the last person exits the car. This is marked by both feet of participant being placed on the platform. The trial end will be announced by Volpe staff. announced
- DR notes down the trial end time on the data sheet.

Two Door Trials: 3, 4, 9, 10

- Stand outside door B, to the right of door, close to the car. Make sure that you have a clear view of the door and the approach to the door, but out of the way of exiting participants.
- SWO starts stop watch when the trial commences as indicated by the radio signal from Volpe staff announcer.
- SWO notes the time that the first person exits the car. This is marked by both feet of participant being placed on the platform.
- DR notes down the time and any other observations on the data sheet.
- SWO notes the time that the last person exits the car. This is marked by both feet of participant being placed on the platform. The trial end will be announced by Volpe staff.
- DR notes down the trial end time on the data sheet.

MARSHAL 1: (M1)

Single Door Trials: 1, 5, 7, 11

- Stand opposite active door on the far side of the platform.
- Role is to expedite movement of participants away from the exit towards M2. If participants mill around the exit on the platform, they may negatively affect the flow rate of participants leaving the car, so they must be cleared ASAP.

Adjacent Door Trials: 2, 6, 8, 12

- Stand in seat row several rows behind OBT.
- Role is to expedite movement of participants out of the adjacent car. If participants remain too long in the car, they may negatively affect the flow rate of participants entering the car, so they must be cleared ASAP.

Two Door Trials: 3, 4, 9, 10

- Stand opposite Door A on the far side of the platform.
- Role is to expedite movement of participants away from the exit towards M2. If participants mill around the exit on the platform they may negatively affect the flow rate of participants leaving the car, so they must be cleared ASAP.

MARSHAL 2: (M2)

Single Door trials: 1, 5, 7, 11

- Stand outside egress car half way along the car.
- Role is to expedite movement of participants down the platform to M3/M4.

Adjacent Door Trials: 2, 6, 8, 12

- Stand outside adjacent car end door, to the right of the door (out of the way of the participant flow).
- Role is to expedite movement of participants down the platform to M3/M4.

Two door Trials: 3, 4, 9, 10

- Stand away from the egress car, approximately a half car away from door A.
- Role is to marshal participants, organising them into two groups, Group1 will be seated in the front half of car in the next trial and the second group will be seated in the rear half of the car in the second trial.
- Once the egress car is empty can begin loading participants for the next trial.
- Load Group 2 first through Door A.
- Load Group1 next through Door A.

MARSHAL 3: (M3)

Single Door Trials: 1, 5, 7, 11

- Stand down the platform opposite the unused door of the egress car.
- Role is to marshal participants, organising them into two groups, Group1 will be seated in the front half of car in the next trial and the second group will be seated in the rear half of the car in the second trial.
- Once the egress car is empty, begin loading participants for the next trial.
- Load the rear group first.
- Both groups should be loaded through the same door.

Adjacent Door Trials: 2, 6, 8, 12

- Stand down the platform opposite the furthest door of the egress car.
- Role is to marshal participants, organising them into two groups, Group1 will be seated in the front half of car in the next trial and the second group will be seated in the rear half of the car in the second trial.
- Once the egress car is empty, begin loading participants for the next trial.
- Load the rear group first.
- Both groups should be loaded through the same door.

Two Door Trials: 3, 4, 9, 10

- Stand opposite Door B on the far side of the platform.
- Role is to expedite movement of participants away from the exit towards M4. If participants mill around the exit on the platform they may negatively affect the flow rate of participants leaving the car, so they must be cleared ASAP.

MARSHAL 4: (M4)

Single Door Trials: 1, 5, 7, 11

- Stand down the platform opposite the unused door of the egress car.
- Role is to marshal participants, organising them into two groups, Group1 will be seated in the front half of car in the next trial and the second group will be seated in the rear half of the car in the second trial.
- Once the egress car is empty, begin loading participants for the next trial.
- Load the rear group first.
- Both groups should be loaded through the same door.

Adjacent Door Trials: 2, 6, 8, 12

- Stand down the platform opposite the furthest door of the egress car.
- Role is to marshal participants, organizing them into two groups, group1 will be seated in the front half of car in the next trial and the second group will be seated in the rear half of the car in the second trial.
- Once the egress car is empty, begin loading participants for the next trial.
- Load the rear group first.
- Both groups should be loaded through the same door.

Two Door Trials: 3, 4, 9, 10

- Stand away from the egress car, approximately a half car away from door B.
- Role is to marshal participants, organizing them into two groups, Group 1 will be seated in the front half of car in the next trial and the second group will be seated in the rear half of the car in the second trial.
- Once the egress car is empty, begin loading participants for the next trial.
- Load Group 2 first through door B.
- Load Group1 next through door B.

Appendix F. Main Experiment – Sample Observer Critique Sheets

Volpe/MBTA Egress Experiment

August 25, 2005

OBSERVER CRITIQUE SHEETS - (One each completed for Trials 1, 7)

EVALUATOR'S NAME
REPRESENTING:
ADDRESS
PHONE
E-MAIL

To Platform from 1 End Door - Emergency lighting

1. Trial Start Time _____ Time: 1st person <u>to step onto platform</u> _____ Last person _____
2. Volpe Leader Actions / Instructions
   a. Clear / Understandable
   b. Audible?
   c. Other comment
3. Marshal (Observer) Actions / Instructions
   a. Clear / Understandable?
   b. Audible?
   c. Other comment
4. Describe Occupant behavior / actions “of interest”
   a. Prior to Trial
   b. At signal to leave car
   c. During car exiting
   d. Persons with mobility impairments
5. Other Comments

Volpe/MBTA Egress Experiment

August 25, 2005

OBSERVER CRITIQUE SHEETS *(One each completed for Trials 2, 8)*

EVALUATOR'S NAME
REPRESENTING:
ADDRESS
PHONE
E-MAIL

To Next Car - Normal lighting

1. Trial Start Time ______ Time: 1st person <u>to step into next car</u> _____ Last person _____

2. Volpe Leader Actions / Instructions

   a. Clear / Understandable

   b. Audible?

   e. Other comment

3. Marshal (Observer) Actions / Instructions

   a. Clear / Understandable?

   b. Audible?

   f. Other comment

4. Describe Occupant behavior / actions "of interest"

   a. Prior to Trial

   b. At signal to leave car

   c. During car exiting

   d. Persons with mobility impairments

5. Other Comments

Volpe/MBTA Egress Experiment

August 25, 2005

OBSERVER CRITIQUE SHEETS *(One each completed for Trials 3, 9)*

EVALUATOR'S NAME
REPRESENTING:
ADDRESS
PHONE
E-MAIL

To Platform Using <u>Both</u> Doors - Emergency lighting

1. Trial Start Time: ____ **A** End Time - 1st person to <u>step onto platform</u> ____ Last person ____

   B End Time - 1st person to <u>step onto platform</u> ____ Last person ____

2. Volpe Leader Actions / Instructions
   a. Clear / Understandable?
   b. Audible?
   c. Other comment

3. Marshal (Observer) Actions / Instructions
   a. Clear / Understandable?
   b. Audible?
   c. Other comment

4. Describe Occupant behavior / actions “of interest”
   a. Prior to Trial
   b. At signal to leave car
   c. During car exiting
   d. Persons with mobility impairments

5. Other Comments

Volpe/MBTA Egress Experiment

August 25, 2005

OBSERVER CRITIQUE SHEETS *(One each completed for Trials 4, 10)*

EVALUATOR'S NAME
REPRESENTING:
ADDRESS
PHONE
E-MAIL

To Platform Using Both Doors - Normal lighting

1. Trial Start Time _____ **A** End Time - 1st person to step on platform ______ Last person _____

B End Time - 1st person to step on platform ______ Last person _____

2. Volpe Leader Actions / Instructions
   a. Clear / Understandable?
   b. Audible?
   c. Other comment

3.. Marshal (Observer) Actions / Instructions
   a. Clear / Understandable?
   b. Audible?
   g. Other comment

3. Describe Occupant behavior/actions “of interest”
   a. Prior to Trial
   b. At signal to leave car
   c. During car exiting
   d. Persons with mobility impairments

5. Other Comments

Volpe/MBTA Egress Experiment

August 25, 2005

OBSERVER CRITIQUE SHEETS *(One each completed for Trials 5, 7)*

EVALUATOR'S NAME
REPRESENTING:
ADDRESS
PHONE
E-MAIL

To Platform from 1 door - Normal Lighting

1. Trial Start Time: ______ Time - 1st person to <u>step on platform</u> ______ Last person ______
2. Volpe Leader Actions/Instructions
   a. Clear/Understandable?
   b. Audible?
   c. Other comment
3. Marshal (Observer) Actions/Instructions
   a. Clear/Understandable?
   b. Audible?
   c. Other comment
4. Describe Occupant behavior/actions “of interest”
   a. Prior to Trial
   b. At signal to leave car
   c. During car exiting
   d. Persons with mobility impairments
5. Other Comments

Volpe/MBTA Egress Experiment

August 25, 2005

OBSERVER CRITIQUE SHEETS - *(One each completed for Trials 6, 12)*

EVALUATOR'S NAME
REPRESENTING:
ADDRESS
PHONE
E-MAIL

To Next Car - Emergency lighting

1. Trial Start Time ______ Time - 1st person to step on platform ______ Last person______

2. Volpe Leader Actions/Instructions

    a. Clear/Understandable?

    b. Audible?

    c. Other comment

3. Marshal (Observer) Actions/Instructions

    a. Clear/Understandable?

    b. Audible?

    c. Other comment

4. Describe Occupant behavior/actions "of interest"

    a. Prior to Trial

    b. At signal to leave car

    c. During car exiting

    d. Persons with mobility impairments

5. Other Comments

Appendix G. Main Experiment – Script

"JKP" means Volpe staff announcer

"VSM" means Volpe staff member, to be assigned to a <u>specific</u> individual.

"CC" means Volpe staff announcer who is operating the computer and can see everything.

Coordination and signaling between Volpe and MBCR staff members inside the test car and those on the platform and adjacent car will be by radios/walkie-talkies.

JKP: Welcome Ladies and Gentlemen and thank you for coming. The purpose of the trials is to measure the time necessary to exit this type of commuter rail car.

Are you sitting in the seat assigned for Trial 1? There will be 12 trials in the experiment and we expect to finish about 7 pm. After each one, you will change seats according to the Seat Assignment Sheet we've given you. If you ever have a question about your seat number, please use one of the staff members who are wearing red hats. As you can see, there are several small video cameras and microphones located around the car. All of the video and audio are being recorded on this computer at the center of the car.

If during any of the trials, you hear someone yell "STOP," please stop moving immediately and listen to the special announcement, and then follow the directions of the staff in the red hats.

Does everyone have a Pen? Does everyone have a questionnaire? Please mark it with your vest number now. ***VSMs to explain questionnaire****:* There are 6 questions to be answered after each trial. You may check more than one box if necessary. Your answers will help us better understand the factors that affect exit time.

In all the trials, we want you to walk, **NOT** run to the exit that you are directed to use. Walk briskly, as though you are late for an appointment, **BUT PLEASE DON'T PUSH**. If anything slows you down, please make note of it on the questionnaire you have.

When a trial is about ready to start, I'll give you a warning and raise this blue flag. **BUT** don't move until I **DROP** the flag **AND** blow this whistle. I'm going to give the signals once for practice, so you'll know how the flag looks and how the whistle sounds. (raise flag, then blow whistle/drop flag). At the end of each trial, I will blow the whistle twice. Any questions before we start the first Trial??

1st TRIAL: 1 DOOR – Em Lighting (VSMs: take positions on platform)

JKP: For the first trial, we want you to exit to the platform through Door ____ only. When you get to the platform, keep walking and follow the directions of the staff members in red hard hats. OK, here we go.

(Start video recording.) (**<u>Normal</u> lights go <u>off</u>, <u>emergency</u> lighting remains <u>on.</u>**) (Blow whistle/drop flag and signal VSM on platform.) (VSM starts stopwatch when 1st person steps onto platform.) (CC tells VSMs on platform when last person is approaching vestibule and VSMs on platform radio CC when last person is out.) (Stop video after last person has stepped onto platform.) (VSM stops stopwatch and writes down time for last person stepping off car.) (JKP blows whistle twice.) **(Lights return to <u>normal.</u>)**

VSMs on platform: Please return to the car through both doors and sit in your assigned seat for Trial 2. Please complete the questionnaire

Appendix H. Main Experiment – Trial Questionnaire Data Summary

QUESTIONS	NUMBER	PERCENTAGE OF RESPONSES
TRIAL 1: Platform - 1 door - Emergency lighting (above seats 41- 43 very dim or not on inside car)		
1. I was seated facing the exit that I used to leave the car		
A True	42	51.85%
B False	39	48.15%
Total (Note: only 81 person participated in Trial 1)	81	100.00%
2. The lighting level:		
A made it hard to locate the exit	8	7.62%
B caused me to walk slower	20	19.05%
C made me feel that I may trip over	10	9.52%
D made me feel that I would bump into someone	17	16.19%
E did not cause me any difficulties	50	47.62%
Total	105	100.00%
3. I selected which exit to use because:		
A I was following instructions	74	60.66%
B it was nearest	25	20.49%
C it had the shortest line of people	6	4.92%
D I followed the crowd	17	13.93%
Total	122	100.00%
4. In leaving my seat:		
A I had no difficulties in getting into the aisle	49	39.52%
B I was slowed down by the person sitting next to me	18	14.52%
C I had to wait for a gap in the line before getting into the aisle	27	21.77%
D people let me into the line, even though there was a long line	28	22.58%
E I had to push my way into the aisle	2	1.61%
Total	124	100.00%
5. When I was in the aisle / line moving towards the exit:		
A I could walk at the speed I wanted to	24	16.55%
B I had to walk slowly since the line was moving slowly	53	36.55%
C I sometimes stopped to let people into the line	18	12.41%
D I tried to pass people but couldn't due to the crowd	3	2.07%
E I didn't try to pass people because it was unnecessary/impolite	44	30.34%
F people behind me were pushing me	2	1.38%
G I was moving slowly because I felt tired	1	0.69%
Total	145	100.00%
6. On exiting the car, I stepped out:		
A normally	75	92.59%
B slowly because I thought I may fall	4	4.94%
C holding onto the grab railing to assist me/support myself	2	2.47%
Total	81	100.00%

QUESTIONS	NUMBER	PERCENTAGE OF RESPONSES
TRIAL 2: Next car - End door - Normal lighting		
1. I was seated facing the exit that I used to leave the car		
A True	45	54.22%
B False	38	45.78%
Total	83	100.00%
2. The lighting level:		
A made it hard to locate the exit	2	2.33%
B caused me to walk slower	7	8.14%
C made me feel that I may trip over	2	2.33%
D made me feel that I would bump into someone	3	3.49%
E did not cause me any difficulties	72	83.72%
Total	86	100.00%
3. I selected which exit to use because:		
A I was following instructions	82	74.55%
B it was nearest	7	6.36%
C it had the shortest line of people	3	2.73%
D I followed the crowd	18	16.36%
Total	110	100.00%
4. In leaving my seat:		
A I had no difficulties in getting into the aisle	43	32.82%
B I was slowed down by the person sitting next to me	17	12.98%
C I had to wait for a gap in the line before getting into the aisle	35	26.72%
D People let me into the line, even though there was a long line	36	27.48%
E I had to push my way into the aisle	0	0.00%
Total	131	100.00%
5. When I was in the aisle / line moving towards the exit:		
A I could walk at the speed I wanted to	32	21.33%
B I had to walk slowly since the line was moving slowly	51	34.00%
C I sometimes stopped to let people into the line	21	14.00%
D I tried to pass people but couldn’t due to the crowd	9	6.00%
E I didn’t try to pass people because it was unnecessary/impolite	37	24.67%
F people behind me were pushing me	0	0.00%
G I was moving slowly because I felt tired	0	0.00%
Total	150	100.00%
6. On exiting the car, I stepped out:		
A normally	82	96.47%
B slowly because I thought I may fall	1	1.18%
C holding onto the grab railing to assist me/support myself	2	2.35%
Total	85	100.00%

QUESTIONS	NUMBER	PERCENTAGE OF RESPONSES
TRIAL 3: Platform - Both doors - Emergency lighting (above seats 41- 43 very dim or not on inside car)		
1. I was seated facing the exit that I used to leave the car		
A True	53	63.86%
B False	30	36.14%
Total	83	100.00%
2. The lighting level:		
A made it hard to locate the exit	8	7.55%
B caused me to walk slower	22	20.75%
C made me feel that I may trip over	5	4.72%
D made me feel that I would bump into someone	15	14.15%
E did not cause me any difficulties	56	52.83%
Total	106	100.00%
3. I selected which exit to use because:		
A I was following instructions	25	19.69%
B it was nearest	71	55.91%
C it had the shortest line of people	15	11.81%
D I followed the crowd	16	12.60%
Total	127	100.00%
4. In leaving my seat:		
A I had no difficulties in getting into the aisle	42	29.79%
B I was slowed down by the person sitting next to me	22	15.60%
C I had to wait for a gap in the line before getting into the aisle	35	24.82%
D people let me into the line, even though there was a long line	33	23.40%
E I had to push my way into the aisle	9	6.38%
Total	141	100.00%
5. When I was in the aisle / line moving towards the exit:		
A I could walk at the speed I wanted to	29	20.00%
B I had to walk slowly since the line was moving slowly	48	33.10%
C I sometimes stopped to let people into the line	24	16.55%
D I tried to pass people but couldn't due to the crowd	5	3.45%
E I didn't try to pass people because it was unnecessary/impolite	37	25.52%
F people behind me were pushing me	2	1.38%
G I was moving slowly because I felt tired	0	0.00%
Total	145	100.00%
6. On exiting the car, I stepped out:		
A normally	82	95.35%
B slowly because I thought I may fall	2	2.33%
C holding onto the grab railing to assist/support myself	2	2.33%
Total	86	100.00%

QUESTIONS	NUMBER	PERCENTAGE OF RESPONSES
TRIAL 4: Platform - 2 doors - Normal lighting		
1. I was seated facing the exit that I used to leave the car		
A True	48	57.14%
B False	36	42.86%
Total	84	100.00%
2. The lighting level:		
A made it hard to locate the exit	1	1.15%
B caused me to walk slower	2	2.30%
C made me feel that I may trip over	3	3.45%
D made me feel that I would bump into someone	2	2.30%
E did not cause me any difficulties	79	90.80%
Total	87	100.00%
3. I selected which exit to use because:		
A I was following instructions	26	19.26%
B it was nearest	74	54.81%
C it had the shortest line of people	21	15.56%
D I followed the crowd	14	10.37%
Total	135	100.00%
4. In leaving my seat:		
A I had no difficulties in getting into the aisle	51	40.48%
B I was slowed down by the person sitting next to me	16	12.70%
C I had to wait for a gap in the line before getting into the aisle	27	21.43%
D people let me into the line, even though there was a long line	28	22.22%
E I had to push my way into the aisle	4	3.17%
Total	126	100.00%
5. When I was in the aisle/line moving towards the exit:		
A I could walk at the speed I wanted to	37	27.21%
B I had to walk slowly since the line was moving slowly	43	31.62%
C I sometimes stopped to let people into the line	19	13.97%
D I tried to pass people but couldn't due to the crowd	3	2.21%
E I didn't try to pass people because it was unnecessary/impolite	33	24.26%
F people behind me were pushing me	0	0.00%
G I was moving slowly because I felt tired	1	0.74%
Total	136	100.00%
6. On exiting the car, I stepped out:		
A normally	83	96.51%
B slowly because I thought I may fall	1	1.16%
C holding onto the grab railing to assist me/support myself	2	2.33%
Total	86	100.00%

QUESTIONS	NUMBER	PERCENTAGE OF RESPONSES
TRIAL 5: Platform - 1 door - Normal lighting		
1. I was seated facing the exit that I used to leave the car		
A True	42	50.00%
B False	42	50.00%
Total	84	100.00%
2. The lighting level:		
A made it hard to locate the exit	4	4.71%
B caused me to walk slower	4	4.71%
C made me feel that I may trip over	0	0.00%
D made me feel that I would bump into someone	2	2.35%
E did not cause me any difficulties	75	88.24%
Total	85	100.00%
3. I selected which exit to use because:		
A I was following instructions	75	68.18%
B it was nearest	17	15.45%
C it had the shortest line of people	5	4.55%
D I followed the crowd	13	11.82%
Total	110	100.00%
4. In leaving my seat:		
A I had no difficulties in getting into the aisle	43	33.33%
B I was slowed down by the person sitting next to me	23	17.83%
C had to wait for a gap in the line before getting into the aisle	29	22.48%
D people let me into the line, even though there was a long line	31	24.03%
E I had to push my way into the aisle	3	2.33%
Total	129	100.00%
5. When I was in the aisle/line moving towards the exit:		
A I could walk at the speed I wanted to	27	18.12%
B I had to walk slowly since the line was moving slowly	57	38.26%
C I sometimes stopped to let people into the line	24	16.11%
D I tried to pass people but couldn't due to the crowd	2	1.34%
E I didn't try to pass people because it was unnecessary/impolite	37	24.83%
F people behind me were pushing me	1	0.67%
G I was moving slowly because I felt tired	1	0.67%
Total	149	100.00%
6. On exiting the car, I stepped out:		
A normally	83	96.51%
B slowly because I thought I may fall	1	1.16%
C holding onto the grab railing to assist me/support myself	2	2.33%
Total	86	100.00%

QUESTION	NUMBER	PERCENTAGE OF RESPONSES
TRIAL 6: Next car - End door - Emergency lighting (above seats 41- 43 very dim or not on inside car)		
1. I was seated facing the exit that I used to leave the car		
A True	45	53.57%
B False	39	47.43
Total	84	100.00%
2. The lighting level:		
A made it hard to locate the exit	7	7.22%
B caused me to walk slower	20	20.62%
C made me feel that I may trip over	5	5.15%
D made me feel that I would bump into someone	8	8.25%
E did not cause me any difficulties	57	58.76%
Total	97	100.00%
3. I selected which exit to use because:		
A I was following instructions	78	72.22%
B it was nearest	9	8.33%
C it had the shortest line of people	2	1.85%
D I followed the crowd	19	17.59%
Total	108	100.00%
4. In leaving my seat:		
A I had no difficulties in getting into the aisle	35	26.12%
B I was slowed down by the person sitting next to me	22	16.42%
C had to wait for a gap in the line before getting into the aisle	41	30.60%
D people let me into the line, even though there was a long line	33	24.63%
E I had to push my way into the aisle	3	2.24%
Total	134	100.00%
5. When I was in the aisle/line moving towards the exit:		
A I could walk at the speed I wanted to	31	20.39%
B I had to walk slowly since the line was moving slowly	57	37.50%
C I sometimes stopped to let people into the line	21	13.82%
D I tried to pass people but couldn't due to the crowd	3	1.97%
E I didn't try to pass people because it was unnecessary/impolite	38	25.00%
F people behind me were pushing me	1	0.66%
G I was moving slowly because I felt tired	1	0.66%
Total	152	100.00%
6. On exiting the car, I stepped out:		
A normally	82	96.47%
B slowly because I thought I may fall	1	1.18%
C holding onto the side rails to support myself	2	2.35%
Total	85	100.00%

QUESTIONS	NUMBER	PERCENTAGE OF RESPONSES
TRIAL 7: Platform - 1 door - Emergency lighting (above seats 41- 43 very dim or not on inside car)		
1. I was seated facing the exit that I used to leave the car		
A True	41	48.81%
B False	43	51.19%
Total	84	100.00%
2. The lighting level:		
A made it hard to locate the exit	6	6.19%
B caused me to walk slower	19	19.59%
C made me feel that I may trip over	4	4.12%
D made me feel that I would bump into someone	12	12.37%
E did not cause me any difficulties	56	57.73%
Total	97	100.00%
3. I selected which exit to use because:		
A I was following instructions	82	70.69%
B it was nearest	16	13.79%
C it had the shortest line of people	2	1.72%
D I followed the crowd	16	13.79%
Total	116	100.00%
4. In leaving my seat:		
A I had no difficulties in getting into the aisle	44	33.59%
B I was slowed down by the person sitting next to me	28	21.37%
C I A341had to wait for a gap in the line before getting into the aisle	27	20.61%
D people let me into the line, even though there was a long line	27	20.61%
E I had to push my way into the aisle	5	3.82%
Total	131	100.00%
5. When I was in the aisle/line moving towards the exit:		
A I could walk at the speed I wanted to	30	19.35%
B I had to walk slowly since the line was moving slowly	57	36.77%
C I sometimes stopped to let people into the line	24	15.48%
D I tried to pass people but couldn't due to the crowd	3	1.94%
E I didn't try to pass people because it was unnecessary/impolite	40	25.81%
F people behind me were pushing me	1	0.65%
G I was moving slowly because I felt tired	0	0.00%
Total	155	100.00%
6. On exiting the car, I stepped out:		
A normally	80	93.02%
B slowly because I thought I may fall	4	4.65%
C holding onto the grab railing to assist me/support myself	2	2.33%
Total	86	100.00%

QUESTIONS	NUMBER	PERCENTAGE OF RESPONSES
TRIAL 8: Next car - End door - Normal lighting		
1. I was seated facing the exit that I used to leave the car		
A True	48	57.14%
B False	36	0.00%
Total	84	100.00%
2. The lighting level:		
A made it hard to locate the exit	2	2.27%
B caused me to walk slower	7	7.95%
C made me feel that I may trip over	1	1.14%
D made me feel that I would bump into someone	1	1.14%
E did not cause me any difficulties	77	87.50%
Total	88	100.00%
3. I selected which exit to use because:		
A I was following instructions	81	72.97%
B it was nearest	8	7.21%
C it had the shortest line of people	3	2.70%
D I followed the crowd	19	17.12%
Total	111	100.00%
4. In leaving my seat:		
A I had no difficulties in getting into the aisle	49	40.83%
B I was slowed down by the person sitting next to me	16	13.33%
C had to wait for a gap in the line before getting into the aisle	29	24.17%
D people let me into the line, even though there was a long line	22	18.33%
E I had to push my way into the aisle	4	3.33%
Total	120	100.00%
5. When I was in the aisle/line moving towards the exit:		
A I could walk at the speed I wanted to	33	23.08%
B I had to walk slowly since the line was moving slowly	55	38.46%
C I sometimes stopped to let people into the line	20	13.99%
D I tried to pass people but couldn't due to the crowd	1	0.70%
E I didn't try to pass people because it was unnecessary/impolite	33	23.08%
F people behind me were pushing me	0	0.00%
G I was moving slowly because I felt tired	1	0.70%
Total	143	100.00%
6. On exiting the car, I stepped out:		
A normally	83	96.51%
B slowly because I thought I may fall	1	1.16%
C holding onto the grab railing to assist me/support myself	2	2.33%
Total	86	100.00%

QUESTIONS	NUMBER	PERCENTAGE OF RESPONSES
TRIAL 9: Platform - 2 doors - Emergency lighting (above seats 41- 43 very dim or not on inside car)		
1. I was seated facing the exit that I used to leave the car		
A True	59	70.24%
B False	25	29.76%
Total	84	100.00%
2. The lighting level:		
A made it hard to locate the exit	10	10.20%
B caused me to walk slower	15	15.31%
C made me feel that I may trip over	4	4.08%
D made me feel that I would bump into someone	8	8.16%
E did not cause me any difficulties	61	62.24%
Total	98	100.00%
3. I selected which exit to use because:		
A I was following instructions	36	27.48%
B it was nearest	63	48.09%
C it had the shortest line of people	17	12.98%
D I followed the crowd.	15	11.45%
Total	131	100.00%
4. In leaving my seat:		
A I had no difficulties in getting into the aisle	48	41.38%
B I was slowed down by the person sitting next to me	19	16.38%
C I had to wait for a gap in the line before getting into the aisle	30	25.86%
D people let me into the line, even though there was a long line	17	14.66%
E I had to push my way into the aisle	2	1.72%
Total	116	100.00%
5. When I was in the aisle/line moving towards the exit:		
A I could walk at the speed I wanted to	39	28.47%
B I had to walk slowly since the line was moving slowly	40	29.20%
C I sometimes stopped to let people into the line	19	13.87%
D I tried to pass people but couldn't due to the crowd	2	1.46%
E I didn't try to pass people because it was unnecessary/impolite	36	26.28%
F people behind me were pushing me	1	0.73%
G I was moving slowly because I felt tired	0	0.00%
Total	137	100.00%
6. On exiting the car, I stepped out:		
A normally	82	95.35%
B slowly because I thought I may fall	2	2.33%
C holding onto the grab railing to assist me/support myself	2	2.33%
Total	86	100.00%

QUESTIONS	NUMBERS	PERCENTAGE OF RESPONSES
TRIAL 10: Platform - 2 doors - Normal lighting		
1. I was seated facing the exit that I used to leave the car		
A True	53	63.10%
B False	31	36.10%
Total	84	100.00%
2. The lighting level:		
A made it hard to locate the exit	2	2.33%
B caused me to walk slower	2	2.33%
C made me feel that I may trip over	1	1.16%
D made me feel that I would bump into someone	2	2.33%
E did not cause me any difficulties	79	91.86%
Total	86	100.00%
3. I selected which exit to use because:		
A I was following instructions	30	22.56%
B it was nearest	74	55.64%
C it had the shortest line of people	14	10.53%
D I followed the crowd.	15	11.28%
Total	133	100.00%
4. In leaving my seat:		
A I had no difficulties in getting into the aisle	45	37.50%
B I was slowed down by the person sitting next to me	21	17.50%
C I had to wait for a gap in the line before getting into the aisle	30	25.00%
D people let me into the line, even though there was a long line	20	16.67%
E I had to push my way into the aisle	4	3.33%
Total	120	100.00%
5. When I was in the aisle/line moving towards the exit:		
A I could walk at the speed I wanted to	31	21.99%
B I had to walk slowly since the line was moving slowly	50	35.46%
C I sometimes stopped to let people into the line	18	12.77%
D I tried to pass people but couldn't due to the crowd	2	1.42%
E I didn't try to pass people because it was unnecessary/impolite	36	25.53%
F people behind me were pushing me	2	1.42%
G I was moving slowly because I felt tired	2	1.42%
Total	141	100.00%
6. On exiting the car, I stepped out:		
A normally	82	96.47%
B slowly because I thought I may fall	2	2.35%
C holding onto grab railing to assist me/support myself	1	1.18%
Total	85	100.00%

QUESTIONS	NUMBER	PERCENTAGE OF RESPONSES
TRIAL 11: Platform - 1 door - Normal lighting		
1. I was seated facing the exit that I used to leave the car		
A True	45	53.57%
B False	39	46.43%
Total	84	100.00%
2. The lighting level:		
A made it hard to locate the exit	3	3.53%
B caused me to walk slower	1	1.18%
C made me feel that I may trip over	1	1.18%
D made me feel that I would bump into someone	0	0.00%
E did not cause me any difficulties	80	94.12%
Total	85	100.00%
3. I selected which exit to use because:		
A I was following instructions	79	71.17%
B it was nearest	14	12.61%
C it had the shortest line of people	5	4.50%
D I followed the crowd.	13	11.71%
Total	111	100.00%
4. In leaving my seat:		
A I had no difficulties in getting into the aisle	48	40.68%
B I was slowed down by the person sitting next to me	17	14.41%
C had to wait for a gap in the line before getting into the aisle	30	25.42%
D people let me into the line, even though there was a long line	20	16.95%
E I had to push my way into the aisle	3	2.54%
Total	118	100.00%
5. When I was in the aisle/line moving towards the exit:		
A I could walk at the speed I wanted to	28	20.90%
B I had to walk slowly since the line was moving slowly	57	42.54%
C I sometimes stopped to let people into the line	16	11.94%
D I tried to pass people but couldn't due to the crowd	1	0.75%
E I didn't try to pass people because it was unnecessary/impolite	31	23.13%
F people behind me were pushing me	0	0.00%
G I was moving slowly because I felt tired	1	0.75%
Total	134	100.00%
6. On exiting the car, I stepped out:		
A normally	83	97.65%
B slowly because I thought I may fall	1	1.18%
C holding onto the grab railing to assist me / support myself	1	1.18%
Total	85	100.00%

QUESTIONS	NUMBER	PERCENTAGE OF RESPONSES
TRIAL 12: Next car - End door - Emergency lighting (above seats 41- 43 very dim or not on inside car)		
1. I was seated facing the exit that I used to leave the car		
A True	43	51.19%
B False	41	48.81%
Total	84	100.00%
2. The lighting level:		
A made it hard to locate the exit	5	5.00%
B caused me to walk slower	20	20.00%
C made me feel that I may trip over	5	5.00%
D made me feel that I would bump into someone	8	8.00%
E did not cause me any difficulties	62	62.00%
Total	100	100.00%
3. I selected which exit to use because:		
A I was following instructions	82	76.64%
B it was nearest	11	10.28%
C it had the shortest line of people	2	1.87%
D I followed the crowd	12	11.21%
Total	107	100.00%
4. In leaving my seat:		
A I had no difficulties in getting into the aisle	41	36.94%
B I was slowed down by the person sitting next to me	26	23.42%
C I had to wait for a gap in the line before getting into the aisle	24	21.62%
D people let me into the line, even though there was a long line	18	16.22%
E I had to push my way into the aisle	2	1.80%
Total	111	100.00%
5. When I was in the aisle/line moving towards the exit:		
A I could walk at the speed I wanted to	38	26.76%
B I had to walk slowly since the line was moving slowly	48	33.80%
C I sometimes stopped to let people into the line	21	14.79%
D I tried to pass people but couldn't due to the crowd	2	1.41%
E I didn't try to pass people because it was unnecessary/impolite	31	21.83%
F people behind me were pushing me	1	0.70%
G I was moving slowly because I felt tired	1	0.70%
Total	142	100.00%
6. On exiting the car, I stepped out:		
A normally	81	98.78%
B slowly because I thought I may fall	0	0.00%
C holding onto the grab railing to assist me / support myself	1	1.22%
Total	82	100.00%

Appendix I. Side Door Stairway Step Experiment 1 – Participant Characteristic and Comment Data

Side Door Steps/ Step Box to Planking / Ballast April 19, 2006 - Vest number

VEST	GENDER	AGE GROUP	HEIGHT	WEIGHT (lbs)	COMMUTER RAIL PASS / COMMENTS #
1	F	30 - 50	5 ft - 5 ft 5 in	200 - 249	Y
2**	F	Over 50	5 ft 5 in - 6 ft	200 - 249	N
3	M	30 - 50	5 ft 6 in - 6 ft	200 - 249	Y
4	F	Over 50	5 ft - 5 ft 5 in	100 - 149	N
5	M	Under 30	5 ft 6 in - 6 ft	100 - 149	Y
6	M	30 - 50	Above 6 ft	150 - 199	Y
7	M	Over 50	5 ft 6 in - 6 ft	150 - 199	N
8	F	Over 50	5 ft - 5 ft 5 in	250 and above	N
9	M	30 - 50	5 ft 6 in - 6 ft	150 -199	Y
10	F	30 - 50	5 ft - 5 ft 5 in	150 - 199	Y
11	M	Under 30	5 ft 5 - 6 ft	100 - 149	N
12	F	30 - 50	5 ft – 5 ft 6 in	100 - 149	Y
13*	M	30 - 50	Over 6 ft	150 - 199	N
14	F	Over 50	5 ft - 5 ft 5 in	150 - 199	Y
15	M	30 - 50	5 ft - 5 ft.5 in	100 - 149	N

* Participated in 8-25-05 egress trial

\# See attached participant comments

** Participated in 5-31-06 egress trial

Side Door Steps/Step Box to Planking/Ballast April 19, 2006
Vest Number & Comments

VEST #	COMMENTS
1	Take the commuter rail from North Station to Lowell about 3-4 times per year. They are both "high platform" stations. I don't think I've ever taken [or] gotten on or off at a "low platform" station. Noticed that when I was leaving the train by myself, I was more careful. I waited until both feet were planted on a step before I went to the next one. Each step was slightly too high for my comfort. However, when I was in a crowd, and I knew people were waiting behind me, I went down the steps normally--one step, one foot. It felt a bit precarious, but it seemed like the right thing to do so as not to detain the people behind me. I probably would have done both the individual and group egress exactly as I did them yesterday under "real world" conditions.
2	Never rode a train. The step between the yellow stool and the bottom rung of the stairs was quite high coming up and going down. I felt safer coming down backward, or at least sideways. Also crossing the tracks was difficult—the only place to steady myself was the end of the car.
3	Not regular rider. High platform 10-12 times.
4	Occasionally take the commuter rail from low platform station to another low platform station and from high platform station to low platform station. Was impressed that you had a representative sample of volunteers, in terms of ages and weight and ability (disability), so your results should be useful. Did not understand why people had to climb into an adjacent car, after getting off, instead of waiting on the ground for the "all clear" signal (this was extra effort for those heavier than normal, or for the mobility-impaired fellow. (Volpe Note: Did for safety reasons due to uneven ballast.)
5	Take commuter rail each day. High platform and low platform, but does have handicap access. The only thing that I noticed was that in the individual trials when I got to the top of the stairs, I usually had to wait due to someone in front still climbing down. This is not unusual to the behavior that I find on the commuter rail normally.
6	Not regular commuter rail rider. Used the commuter rail zero times in the last year but have ridden the commuter rail in the past. In the past, I have used both high and low platforms.
7	Not a regular commuter rail rider. Have ridden commuter rail twice in the last year. Of the 4 egresses in the last year, one was "high platform," three were "low platform." Didn't have any noticeable problems, per se. As the trials progressed, I did become more aware of the placement of the hand rails, and more deliberate about using one, or the other (I believe one extended higher and thus was easiest to grasp, but not sure.) There was a slight leap to the stool that seemed to present a problem to some people, and would hold up those behind. Maybe this is a good thing for someone who might otherwise be too cavalier (and not as careful) about jumping down. When I was in front in such a situation, I recall being a little shocked after a rushed leap.
8	Take the commuter rail daily at Porter Square. Porter Square has both high and low platforms - Always use the low platform. Also use the Littleton station, which is a low platform station.

Side Door Steps/ Step Box to Planking/Ballast April 19, 2006 - Gender

GENDER	VEST	AGE GROUP	HEIGHT	WEIGHT (lbs)	COMMUTER RAIL PASS / COMMENTS #
M	7	Over 50	5 ft 6 - 6 ft	150 - 199	N
M	3	30 - 50	5 ft 6 in - 6 ft	200 - 249	Y
M	11	Under 30	5 ft 6 in - 6 ft	100 - 149	N
M	9	30 - 50	5 ft 6 in - 6 ft	150 - 199	Y
M *	13	30 - 50	Over 6 ft	150 - 199	N
M	6	30 - 50	Over 6 ft	150 - 199	Y
M	5	Under 30	5 ft 6 in - 6 ft	100 - 149	Y
M	15	30 - 50	5 ft - 5 ft.5 in	100 - 149	N
F **	2	Over 50	5 ft 6 in - 6 ft	200 - 249	N
F	4	Over 50	5 ft - 5 ft 5 in	100 - 149	N
F	14	Over 50	5 ft - 5 ft 5 in	150 - 199	Y
F	8	Over 50	5 ft - 5 ft 5 in	250 and above	N
F	1	30 - 50	5 ft - 5 ft 5 in	200 - 249	Y
F	10	30 - 50	5 ft - 5 ft 5 in	150 - 199	Y
F	12	30 – 50	5 ft - 5 ft 5 in	100 -149	Y

* Participated in the 8-25-05 egress trial

\# See attached participant comments

** Participated in the 5-31-06 egress trial

Side Door Steps/ Step Box to Planking / Ballast April 19, 2006 - Age

AGE GROUP	GENDER	VEST	HEIGHT	WEIGHT (lbs)	COMMUTER RAIL PASS / COMMENTS#
Under 30	M	5	5 ft 6 in - 6 ft	100 - 149	Y
Under 30	M	11	5 ft 6 in - 6 ft	100 - 149	N
30 - 50	M	3	5 ft 6 in - 6 ft	200 - 249	Y
30 - 50	M	9	5 ft 6 in - 6 ft	150 - 199	Y
30 - 50	M	13*	Over 6 ft	150 - 199	N
30 - 50	M	15	5 ft - 5 ft.5 in	100 - 149	N
30 - 50	M	6	Over 6 ft	150 - 199	Y
30 - 50	F	1	5 ft - 5 ft 5 in	200 - 249	Y
30 – 50	F	10	5 ft - 5 ft 5 in	150 - 199	Y
30 - 50	F	12	5 ft - 5 ft 5 in	100 - 149	Y
Over 50	M	7	5 ft 6 in - 6 ft	150 - 199	N
Over 50	F	2**	5 ft 6 in - 6 ft	200 - 249	N
Over 50	F	4	5 ft - 5 ft 5 in	100 - 149	N
Over 50	F	14	5 ft - 5 ft 5 in	150 - 199	Y
Over 50	F	8	5 ft - 5 ft 5 in	250 and above	N

* Participated in 8-25-05 egress trial   # See attached participant comments

** Participated in 5-31-06 egress trial

Appendix J. Side Door Stairway Step Experiment 1 – Scripts

MBTA MAINTENANCE YARD
COMMUTER RAIL CAR STAIRWAY EGRESS TRIALS
April 19, 2006

SCRIPT 1: INDIVIDUAL EXITS

DISPLAY CAR SIGNS FOR I1, Change signs after each trial.

Volpe Staff: For the following trials, I will call out vest numbers. When you hear your number and the whistle, please get up and proceed to this end of the car and go out the side door and down the steps to the step stool and down to the ground. Please do not take any of your belongings and please walk quickly as you can. After you leave the car, walk immediately to your left so that you are not blocking the person who is following behind you. You will immediately use the stairway and the door to get back on the car next to this car. Please wait until we give you the signal to come back to this car from the other car. If anyone has a major difficulty, yell "STOP," or if you hear me blow this whistle, everybody stop in place and listen to instructions from one of us or MBTA staff. Any questions?

Trial I1

#1 SIGNAL

Take a new seat for ***Trial I2*.**
OK, now we'll do it again.

#2 SIGNAL

Take a new seat for ***Trial I3***.
OK, now we'll do it again.

#3 SIGNAL

Take a new seat for ***Trial I4***.
OK, now we'll do it again.

#4 SIGNAL

Take a new seat for ***Trial I5.***

#5 SIGNAL

MBTA MAINTENANCE YARD
COMMUTER RAIL CAR STAIRWAY EGRESS TRIALS
April 19, 2006

SCRIPT 2: GROUP EXITS

DISPLAY CAR SIGNS FOR G1, Change signs after each trial.

Volpe Staff: For the following trials, we want you to sit in seats as assigned. [Is] Everyone in your seat assignment, so that we can start? OK. Now we'll do a few trials in which you all get up and exit all at once, just as you would when the train arrives at your stop. Please do not take any of your belongings and please walk quickly, but do not push. I'll give this SIGNAL (sound it). When you hear it, everybody go to the end of the car to get off down the steps, onto the step stool, down to the ground, and then immediately walk to your left so that you are not blocking the person behind you. You will immediately use the stairway and the side door to get back on the car next to this car. Please wait until we give you the signal to come back into this car from the other car. If anyone has a major difficulty, yell "STOP," or if you hear me blow this whistle, everybody stop in place and listen to instructions from one of us or MBTA staff.
Any questions?

#1 SIGNAL

Take a new seat according to the list we gave you for ***Trial G2.***
OK, now we'll do it again.

#2 SIGNAL

Take a new seat according to the list we gave you for ***Trial G3***.
OK, now we'll do it again.

#3 SIGNAL

Take a new seat accordingly to the list we gave you for ***Trial G4***.
OK, now we'll do it again.

#4 SIGNAL

Take a new seat according to the list we gave you for ***Trial G5.***

#5 SIGNAL

Thank you very much for participating. Now, please give your vest back to Raquel. Please also check to see to make sure you have all of your belongings.

Appendix K. Side Door Stairway Step Experiment 1 – Group Seat Assignment

SEAT ASSIGNMENT (April 19, 2006)					
SEAT #	G1	G2	G3	G4	G5
1	6	4	7	9	6
2	14	10	2	4	7
3	3	2	12	13	14
4	15	9	4	11	1
5	2	11	14	1	11
6	10	12	11	14	2
7	5	1	13	2	15
8	1	15	15	15	10
9	8	3	9	8	8
10	13	14	1	12	5
11	11	7	6	6	12
12	12	13	8	8	3
13	9	5	3	3	9
14	4	8	10	10	13
15	3	6	5	5	4

NOTE: The numbers under the Trials columns are the Vest numbers for each individual who was assigned to sit in the seat number for each group trial.

Appendix L. Side Door Stairway Step Experiment 1 – Observer Note Sheets

MBTA STAIRWAY EGRESS TRIALS APRIL 19, 2006 (*also used for Experiment 2 May 31, 2006*)

INDIVIDUAL OBSERVER NAME

Trial # 1 TIME			**Trial # 2 TIME**			**Trial # 3 TIME**			**Trial # 4 TIME**			**Trial # 5 TIME**		
Vest #	Start	Stop	Vest #	Start	Stop	Vest #	Start	Stop	Vest #	Start	Stop	Vest #	Start	Stop

START TIME: WHEN PERSON PUT FIRST FOOT ON SIDE DOOR THRESHOLD STOP TIME: WHEN LAST FOOT STEPS ON PLATFORM

COMMENTS

Trial 1:

Trial 2:

Trial 3:

Trial 4:

Trial 5

Side Door Stairway Step Experiment 1 – Observer Note Sheet Comments

APRIL 19, 2006 (Also used for Experiment 2, May 31, 2006)

GROUP

OBSERVER NAME:

Trial 1

1. Trial Start Time _____ *Time*: 1st person to step onto threshold______ Last person ______

   1st person to step onto platform _______Last person _______

2. Volpe Leader Actions / Instructions

   a. Clear / Understandable

   c. Audible?

   c. Other comment

3. Describe Occupant behavior / actions "of interest" during trial before stepping down, on steps, and on reaching platform

1. Other Comments

Trial 2

1. Trial Start Time ______ *Time:* 1st person to5 step onto threshold ________ Last person_________

   1st person to step onto platform ________Last person__________

2. Volpe Leader Actions / Instructions

   a. Clear / Understandable

   d. Audible?

   c. Other comment

3. Describe Occupant behavior / actions "of interest" during trial before stepping down, on steps, and on reaching platform

4. Other Comments

Appendix M. Side Door Stairway Experiment 2 – Participant Characteristic and Comment Data

Steps to "Low Platform" Pavement, May 31, 2006 – Vest number

VEST	GENDER	AGE GROUP	HEIGHT	WEIGHT (lbs)	COMMUTER PASS / COMMENT #
1*	F	30-50	5 ft - 5-5 ft	150-199	Y
2	M	30-50	Over 6 ft	200-249	N
3*	F	Over 50	Over 6 ft	200-249	Y
4	F	Under 30	5 ft to 5 6 ft	100-149	N
5	M	30-50	5 ft 6 in to 6 ft	150-199	Y
6	M	Over 50	5 ft to 5 ft 6 in	150-199	Y
7	M	Under 30	Over 6 ft	200-249	N
8	M	30-50	5 ft 6 in to 6ft	150-199	N
9	M	Under 30	Over 6 ft	150-199	Y
10	F	Under 30	5 ft to 5 ft 6 in	100-149	Y
11**	F	Over 50	5 ft 6 in to 6 ft	200-249	N
12	F	30-50	5 ft to 5 ft 6 in	150-199	Y
13	M	Over 50	5 ft 6 in to 6 ft	200-249	N
14	M	30-50	6 ft and Over	150-199	Y
15	M	Under 30	5 ft to 5 ft 6 in	100-149	N
16	M	Under 30	5 ft to 5 ft 6 in	150-199	N
17***	F	Under 30	5 ft 6 in to 6 ft	200-249	N

* Participated in the 8-25-05 egress trial

** Participated in the 4-19-06 egress trial

*** Was observer for 8-25-05 egress trial

See attached participant comments

Step to Low Platform Pavement May 31, 2006
Vest Number and Comments

VEST #	COMMENTS
1	Use the commuter rail train approximate 3 times a month Platform is higher
2	No commuter rail pass Rarely take commuter rail
3	Monthly commuter pass and ride daily Steps to get on the train and off (Porter Square)
4	No monthly commuter pass; commute by bus and subway Ride commuter rail 1 or 2 times per month Usually get off at low platform station
5	Commuter rail pass and ride daily Exit on high platform and low stations)
6	Have commuter rail pass and ride daily. Have worked on RR and have been trained to use railings Get off at “low” platform station
7	No monthly commuter rail pass Never have ridden the commuter rail When ride Amtrak, both low; high platforms
8	Use subway, not commuter rail for commuting Use commuter rail occasionally for Monday-work/leisure transport 3-4 annually
9	Ride commuter rail into work. My station does not have an elevated platform Stepping down the car is not similar to my experience at high platform station M - F.
10	Commuter rail pass and ride 3 day a week Use high platform station at both ends
11	Never ride the train
12	Use commuter rail everyday at Porter Square
13	Don’t ride commuter rail
14	No commuter rail pass – not regular rider Take the MBTA commuter rail 4-5 times per year Most common stations boarding at 2 low platforms, and high platform
15	No commuter rail pass Ride the commuter rail 3 times a year Typically get off at low platform stations
16	No commuter rail pass (but I do have a combo bus/T pass) First time on a Boston commuter rail train (but have ridden on commuter trains in other countries/cities)
17	Have subway pass, use twice a day 5 days a week Use commuter rail maybe 2-4 times a year.

Steps to "Low Platform" Pavement, May 31, 2006 - Gender

GENDER	VEST	AGE GROUP	HEIGHT	WEIGHT (lbs)	COMMUTER PASS / COMMENT#
F	1*	30 - 50	5 ft to 5 ft 6 in	150-199	N
F	3*	Over 50	6 ft and Over	200-249	Y
F	4	Under 30	5 ft 5 in to 6 ft	100-149	N
F	10	Under 30	5 ft to 5 ft 6 in	100-149	Y
F	11**	Over 50	5 ft 6 in to 6 ft	200-249	N
F	12	30 - 50	5 ft to 5.6 ft	150-199	Y
F	17***	Under 30	5 ft 5 in to 6 ft	200-249	N
M	2	30 - 50	6 ft and Over	200-249	N
M	5	30 - 50	5 ft 6 in to 6 ft	150-199	Y
M	6	Over 50	5 ft 6 in to 6 ft	150-199	Y
M	7	Under 30	6 ft and Over	200-249	N
M	8	30 - 50	5 ft 6 in to 6 ft	150-199	N
M	9	Under 30	6 ft and Over	150-199	Y
M	13	Over 50	5 ft 6 in - 6 ft	200-249	N
M	14	30 - 50	Over 6 ft	150-199	Y
M	15	Under 30	5 ft 6 in - 6 ft	100-149	N
M	16	Under 30	5 ft - 5 ft 5 ft	150-199	N

* Participated in the 8-25-05 egress trial

** Participated in the 4-19-06 egress trial

*** Was observer for 8-25-05 egress trial

Steps to "Low Platform" Pavement, May 31, 2006 – Age Group

AGE GROUP	VEST	GENDER	HEIGHT	WEIGHT	COMMUTER PASS / COMMENT#
30 - 50	1*	F	5 ft to 5 ft 5 in	150-199	N
30 - 50	12	F	5 ft to 5 ft 5 in	150-199	Y
30 - 50	2	M	6 ft and Over	200-249	N
30 - 50	5	M	5 ft 6 in to 6 ft	150-199	Y
30 - 50	8	M	5 ft 6 in to 6 ft	150-199	N
30 - 50	14	M	6 ft and Over	150-199	Y
Over 50	3*	F	6 ft and Over	200-249	Y
Over 50	11**	F	6 ft 6 in to 6 ft	200-249	N
Over 50	6	M	5 ft to 5 ft 6 in	150-199	Y
Over 50	13	M	5 ft 6 in to 6 ft	200-249	N
Under 30	4	F	5 ft to 5 ft 6 in	100-149	N
Under 30	10	F	5 ft to 5 ft 6 in	100-149	Y
Under 30	17***	F	5 ft 6 in to 6 ft	200-249	N
Under 30	7	M	6 ft and Over	200-249	N
Under 30	9	M	6 ft and Over	150-199	Y
Under 30	15	M	5 ft to 5 ft.6 in	100-149	N
Under 30	16	M	5 ft to 5 ft 6 in	150-199	N

* Participated in the 8-25-05 egress trial

** Participated in the 4-19-06 egress trial

*** Was observer for 8-25-05 egress trail

See previous page

Appendix N. Side Door Stairway Step Experiment 2 – Script

MBTA MAINTENANCE YARD
COMMUTER RAIL STAIRWAY EGRESS TRIALS
May 31, 2006

SCRIPT 1: INDIVIDUAL EXITS

DISPLAY CAR SIGNS FOR I1, Change signs after each trial.

Volpe Staff: For the following trials, I will randomly call out vest numbers. When you hear your number and the whistle, please get up and proceed to this end of the car and go out the side door, down the steps to the step stool and down to the ground, as quickly as you can. [Is] Everyone in your seats? OK.   Please do not carry any belongings when you leave car and after you reach the ground, immediately walk to your right so that you are not blocking the person behind you. Please wait until we give you the signal to get back on the car. If anyone has a major difficulty, yell "STOP", or if you hear me blow this whistle, everybody stop in place and listen to instructions from one of us or MBTA staff. Any questions?

Trial I3

#1 SIGNAL

Take a new seat for ***Trial I2.***
OK, now we'll do it again.

#2 SIGNAL

Take a new seat for ***Trial I3***.
OK, now we'll do it again.

#3 SIGNAL

Take a new seat or ***Trial I4***.
OK, now we'll do it again.

#4 SIGNAL

Take a new seat for ***Trial I5.***

#5 SIGNAL

MBTA MAINTENANCE YARD
COMMUTER RAIL STAIRWAY EGRESS TRIALS
May 31, 2006

SCRIPT 2: GROUP EXITS

DISPLAY CAR SIGNS FOR G1, Change signs after each trial.

Volpe Staff: For the following trials, we want you to sit in seats as assigned. [Is] Everyone in your seat assignment, so that we can start? OK. Now we'll do a few trials in which you all get up and exit all at once, just as you would when the train arrives at your stop. Please walk quickly, but do not push. I'll give this SIGNAL (sound it). When you hear it, everybody get up and proceed to this end of the car to get off down the steps, then immediately walk to your right so that you are not blocking the person behind you. Please wait until we give you the signal to get back on the car. If anyone has a major difficulty, yell "STOP", or if you hear me blow this whistle, everybody stop in place and listen to instructions from one of us or MBTA staff. We also have a very brief questionnaire that we will give you after each trial to complete before we start the next trial. You will leave the questionnaire in your seat each time you leave the car. When you return to the car, we will give it back to you to fill out before we start the next trial. Any questions?

#1 SIGNAL

Take a new seat according to the list we gave you for ***Trial G2.***
OK, now we'll do it again.

#2 SIGNAL

Take a new seat according to the list we gave you for ***Trial G3***.
OK, now we'll do it again.

#3 SIGNAL

Take a new seat accordingly to the list we gave you for ***Trial G4***.
OK, now we'll do it again.

#4 SIGNAL

Take a new seat according to the list we gave you for ***Trial G5.*** For this Trial, please do not talk to anyone on your way out.

#5 SIGNAL

Thank you very much for participating. Now, please give your vest and questionnaire back to Raquel. And now, please check to see if you have left any of your belongings.

Appendix O. Side Door Stairway Step Experiment 2 – Group Seat Assignment

SEAT ASSIGNMENTS (May 31, 2006)					
SEAT #	G1	G2	G3	G4	G5
1	17	4	7	9	6
2	6	10	18	4	7
3	14	2	2	13	16
4	3	16	12	11	14
5	15	9	4	17	1
6	2	11	16	1	11
7	10	12	14	14	2
8	18	1	11	2	15
9	5	15	13	15	17
10	1	3	15	8	10
11	8	14	9	16	8
12	13	17	1	12	5
13	11	7	6	6	12
14	12	13	8	10	3
15	16	5	3	5	18
16	9	8	17	18	9
17	4	6	10	3	13
18	7	18	5	7	4

NOTE: The numbers under the Trials columns are the Vest numbers for each individual who was assigned to sit in the seat number for each group trial.

Appendix P. Side Door Stairway Step Experiment 2 – Participant Questionnaire Form

MBTA STAIRWAY EGRESS EXPERIMENT - MAY 31, 2006

VEST NUMBER* _______ QUESTION /RESPONSE**	TRIAL NUMBER				
	1	2	3	4	5
1. I was seated facing the exit that I used to leave the car					
A True					
B False					
2. In leaving my seat:					
A I had no difficulties in getting into the aisle					
B I was slowed down by the person sitting next to me					
C I had to wait for a gap in the line before getting into the aisle					
D people let me into the line					
E I had to push my way into the aisle					
3. When I was in the aisle / line moving towards the exit:					
A I could walk at the speed I wanted to					
B I had to walk slowly since the line was moving slowly					
C I sometimes stopped to let people into the line					
D I tried to pass people but couldn't due to the crowd					
E I didn't try to pass people because it was unnecessary / impolite					
F people behind me were pushing me					
G I was moving slowly because I felt tired					
4. On exiting the car: I stepped down the steps					
A normally					
B slowly					
C holding onto the side grab railing to assist me / support myself					

* Separate form completed by each participant for each egress trial, after each of 12 trials.

** Participants were told to check as many responses as they believed applicable.

Appendix Q. Side Door Stairway Step Experiment 2 – Questionnaire Data

Group Trial 1 - May 31, 2006

QUESTION / RESPONSE	TOTALS	PERCENTAGE OF RESPONSES
1. I was seated facing the exit that I used to leave the car:		
A True	12	73
B False	5	29
Total	17	100
2. In leaving my seat:		
A I had no difficulties in getting into the aisle	10	59
B I was slowed down by the person sitting next to me	3	18
C I had to wait for a gap in the line before getting into the aisle	3	18
D people let me into the line	5	29
E I had to push my way into the aisle	2	12
Total	23	136
3. When I was in the aisle /line moving towards the exit:		
A I could walk at the speed I wanted to	7	41
B I had to walk slowly since the line was moving slowly	9	53
C I sometimes stopped to let people into the line	4	24
D I tried to pass people but couldn't due to the crowd	2	12
E I didn't try to pass people because it was unnecessary/ impolite	6	35
F people behind me were pushing me	0	0
Total	28	165
4. On exiting the car, I stepped out:		
A normally	10	59
B slowly	3	18
C holding onto the side rails to support myself	10	59
Total	23	136

Group Trial 2 - May 31, 2006

QUESTION / RESPONSE	TOTALS	PERCENTAGE OF RESPONSES
1. I was seated facing the exit that I used to leave the car:		
A True	12	71
B False	5	29
Totals	17	100
2. In leaving my seat:		
A I had no difficulties in getting into the aisle	10	59
B I was slowed down by the person sitting next to me	3	18
C I had to wait for a gap in the line before getting into the aisle	3	18
D people let me into the line	5	29
E I had to push my way into the aisle	2	12
Total	23	136
3. When I was in the aisle /line moving towards the exit:		
A I could walk at the speed I wanted to	7	41
B I had to walk slowly since the line was moving slowly	9	53
C I sometimes stopped to let people into the line	4	24
D I tried to pass people but couldn't due to the crowd	2	12
E I didn't try to pass people because it was unnecessary/ impolite	6	35
F people behind me were pushing me	0	0
Total	28	165
4. On exiting the car, I stepped out:		
A normally	10	59
B slowly	3	18
C holding onto the side rails to support myself	10	59
Total	23	136

Group Trial 3 - May 31, 2006

QUESTION / RESPONSE	TOTALS	PERCENTAGE OF RESPONSES
1. I was seated facing the exit that I used to leave the car:		
A True	13	76
B False	4	24
Total	17	100
2. In leaving my seat:		
A I had no difficulties in getting into the aisle	7	41
B I was slowed down by the person sitting next to me	5	29
C I had to wait for a gap in the line before getting into the aisle	8	47
D people let me into the line	8	47
E I had to push my way into the aisle	0	0
Total	28	124
3. When I was in the aisle /line moving towards the exit:		
A. I could walk at the speed I wanted to	3	18
B I had to walk slowly since the line was moving slowly	14	82
C I sometimes stopped to let people into the line	5	29
D I tried to pass people but couldn't due to the crowd	2	12
E I didn't try to pass people because it was unnecessary/ impolite	5	29
F people behind me were pushing me	0	0
Total	29	
4. On exiting the car, I stepped out:		
A normally	9	53
B slowly	3	18
C holding onto the side rails to support myself	8	47
Total	20	118

Group Trial 4 - May 31, 2006

QUESTION / RESPONSE	TOTALS	PERCENTAGE OF RESPONSES
1. I was seated facing the exit that I used to leave the car:		
A True	11	65
B False	7	41
Total	18	106
2. In leaving my seat:		
A I had no difficulties in getting into the aisle	6	35
B I was slowed down by the person sitting next to me	4	24
C I had to wait for a gap in the line before getting into the aisle	9	53
D people let me into the line	7	41
E I had to push my way into the aisle	2	12
Total	28	165
3. When I was in the aisle/line moving towards the exit:		
A I could walk at the speed I wanted to	5	29
B I had to walk slowly since the line was moving slowly	12	71
C I sometimes stopped to let people into the line	5	29
D I tried to pass people but couldn't due to the crowd	0	0
E I didn't try to pass people because it was unnecessary/ impolite	7	41
F people behind me were pushing me	0	0
Total	29	171
4. On exiting the car, I stepped out:		
A normally	10	59
B slowly	3	18
C holding onto the side rails to support myself	10	59
Total	23	136

Group Trial 5 - May 31, 2006

VEST ______ QUESTION / RESPONSE* **	TOTALS	PERCENTAGE OF RESPONSES
1. I was seated facing the exit that I used to leave the car:		
A True	12	71
B False	5	29
	17	100
2. In leaving my seat:		
A I had no difficulties in getting into the aisle	5	29
B I was slowed down by the person sitting next to me	8	47
C I had to wait for a gap in the line before getting into the aisle	8	47
D people let me into the line	6	35
E I had to push my way into the aisle	3	18
	9	136
3. When I was in the aisle/line moving towards the exit:		
A I could walk at the speed I wanted to	6	35
B I had to walk slowly since the line was moving slowly	11	65
C I sometimes stopped to let people into the line	2	12
D I tried to pass people but couldn't due to the crowd	0	0
E I didn't try to pass people because it was unnecessary/ impolite	7	41
F people behind me were pushing me	1	6
	27	149
4. On exiting the car, I stepped out:		
A normally	11	65
B slowly	4	24
C holding onto the side rails to support myself	9	53
	24	142

* Separate form completed by each participant for each egress trial, after each of 12 trials.

** Participants were told to check as many responses as they believed applicable.