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Under FRA sponsorship, a series of three experimental egress trials was conducted in 2005 and 2006 to obtain human factors data relating to the amount of time necessary for individuals to exit from a passenger rail car. This final report describes the results of all these emergency egress experiment trials.

To FRA's knowledge, the 2005 commuter rail car egress experiment was the first time that U.S. passenger rail car egress time trials were conducted with commuter rail passengers as test participants.

Controlled variables included egress from the commuter rail car using side door(s) to a high-platform, low-platform, or right-of-way location, or using an end door to an adjacent car; as well as lighting conditions.

Participant egress times varied significantly by the 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 experiment data will also be used as input for the development of a passenger rail car emergency egress simulation computer model that can predict emergency evacuation time for a variety of passenger rail car configurations.

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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	=	0.9 tonne (t) (lb)

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

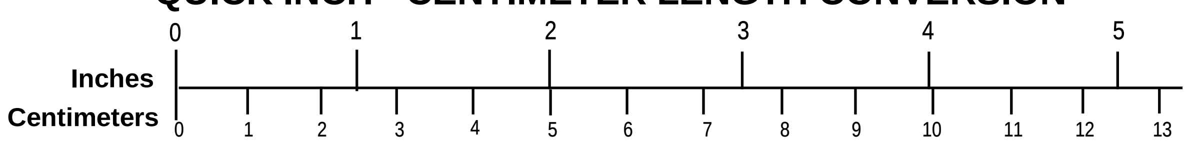
VOLUME (APPROXIMATE)

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)

TEMPERATURE (EXACT)

[(9/5) y + 32] °C = x °F

QUICK INCH - CENTIMETER LENGTH CONVERSION



QUICK FAHRENHEIT - CELSIUS TEMPERATURE CONVERSIO

°F	-40°	-22°	-4°	14°	32°	50°	68°	86°	104°	122°	140°	158°	176°	194°	212°
°C	-40°	-30°	-20°	-10°	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°

For more exact and or other conversion factors, see NIST Miscellaneous Publication 286, Units of Weights and Measures. Price $2.50 SD Catalog No. C13 10286

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August 25, 2005 Egress Experiment Trials, MBTA 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 Ms. Calderon who provided overall management of all administrative tasks related to participant recruitment and check-in/checkout, as assisted by Mariana Vasquez, Volpe Center.

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

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EXECUTIVE SUMMARY

U.S. intercity passenger and commuter rail train system operators have maintained a very good safety record, and the number of passenger trains involved in accidents or other emergency situations is low. The majority of passenger train emergencies are usually resolved quickly and evacuation from the train is not necessary since passengers are generally safer if they remain on the train. Nevertheless, emergency situations continue to occur and, at times, they result in occupant casualties. In certain cases, the delay, difficulty, or inability of passengers and crew to safely and quickly evacuate the train can contribute to the number and severity of casualties.

The majority of Federal Railroad Administration (FRA), U.S. Department of Transportation (U.S. DOT) regulations for passenger train emergency systems are specified in Title 49, Code of Federal Regulations (49 CFR), *Part 238, Passenger Equipment Safety Standards* and *Part 239, Passenger Train Emergency Preparedness.* The intent of the FRA regulations is to ensure the safety of intercity and commuter rail passengers and crew, and the safe, timely, and effective evacuation of passenger trains when necessary during emergencies.

FRA's Office of Research and Development is sponsoring an ongoing research program that is investigating how to enhance the safety of passengers and crew during passenger train emergencies. One aspect of the FRA research program is directed at evaluating the potential applicability to passenger trains of performance-based criteria that specify evacuation times.

Emergency egress from a passenger train is a complex process that depends on a number of dynamic factors and conditions. Many variables that affect the time necessary for passengers to exit from a passenger train in an unusual or emergency situation must be identified and considered.

No single or uniform methodology currently exists for evaluating the passenger rail car emergency egress system as a whole, or the effects on egress times of failures within this system. However, using data from actual passenger rail car egress experiments and refinements to existing egress model simulation calculations, time-based egress computer models could be expected to provide reasonable predictions of necessary egress times for different passenger rail car types with the rail car upright and passengers exiting either from one upright car to the adjacent car, onto high or low station platforms, or to the right-of-way (ROW).

This report describes the results a series of three egress experiments completed by staff of the John A. Volpe National Transportation Systems Center (Volpe 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 from a single-level commuter rail car to different locations.

The Volpe Center egress experiments were conducted in a manner specifically intended to collect egress time data, which when combined with the known physical characteristics and egress behavior of each participant in the experiments, the physical characteristics of the commuter rail cars, and the environment at the time the data were recorded, can be used to establish estimates and norms for passenger rail car egress times and to evaluate various aspects of car design that may impede prompt emergency egress.

The main experiment on August 25, 2005, at North Station, Boston, involved a series of egress trials by individuals who exited into an adjacent rail car using an end door or onto the high-level station platform using one or two side doors, under normal and emergency lighting conditions. To FRA's knowledge, the 2005 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.

Two additional experiments, consisting of a series of more limited egress trials, were conducted at the MBTA Commuter Rail Maintenance Facility, Somerville, MA on April 19 and May 31, 2006, for individuals to exit from the commuter rail car using the car side-door stairway to the ROW and to a low-platform location.

Participant egress times during the 2005 and 2006 egress experiments varied significantly by the number of passenger rail car exits used and the exit route taken. Results of the 2005 high-platform egress experiment trials (best-case) indicated consistent egress flow rates and total egress times by participants across trials, with minimal learning effects due to repetition and no apparent fatigue effect. No significant difference was observed between egress trials conducted under normal lighting or emergency lighting-only conditions, because of the high density in the aisles, which slowed the egress flow rate, as well as the high level of emergency lighting (well-lit car end door and vestibule areas) that enabled the participants to see and exit from the rail car without hesitation when they reached the end and side doors.

The 2005 and 2006 egress experiment data and extrapolations show that:

- Doubling the number of doors used to exit from the commuter rail car cuts egress time almost in half, if each door is used by the same number of persons;
- Egress to the low-platform location takes about 50% longer than egress to a high-platform location; and
- Egress to the ROW location (even using a step box) takes about twice as long as egress to a low-platform location.

However, it is emphasized that all observed data and extrapolated egress time estimates generated from the egress experiments described in this report are representative of best-case conditions, and do not reflect actual egress from a passenger rail car under actual emergency conditions.

1. INTRODUCTION

One goal of the Federal Railroad Administration (FRA), U.S. Department of Transportation (U.S. DOT), 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), *Part 238, Passenger Equipment Safety Standards* and *Part 239, Passenger Train Emergency Preparedness*, 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, crew, and response personnel during emergency situations.

In the majority of passenger train emergencies, it is not necessary to evacuate passengers since they are often safer remaining on board the train. However, the National Transportation Safety 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 were 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 crew and passenger evacuation from passenger trains, 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 applicability 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 also 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 from an aircraft) to passenger rail equipment [12].

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

1.1 PURPOSE

Occupant egress time data egress experiments described in this final report (and any future experiments) are intended to provide a basis for estimating the best-case egress times from passenger rail cars and evaluating various design aspects that may enhance or hinder timely egress during an emergency which occurs in the unique railroad operating environment.

Computer models that simulate the egress behavior of passengers from passenger rail cars are a cost-effective means of generating such estimates. However, egress computer models must be validated and calibrated with occupant behavioral data from actual passenger rail car egress trials, as well as data for rail car geometry and other variables (such as lighting condition or type of exit location), for which those trials were conducted.

Accordingly, the data generated from the three series of commuter rail car egress experiments described in this report will be used in the development of an egress computer model with the capability to estimate emergency evacuation times from different rail car configurations under a variety of emergency conditions. FRA provided funding to the University of Greenwich, United Kingdom (UK), to adapt an existing EXODUS® evacuation computer model for application to U.S. passenger rail car emergency egress time prediction.

The information obtained from the passenger train egress experiments described in this report and the passenger rail car egress computer model development is intended 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 and emergency signs. In addition, the new prototype railEXODUS® computer egress model is intended for use by FRA, passenger railroad system operators, and rail car designers to evaluate U.S. passenger equipment emergency evacuation-related design features and emergency procedures.

1.2 SCOPE

The general focus of the commuter rail car egress experiments described in this report was the obtaining of observational and video recording data for participants who used a variety of different doors and exit path routes to exit to selected locations. The selected egress routes reflected the unique operational conditions of the railroad environment.

The three series of human factors egress experiments were designed and conducted by the Volpe Center. The main experiment, consisting primarily of 12 egress time trials, was conducted in cooperation with the MBTA at North Station, Boston, MA, on August 25, 2005, using commuter rail cars. 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 location, using one or two side doors, or to an adjacent car using the end door; under both normal and emergency lighting conditions.

Two other very limited experiments were also conducted on the same date in 2005 at the North Station location in order to obtain data relating to mobility-impaired participant walking speeds.

In addition, two follow-up 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 the time necessary for individuals using a typical commuter rail car side-door stairway to exit from the car to the right-of-way (ROW) and to a pavement simulating a low-platform station location. The latter two egress locations reflect the unique environment of railroad operations.

1.3 OBJECTIVES

The objectives of the three egress experiments described in this report were to obtain highly detailed observational human factors data related to the length of time necessary for individuals to:

- Exit from a single-level commuter rail car to a high-platform station location using one or two side doors, or to another car using an end door, under both normal and emergency lighting conditions; and
- Exit to other exterior locations, using side-door stairway steps.

The remaining sections of this chapter provide additional context for the three series of egress experiments by presenting: 1) brief background information relating to egress time prediction in relation to emergency evacuation; 2) review of regulations/requirements relating to emergency egress issued by FRA and other DOT agencies, as well as other organizations; 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[*] due to 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 must be longer than its necessary evacuation time. For example, if the growth of a rail car interior fire produces untenable conditions <u>after</u> 45 seconds, the evacuation time necessary for passengers and crew to exit from the car must be <u>less</u> than 45 seconds. (See additional discussion relating to passenger train minimum and available evacuation time in Reference [13]). This safety criterion becomes essential to evaluate, especially as FRA transitions from prescriptive safety standards to performance-based regulations for passenger train safety. 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.

(Due to 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 further discussed in the next section, U.S. DOT 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 Current emergency evacuation-related requirements are summarized in the next section.

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[*] Untenable means conditions that are hazardous to persons, e.g., elevated temperatures, smoke conditions.

1.5 PUBLIC TRANSPORTATION VEHICLE EGRESS REQUIREMENTS

The majority of U.S. 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. While FRA, FAA, and U.S. Coast Guard (USCG)[**] all recognize the importance of operating crew who are properly trained in emergency preparedness planning and procedures, the remainder of this section focuses on public transportation vehicle design requirements related to emergency exits and related egress items.

1.5.1 Passenger Trains

FRA regulations contained in Title 49, Code of Federal Regulations (49 CFR), *Part 238* and *Part 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 emergency window exits and doors intended for passenger egress, 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.

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 conspicuously marked emergency-window exits and two conspicuously 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, to 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 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 rail cars) and clearly visible emergency exits that are rapid and easy to operate must both be available to passengers and train crew and that clearly visible rescue access points be available to emergency responders in order to facilitate passenger and crew evacuation from trains when necessary in an emergency.

[**] USCG was part of U.S. DOT from 1967 to 2003; it was subsequently moved to Department of Homeland Security.

1.5.2 Aircraft

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 escape path 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 due to fire. It should be noted that FAA regulations are based on the premise that, in the majority of cases, passengers and crew must evacuate the aircraft as soon as possible due to 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 Motorcoaches

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

1.5.4 Passenger Ships

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 (SOLAS) 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 (IMO) 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 one 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 and gender,
  - Weight (body mass),
  - Agility and strength,
  - Mobility impairments (including injuries and disabilities),
  - Number of persons in rail car,
  - Seat location, and
  - Frequency of rail travel and familiarity with car;
- Rail Car Geometry and Configuration
  - Car type,
  - Number of levels (single or multi-level),
  - Number and arrangement of seats,
  - Aisle and stairway arrangement, and
  - Door and window location, size, and operation;

- Operating Environment
  - Location of emergency,
    - Station
      + High-platform: best case
      + Low-platform, and
    - ROW (ballast, tunnel, bridge): worst case
  - Time of day and lighting conditions,
  - Weather conditions,
  - Platform or ROW conditions,
  - Car condition (damage) and orientation of car(s), and
  - Hazardous condition
    - Fire,
    - Smoke, and
    - Water immersion;
- Train Crew (and emergency responder) Training
  - Plan and procedures and
  - Equipment;
- Passenger Awareness;
- Passenger Assistance in Exiting,
  - Direction and assistance from train crew,
  - Assistance from other passengers; and
- Assistance from emergency response personnel.

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

The egress experiments described in this report were intended to obtain data only for selected passenger characteristics and egress behavior, as well as for commuter rail car and railroad operating environment variables that could be controlled, as described in Chapters 2 and 3. Accordingly, while 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 included.

1.6.2 Computer Egress Simulation Models

A computer model that can simulate egress from passenger rail cars could include all of the variables listed above, as well as consider the results of experimental egress trials for calibration and validation of the model.

A previous 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 reduce 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 potential 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.

In order 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 and analysis of the protocols of the two follow-up egress experiment trials conducted for persons exiting from a single-level car using the side-door stairway steps to ROW and low-platform locations.

Chapter 4 summarizes the results of the analysis of the observed and quantitative data obtained from the 2005 and 2006 egress experiments and discusses further use of the egress data.

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

Appendices I though Q contain information related to the two follow-up side-door stairway egress experiments conducted in 2006.

2. HIGH-PLATFORM EGRESS EXPERIMENT

This chapter provides an overview of the series of 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 involved individuals who exited a single-level commuter rail car by using either one or more side doors onto either a high-platform location, or by using an end door to exit to an adjacent car, under two different lighting conditions.

The measurement of passenger rail car occupant egress flow rates, egress times, and walking speeds were the objectives of the Volpe Center-conducted experiment 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, while 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 egress experiments described in this report.

Experimental egress flow rate and time 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 persons, while individuals receive no such incentives in noncompetitive experiments. In some competitive aircraft evacuation experiments, incentives resulted in individuals behaving so aggressively that some persons became jammed in the exits and sustained injuries. While 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 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 controllable variables that influence participant movement from his or her seat in the original commuter rail car to either the adjacent commuter car or onto the high-platform location, are described in the remainder of this chapter.

2.1 TYPE AND NUMBER OF EGRESS TRIALS

To establish a baseline passenger 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. The 12 trials included egress 1) onto the station high-level platform using one or two side doors, and 2) into an adjacent car, using an end door, under both normal and emergency lighting conditions. The order of the main experiment egress trials (which were randomly repeated, 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 what they learned from the preceding trial (see Table 1). Each participant was also assigned to a different seat for each of the 12 egress trials (see Section 2.5).

Table 1. High-Platform Main Experiment Egress Trials

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

In addition to the 84 persons who participated in the high-platform main experiment egress trials, 2 persons 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 AND HIGH-PLATFORM STATION ARRANGEMENT

The 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 in Boston. 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 2.5 through 2.7.

The two-car consist, used for the experiments contained a cab/coach car and a coach car, and 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 MBTA transit police to isolate the train from other commuter rail

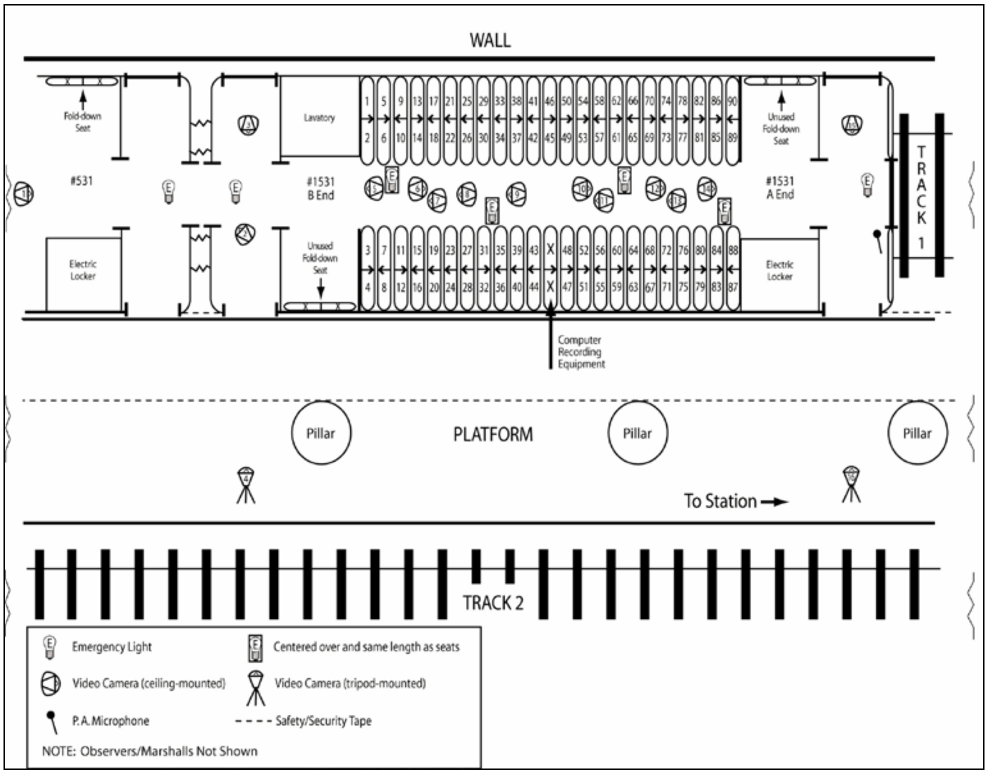

Figure 1. Main Egress Experiment Schematic: Car Interior and High-Platform Arrangement – North Station, Boston, MA

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 location without the need to step down the car side-door stairway used at certain stations to reach "low-platform" locations (see Chapter 3).

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 exteriors 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 2.3.))

(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, 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 interior and exterior (b) "B" end interior and exterior

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 persons 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 Inter-car Diaphragm (to 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 persons 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 (47.5 centimeters) and the distance (gap) between the facing seats was 12 inches (30 centimeters)) (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 used by the participants in Car #1531. (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 inches (76.2 centimeters).

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, combined with station lighting coming through the open side doors, provided 3 to 5 foot-candle (fc) (32 to 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 (as well as Car #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 [23]. 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 (IRB) 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," since 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, 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 persons who applied in accordance with the FAA-required evacuation test demographic guidelines [15]:

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

However, the target distribution for the main high-platform 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 to 29,
  - 30 to 50, and
  - Over 50.

The target distribution was modified to include a higher proportion of women than that required by FAA, but a slightly lower proportion of older persons, in order to more accurately reflect the commuter rail rider population. However, the actual distribution of the 84 persons 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 participants in terms of physical fitness, the differences between planned and actual demographics were assumed to have no effect on 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 persons is contained in Appendix B.

Table 2. Main Experiment: Participant Characteristics

VARIABLE	NUMBER	PERCENTAGE*
GENDER		
Female	44	52
Male	40	48
Total	84	100
AGE GROUP		
Under 30	25	30
30 to 50	33	39
Over 50	26	31
Total	84	100
HEIGHT		
Under 5 ft	1	1
5 ft to 5 ft 6 in	37	44
5 ft 6 in to 6 ft	36	42
6 ft and over	11	13
Total	84	100
WEIGHT (lb)		
Under 100	1	1
100 to 149	26	30
150 to199	45	53
200 to 249	10	12
250 and above	2	2
Total	84	100

* Percentages may not be exact and not add exactly to 100% due to rounding.

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

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

All 84 participants in both the main high-platform egress trials and the 2 mobility-impaired participants in the other more limited egress trials were instructed to exit the cars for their respective trials in an orderly manner, as quickly as possible, 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.)

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 offered to the 84 participants during the main experiment high-platform egress trials to compel them to exit the commuter rail car by reaching the end and/or side doors before other participants.

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;
- 16 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 feet (4.6 meters). However, to ensure participant safety, yellow security tape was installed around and between the platform canopy support columns to block off an approximately 4 foot (1.2 meter)-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, which were approximately 10 feet (3 meters) wide. In addition, after Trial 1, participants who used the "B" end side door to exit the car were directed to go towards the center of the car on the Track 1 platform. The normal station platform ceiling lights were operational, providing bright light (about 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 inches (10 centimeters), and the "B" end gap was 3.5 inches (8.9 centimeters).

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

CAR COMPONENTS		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) / 287 cm (2.9 m)
	Width between side doors	46 in (3 ft 10 in) / 117 cm (1.2 m)
DIAPHRAGM	Length	25 in (1 ft 1 in) / 63 cm (.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 (.76 m)
All Seats	Cushion depth (front edge to back)	18 in (1 ft 6 in) / 46 cm (.46 m)
	Cushion length	36 in (3 ft) / 91 cm (.91 m)
	Width between armrests	37.5 in (3 ft 1 in) / 95 cm (.95 m)
Transverse Seats	Width between front of cushion to back of next seat	18 in (1 ft 6 in) / 46 cm (.46 m)
	Clear opening	12 in (1 ft) / 30 cm (.30 m)
	Pitch	33 in (2 ft 9 in) / 84 cm (.84 m)
	Front of armrest of first seat to end door "A" and "B" end	93 in (7 ft 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 (.45 m)
End Door (to Vestibule)	Frame opening, gasket-to-gasket	37.5 in (3 ft 1.5 in) / 95 cm (.95 m)
	Clear opening	33 in (2 ft 9 in) / 84 cm (.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 in) / 119 cm (1.2 m)
	Frame opening, gasket-to-gasket	39 in (3 ft 3 in) / 99 cm (1 m)
	Height	78 in (7 ft 6 in) / 198 cm (2 m)

* SI units rounded

Figure 6. Car #1531: Side Door and Platform Gap – "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 to 30 fc (215 to 324 lux) at the floor. The car floor-level illuminance values under emergency lighting conditions are listed in Table 4.

Table 4. Illumination Levels: Emergency Light Fixture Locations

LOCATION	FLOOR-LEVEL ILLUMINANCE (fc)
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

Although 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 and provided bright light outside the car and on the surface of the platform—at least 10 fc (108 lux).

2.5.4 Participant Data

One hundred and four individuals 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. Eighty-four people actually participated in the 12 main high-platform experiment egress trials. Two other individuals participated in two other more limited egress trials.

To reduce the impact of learning effects from the repetitive nature of the actions performed by people 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: Registration; Participants with Vest Number Assignments

Seat assignments were randomly generated and the order of egress trials was arranged to: 1) reduce bias from possible learning effects and 2) 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. Participants were recruited from a pool of persons who regularly ride the commuter train service and were not required to open any side or end doors (see Section 2.5.4); they 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). Accordingly, Volpe Center staff believe that potential learning effects were minimal. In the two side-door egress trials, participants were instructed to exit as quickly as possible, but were not given specific direction as to which door to use. Sections 2.5.5 through 2.5.7 contain more information about 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 2 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 magnetically mounted on the ceiling PA loudspeaker outer cover plate.

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

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

Figure 9. Car #1531: Exterior Video Camera – "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.

For data analysis, the *GeoVision*® software was configured to record at a resolution of 320 x 240 pixels, and at the maximum allowable frame rate of 30 frames per second (fps). Due to 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 kHz. 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, since every frame was time stamped and the gaps were no longer than 67 milliseconds. However, viewing 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 (kbps) 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

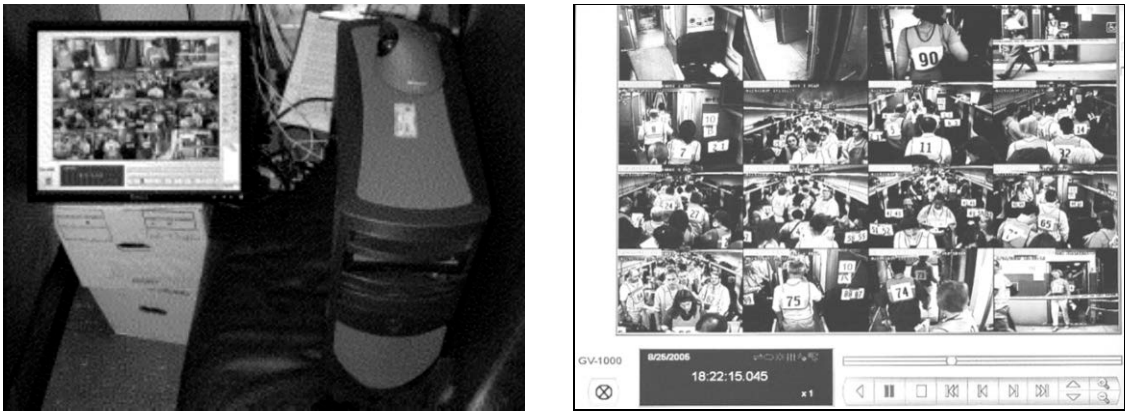

Figure 10. Video Data Recording Screen and Hard Drive; Screen: Close-up

1/100 second was superimposed in the upper right corner of each video to display the elapsed time in h:mm:ss.sss. For each trial, the composite videos show all 16 camera views at their original 320 x 240 pixel size, laid out on a 4 x 4 matrix grid (1280 x 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 each camera view labeled.

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 x 480 pixels) to increase resolution of details. Figure 11 (b) shows a close-up of the Camera 16 view from the same trial.

(a) All camera view (b) Camera 16

Figure 11. Video Screen Views: Converted Video Media Format

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 locations selected by the individual for the two door-to-platform egress trials and the reason(s) those locations were selected; the effect the type of lighting (normal or emergency) had on the person's ability to exit; and any 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 comprised of two observers (see Appendix E), took notes (see Appendix F) during each of the 12 trials on 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.

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

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 reenter that car when each egress trial was completed and assisted participants in locating their new seat assignment for the next trial.

2.6 MAIN HIGH-PLATFORM EGRESS 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 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 instructed 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.

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 asked 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.

Persons 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 reenter 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 conspicuously 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 analysis. 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. Participants were then directed to the checkout table to turn in their questionnaires and vests, and 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 12 main experiment high-platform egress trials:

- Trial number;
- Exit route;
- Lighting condition;
- Time of start signal (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” onto 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 car 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 persons using each exit route.

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

- Total egress time – the total elapsed time from the moment the signal to exit was given until the last person stepped onto the platform or adjacent car;
- Egress flow rate – the number of persons per unit of time flowing through an exit; persons per second (pps) and
- Walking speed – distance traveled per unit of time (observed in this experiment while subjects walked through the vestibule to the adjacent car).

The main experiment high-platform egress trials 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.

The data in Table 5 show 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 according to Equations 1 and 2 for each route:

$$FR = N / FT \tag{1}$$

FR = flow rate

N = number of participants

FT = flow time

$$FT = T_L - T_F \tag{2}$$

T_L = time of first person out

T_F = time of last person out.

The average elapsed time from the start of the egress trial (flag drop and whistle sound) to the first person to exit in each trial ranged from 4 to 7 seconds, with an average of 5 seconds. As Table 6 shows, the elapsed times from the start of each trial and the first person and last person events and the egress 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, 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 since, as noted previously, both car vestibules and the station high platform were well lit.

The average egress flow rate was about 0.9 persons per second from Car #1531. The greatest deviation occurred during Trial 3, due to congestion on the platform that reduced the flow rate to about 0.7 persons per second.

The total observed egress time for 84 seated participants, using a single exit route during egress trials (either one side door to the high platform or end door to the adjacent car), averaged about 100 seconds (1 minute, 40 seconds). Trials for which participants used two side doors to exit to the high platform averaged about 58 seconds, decreasing the egress time by about half.

Based on the video data, the egress flow rates from Car #1531 appeared to be unaffected by the type of egress path route used by the participants (through end door to the adjacent car or from one or two side doors to the high 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 (Equation 3) to estimate passenger car total egress time in relation to seating configurations and load factors:

Table 5. High-Platform Main Experiment: Observed Event Times and Passenger Counts (from Video 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 yous

KEY: A = Adjacent car
P1 = Platform one-door
P2 = Platform two door
N = Normal lighting
E = Emergency lighting
Time = hh:mm:ss – Military time (The first experiment trial began at 5:33.47 pm)

[#] Note: Event and egress flow rates represent best-case conditions and do <u>not</u> reflect actual emergency conditions.

Table 6. High-Platform Main Experiment: Elapsed Event Time Data and Calculated Egress Flow Rates[#]

TRIAL #	EXIT	LIGHTS	RESEATING 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	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: hh:mm:ss

[#] Event times and egress flow rates represent best-case conditions which do not reflect actual emergency conditions.

$T_{total} = T_{fo} + (N/FR)$ where T_{total} = total egress time (seconds (s)) (3)

T_{fo} = time for first person out (averaging about 5 seconds in these trials)

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

N = number of participants (divide N by number of doors, if more than 1 door).

Based on this equation, using the 5-second average elapsed time for the first person out and the exact flow rate value (.87 persons per second), egress time estimates were extrapolated, as shown in Table 7, for a single-level fully loaded commuter rail car with 92 or 130 seated occupants (no standees), under similarly favorable circumstances.

Table 7. Fully Loaded Car: High-Platform/Adjacent Car – Egress Time Estimates

LOCATION	TYPE AND NUMBER OF DOORS	NUMBER OF SEATED PASSENGERS (No standees)	TOTAL EGRESS TIME # (s / min, s)
HIGH-PLATFORM/ ADJACENT CAR	One side or end door	92	111 s (1 min, 51 s)
		130	154 s (2 min, 34 s)
	Two side doors	92	58 s
		130	79 s (1 min, 19 s)

Representative of best-case conditions which do not reflect actual emergency conditions.

Although comparable passenger train egress experimental data are not available, a body of data from actual egress flow rate measurements from various North American transit operations exists [24] [25]. 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 (e.g., exiting) passengers range from 1.4 to approximately 2 seconds per person. This range is naturally higher than the average of 1.1 seconds per person (the reciprocal of 0.87 pps) measured in the main high-platform egress experiment, because when exiting under normal circumstances, some individuals leave gaps in the flow, thus increasing the overall egress time.

However, the persons who participated 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 persons did not occur.

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

The walking speed of participants could be estimated from the video captured by Camera 4 (see Figure 13), which showed their transit through the vestibule—a distance of 3.7 feet (1.1 meters) during egress to the adjacent car. These transit times ranged from approximately 0.7 to 0.9 seconds, implying walking speeds of 4 to 5 feet per second (1 to 1.5 meters per second). These values are slightly higher than the design specification for normal walking speed of pedestrians at signalized street crossings of 4 feet per second (1.2 meters per second) [26]. The Canadian government specifies a range of 3.7 to 4.6 feet per second (1.1 to 1.4 meters per second) for the normal walking speed of pedestrians at signalized street crossings [27].

Figure 13. **Video Camera 4: Egress to Adjacent Car – Transit Time**

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 persons with significant mobility issues and resulting lower walking speeds, particularly those older persons with lower agility, would have been included.

The August 2005 egress experiment results demonstrate that passengers of normal agility can exit a fully loaded (no standees) single-level high-capacity passenger rail car to a high-platform location or an adjacent car in less than 2½ minutes, under both normal and emergency-lighting conditions. This time could be long enough to allow all occupants to escape from the majority of probable fire scenarios (e.g., electrical or small trash fires), if detected in a timely manner.

Walking speeds of mobility-impaired persons have been estimated to average below 1.3 feet per second (0.4 m per second) [28]—less than half the speed of the unimpaired participants in the egress trials described in this report. Therefore, it may be necessary to substantially increase the total necessary passenger rail car egress time, depending on the number of mobility-impaired individuals and the behavior of the unimpaired passengers.

The calculated walking speed estimates from this egress experiment are within the range of those in the cited references.

The total necessary average egress time for 130-seated occupants (with no standees) was estimated to be approximately 2½ minutes, when using either a single side door to exit onto a high platform or an end door to exit into an adjacent car, and approximately 1 minute, 20 seconds when using two side doors to exit onto a high platform.

The 12 main experiment high-platform egress trials generated an extensive baseline data set for event times, egress flow rates and times, and walking speeds for calibration/validation of a computer model that can simulate egress from a passenger rail car.

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, due to 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 car equipment door, did not significantly slow the flow rate.
- The vest numbers of some participants were not visible at times due to backpacks or long hair. (However, due to 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 which is summarized below (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 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 commuter rail car was filled almost to capacity, most participants could not leave their seats immediately. Most had to wait until individuals 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 to 25% of the participants stated that they could walk as fast as they wanted to 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 without holding onto railings). Two individuals consistently stated that they used the handrails when exiting, regardless of the lighting condition. Four participants said they slowed when stepping through the vestibule under emergency lighting, while only one or two persons said they moved slower 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 individuals who volunteered were identified as having significant mobility impairments. Because of safety and time constraints, Volpe Center staff conducted two separate limited egress trials with those two persons as participants; they were told 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 a MBB car with two-by-two seating. Although Car #531 was equipped with fewer seats than Car #1531, the aisle and end door used were both the same width. Previous research has shown that aisle width, not seating configuration, is the principal determinant of egress flow rate [29].

2.9.1 Participant Number 1

The female participant who was in her early 30s and 8 months pregnant was asked to do two trials. In the first trial, she sat in one of the four facing seats at one end of Car #531. When the signal was given by the experiment team member, she was asked to get up from her seat and quickly walk along the inside length of the car (approximately 66 feet (20 meters)) through the open vestibule end door, and then use the open side door to exit the car. The elapsed time from when she started to go down the aisle until she reached the door was 15 seconds, with a walking speed of approximately 4 feet (1.3 meters) per second.

During the second trial, when the signal was given, she 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 her to go the 60 feet (18 meter) distance was 12 seconds, with a walking speed of about 5.2 feet (1.6 meters) per second.

2.9.2 Participant Number 2

The second participant was a male about 40 years of age who walked with a severe limp and used a cane. In the first trial, he sat in one of the four facing seats at one end of Car #531. When the exit signal was given, he was asked to get up from his seat and quickly walk along the aisle the entire inside length of the car (approximately 66 feet (20 meters)) from his seat through the open vestibule end door, and then use the open side door to exit the car. The elapsed time from when he started going down the aisle until he reached the door was 15.3 seconds, with a walking speed of about 4.3 feet (1.3 meters) per second.

During the second trial, when the exit signal was given, 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 him to go the 60 feet (18 meter) distance was 19.8 seconds, with a walking speed of about 3 feet (0.9 meters) per second.

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 best-case walking speed data could be useful as input data for a computer simulation egress model.

2.10 SUMMARY: AUGUST 2005 EGRESS EXPERIMENTS

Commuter rail car egress experiment trials involving 86 persons who were regular train riders were conducted by Volpe Center staff at North Station, Boston, MA, on August 25, 2005.

2.10.1 Main High-Platform Egress Trials

Twelve egress trials were conducted with 84 regular commuter rail rider volunteer participants who exited from a single-level commuter rail car. The egress trials were conducted in random order and with variables unknown to the participants, including normal or simulated emergency lighting.

These main experiment high-platform egress trials generated an extensive baseline data set for event times, egress flow rates and times, and walking speeds of persons exiting from a passenger rail car to: 1) a high platform using one or two side doors, or 2) to an adjacent car through an end door.

It is emphasized that the observed and extrapolated egress data from the August 2005 experiment egress trials for occupants who use either one side door to exit from the single-level commuter rail car to the high platform or an end door to exit to the adjacent car; or two side doors to exit to the high platform represent only best-case conditions which do not reflect actual egress conditions from a passenger rail car under actual emergency conditions.

From the start of an egress trial, an average of 5 seconds elapsed until the first participant was out of the commuter rail car. The average egress flow rate for the 12 trials was about 0.9 persons per second.

Based on the observed egress trial data, the total necessary time to exit from a single-level fully loaded commuter rail car with 84-seated passengers with two-by-two seating (no standees), regardless of lighting condition, averaged 58 seconds, when using two side doors to exit onto a high platform; and 100 seconds (1 minute, 40 seconds), when using either a single side door to exit onto a high platform, or an end door to exit into an adjacent car, regardless of lighting condition.

Doubling the number of side-doors used to exit from the commuter rail car to the high platform decreased the necessary total egress time estimates by almost half.

Using the average 5-second time-to-first-person-out value and the actual egress flow rate (.87 persons per second), the total egress times for seated passengers (no standees) in a higher-capacity single-level passenger rail commuter car with the same end- and side-door configuration for the same conditions were extrapolated. The total necessary average egress time for 92 seated occupants (with no standees) to exit from the single-level fully loaded commuter rail car with the same seating configuration was estimated to be approximately 2 minutes, when using either a single side door to exit onto a high platform or an end door to exit into an adjacent car; and approximately 1 minute when using two side doors to exit onto a high platform.

The total necessary average egress time for 130 seated occupants (with no standees) was estimated to be approximately 2½ minutes, when using either a single side door to exit onto a high platform or an end door to exit into an adjacent car; it was approximately 1 minute, 20 seconds when using two side doors to exit onto a high platform.

Results of the main egress experiment indicated consistent egress times by participants for all trials, with no apparent fatigue effect and minimal learning effects due to repetition. Because of the benign conditions of the egress experiments (well-lit car end door, vestibule areas, and station platform) and the level of emergency lighting was sufficient for the participants to see the exit path, there was no significant change in the egress times or the egress flow rates under emergency and normal lighting conditions.

The August 2005 egress experiment results demonstrate that passengers of normal agility can evacuate a fully loaded (no standees) single-level high-capacity passenger rail car to a high-platform location or an adjacent car in less than 2½ minutes, under both normal and emergency-lighting conditions. This time could be long enough to allow all occupants to escape from the majority of probable fire scenarios (e.g., electrical or small trash fires), if detected in a timely manner. However, the walking speed of persons with mobility impairments may be less than half the speeds observed in the 12 main high-platform experiment egress trials described in this report. Therefore, it may be necessary to substantially increase the total necessary passenger car egress time, depending on the number of persons with mobility impairments and the behavior of the unimpaired passengers.

2.10.2 Mobility-Impaired Individual Egress Experiment

Measurement of the walking speeds of mobility-impaired individuals was not an objective of this study. However, two volunteers with conditions (one was pregnant and another had a severe limp and walked with a cane) that might have slowed their walking speeds and thus affected the time to exit the rail car in an emergency, were observed during two very brief separate egress trials which were conducted prior to the main high-platform egress experiment trials. Although extremely limited, the resulting walking speed data provide additional best-case data points for use in the egress simulation computer model.

3. EGRESS EXPERIMENTS: SIDE-DOOR STAIRWAY

To obtain egress time data for passengers exiting from a commuter rail car using the side-door stairway steps to reach the ROW between stations and the pavement at a low-platform station, a series of two follow-up egress experiments were conducted in cooperation with the MBTA. The experiments took place at the Commuter Rail Maintenance Facility, Somerville, MA, on April 19 and May 31, 2006. These side-door stairway egress data, in conjunction with the data collected and analyzed from the main high-platform egress experiment described in Chapter 2, are intended for use in estimating passenger rail car occupant egress times.

3.1 GENERAL

Each of the 2 commuter rail car experiments using side-doors stairway 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 location. 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 (gender, age, weight, and height) that had been collected previously for the 2005 experiment participants was obtained for each Volpe Center participant in the 2006 trials (see Sections 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 was assigned different seat numbers for each of the egress trials.

3.1.2 Video and Audio Data Collection

For both egress experiments, three tripod-mounted mini-digital 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 towards the side exit door and stairway steps to provide a wide-angle view of participants exiting the car. Two other cameras were placed 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 in the next sections.) The vestibule camcorder recorded audio from its internal microphone, while the external cameras were fed from a wireless microphone worn by the Lead Experimenter who provided directions to participants. For each egress trial, the video and 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 minutes (see Sections 3.2.2 and 3.3.3 for additional information.).

3.2 EGRESS USING SIDE-DOOR STAIRWAY TO ROW

3.2.1 Participants and Car Configuration

Fifteen Volpe Center employees participated in each of the ten egress trials which involved egress from the commuter rail car to the ROW using a side-door stairway. Appendix I contains age, height, weight, and gender information for each of the participants who were roughly balanced according to gender and age. One mobility-impaired individual and three other persons 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 14 shows a schematic of Car #237. For safety reasons, a new Kawasaki bilevel car (Car #930) was coupled to the Bombardier car to provide a temporary holding area for participants to return to after each of the ten trials before the start of the next trial.

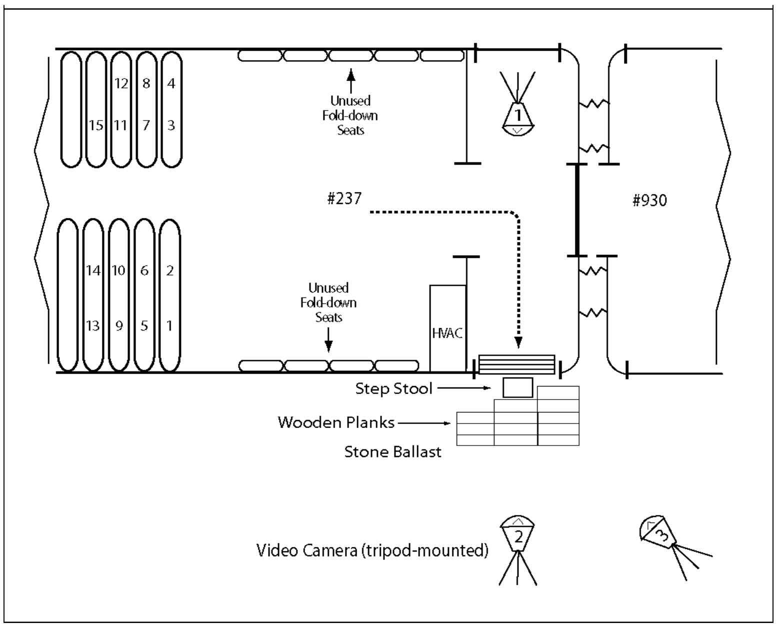

Figure 14. Car #237: Schematic – Side-Door Side Stairway (via Step Box) to ROW

Figure 15 illustrates the location of the interior car vestibule video camera and the two external video cameras.

The side-door stairway consisted of four steps, each with a riser height of 8⅝ inches (22.9 centimeters). The total stairway step distance measured from the side door sill threshold to the bottom step was 33 inches (84 centimeters). For safety reasons, since the difference in height between the bottom step of the side-door stairs of Car #237 and the ballast/ground surface was 25 inches (64 centimeters), a step box was used for persons to step down onto to reduce the step down distance from that bottom step to 16 inches (41 centimeters). In addition, 2 inch (5 centimeter)-thick wooden planking covered the immediate ballast surface area around the step box as an additional safety precaution. Figure 16 shows interior views of the rail car side-door stairway, as well as an exterior view of the side-door stairway step box, planking, and ballast at track level.

Figure 15. Car #237: Side-Door Stairway – Interior and Exterior Video Cameras

(a) Interior views (b) Exterior view

Figure 16. Car #237: Side-Door Stairway Steps

Participants were seated, all facing forward, in numbered seats in the first four rows of Car #237 (see Figure 17). The distance from the first row to the interior vestibule end door used to exit the car was 8 feet (2.4 meters).

Figure 17. Car #237: Interior – Seat Numbers and Participants

3.2.2 Egress Trial Procedure

As noted earlier, ten trials were conducted. The procedure used to direct participant actions for both side-door experiments was similar to that used in 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 planking 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 at a faster pace than the individual trials with only as much time between trials as was necessary for persons to enter the car and to be reseated.

Participants were directed to leave the rail 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 J).

Figure 18 shows the interior vestibule end door of Car #237, taped open to provide the same 33 in (84 cm)-width as the MBB end door used in the 2005 egress experiment. Figure 18 also shows participants leaving Car #237 via the car end door and entering the vestibule, and then exiting from the car using the side-door stairway steps during one of the egress trials.

Figure 18. Car #237: View of End Door, Group Passing through End Door, and Individual Descending Side-Door Stairway Steps

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.)

3.2.3 Video and Audio Format

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

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 one-hundredth of a second were added. The final video clips were also converted to an alternate video viewing media format, 720 x 540 pixel images compressed to a 4,121-kbps rate. Figure 19 shows a still image of the composite view (3 views) and a still image of an individual view for Group Trial 3 after format conversion.

Figure 19. Car #237: Side-Door Stairway – Example Video Composite and Single Screen

3.2.4 Observers

Two Volpe Center staff members who served as observers were located approximately 20 feet (6 meters) 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 co-leaders, as well as by Volpe Center audiovisual technical staff.

3.2.5 Data Analysis and Discussion

3.2.5.1 *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 or ballast) for each participant were measured. (Note: Some persons stepped directly down from the stairway steps onto the ballast, instead of first onto the planking, either partially or entirely.)

In addition, the video recordings of the five group egress trials 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 the planking;
- Time at which the last person to exit Car #237 reached the ROW (instant when both feet touched planking); and
- Count of participants (passenger count).

Data from the group trials, shown in Table 8, show consistency in egress flow times and flow rates. The average elapsed time for the first person out was about 9 seconds. The average total egress time for the five group egress trials was 53 seconds. Equations 1 and 2 (see Chapter 2) were used to calculate the egress flow rates. The average egress flow rate was approximately 0.3 persons per second. These data show that the egress flow rates for passengers who use the side-door stairway steps to exit from a rail car to the ROW (track) level, even with a step box, are much lower (only about a third) than those for egress to the high-level station platform (which averaged approximately 0.9 persons per second).

Table 8. Side-Door Stairway to ROW (Step Box and Planking): Egress Data – 1 Door

TRIAL #	START TIME	FIRST OUT (s)	LAST OUT (s)	COUNT	EGRESS FLOW TIME (s)	EGRESS 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
Average		8.84	52.99	15	44.15	.34

Representative of best-case conditions (using one side-door stairway), which do not reflect actual emergency conditions.

For a fully loaded commuter rail car of 92 or 130 seated passengers (no standees), the average 9-second elapsed time value was used with the actual egress flow rate value (.34 persons per second) to extrapolate total egress time estimates (see Equation 3 in Chapter 2) for one and two side-door stairways, as shown in Table 9.

No indications were observed of learning or fatigue effects. It is also noted that a larger or smaller proportion of mobility-impaired occupants will likely impact the difference in passenger egress times.

Table 9. Fully Loaded Car: Side-Door-Stairway to ROW – Egress Time Estimates

LOCATION	TYPE AND NUMBER OF DOORS	NUMBER OF SEATED PASSENGERS (No standees)	TOTAL EGRESS TIME# (s/min, s)
ROW (step box to planking)	One side-door stairway	92	279 s (4 min, 30 s)
		130	394 s (6 min, 4 s)
	Two side-door stairways	92	144 s (2 min, 24 s)
		130	203 s (3 min, 23 s)

Representative of best-case conditions which do not reflect egress during actual emergency conditions.

Doubling the number of side-door stairways used to exit, as shown in Table 9 decreases the total egress time estimates by about half, if each door is used by the same number of persons.

However, whether one or two side-door stairways are used to exit from a single car, individuals who have low agility or other mobility issues will likely find it difficult to exit to the ROW without additional assistance from the train crew or other passengers, which would therefore increase the actual egress time.

The video recordings from the individual egress trials showed major differences between individuals in the time required to descend the side-door stairway steps. Very agile participants completed the descent in just over 2 seconds and did not hold onto the handrail. Agile persons usually used one or both of the railings. Less agile persons needed to turn sideways and hold on to at least one of the handrails or turn around completely and hold onto the railings with both hands as shown in Figure 20.

(a) Typical agility (b) Lowest agility

Figure 20. Participant Agility: Using Step Box

The actions of the lowest agility participants increased the total time required to descend from the top step to the step box and planking by 10 to 12 seconds. The implication is that if a passenger rail car were loaded with a high proportion of seated persons of low agility, egress to the ROW, even using a step box, could take much longer than egress by the same group to a high-level platform. This is an important consideration since passengers may become injured during a severe accident, such as a passenger train collision, derailment, or fire.

3.2.5.2 *Participant Data*

Although the participants were not required to complete a detailed questionnaire for each trial of this experiment, information derived from the "sign-up" data that they initially provided and later comments (see Appendix H) are highlighted below:

- 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 due to cerebral palsy.
- Several participants stated that they learned to make better use of the handrails to descend the side-door stairway steps and to the step box as the trials progressed.

3.2.5.3 *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, because there were multiple participants 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 box 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 group egress flow rate for the 15 participants who exited from the commuter rail car to the ROW, using one side-door stairway, with a step box (to planking), during the April 2006 egress experiment trials averaged 0.3 persons per second. Accordingly, egress flow rates for passengers who exit from a passenger rail car to the ROW ballast/track level, using the side-door stairway steps, even with a step box, are likely to be much lower than those for egress to a high-level station platform (which averaged about 0.9 persons per second during the main high-platform egress trials) described in Chapter 2 of this study.

For a fully loaded commuter rail car with 92 seated passengers (no standees) who use one side-door stairway and a step box to exit to the ROW, the total egress time estimates were about 4½ minutes; and about 2 minutes, 24 seconds, if two side-door stairways were used.

For 130 seated passengers (no standees), the total egress time estimates were about 6 minutes if one side-door stairway was used to exit from the commuter rail car; and about 3 minutes and 20 seconds, if two side-door stairways were used.

Each of the observed lower agility participants increased the total time required to descend from the top step of the side-door stairway down to the ROW planking by 10 to 12 seconds. Accordingly, the proportion of mobility-impaired occupants may have a significant impact on the egress flow rate from a rail car and thus total passenger egress times. The implication is that if a passenger rail car were loaded with a high proportion of persons of low agility, egress to the ROW, even using a step box, could take much longer than egress by the same group to a high-level platform. This is an important consideration since passengers may become injured during an emergency, such as a passenger train collision/derailment or fire.

The use of two side-door stairway exits will likely decrease the time necessary to exit from the commuter rail car. However, whether one or two side-door stairways are used to exit from a single car, individuals who have low agility or other mobility issues will likely find it difficult to exit to the ROW without additional assistance from the train crew or other passengers.

The egress trials generated an extensive baseline data set for event times, egress flow rates, and total egress times of occupants who exit from a passenger rail car side-door stairway to the ROW, a unique feature of the railroad operating environment.

However, it is emphasized that the observed and extrapolated egress flow rate and egress time data for egress to the ROW, using one side-door stairway (and two side-door stairways) from the single-level commuter rail car represent best-case conditions (including use of the step box), which do <u>not</u> reflect actual egress from a passenger rail car under actual emergency conditions.

3.3 EGRESS USING SIDE-DOOR STAIRWAY TO LOW PLATFORM

3.3.1 Participants and Car Configuration

The second egress experiment also consisted of ten trials. Seventeen Volpe Center employees participated in each of 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 persons. Several of the other 16 participants were perceived to be very agile. Appendix M contains age, height and weight, and gender information for the 17 persons.

A single-level MBB car with the same interior configuration as that used at North Station in 2005 was used. Figure 21 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 22 illustrates the location of the interior vestibule video camera and two exterior video cameras.

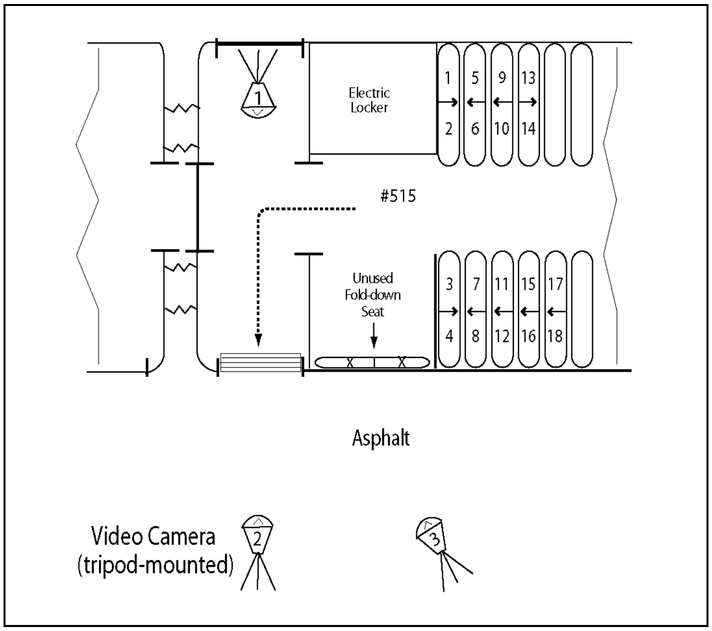

Figure 21. Car #515: Schematic – Side-Door Stairway to Low-Platform

Figure 22. Car #515: Side-Door Stairway – Interior and Exterior Video Cameras

Figure 23 shows the interior seat arrangement of Car #515, as well as the seated participants wearing vests, both identified by identification numbers.

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 specified 18 participants; however, one volunteer was unable to participate.) Some seats were transverse, and some seats faced each other and did not face the end exit door used by the participants. The distance from the first rows to the open end door used by participants was about 8 feet (2.4 meters).

Figure 23. Car #515: Interior – Seat Numbers and Participants

Figure 24 shows seated participants 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 24. Car #515: Interior View from Rear of Car during Egress Trial

Figure 25 shows the interior and exterior views of the side-door stairway used by the participants to exit from the commuter rail car during the egress experiment trials.

(a) Interior views (b) Exterior view

Figure 25. Car #515: Side-Door Stairway and Low Platform (Pavement)

The side-door stairway had four steps, each with a riser height of $8\frac{5}{8}$ inches (22.9 centimeters). The total stairway step distance measured from the door sill threshold to the bottom step was 33 inches (83.8 centimeters). The height between the bottom step of the side-door stairs of Car #515 and the pavement (e.g., low platform) was 15 inches (38 centimeters), which is less than the 16 inches (40.6 centimeters) from the bottom step to the step box described in Section 3.2.

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 exit and 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 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 persons off the car), the participants proceeded back into Car #515 using the same side-door stairway they had used to exit the car.

3.3.3 Video and Audio Format

The same video and audio conversion process, as described in Section 3.2.4, was completed to enable Volpe Center staff to analyze the video data. Figure 26 shows still photos of the composite view (three views) and an individual view for Group Trial 4.

Figure 26. Car #515: Side-Door Stairway – Example Video: Group Trial 4

Three Volpe Center staff members who acted as observers were located approximately 20 feet (6.1 meters) from Car #237, directly in front of the exterior of the side-door stairway. The 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 co-leaders, one of whom stayed on the car and the other who moved on and off the car, as well as by the Volpe Center 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

3.3.5.1 *Video*

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

As for the previous side-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).

The group trial average total egress time was approximately 31 seconds. Using Equations 1 and 2 (see Chapter 2), the egress flow rate was calculated to be approximately 0.7 persons per second. The group trial data (see Table 10) show consistency in egress flow rates.

Table 10. Side-Door Stairway to Low Platform (Pavement): Egress Data – 1 Door

TRIAL #	START TIME	FIRST OUT (s)	LAST OUT (s)	COUNT	EGRESS FLOW TIME (s)	EGRESS 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
Average		5.99	30.66	17	24.68	.69

Representative of best-case conditions (using one-side-door stairway), which do not reflect actual emergency conditions.

The average of the elapsed time for the first person out (approximately 6 seconds) and the exact flow rate value (.69) were used to extrapolate (see Equation 3 in Chapter 2) the total egress time for 92 or 130 seated passengers to exit from a fully loaded commuter rail car (with no standees) to the low platform using one or two side-door stairways, as shown in Table 11.

Doubling the number of side-door stairways used to exit, as shown in Table 11, decreases the total egress time estimates by about half, if each door is used by the same number of persons. Factors accounting for the higher egress flow rate and faster egress times in the May 2006 side-door stairway egress experiment trials compared with the April 2006 side-door stairway trials include:

- Greater agility of passengers;
- A shorter distance to step out from the stairway;
- Shorter drop from the bottom step of the stairway to the track level (in this case pavement); and
- A much larger and flat surface to step onto.

Table 11. Fully Loaded Car: Side-Door Stairway to Low Platform – Egress Time Estimates

LOCATION	TYPE AND NUMBER OF DOORS	NUMBER OF SEATED PASSENGERS (No standees)	TOTAL EGRESS TIME# (s/min, s)
LOW PLATFORM (Pavement)	One side-door stairway	92	139 s (2 min, 19 s)
		130	195 s (3 min, 15 s)
	Two side-door stairways	92	73 s (1 min, 13 s)
		130	101 s (1 min, 41 s)

Representative of best-case conditions which do not reflect actual emergency conditions.

In addition, the May 2006 experiment trials had only one participant of very low agility, while the April 2006 experiment trials had four such persons. Figure 27 shows participants with typical and lowest agility exiting from Car #515 during Group Trial 2.

The large, even, and level asphalt pavement "landing area" permitted participants to make a less-cautious descent than during the April 2006 side-door stairway egress experiment, when they had stepped from the bottom step of the stairway down to the smaller 18 inches (45.7 centimeters) surface of the step stool (slightly unsteady on the ballast), and then to the planking. Instead, in this experiment, individuals stepped directly down from the steps to the pavement (and did not have to step out to reach the step box, which had previously been used for safety reasons). Accordingly, some participants walked down the stairway without touching the handrails, while 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 individual with the lowest agility, who had also participated in the April 2006 trials, came down the side-door stairs facing forward, decreasing her descent time by half.

(a) Typical agility (b) Lower agility

Figure 27. Participant Agility

However, it is important to note that the step-down distance from the bottom step of the side-door stairway to the pavement at numerous passenger train low-platform station locations will be greater than the distance that passengers were required to traverse during the 2006 low-platform egress experiments, and step boxes are not usually available for use at commuter rail stations. A greater step-down distance will likely increase the time to exit from the car for all passengers, especially those persons with lower agility.

Moreover, whether one or two side-door stairways are used to exit from a single car, individuals who have low agility or other mobility issues may find it difficult to exit to the low-platform location without some additional assistance from the train crew or other passengers, which could further increase the actual egress time.

3.3.5.2 ***Participant Data***

Participants completed a very brief questionnaire after each of the group egress trials. The following information from the questionnaires, initial participant “sign-up” data, and later participant comments (see Appendix M) is highlighted below:

- Two participants had very high body mass index values; 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.

3.3.5.3 ***Observers***

As with the April 2006 experiment, the two observers noted a time gap of several seconds between some of the slower participants in the group trials, which was also evident in the video recordings. Since the egress flow rate of the participants was double the rate during the first experiment, and multiple persons were again on the side-door 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 actually calculate the egress flow rate.

3.3.6 Summary

The May 2006 egress experiment trials involved a group of 17 participants who used one side-door stairway to descend from a single-level commuter rail car to a low-platform pavement location.

The average total egress time for the five group egress trials was 31 seconds, and the average time for the first person out was 6 seconds. The egress flow rate was about 0.7 persons per second.

Doubling the number of side-door stairways used to exit from the commuter rail car decreases the necessary total egress time estimates by approximately half, if each door is used by the same number of occupants to exit.

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

Whether one or two side-door stairways are used to exit from a single car, individuals who have low agility or other mobility issues may find it difficult to exit to the low-platform location without some additional assistance from the train crew or other passengers because of the distance between the last stairway step and the track-level pavement; this in turn reduces the egress flow rate which could further increase the actual total necessary egress time.

3.4 COMPARISON OF APRIL AND MAY 2006 EXPERIMENTS

In the April 2006 egress to ROW experiment, participants exited the commuter rail car by using a step box after stepping down from the last step of the side-door stairway since the exit location surface consisted of wooden planking and ballast. In the May 2006 egress low-platform 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.

Egress by the participants from the commuter rail car using the side-door stairway proceeded faster in the May 2006 egress experiment trials than in the April 2006 egress trials. The shorter step down from the bottom of the stairway to the low-platform pavement (versus use of the step box to step down to the planking/ROW) was the principal factor that increased the average egress flow rate, which doubled (approximately 0.7 versus about 0.3 persons per second) between the two series of egress experiment trials. The elapsed time to the first person out of the rail car was as high as 12 seconds in the April 2006 experiment, but only 7 seconds in the May 2006 experiment, while averaging 9 seconds in the former and 6 seconds in the latter.

Table 12 shows the extrapolations from the April and May 2006 egress experiment trial data used to develop total average egress time estimates for occupants exiting from a fully loaded single-level commuter rail car with 92 or 130 seated passengers (with no standees), using either one or two side-door stairways.

Table 12. Fully Loaded Car: Side-Door Stairway – Egress Time Estimates

LOCATION	TYPE AND NUMBER OF DOORS	NUMBER OF SEATED PASSENGERS (No standees)	TOTAL EGRESS TIME# (s/min, s)
ROW (Step box to planking)	One side-door stairway	92	279 s (4 min, 30 s)
		130	394 s (6 min, 4 s)
	Two side-door stairways	92	144 s (2 min, 24 s)
		130	203 s (3 min, 23 s)
LOW PLATFORM (Pavement)	One side-door stairway	92	139 s (2 min, 19 s)
		130	195 s (3 min, 15 s)
	Two side-door stairway	92	73 s (1 min, 13 s)
		130	101 s (1 min, 41 s)

Representative of best-case conditions which do not reflect egress during actual emergency conditions.

The trial data and the extrapolations show that:

- Doubling the number of side-door stairways used to exit decreases the egress time estimates by approximately half, if each door is used by the same number of persons, and
- Egress to the ROW location (even using a step box) takes approximately twice as long as egress to a low-platform location.
- The height of the drop from the bottom side-door stairway step to the ROW (planking/ballast/ track level) or low-platform location, as well as various physical aspects of the landing area (large size, firmness, level surface, etc.) exerted strong influences on the egress flow rate that were beyond the scope of this study to fully investigate. However, such factors were observed to have the greatest effect on the behavior of persons possessing low agility.
- While some agile persons descended in less than 2 seconds without using the side-door stairway handrails, less agile participants typically held both handrails and proceeded very slowly down the stairway steps, thus slowing down all persons behind them.

This result is in contrast to occupant travel along wide aisles in buildings that allow agile individuals to overtake persons with mobility limitations.

At the flow rates observed for descent from the side-door stairway to the ROW (using a step box placed on planking at the ballast track level to simulate best-case), with 27 percent of individuals categorized as low agility, the total extrapolated time to exit from a high-capacity, fully loaded single-level coach of seated passengers using one side-door stairway was estimated to exceed 6 minutes. Had these persons had to step down the full distance from the bottom step of the car side stairway to the track-level ballast without the step box, these egress times would have been much longer, and there could have been a higher risk of personal injury.

In addition, during a passenger train situation requiring emergency egress, one or more rail car side-door stairways may not be available for passenger use because of the following: 1) crash damage or other reason, or 2) in the specific case of Amtrak's *Acela Express* trainsets, the cars are designed only for high-platform operation and thus are not equipped with integral side stairways. Accordingly, egress flow rate estimates for occupants using side or end doors to exit to low-platform or ROW locations would decrease as a result of occupant use of the "sitting jump" method from the floor of the door sill. For the *Acela Express* trainset, occupant use of either the portable stairway (provided underneath each power car), or the ladder (installed in each passenger car), <u>after they are deployed</u> would increase total egress time estimates.

3.5 SUMMARY

The 2006 egress experiment trials involved two different groups of Volpe Center participants who exited from single-level commuter rail car by using one side-door stairway to descend to: 1) the ROW location (by using a step box to planking placed on ballast at the track level), and 2) a simulated low-platform station (pavement) location.

Both 2006 series of egress experiment trials generated an extensive baseline data set for event times, egress flow rates, and total egress times of persons exiting from a typical single-level commuter rail car by using a side-door stairway to simulated ROW low-platform station locations, both unique features of the railroad operating environment.

It is emphasized that the 2006 egress experiment data represent best-case conditions which do <u>not</u> reflect actual egress from a passenger rail car under actual emergency conditions.

Egress by the participants from the commuter rail car proceeded much faster in the May 2006 egress experiment trials than in the April 2006 egress trials. The shorter step down from the bottom step of the side-door stairway to the low-platform pavement (versus using the step box to step down to the ROW track level), was the principal factor that increased the average egress flow rate, which doubled (approximately 0.7 persons per second versus about 0.3 persons per second) between the April and May 2006 egress trials.

The 2006 commuter rail car egress experiment trial data and extrapolated egress time estimates (see Table 12) showed that:

- Doubling the number of side-door stairways used to exit decreases the total necessary egress time estimates by approximately half, if each door is used by the same number of occupants.

- Egress to the ROW location (even using a step box) takes approximately twice as long as egress to a low platform.

Observation of the 2006 egress experiment video recordings showed that the height of the drop from the bottom step of the side-door stairway to the ROW track level (step box/planking/ ballast) and low-platform locations, as well as various physical aspects of the landing area (large size, firmness, level surface, etc.) exerted strong influences on the egress flow rate, which were observed to have the greatest effect on the behavior of persons possessing low agility. These influences were particularly true during the April 2006 egress trials involving occupants who exited to the ROW.

Whether one or more side-door stairways are used to exit from a single passenger rail car, individuals who have low agility or other mobility issues may find it difficult to exit to a low-platform location or to the ROW, depending on the height of the bottom step of the side-door stairway (even with a step box), without additional assistance from the train crew or other passengers, thus increasing the total egress time. Accordingly, the total egress time estimate for the necessary time to exit from a passenger rail car with a high number of persons with mobility limitations should be increased substantially.

In addition, if passenger rail side-door stairways are not available or cannot be used, the total necessary egress time estimates would be required to be much longer.

4. SUMMARY

This report describes a series of three commuter rail car egress experiments that were conducted in 2005 and 2006 by Volpe Center staff, in cooperation with the MBTA. The 2005 experiments are believed to be the first egress experiments using U.S. commuter rail cars and regular passengers recruited from the general public ridership.

This chapter summarizes the results of the analysis of the observed and quantitative data which were collected and analyzed from the three egress experiments. In addition, additional uses of the egress experiment data and further research are discussed.

4.1 COMMUTER RAIL CAR EGRESS EXPERIMENTS

The only current means to estimate occupant egress time is to conduct actual simulated passenger rail car emergency evacuations or egress experiments. Efforts to develop egress time estimates for passenger rail cars, based on formulas derived from observations of evacuations of buildings or aircraft, have not considered egress factors relating to the unique railroad operating environment. For example, if only one exit door is available, or if passengers must exit from the car at other than high-platform station locations, the drop in height from the lowest step of a car side-door stairway (if available) is much higher to the low platform or ROW, therefore reducing the egress flow rate and thus increasing total egress time.

Accordingly, the 2005 main high-platform egress experiment trials and the two series of 2006 egress experiment trials generated an extensive observational and quantitative baseline data set for occupant event times, egress flow rates, total egress times, and walking speeds (the latter only for 2005), for commuter rail car egress time estimates using different exit paths. Occupant egress time data obtained from the egress experiments described in this report (and any future experiments) are intended to provide a basis for: 1) estimating the best-case egress times from a single commuter rail car with different seating configurations using a variety of exit paths, and 2) providing a benchmark for calibration and validation of simulation models that may be used to evaluate various design aspects that may enhance or hinder timely egress during an emergency.

It is emphasized that all observed data and extrapolated estimates generated from the egress experiments described in this report are representative of best-case conditions and do not reflect actual egress from a passenger rail car under actual emergency conditions.

The main high-platform egress experiments conducted in August 2005 involved 84 regular commuter rail riders who exited from a typical single-level commuter rail car during a series of 12 trials. The selected participants were intended to represent a typical demographic range in terms of gender, age, height, and weight. The egress trials were conducted in a random order and involved exiting from the commuter rail car to a high-platform location using one or two side doors or an end door to an adjacent rail car under normal and emergency lighting conditions.

In the April 2006 egress to ROW experiment, 15 Volpe Center participants exited from a commuter rail car using a step box after stepping down from the last step of the side-door stairway; the track-level surface consisted of wooden planking and ballast. In the May 2006 egress to low-platform experiment, 17 Volpe Center participants exited from a commuter rail car by stepping off the last step of the side-door stairway directly onto flat pavement, simulating the height of a low-platform station. Compared with the 2005 high-platform egress experiment, several persons in each of the 2006 egress experiments were not regular commuter rail riders. However, the selected participants still represented a typical demographic range in terms of gender, age, height, and weight.

Results of the high-platform egress experiment trials (best-case) indicated consistent egress flow rates and total egress times by participants across trials, with no apparent fatigue effect and minimal learning effects due to repetition. No significant difference was observed between the egress trials conducted under normal lighting or emergency lighting-only conditions because of the high density in the aisles (which slowed the egress flow rate), as well as the high level of emergency lighting (well-lit car end door and vestibule areas) that enabled participants to see and exit from the car without hesitation after reaching the end and side doors.

Egress flow rates were highest for egress to the high platform (approximately 0.9 persons per second), followed by egress to the low-platform (approximately 0.7 persons per second, and egress to the ROW via step box to the planking/track level (approximately 0.3 persons per second). These egress flow rates were used to extrapolate total egress time estimates for 92 or 130 seated passengers (no standees) exiting from a fully loaded commuter rail car using different exit path locations, as shown in Table 13.

Table 13. Fully Loaded Car: All Doors – Egress Time Estimates

LOCATION	TYPE AND NUMBER OF DOORS	NUMBER OF SEATED PASSENGERS (No standees)	EGRESS TIME # (s/min, s)
HIGH-PLATFORM/ ADJACENT CAR	One side or end door	92	111 s (1 min, 51 s)
		130	154 s (2 min, 34 s)
	Two side doors	92	58 s
		130	79 s (1 min, 19 s)
ROW (Step box to planking)	One side-door stairway	92	279 s (4 min, 30 s)
		130	394 s (6 min, 4 s)
	Two side-door stairways	92	144 s (2 min, 24 s)
		130	203 s (3 min, 23 s)
LOW PLATFORM (Pavement)	One side-door stairway	92	139 s (2 min, 19 s)
		130	195 s (3 min, 15 s)
	Two side-door stairways	92	73 s (1 min, 13 s)
		130	100 s (1 min, 40 s)

Representative of best-case conditions which do not reflect actual emergency conditions

The 2005 and 2006 egress experiment data and extrapolations show that:

- Doubling the number of doors used to exit from the commuter rail car cuts egress time almost in half, if each door is used by the same number of persons;
- Egress to a low-platform location takes approximately 50% longer than egress to a high platform; and
- Egress to the ROW location (even using a step box) takes about twice as long as egress to a low-platform location.

Figure 28 shows a graphical comparison of estimated total egress times for different numbers of occupants using different door exit paths from the commuter rail car.

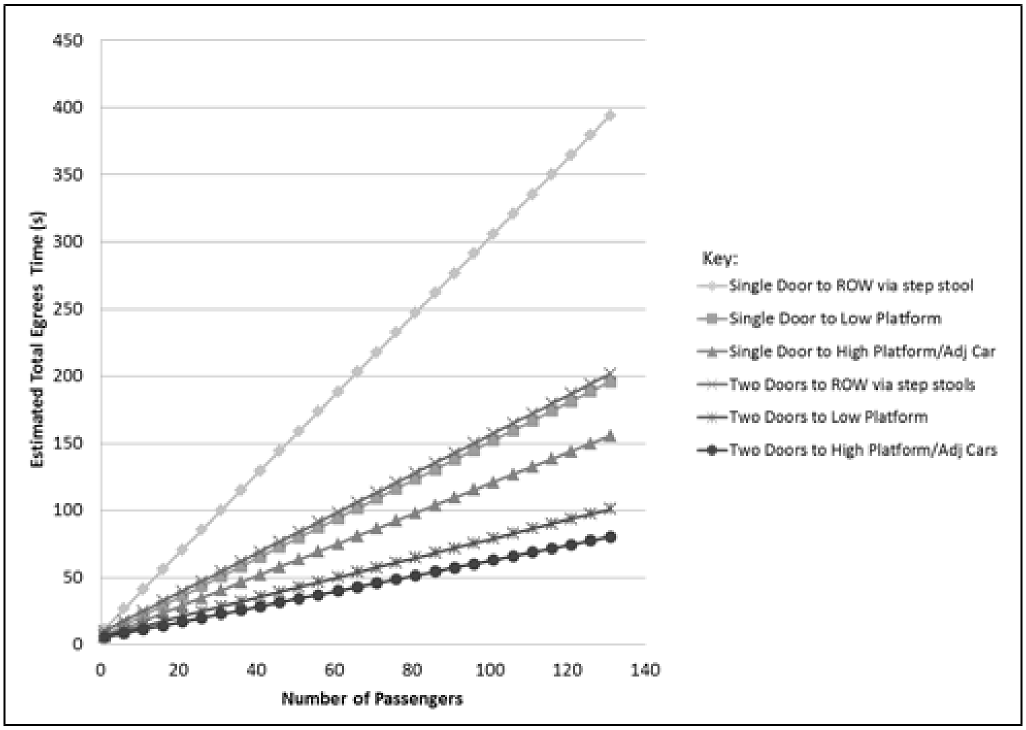

Figure 28. Fully Loaded Car: Egress Time Estimates – Different Exit Path Routes

Measurement of the walking speeds of mobility-limited individuals was not an objective of this study. However, two volunteers, a pregnant female and a male individual who walked with a severe limp and used a cane, conditions that might have slowed their walking speeds and thus affected the time to exit the rail car in an emergency, were observed during very limited egress trials conducted prior to the 2005 main high-platform experiment egress trials. The two participants each first separately walked inside along the length of the commuter rail car and exited from a side door onto the high platform through an open door, and then separately exited the rail car and walked along the outside of the car on the high platform to the other end of the car. Although extremely limited, the resulting walking speed data could be useful as input data for a computer model that simulates egress from passenger rail cars.

In addition, during a passenger train situation requiring emergency egress, one (or more) passenger rail car side-door stairways may not be available for occupant use to exit from a rail car due to: 1) crash damage or other reason; or 2) in the specific case of Amtrak's *Acela Express* trainsets, the cars are designed only for high-platform operation and thus are not equipped with integral side-door stairways. Accordingly, egress flow rate estimates for occupants using side or end doors to exit to low-platform or ROW locations would decrease as a result of occupant use of the "sitting push off" method from the floor of the door sill. For the *Acela Express* trainset, occupant use of either the portable stairway (provided underneath each power car), or the ladder (installed in each passenger car), after they are deployed, would increase total egress time estimates.

4.2 USAGE OF EGRESS TIME DATA IN EGRESS MODELING

Individual-movement models that simulate egress models could be a cost-effective means of achieving these objectives:

- Estimating total necessary egress time estimates which are affected by:
  - Rail car configurations,
  - Population demographics and/or disabilities, and
  - Type of emergency conditions; and
- Evaluation of the effects of various car design changes that may affect egress flow rates and total egress time.

However, for rail car occupant egress time estimates to realistically reflect actual railroad operating conditions and actual egress exit paths by passengers from the cars, computer models must be validated and calibrated with occupant behavior and movement data from actual egress trials. Data for rail car geometry and other variables such as lighting, for which those trials were conducted, must also be considered.

FRA has partially funded the development of a new prototype railEXODUS® egress computer model by the University of Greenwich, which can model individual movement egress times from U.S. passenger rail cars [30]. This new software can be used to develop more realistic egress time estimates for occupants using various exit paths or combinations of paths from passenger rail cars that reflect the unique railroad operating environment. If evacuation from a rail car is necessary during an emergency, exiting to low-platform or ROW locations may be the only alternatives, instead of the faster and safer egress to the adjacent car or to high-platform stations.

Calibration of the new prototype railEXODUS® software requires a great quantity of detailed data regarding the timing of all the movements of each individual occupant using various exit paths from the passenger rail car. The Volpe Center egress experiments were conducted in a manner specifically intended to provide this data, based on actual occupant movement behavior under realistic egress conditions. The experiments provided exiting data for egress from the rail car to egress to a high-platform station or to an adjacent car and egress from the car using side-door stairways to low-platform or ROW locations. Accordingly, the data obtained from the video recordings and other related information generated during the commuter rail car egress experiments described in this report, when combined with the known physical characteristics and egress behavior of each participant in the experiments, the physical characteristics of the commuter rail cars, and the environment at the time the data were recorded, provide a key means to calibrate the new passenger rail car egress computer software.

As noted previously in Section 4.1, passengers with low agility or other mobility limitations can increase total egress times, even to a high-platform station or the adjacent car, to values higher than those observed in the commuter rail car experiments. Moreover, if one or more side-door stairways are not available or cannot be used, the total necessary egress time estimates to exit to ROW and low-platform locations would be much longer, particularly if even a few passengers have mobility limitations, requiring assistance from the train crew or other passengers. This effect would be magnified if a large number of persons with low agility or other mobility limitations are on board the rail car.

An important feature of the new prototype railEXODUS® software is the capability to include different numbers of occupants with varying degrees of agility and other mobility impairments for various passenger rail car configurations and with various combinations of available egress paths, while also simulating other emergency conditions, such as emergency lighting.

The information obtained from the experiments described in this report and the development of the new prototype railEXODUS® software are intended to assist FRA in determining what, if any, revisions should be made to FRA regulations to enhance passenger train safety, particularly in terms of the number, type, size, and distribution of emergency exits, as well as other design features, such as emergency lighting and emergency signs.

4.3 FURTHER RESEARCH

Individual agility and physical obstacles have a significant impact on the amount of time necessary for individuals to exit from a passenger rail car. This suggests that future egress experiments conducted under conditions intended to simulate real emergencies should employ “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.

Additional experiments with passenger rail cars under other accident scenario conditions (cars tilted, etc.) would also provide important data inputs for the new FRA-funded passenger rail car egress software. 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 computer models that simulate egress behavior under emergency conditions could reduce the number of actual evacuation tests that need to be performed to determine egress times for various passenger rail car designs.

However, in recognition of the potential hazards, as noted in Chapter 2, Federal regulations now require that any experiment with human participants be examined and approved by an Institutional Review Board (IRB) [23]. These regulations require that subjects be fully informed of the purpose of the research, what procedures will be followed in the experiment, what benefits will accrue to the subjects or to society, what records will be kept, and any foreseeable risks or discomforts they may experience. Risks must be minimized and must be reasonable in relation to the benefits of the research. There are also various requirements related to the protection of the privacy of personal data.

Because of experience with aircraft evacuations and other evacuation tests, an IRB may not approve passenger rail car egress experiments that include higher risk scenarios (exiting from cars extremely tilted on their sides, exiting "drops" from windows, etc.) than the experiments described in this report. Moreover, it is preferable that experience with additional minimal-risk scenarios be gained before planning for higher risk evacuation conditions.

Under FRA sponsorship and with the partnership of the Washington Metropolitan Area Transit Authority (WMATA) and New Jersey Transit, an Emergency Evacuation Simulator (Rollover Rig) for passenger cars was constructed at the WMATA Training Facility located in Landover, MD (see Figure 29).


Figure 29. FRA Rollover Rig Exterior and Interior: 45 Degree Angle

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 [31]. The Rollover Rig provides a safe environment for emergency responders to practice internal and external evacuation of a derailed rail car. In addition, as part of the FRA emergency system rulemaking initiative, the Rollover Rig has been used to demonstrate different types of emergency evacuation-related equipment to government agency and industry groups.

With the cooperation of FRA and the American Public Transportation Association (APTA), in late 2006 the Volpe Center conducted an extensive egress-related demonstration for the FRA Railroad Safety Advisory Committee (RSAC) participants using the Rollover Rig. The objectives were to show participants the effect of rail car angle and different levels of emergency lighting, types of signs, etc., on exit identification and operation, as well as egress time.

In early 2010, as part of a Transportation Research Board Human Factor Transportation Emergency Egress Workshop, Volpe Center staff conducted a demonstration for 19 participants at the Rollover Rig facility [32]. The demonstrations were conducted when the commuter rail car was upright and after the car was tilted to angles of 10 and 15 degrees. The objective was to show participants the difference in walking along the car interior and exiting from the car side-door at the different angles. A report is currently in preparation that describes the results of the 2006 and 2010 Rollover Rig demonstrations.

Volpe Center staff recently learned of a Spanish research effort to develop a computer egress model that used passenger train evacuation drill data [33] [34]. However, it was not possible to include a comparison of the Volpe Center egress experiment and Spanish evacuation drill egress time results or a description of the new Spanish passenger train computer model in this report.

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APPENDIX A. Egress 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 **617-XXX-XXXX (*Volpe Center contact)***
9:00 AM – 4:30 PM, Monday-Friday.
SIGN-UP DEADLINE: August 18, 4:30 PM.

APPENDIX B. Main Egress Experiment: Participant Distribution Data

FEMALES	AGE	HEIGHT	WEIGHT
44	Under 30 – 17	Under 5 ft – None	
		5 ft to 5 ft 6 in – 11	Under 100 – 1
			100–149 – 8
			150–199 – 2
			200–249 – None
			250+ – None
		5 ft 6 in to 6 ft – 6	Under 100 – None
			100–149 – 2
			150–199 – 4
			200–249 – None
			250 +- – None
		Over 6 ft – None	
	30 to 50 – 15	Under 5 ft – 1	Under 100 – None
			100–149 – None
			150–199 – 1
			200–249 – None
			250+ – None
		5 ft to 5 ft 6 in – 13	Under 100 – None
			100–149 – 8
			150–199 – 5
			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 6 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

Main Egress Experiment: Participant Distribution Data (2)

MALES	AGE	HEIGHT	WEIGHT
40	Under 30 – 8	Under 5 ft – None	
		5 ft to 5 ft 6 in – 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
	30 to 50 – 18	Under 5 ft – None	
		5 ft to 5 ft 6 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 – 6
			200–249 – 2
			250+ – None
		Over 6 ft – 6	Under 100 – None
			100–149 – None
			150–199 – 5
			200–249 – 2
			250+ – 1
	Over 50 – 14	Under 5 ft – None	
		5 ft to 5 ft 6 in – 3	Under 100 – None
			100–149 – None
			150–199 – 3
			200–249 – None
			250+ – None
		5 ft 6 in to 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

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: Six 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 # __ * QUESTIONS /RESPONSE** TRIAL	1	2	3	4	5	6	7	8	9	10	11	12
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												
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 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 because of 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 might fall												
C holding onto the grab railing to assist/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 to be true.

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 trial commences s, 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 Volpe staff.
- 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 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 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 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.
- 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 after they leave the car away from the door by organizing them into two groups which will enter by the two side doors.
- Once the egress car is empty, begin loading participants for the next trial. Each group will be seated per the seat assignment sheet for each trial.

MARSHAL 3: (M3)

Single Door Trials: 1, 5, 7, 11

- Stand down the platform opposite the unused exit door of the egress car.
- Role is to marshal participants, organizing them after they leave the car by them onto two groups which will enter by the two side doors.
- Once the egress car is empty, begin loading participants for the next trial. Each group will be seated per the seat assignment sheet for each trial.

Adjacent Door Trials: 2, 6, 8, 12

- Stand down the platform opposite the furthest door of the egress car.
- Role is to marshal participants after they leave the car by them organizing them into two groups which will enter by the two side doors.
- Once the egress car is empty, begin loading participants for the next trial. Each group will be seated per the seat assignment sheet for each trial.

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 exit door of the egress car.
- Role is to marshal participants, organizing them into two groups.
- Role is to marshal participants after they leave the car by them onto two groups which will enter by the two side doors.
- Once the egress car is empty, begin loading participants for the next trial. Each group will be seated per the seat assignment sheet for each trial.

Adjacent Door Trials: 2, 6, 8, 12

- Stand down the platform opposite the furthest exit door of the egress car.
- Role is to marshal participants after they leave the car by them onto two groups which will enter by the two side doors.
- Once the egress car is empty, begin loading participants for the next trial. Each group will be seated per the seat assignment sheet for each trial.

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, after they leave the car by organizing them two groups which will enter by the two side doors.
- Once the egress car is empty, begin loading participants for the next trial. Each group will be seated per the seat assignment sheet for each trial

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 to step into next car _____ 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 3, 9)*

EVALUATOR'S NAME:
REPRESENTING:
ADDRESS:
PHONE:
E-MAIL:

To Platform Using Both Doors – Emergency lighting

1. Trial Start Time: ____ **A** End Time – 1st person to step onto platform ____ Last person ____

   B End Time – 1st person to step onto 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

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?

   c. 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 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

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 specific 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 at about 7 p.m. 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 ask one of the staff members wearing red hats. As you can see, there are several small video cameras and microphones located around the car. All 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, 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 six 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.

During 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.) (**Normal lights go off, emergency lighting remains on.**) (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 normal.)**

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 / RESPONSES*	PARTICIPANT RESPONSES	
	Number**	**Percentage**
TRIAL 1: Platform - 1 door - Emergency lighting (above seats 41- 43 very dim inside car)		
1. I was seated facing the exit that I used to leave the car		
A True	42	52
B False	39	48
Total (Note: only 81 persons participated in Trial 1)	81	
2. The lighting level:		
A made it hard to locate the exit	8	10
B caused me to walk slower	20	25
C made me feel that I may trip over	10	12
D made me feel that I would bump into someone	17	21
E did not cause me any difficulties	50	62
Total	105	
3. I selected which exit to use because:		
A I was following instructions	74	91
B it was nearest	25	31
C it had the shortest line of people	6	7
D I followed the crowd	17	21
Total	122	
4. In leaving my seat:		
A I had no difficulties in getting into the aisle	49	60
B I was slowed down by the person sitting next to me	18	22
C I had to wait for a gap in the line before getting into the aisle	27	33
D people let me into the line, even though there was a long line	28	35
E I had to push my way into the aisle	2	2
Total	124	
5. When I was in the aisle / line moving towards the exit:		
A I could walk at the speed I wanted to	24	30
B I had to walk slowly since the line was moving slowly	53	65
C I sometimes stopped to let people into the line	18	22
D I tried to pass people but couldn't due to the crowd	3	4
E I didn't try to pass people because it was unnecessary/impolite	44	54
F people behind me were pushing me	2	2
G I was moving slowly because I felt tired	1	1
Total	145	
6. On exiting the car, I stepped out:		
A normally	75	93
B slowly because I thought I may fall	4	5
C holding onto the grab railing to assist me/support myself	2	2
Total	81	

* Passengers completes the questions after each of the 12 trials.

** Participants were told to check as many responses as they believed to be true

QUESTIONS / RESPONSES	PARTICPANT RESPONSES	
	Number	Percentage
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
B False	38	46
Total	83	
2. The lighting level:		
A made it hard to locate the exit	2	2
B caused me to walk slower	7	8
C made me feel that I may trip over	2	2
D made me feel that I would bump into someone	3	4
E did not cause me any difficulties	72	22
Total	86	
3. I selected which exit to use because:		
A I was following instructions	82	99
B it was nearest	7	8
C it had the shortest line of people	3	4
D I followed the crowd	18	22
Total	110	
4. In leaving my seat:		
A I had no difficulties in getting into the aisle	43	52
B I was slowed down by the person sitting next to me	17	20
C I had to wait for a gap in the line before getting into the aisle	35	42
D People let me into the line, even though there was a long line	36	43
E I had to push my way into the aisle	0	0
Total	131	
5. When I was in the aisle / line moving towards the exit:		
A I could walk at the speed I wanted to	32	39
B I had to walk slowly since the line was moving slowly	51	61
C I sometimes stopped to let people into the line	21	25
D I tried to pass people but couldn't due to the crowd	9	11
E I didn't try to pass people because it was unnecessary/impolite	37	45
F people behind me were pushing me	0	0
G I was moving slowly because I felt tired	0	0
Total	150	
6. On exiting the car, I stepped out:		
A normally	82	99
B slowly because I thought I may fall	1	1
C holding onto the grab railing to assist me/support myself	2	2
Total	85	

QUESTIONS /RESPONSES	PARTICPANT RESPONSES	
	Number	Percentage
TRIAL 3: Platform - Both doors - Emergency lighting (above seats 41- 43 very dim inside car)		
1. I was seated facing the exit that I used to leave the car		
A True	53	64
B False	30	36
Total	83	
2. The lighting level:		
A made it hard to locate the exit	8	10
B caused me to walk slower	22	27
C made me feel that I may trip over	5	6
D made me feel that I would bump into someone	15	18
E did not cause me any difficulties	56	67
Total	106	
3. I selected which exit to use because:		
A I was following instructions	25	30
B it was nearest	71	86
C it had the shortest line of people	15	18
D I followed the crowd	16	19
Total	127	
4. In leaving my seat:		
A I had no difficulties in getting into the aisle	42	51
B I was slowed down by the person sitting next to me	22	27
C I had to wait for a gap in the line before getting into the aisle	35	42
D people let me into the line, even though there was a long line	33	40
E I had to push my way into the aisle	9	11
Total	141	
5. When I was in the aisle / line moving towards the exit:		
A I could walk at the speed I wanted to	29	35
B I had to walk slowly since the line was moving slowly	48	58
C I sometimes stopped to let people into the line	24	29
D I tried to pass people but couldn't due to the crowd	5	6
E I didn't try to pass people because it was unnecessary/impolite	37	45
F people behind me were pushing me	2	2
G I was moving slowly because I felt tired	0	0
Total	145	
6. On exiting the car, I stepped out:		
A normally	82	99
B slowly because I thought I may fall	2	2
C holding onto the grab railing to assist/support myself	2	2
Total	86	

QUESTIONS / RESPONSES	PARTICIPANT RESPONSES	
	Number	Percentage
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.
B False	36	43
Total	84	
2. The lighting level:		
A made it hard to locate the exit	1	1%
B caused me to walk slower	2	2
C made me feel that I may trip over	3	4
D made me feel that I would bump into someone	2	2.
E did not cause me any difficulties	79	94
Total	87	
3. I selected which exit to use because:		
A I was following instructions	26	31
B it was nearest	74	88
C it had the shortest line of people	21	25
D I followed the crowd	14	17
Total	135	
4. In leaving my seat:		
A I had no difficulties in getting into the aisle	51	61
B I was slowed down by the person sitting next to me	16	19
C I had to wait for a gap in the line before getting into the aisle	27	32
D people let me into the line, even though there was a long line	28	33
E I had to push my way into the aisle	4	5
Total	126	
5. When I was in the aisle / line moving towards the exit:		
A I could walk at the speed I wanted to	37	32
B I had to walk slowly since the line was moving slowly	43	68
C I sometimes stopped to let people into the line	19	29
D I tried to pass people but couldn't due to the crowd	3	2
E I didn't try to pass people because it was unnecessary/impolite	33	44
F people behind me were pushing me	0	1
G I was moving slowly because I felt tired	1	1
Total	136	
6. On exiting the car, I stepped out:		
A normally	83	99
B slowly because I thought I may fall	1	1
C holding onto the grab railing to assist me/support myself	2	2
Total	86	

QUESTIONS / RESPONSES	PARTICPANT RESPONSES	
	Number	**Percentage**
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	
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	
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	
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	
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	
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	

QUESTIONS / RESPONSES	PARTIPCANT RESPONSES	
	Number	Percentage
TRIAL 6: Next car - End door - Emergency lighting (above seats 41- 43 very dim inside car)		
1. I was seated facing the exit that I used to leave the car		
A True	45	54
B False	39	46
Total	84	
2. The lighting level:		
A made it hard to locate the exit	7	8
B caused me to walk slower	20	24
C made me feel that I may trip over	5	6
D made me feel that I would bump into someone	8	10
E did not cause me any difficulties	57	68
Total	97	
3. I selected which exit to use because:		
A I was following instructions	78	93
B it was nearest	9	11
C it had the shortest line of people	2	2
D I followed the crowd	19	23
Total	108	
4. In leaving my seat:		
A I had no difficulties in getting into the aisle	35	42
B I was slowed down by the person sitting next to me	22	26
C had to wait for a gap in the line before getting into the aisle	41	49
D people let me into the line, even though there was a long line	33	39
E I had to push my way into the aisle	3	4
Total	134	
5. When I was in the aisle / line moving towards the exit:		
A I could walk at the speed I wanted to	31	37
B I had to walk slowly since the line was moving slowly	57	68
C I sometimes stopped to let people into the line	21	25
D I tried to pass people but couldn't due to the crowd	3	4
E I didn't try to pass people because it was unnecessary/impolite	38	45
F people behind me were pushing me	1	1
G I was moving slowly because I felt tired	1	1
Total	152	
6. On exiting the car, I stepped out:		
A normally	82	99
B slowly because I thought I may fall	1	1
C holding onto the side rails to support myself	2	2
Total	85	

QUESTIONS / RESPONSES	PARTICPANT RESPONSES	
	Number	**Percentage**
TRIAL 7: Platform - 1 door - Emergency lighting (above seats 41- 43 very dim inside car)		
1. I was seated facing the exit that I used to leave the car		
A True	41	49
B False	43	51
Total	84	
2. The lighting level:		
A made it hard to locate the exit	6	7
B caused me to walk slower	19	23
C made me feel that I may trip over	4	5
D made me feel that I would bump into someone	12	14
E did not cause me any difficulties	56	67
Total	97	
3. I selected which exit to use because:		
A I was following instructions	82	98
B it was nearest	16	19
C it had the shortest line of people	2	2
D I followed the crowd	16	19
Total	116	
4. In leaving my seat:		
A I had no difficulties in getting into the aisle	44	52
B I was slowed down by the person sitting next to me	28	33
C I A341had to wait for a gap in the line before getting into the aisle	27	32
D people let me into the line, even though there was a long line	27	32
E I had to push my way into the aisle	5	6
Total	131	
5. When I was in the aisle / line moving towards the exit:		
A I could walk at the speed I wanted to	30	36
B I had to walk slowly since the line was moving slowly	57	68
C I sometimes stopped to let people into the line	24	29
D I tried to pass people but couldn't due to the crowd	3	4
E I didn't try to pass people because it was unnecessary/impolite	40	48
F people behind me were pushing me	1	1
G I was moving slowly because I felt tired	0	0
Total	155	
6. On exiting the car, I stepped out:		
A normally	80	95
B slowly because I thought I may fall	4	5
C holding onto the grab railing to assist me/support myself	2	2
Total	86	

QUESTIONS / RESPONSES	PARTICIPANT RESPONSES	
	Number	**Percentage**
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
B False	36	43
Total	84	
2. The lighting level:		
A made it hard to locate the exit	2	2
B caused me to walk slower	7	8
C made me feel that I may trip over	1	1
D made me feel that I would bump into someone	1	1
E did not cause me any difficulties	77	92
Total	88	
3. I selected which exit to use because:		
A I was following instructions	81	96
B it was nearest	8	10
C it had the shortest line of people	3	4
D I followed the crowd	19	23
Total	111	
4. In leaving my seat:		
A I had no difficulties in getting into the aisle	49	58
B I was slowed down by the person sitting next to me	16	19
C had to wait for a gap in the line before getting into the aisle	29	35
D people let me into the line, even though there was a long line	22	26
E I had to push my way into the aisle	4	5
Total	120	
5. When I was in the aisle / line moving towards the exit:		
A I could walk at the speed I wanted to	33	39
B I had to walk slowly since the line was moving slowly	55	65
C I sometimes stopped to let people into the line	20	24
D I tried to pass people but couldn't due to the crowd	1	1
E I didn't try to pass people because it was unnecessary/impolite	33	39
F people behind me were pushing me	0	0
G I was moving slowly because I felt tired	1	1
Total	143	
6. On exiting the car, I stepped out:		
A normally	83	99
B slowly because I thought I may fall	1	1
C holding onto the grab railing to assist me/support myself	2	2
Total	86	

QUESTIONS / RESPONSES	PARTICPANT RESPONSES	
	Number	**Percentage**
TRIAL 9: Platform - 2 doors - Emergency lighting (above seats 41- 43 very dim inside car)		
1. I was seated facing the exit that I used to leave the car		
A True	59	70
B False	25	30
Total	84	
2. The lighting level:		
A made it hard to locate the exit	10	12
B caused me to walk slower	15	18
C made me feel that I may trip over	4	5
D made me feel that I would bump into someone	8	10
E did not cause me any difficulties	61	73
Total	98	
3. I selected which exit to use because:		
A I was following instructions	36	43
B it was nearest	63	75
C it had the shortest line of people	17	20
D I followed the crowd.	15	18
Total	131	
4. In leaving my seat:		
A I had no difficulties in getting into the aisle	48	57
B I was slowed down by the person sitting next to me	19	23
C I had to wait for a gap in the line before getting into the aisle	30	36
D people let me into the line, even though there was a long line	17	20
E I had to push my way into the aisle	2	2
Total	116	
5. When I was in the aisle / line moving towards the exit:		
A I could walk at the speed I wanted to	39	46
B I had to walk slowly since the line was moving slowly	40	48
C I sometimes stopped to let people into the line	19	23
D I tried to pass people but couldn't due to the crowd	2	2
E I didn't try to pass people because it was unnecessary/impolite	36	43
F people behind me were pushing me	1	1
G I was moving slowly because I felt tired	0	0
Total	137	
6. On exiting the car, I stepped out:		
A normally	82	98
B slowly because I thought I may fall	2	2
C holding onto the grab railing to assist me/support myself	2	2
Total	86	

QUESTIONS / RESPONSES	PARTICPANT RESPONSES	
	Numbers	Percentage
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
B False	31	37
Total	84	
2. The lighting level:		
A made it hard to locate the exit	2	2
B caused me to walk slower	2	2
C made me feel that I may trip over	1	1
D made me feel that I would bump into someone	2	2
E did not cause me any difficulties	79	94
Total	86	
3. I selected which exit to use because:		
A I was following instructions	30	36
B it was nearest	74	88
C it had the shortest line of people	14	17
D I followed the crowd.	15	18
Total	133	
4. In leaving my seat:		
A I had no difficulties in getting into the aisle	45	54
B I was slowed down by the person sitting next to me	21	25
C I had to wait for a gap in the line before getting into the aisle	30	36
D people let me into the line, even though there was a long line	20	24
E I had to push my way into the aisle	4	5
Total	120	
5. When I was in the aisle / line moving towards the exit:		
A I could walk at the speed I wanted to	31	37
B I had to walk slowly since the line was moving slowly	50	60
C I sometimes stopped to let people into the line	18	21
D I tried to pass people but couldn't due to the crowd	2	2
E I didn't try to pass people because it was unnecessary/impolite	36	43
F people behind me were pushing me	2	2
G I was moving slowly because I felt tired	2	2
Total	141	
6. On exiting the car, I stepped out:		
A normally	82	98
B slowly because I thought I may fall	2	2
C holding onto grab railing to assist me/support myself	1	1
Total	85	

QUESTIONS / QUESTIONS	PARTICIPANT RESPONSES	
	Number	**Percentage**
TRIAL 11: Platform - 1 door - Normal lighting		
1. I was seated facing the exit that I used to leave the car		
A True	45	54
B False	39	46
Total	84	
2. The lighting level:		
A made it hard to locate the exit	3	4
B caused me to walk slower	1	1
C made me feel that I may trip over	1	11
D made me feel that I would bump into someone	0	0
E did not cause me any difficulties	80	95
Total	85	
3. I selected which exit to use because:		
A I was following instructions	79	94
B it was nearest	14	17
C it had the shortest line of people	5	6
D I followed the crowd.	13	15
Total	111	
4. In leaving my seat:		
A I had no difficulties in getting into the aisle	48	57
B I was slowed down by the person sitting next to me	17	20
C had to wait for a gap in the line before getting into the aisle	30	36
D people let me into the line, even though there was a long line	20	24
E I had to push my way into the aisle	3	4
Total	118	
5. When I was in the aisle / line moving towards the exit:		
A I could walk at the speed I wanted to	28	33
B I had to walk slowly since the line was moving slowly	57	68
C I sometimes stopped to let people into the line	16	19
D I tried to pass people but couldn't due to the crowd	1	1
E I didn't try to pass people because it was unnecessary/impolite	31	37
F people behind me were pushing me	0	0
G I was moving slowly because I felt tired	1	1
Total	134	
6. On exiting the car, I stepped out:		
A normally	83	99
B slowly because I thought I may fall	1	1
C holding onto the grab railing to assist me / support myself	1	1
Total	85	

QUESTIONS / RESPONSES	PARTICIPANT RESPONSES	
	Number	**Percentage**
TRIAL 12: Next car - End door - Emergency lighting (above seats 41- 43 very dim inside car)		
1. I was seated facing the exit that I used to leave the car		
A True	43	51
B False	41	49
Total	84	
2. The lighting level:		
A made it hard to locate the exit	5	6
B caused me to walk slower	20	24
C made me feel that I may trip over	5	6
D made me feel that I would bump into someone	8	10
E did not cause me any difficulties	62	74
Total	100	
3. I selected which exit to use because:		
A I was following instructions	82	98
B it was nearest	11	13
C it had the shortest line of people	2	2
D I followed the crowd	12	14
Total	107	
4. In leaving my seat:		
A I had no difficulties in getting into the aisle	41	49
B I was slowed down by the person sitting next to me	26	31
C I had to wait for a gap in the line before getting into the aisle	24	29
D people let me into the line, even though there was a long line	18	21
E I had to push my way into the aisle	2	2
Total	111	
5. When I was in the aisle / line moving towards the exit:		
A I could walk at the speed I wanted to	38	45
B I had to walk slowly since the line was moving slowly	48	57
C I sometimes stopped to let people into the line	21	25
D I tried to pass people but couldn't due to the crowd	2	2
E I didn't try to pass people because it was unnecessary/impolite	31	37
F people behind me were pushing me	1	1
G I was moving slowly because I felt tired	1	1
Total	142	
6. On exiting the car, I stepped out:		
A normally	81	96
B slowly because I thought I may fall	2	2
C holding onto the grab railing to assist me / support myself	1	1
Total	84	

APPENDIX I. Side-Door Stairway (ROW) Experiment 1: Participant Characteristic and Comment Data

Side-Door Stairway and Step Box to Planking (ROW) 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

** Participated in 5-31-06 egress trial

See attached participant comments

Side-Door Stairway and Step Box to Planking (ROW) 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 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-platform stations.
7	Not a regular commuter rail rider. Have ridden commuter rail twice in the last year. Of the four 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 handrails, 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 Stairway and Step Box to Planking (ROW) April 19, 2006
Vest Number & Comments (2)

VEST #	COMMENTS
8	Do not ride commuter rail. Rode commuter rail, about ten years ago. Here are some of my observations about yesterday's experiment. During the first individual run, I tried not to use the handrails when I exited and I had a bit of problem getting onto the stool. As the runs went on, used the handrails as much as could when exiting. Getting onto the stool is difficult because the different step heights. (This is similar to situations when people trip over old staircases when each step has a different height.) For example, heights between adjacent steps in the cart are uniform. But the distance between the last step in the cart and the stool is much bigger. Can envision a lot of people tripping at the bottom when exiting in an emergency situation.
10	Not a regular commuter rail rider. Have taken the commuter rail maybe twice within the last two years. Think my answer would be high platforms.
11	Not a regular rider. Have not ridden in the last year. Have ridden commuter rail (though not as a regular commuter) very occasionally many years ago.
12	Not regular rider. Have ridden but not in the last year. I have used high and low platforms but infrequently. The last step down and first step up were too high. If were traveling to work, would have at least 1 bag, probably 2, and it would be more difficult to exit safely.
13	Regular rider. High platform.
14	Not a commuter rail rider. Not in the last year. But ridden possibly three times. Both types of platform. Enjoyed the experience and hope my comments are helpful. The bottom step was a killer, which I'm sure you are aware of. That bottom step to the step stool was extremely high. On my first individual exit, I wasn't prepared for that height nor the jolt to my left knee. I also, overly confidently, didn't hold onto both railings. After that first exit, I adjusted for step height and also held onto both railings and stepped down onto the stool in a way that was easier on my knee. Clearly you need your hands free to step down to that stool. I wouldn't want to exit that train unless both hands were free to hold onto the railings. I think even my shoulder pocketbook might have caused problems.
15	None

Side-Door Stairway and Step Box to Planking (ROW) April 19, 2006 – Gender

GENDER	VEST	AGE GROUP	HEIGHT	WEIGHT (lb)	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

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

See participant comments

Side-Door Stairway and Step Box to Planking (ROW) April 19, 2006 – Age

AGE GROUP	GENDER	VEST	HEIGHT	WEIGHT (lb)	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 (ROW) Experiment 1: Scripts

MBTA MAINTENANCE YARD
COMMUTER RAIL CAR SIDE-DOOR STAIRWAY (ROW) 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 as 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 SIDE-DOOR STAIRWAY (ROW) EGRESS TRIALS
April 19, 2006

SCRIPT 2: GROUP EXITS

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

<u>Volpe Staff:</u> For the following trials, we want you to sit in seats as assigned. 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 according 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 that you have all of your belongings.

APPENDIX K. Side-Door Stairway (ROW) 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 (G-1 through G-4) are the vest numbers for each individual assigned to sit in the seat number for each group trial.

APPENDIX L. Side-Door Stairway (ROW) Experiment 1: Observer Note Sheet

MBTA STAIRWAY EGRESS TRIALS – APRIL 19, 2006 (*also used for Experiment 2 – May 31, 200*6)

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 puts 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 (ROW) 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.

Trial 2

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

   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 (Low Platform) Experiment 2: Participant Characteristic and Data

Side-Door Stairway to Low-Platform Pavement – May 31, 2006 – Vest Number

VEST	GENDER	AGE GROUP	HEIGHT	WEIGHT (lb)	COMMUTER PASS/ COMMENT #
1*	F	30–50	5 ft to 5 ft 5 in	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 6 ft	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 participant comments on page 108

Side Door Stairway to Low-Platform Pavement May 31, 2006 – Vest Number and Comments

VEST #	COMMENTS
1	Use the commuter rail train approximately 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 and 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 days 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

Stairway to Low-Platform Pavement, May 31, 2006 – Gender

GENDER	VEST	AGE GROUP	HEIGHT	WEIGHT (lb)	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 ft 6 in	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 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 trial

[#] See comments on page 108

Side Door Stairway 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 comments on page 108

APPENDIX N. Side-Door Stairway (Low Platform) Experiment 2: Script

MBTA MAINTENANCE YARD
COMMUTER RAIL SIDE DOOR STAIRWAY(LOW PLATFORM) 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. Everyone in your seats? OK.   Please do not carry any belongings when you leave car; 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 SIDE-DOOR STAIRWAY (LOW PLATFORM) 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. 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 please check to see if you have left any of your belongings.

APPENDIX O. Side-Door Stairway (Low Platform) 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 assigned to sit in the seat number for each group trial.

APPENDIX P. Side-Door Stairway (ROW) 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 (Low Platform) Experiment 2: Questionnaire Data

Side-Door Stairway (Low Platform) Group Trial 1 – May 31, 2006

QUESTION / RESPONSE*	PARTICIPANT RESPONSES**	
	Number	Percentage
1. I was seated facing the exit that I used to leave the car:		
A True	12	71
B False	5	29
Total	17	
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	
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	
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	

* Separate form completed by each participant for each group egress trial.

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

Side-Door Stairway (Low Platform) Group Trial 2 - May 31, 2006

QUESTION / RESPONSE	PARTICPANT RESPONSES	
	Number	Percentage
1. I was seated facing the exit that I used to leave the car:		
A True	12	71
B False	5	29
Totals	17	
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	
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	
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	

Side-Door Stairway (Low Platform) Group Trial 3 - May 31, 2006

QUESTION / RESPONSE	PARTICIPANT RESPONSES	
	Number	Percentage
1. I was seated facing the exit that I used to leave the car:		
A True	13	76
B False	4	24
Total	17	
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	
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	

Side-Door Stairway (Low Platrform) Group Trial 4 - May 31, 2006

QUESTION / RESPONSE	PARTICPANT RESPONSES	
	Number	Percentage
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

Side-Door Stairway (Low Platform) Group Trial 5 - May 31, 2006

QUESTION / RESPONSE	PARTICIPANT RESPONSES	
	Number	**Percentage**
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	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
Total	24	142

APPENDIX R. References

1 Federal Railroad Administration (FRA). Code of Federal Regulations, Title 49, Transportation (49 CFR). Part 238, Passenger Equipment Safety Standards. U.S. Department of Transportation (USDOT). Office of the Federal Register, National Archives and Records Administration, Washington, DC. As of October 1, 2011.

2 FRA. 49 CFR. Part 239, Passenger Train Emergency Preparedness. USDOT. National Archives and Records Administration, Office of the Federal Register, Washington, DC. As of October 1, 2011.

3. National Transportation Safety Board (NTSB). Derailment of Amtrak Train No. 58, City of New Orleans, Near Flora, Mississippi, April 6, 2004. Adopted on July 26, 2005. Report no. RAR-05-02.

4 NTSB. Derailment of Amtrak Train No. 30, The Capitol Limited, on CSX Transportation's Metropolitan Subdivision in Kensington, Maryland, July 29, 2002. Adopted on May 28, 2004. Report no. RAB-04-05.

5 NTSB. Collision of Metrolink Commuter Train and Stake Bed Truck in Burbank, California, January 6, 2003. Adopted on May 28, 2004. Report no. RAB-03-04.

6 NTSB. Derailment of Amtrak Auto Train on the CSXT Railroad Near Crescent City, Florida, April 18, 2002. Adopted on December 2, 2003. Report no. RAR-03-02.

7 NTSB. Collision of Burlington Northern Santa Fe Freight Train With Metrolink Passenger Train, Placentia, California, April 23, 2002. Adopted on October 7, 2003. Report no. RAR-03-04.

8 NTSB. Derailment of Amtrak Train No. 30, The Capitol Limited, on CSX Transportation's Metropolitan Subdivision in Kensington, Maryland, July 29, 2002. Adopted on May 28, 2004. Report no. RAB-04-05.

9 NTSB. Collision and Derailment of Maryland Rail Commuter MARC Train 286 and National Railroad Passenger Corporation AMTRAK Train 29 Near Silver Spring, MD February 16, 1996. Adopted on June 17, 1997. Report no. RAR-97-02.

10 NTSB. Near Head-on Collision and Derailment of Two New Jersey Transit Commuter Trains Near Secaucus, New Jersey February 9, 1996. Adopted on March 25, 1997. Report no. RAR-97-01.

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