UMTA-MA-06-0098-84-2
DOT-TSC-UMTA-84-36

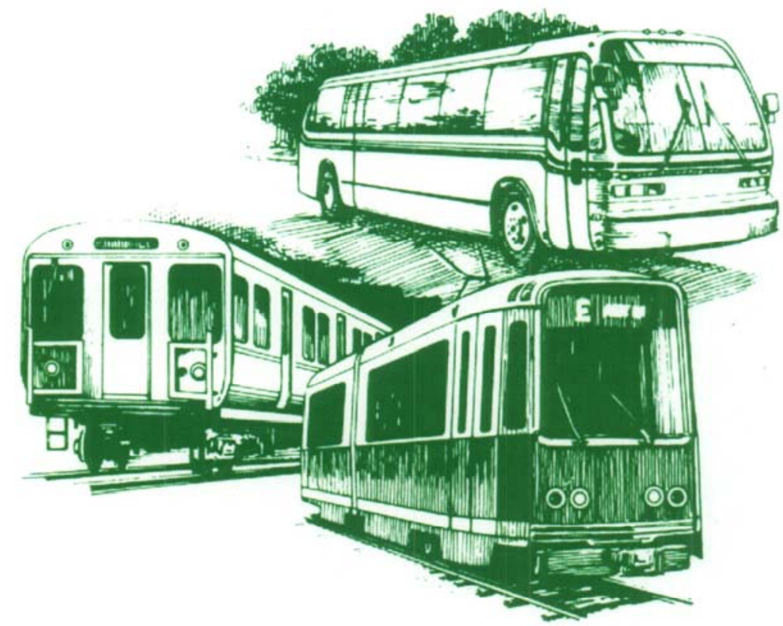
U. S. Department
of Transportation

Federal Transit Administration

Pedestrian Falling Accidents in Transit Terminals

Port Authority of New York
and New Jersey

February 1985
Final Report



Federal Transit Administration

REPORT DOCUMENTATION PAGE	*Form Approved* *OMB No. 0704-0188*

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	February 1985 Reprint December 1997	Final Report June 1984 - October 1984

4. TITLE AND SUBTITLE PEDESTRIAN FALLING ACCIDENTS IN TRANSIT TERMINALS	5. FUNDING NUMBERS U8027/TM854
6. AUTHOR(S) John J. Fruin, Dilip K. Guha, Rolf F. Marshall	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Port Authority of New York and New Jersey* One World Trade Center New York, NY 10048	8. PERFORMING ORGANIZATION REPORT NUMBER DOT-TSC-UMTA-84-36
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) U.S. Department of Transportation Urban Mass Transportation Administration Office of Technical Assistance Washington, DC 20590	10. SPONSORING/MONITORING AGENCY REPORT NUMBER UMTA-MA-06-0098-84-2

11. SUPPLEMENTARY NOTES

*Under Contract to: U.S. Department of Transportation
Research and Special Programs Administration
Volpe National Transportation Systems Center
Cambridge, MA 02142-1093

12a. DISTRIBUTION/AVAILABILITY STATEMENT	12b. DISTRIBUTION CODE
This document is available to the public through the National Technical Information Service, Springfield, VA 22161	

13. ABSTRACT (Maximum 200 words)

Falls are the second largest cause of accidental injury in the U.S. Based on the reports to the Federal Railroad Administration, the U.S. rail transit industry carried 7.25 billion passengers during the period 1976-1980, and these patrons experienced about 10,000 station falls. Analysis of accident reports in one system shows alcohol involvement in 29 percent of all falls and 55 percent of male falls where an ambulance was called. Off-peak incident rates were higher, and the P.M. peak is higher than A.M. Most transit falls are due to personal factors. Station falls cost the transit industry an estimated $1.7 million annually in claims settlements. Societal cost for lost time and hospitalization are about the same. High industry standards of design and maintenance result in lower incident rates and settlements than the general experience. Design improvements are warranted to reduce incident rates, severity, and claims. Use of a uniform accident reporting form, and reporting threshold consistent with U.S. Consumer Products Safety Commission data is recommended. A workshop seminar involving industry representatives indicated support for a uniform industry reporting form and the use of media campaigns to encourage safe practices to avoid falls.

14. SUBJECT TERMS Falling Accidents, Pedestrians, Transit Terminals, Design, Risk Management	15. NUMBER OF PAGES 108
	16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. 239-18
298-102

PREFACE

This study of pedestrian falling accidents in transit terminals was performed by the Port Authority of New York and New Jersey and describes their pedestrian accident experience over a year of data collection. In addition, a discussion of methods to reduce injury claims, issues concerning pedestrian safety, and standardization of injury reporting methods is included. This project was funded by the U.S. Department of Transportation, Urban Mass Transportation Administration (UMTA), Office of Technical Assistance, Safety and Security Staff. It was monitored by the Transportation Systems Center (TSC), Transit Safety and Security Division.

The authors wish to extend their appreciation to Lloyd Murphy and Roy Field of UMTA and Robert Pawlak and Robert Rudich of TSC for the direction, comments, and insights which made publication of this document possible.

METRIC/ENGLISH CONVERSION FACTORS

ENGLISH TO METRIC

LENGTH (APPROXIMATE)

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

AREA (APPROXIMATE)

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

MASS – WEIGHT (APPROXIMATE)

1 ounce (oz)	=	28 grams (gm)
1 pound (lb)	=	45 kilogram (kg)

1 short ton = 2,000 pounds (lb) = 0.9 tonne (t)

VOLUME (APPROXIMATE)

1 teaspoon (tsp)	=	5 milliliters (ml)
1 tablespoon (tbsp)	=	15 milliliters (ml)
1 fluid ounce (fl oz)	=	30 milliliters (ml)
1 cup (c)	=	0.24 liter (l)
1 pint (pt)	=	0.47 liter (l)
1 quart (qt)	=	0.96 liter (l)
1 gallon (gal)	=	3.8 liters (l)
1 cubic foot (cu ft, ft3)	=	0.03 cubic meter (m^3)
1 cubic yard (cu yd, yd3)	=	0.76 cubic meter (m^3)

TEMPERATURE (EXACT)

°C=5/9(°F - 32)

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)

°F=9/5(°C) + 32

QUICK INCH-CENTIMETER LENGTH CONVERSION

INCHES.	0		1		2			3		4			5
CENTIMETERS	0	1	2	3	4	5	6	7	8	9	10	11	12	13

QUICK FAHRENHEIT –CELSIUS TEMPERATURE CONVERSION

°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. Updated 8/1/96

TABLE OF CONTENTS

Secion Page

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

Falls on the same level, and from one level to another, rank second only to the highway casualties as the leading cause of death and injury in the United States. In the period 1976-1980 inclusive, the U.S. Transit Industry reported about 10,000 patron falling accidents in transit stations to the Federal Railroad Administration (FRA), while carrying 7.25 billion passengers. This incident rate is lower than that experienced in industry and in the home, attributable to the transit industry's high standards of design, maintenance and housekeeping.

Based on this study, approximately one out of every four to five victims of a falling accident file a claim for damages against a transit property, alleging negligence. Limited data obtained in the study indicates that industry settlements for claims, excluding administrative costs, are usually lower than the general experience, averaging about $1000 to $1500 per claimant. The estimated total of industry claims settlement cost for pedestrian falling accidents in stations based on passenger exposures and the accident rates developed in the report analysis is about $1.7 million annually. This cost is likely to escalate because of the increasing average age of the population and inflation of medical costs. There is also growing awareness by transit patrons of the possibility of obtaining compensation for damages, even when the victim is personally responsible for the accident. Societal costs of transit station falling accidents in terms of lost time and hospitalization costs are approximately the same as the claims cost. Transit industry administrative costs for risk and claims management significantly exceed the actual cost of claims settlements.

The objective of a Risk and Claims Management Program is to reduce falling accident experience in terms of both frequency and severity of accidents, and to reduce all associated costs. A systematic approach is necessary in a Risk Management Program involving: (1) evaluation and analysis of accident experience, (2) safety inspection of pedestrian facilities, (3) review of facility design, (4) communication of safety information and standards of safe practice, (5) development of cost-effective insurance coverage.

Transit properties participating in this study were found to be using different types of internal accident report forms. Additionally, the consistency and uniformity of falling accident statistics may be affected by varying interpretations of the reporting threshold. Based on an industry consensus, development and use of a standardized accident report form for internal industry use, and consistent external reporting of only ambulance aided falling accidents, is recommended. This data would then be comparable within the industry itself and also with the national statistical base compiled by the U.S. Consumer Products Safety Commission.

A general knowledge of human factors is useful in understanding the causes of falls, and in developing countermeasures to reduce falls. Human locomotion has been likened to a "controlled fall", requiring a complex combination of vision, reaction time and balance, taken for granted by all but the disabled. Walking surfaces must be uniform and provide sufficient surface friction to resist foot forces that occur during locomotion. Stair locomotion, particularly in the down direction, is more complex and requires more attention to step and tread dimensions, handrails and other design details. The moving surface of escalators causes additional perception, reaction, and adjustment problems which add to the probability of falls.

The statistical analysis of more than 1000 pedestrian falling accidents in transit stations shows that:

- There are about 20.7 falling accidents and 8 ambulance aided cases for each 10 million station uses;

- Falls in transit are not significantly different than other types of exposures, and are less than falls in the home;

- Younger and older age groups have greater than average falling experience;

- Alcohol involvement is a significant cause of falls, observed in 29 percent of all reported transit station falls and 55 percent of male falling incidents where an ambulance was required;

- Off-hour and weekend falling accidents are above average when compared to passenger activity, and falls in the P.M. peak period are twice that for the A.M. peak;

- Escalator falls are more common but typically less severe than stair or walking surface falls;

- Approximately 90 percent of reported stairs falls are in the down direction;

- The most common injury location for male falls is the head, and for females, the legs.

In general, few transit falling accidents are caused by design or operating deficiencies. However, this aspect demands attention because of the higher liability associated with accidents due to an inappropriate design or poor housekeeping. Uniformly designed, slip resistant walking surface treatment and consistent and uniform stair dimensioning are important safety considerations. Stair handrails should be designed for graspability and set at the maximum heights allowed by codes. Escalators should be uniformly lighted, have level step runs at top and bottom, and clear spaces at entrance and exit approaches. Escalator skirt lubricants should be applied carefully to avoid overspray and the creation of a slipping hazard. Communication can help reduce falling accidents by informing patrons of high wind or icing conditions on platforms, and also making patrons more aware of safety practices.

A workshop seminar involving representatives of seven rail properties and APTA indicated interest in the development of a uniform industry accident reporting form, divided opinion about using ambulance-aided cases as an accident reporting threshold, and support for the use of “positive approach” media campaigns on an industry-wide basis to alert the public to safe practices to avoid falls.

1.0 INTRODUCTION

Falls on the same level, and from one level to another, result in an estimated 12,000 deaths and 10 million injuries annually in the United States. (1.1) Falls account for about 20 percent of the total of all national accident casualties, ranking second to automobiles as an accident cause. More than 1/2 million persons require hospital treatment each year for fall related injuries, most resulting in activity restrictions and lost time. Falls represent a significant societal expense in terms of lost industrial time, workmen's compensation, costs of medical treatment, and settlement of damage claims of victims. (1.2)

In the period 1976-1980 the U.S. rail transit industry reported to the Federal Railroad Administration (FRA) about 10,000 falling accidents and 2 deaths related to falls occurring on transit stations stairways, platforms and ramps. These transit systems carried 7.25 billion passengers during the period. There are indications that some voluntary reports of falling accidents to the FRA may not have included all falls requiring medical treatment, as suggested by the reporting guidelines. Since the majority of falling incidents involve only minor injuries requiring little or no medical treatment, there may be some doubt about the reporting threshold, potentially affecting the consistency and comparability of falling accident statistics.

The problem of falling accidents in transit stations has implications beyond the injuries sustained by victims. Payments for damage claims for these injuries, and the administrative costs associated with processing these claims, is a significant industry expense which is eventually passed on to society. There are a number of reasons why the financial burden related to such accidents will continue to increase. The factors contributing to the increase are the burgeoning of the costs of medical treatment, the growth in the elderly population and associated higher probability of falling with more severe injury, and the growing awareness of the use of the courts to obtain compensatory damages for falls, even when caused by the personal carelessness of the victim.

1.1 STUDY DESCRIPTION

The study consists of: a review of human factors relating to the design of pedestrian facilities and mechanics of falling; the development and analysis of a data base on transit patron falling accidents in stations to establish the characteristics of victims and accident relationships for various types of pedestrian facilities; a review of industry risk and claims management practices and the costs of falls; the development of recommended design and operating practices to reduce falls; and lastly, a summary of the proceedings of a special industry workshop addressing the falling accident problem.

2.0 HUMAN FACTORS AND FALLS

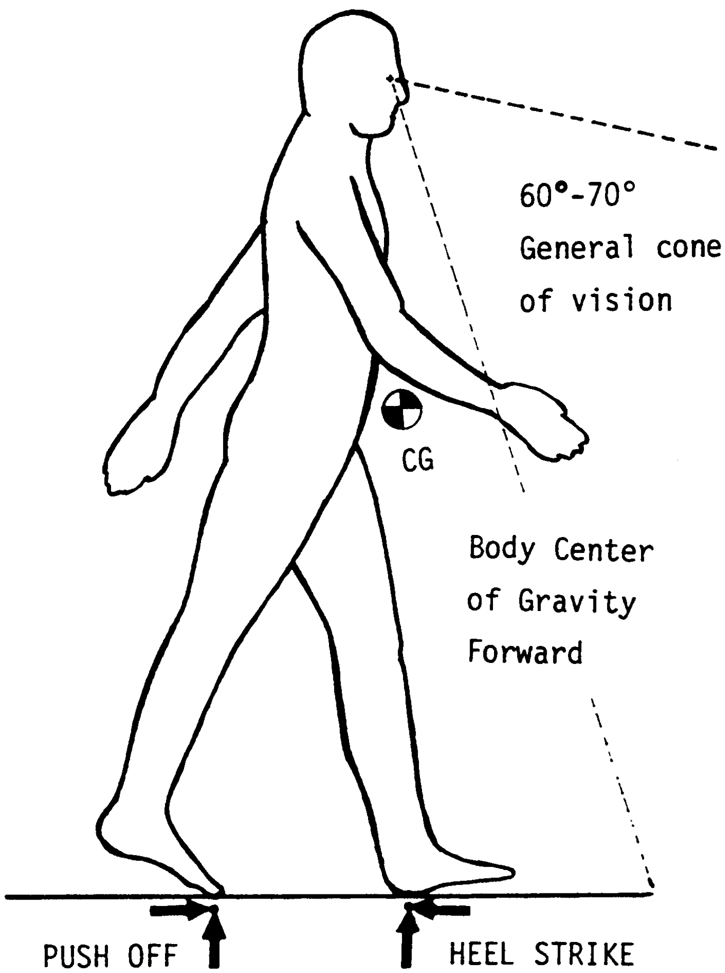
Human locomotion, walking and using stairs, is a relatively complex activity taken for granted by all except the disabled. Photographic studies show that there is a constant threat of falls during walking and stair movement, counteracted only by controlled shifts in body weight and exact placement of the feet. Considering the precise coordination involved, it is remarkable that the pedestrian fall is a relatively rare occurrence. However, virtually everyone is likely to have a serious, injury-causing fall during a lifetime, with a large portion of injuries resulting in permanent disability, and some in death.

A general knowledge of the cycle of movement in walking and on stairs is useful in understanding the causes of falls, and for developing possible countermeasures. Also, human body measurements help establish desirable dimensions for stair treads and risers, ramps, and handrails. Factors such as reaction times, balance, postural sway, and visual perception can also be involved in the falling accident.

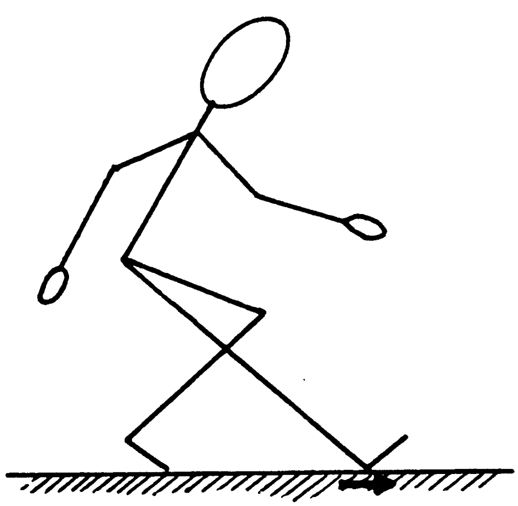
2.1 WALKING

The walking cycle is begun by leaning forward and swinging the leading foot into a heel strike. At about the same time the rear foot begins a rolling push-off and is swung forward for a new heel strike and repeat of the cycle. Both the heel strike and the push-off are the points in the walking cycle when a person is likely to slip. Tripping would likely occur when the leg is swung forward and there is insufficient ground clearance for the foot. Minimum ground clearances of the toe when the foot is swung forward were observed to average 0.6 in. (14 mm) and range between 3/8 and 1-1/2 in. (10 and 38 mm) in one controlled study. (2.1)

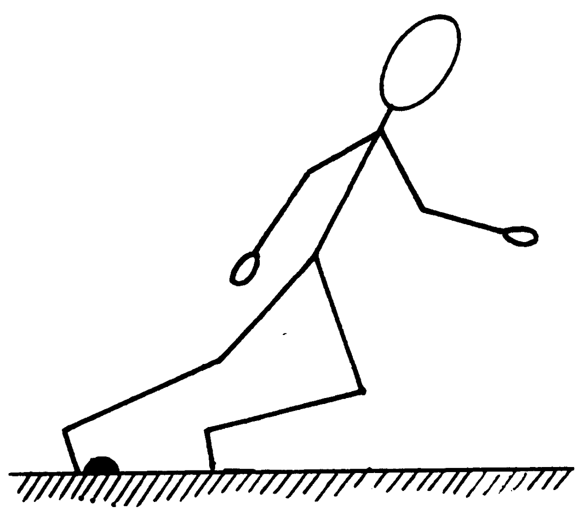
Slip resistance, as determined by the frictional force of shoe materials against the walking surface, is important in preventing falls. The stability of both the heel strike and the push-off is dependent upon sufficient opposing surface friction (see Figure 2-1). Measurements of the horizontal component of foot force at the heel strike have shown that it is about 15 percent of body weight, and 20 percent for the push-off. This corresponds to the minimum walking surface coefficient of friction discussed in greater detail in Section 5.0.



"The walking cycle is begun by leaning forward and swinging the leading foot into a heel strike. At about the same time the rear foot begins a rolling push off and is swung forward for a new heel strike and repeat of the cycle."



Slip at heel strike



Trip after heel strike

FIGURE 2-1. LEVEL WALKING

Walking speed is determined by stride length, pacing rate, and shifts in the body center of gravity. Faster walking requires a forward leaning stance like that used when walking against the wind. Level walking speeds for the general population range between 150 and 350 fpm (.8 and 1.6 mps), and average about 270 fpm (1.4 mps). Average walking speeds for females are about 5 percent slower than males. (2.2) Elderly and handicapped pedestrian locomotion speeds are naturally slower than the general norms.

2.2 STAIR MOVEMENT

Stair climbing and descent is quite different than walking. Instead of selecting a natural pacing distance, the stair tread dictates the same pace for all persons. The stair riser changes patterns of leg and body movement, requiring greater bending of the knee and more careful balance. These differences, combined with the increased energy demands on stairs, inconvenience many who otherwise have little difficulty walking. People with minor vision impairments, knee, hip or ankle restrictions, leg braces, crutches or other prostheses, and coronary or respiratory limitations, experience problems using stairs. Stairs are also a barrier to wheel chair users.

The dimensioning of stairs has been found to have a direct relationship with user convenience and safety. Higher riser heights increase the required range of leg movement, energy consumption, blood pressure, and pulse rate. Narrow treads reduce the area available for placement of foot, affecting balance and contributing to missteps. Uniform dimensioning of stairs and risers is a critical design factor, with differences in step heights as little as 3/16 in. (5 mm) disrupting the pattern of movement and potentially causing falls. (2.3)

2.2.1 Ascent

When climbing stairs, the body center of gravity is shifted forward, and the leading foot is lifted and placed on the first tread for support. Both the leading and rear legs combine for the push-off to provide the power to lift the body. The rear foot is then lifted and swung forward and placed on the upper step ahead and the cycle is repeated. Ascending stair speeds are slower than descent, resulting in lower traffic capacity in the up direction. Ascending stair falls are less frequent and not as severe as descent because the fall can usually be stopped by leaning against the steps above. Also, in the upward direction, the steps ahead are much closer to eye level, giving a better view of the stair (see Figure 2-2).

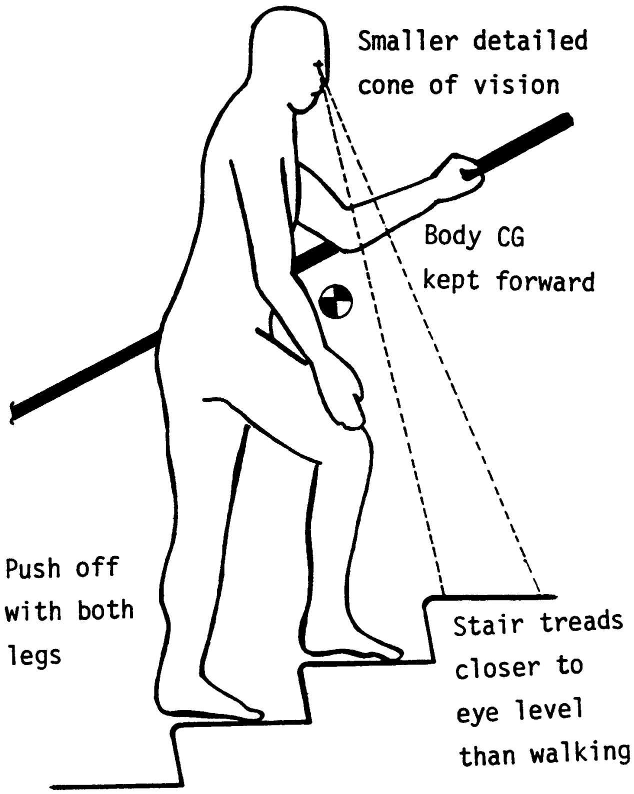
Upward speeds on stairs measured on the slope range between 50 and 150 fpm (0.3 and 0.8 mps) and average about 100 fpm (.5 mps) for the general population. Female climbing speeds average about 5 percent less than males. Speeds vary according to the slope of the stair, with slower speeds on steeper stairs.

2.2.2 Descent

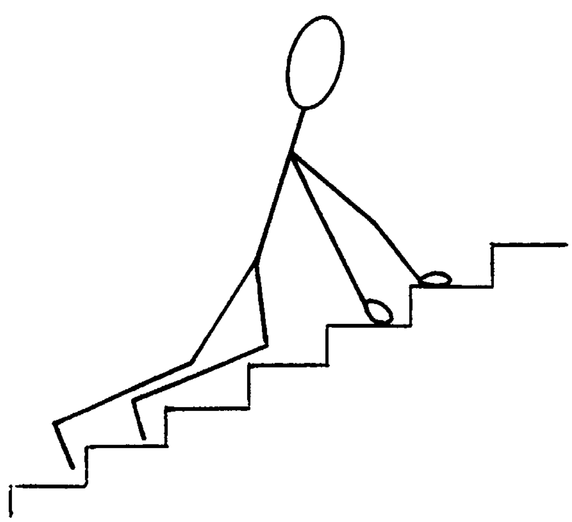
In descending stairs, the body center of gravity is shifted back and the ball of the lead foot is placed on the step below. The lead foot is then leveled for support, and the rear foot lifted, swung forward, and lowered to the next tread. For the best support and ease of movement the step tread should be wide enough to accommodate the length of the foot from ball to the heel, with added clearance for footwear. Narrow treads can cause an awkward turning of the feet, increasing the probability of a misstep. The eye level above the steps in descent is much higher than in ascent. Because of this, and the necessity of keeping the body center of gravity back, the steps are more difficult to see.

Although greater concentration and more careful balance are required for descent, average platoon speeds are faster than ascent due to the assist of gravity. Descending traffic capacity is also higher for this reason. Exceptions would be narrower stairs where a slower pedestrian may block others from passing.

Most stair accidents, and the more severe requiring first aid treatment or hospitalization, occur in descent. Unlike the ascending accident where steps above can help arrest a fall, only the handrail can help stop a descending fall in progress and prevent it from being extended further down the stair. The extension of the fall increases its impact and severity. In addition to increased impact, falls higher up on the stair are more dangerous because the resulting body angle makes a head injury more likely (see Figure 2-3).



"When climbing stairs the body center of gravity is shifted forward and the leading foot is lifted and placed on the first tread for support. Both the leading and rear legs combine for the push-off to provide the power to lift the body. The rear foot is then lifted and swung forward placed on the upper step ahead and the cycle is repeated."



"ascending falls.... are less severe because the fall can usually be stopped by leaning on the steps above."

FIGURE 2-2. STAIR ASCENT

Down speeds on stairs measured along the slope range between 50 and 250 fpm (.3 and 1.3 mps) and average about 140 fpm (.7 mps) for the general population. Female speeds of descent are significantly lower, averaging about 20 percent less than males. (2.2) The unusually slower downward speeds are thought to be related to women’s footwear. Higher heels would tend to shift the center of gravity forward, as opposed to the natural tendency to keep it back. This would encourage more cautious and slower descent. Bifocal eyeglasses can create problems in descent because the pedestrian is looking downward through the near-focus segment of the glasses, distorting perception of the stair.

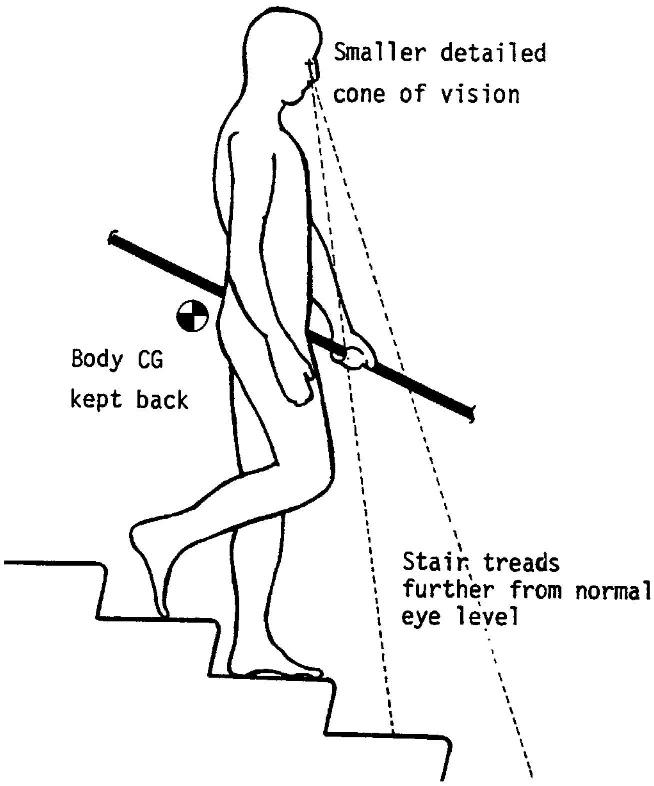
2.3 ESCALATORS

The use of escalators and moving walkways involves the characteristics of walking for boarding and exiting, but with added adjustments for the movement of the treadway. Standees must make adjustments for the effects of escalator angular movement on “postural sway”, a human factors characteristic many persons are unaware of.

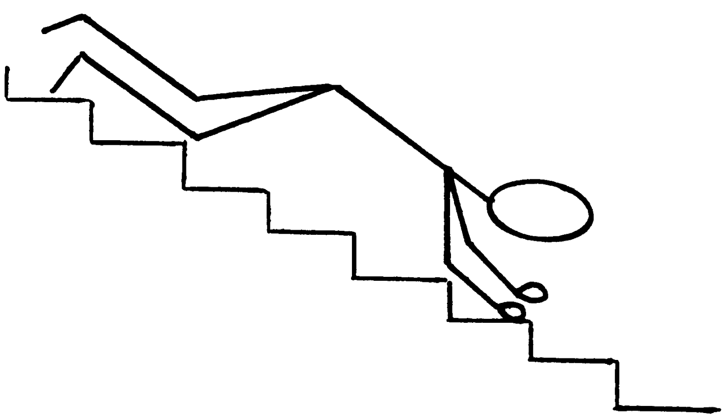
2.3.1 Boarding

People boarding escalators adjust to the speed of the system by means of visual cues provided by the moving treadway and handrail, or more positively by physically grasping the handrail. Handrail and treadway speeds are synchronized. Pedestrians walking directly on the escalator make a downward adjustment from a normal walking speed of about 4.5 fps (1.4 mps) to the escalator speed of 1.5 or 2.0 fps (0.5 or 0.6 mps). Other pedestrians impaired by disabilities and sometimes by carried articles, will come to a complete stop before selecting an escalator step position and boarding.

Step delivery rates for the common escalator speeds cited above are 1.1 and 1.5 steps per second, requiring a relatively quick reaction time for persons moving from standing position. This can be a problem for those with diminished eye, hand, and foot coordination. A photographic study of passengers who stopped before boarding a moving walkway at London airports, showed that they had more balance problems than those who walked on. (2.4)



"In descending stairs the body center of gravity is shifted back and the ball of the lead foot is placed on the step below. The lead foot is then leveled for support, and the rear foot lifted, swung forward, and lowered to the next tread."



"...only the handrail can help stop a descending fall in progress and prevent it from being extended further down the stair."

"...extension increases impact and severity."

"...falls higher up on stair are more dangerous because the resulting body angle makes a head injury more likely."

FIGURE 2-3. STAIR DESCENT

Depending on the step position selected, passengers may have to make other adjustments after boarding an escalator because of the transition of the treadway from a level to stepped surface. This problem occurs mostly with visually impaired passengers who may stand straddling the line between two escalator steps after boarding. These passengers must shift standing positions to avoid being upset as the step rises on an upward moving escalator or lowers on a downward escalator.

In recent years there has been a trend toward increasing the number of flat steps at the entrance and exit of transit system escalators. Typically, older escalators provided 1 to 1-1/2 flat steps at the entrance or exit portal, or a level surface of 16 to 24 in. (406 to 610 mm) before the steps articulate in the upward direction or level off and pass beneath the combplate in the downward direction. Several newer systems have provided 3 to 3-1/2 flat steps for a level surface of 48 to 56 in. (1219 to 1422 mm). (2.5)

The advantages of the extended level surface at the entrance is reported to be the greater pacing distance and reaction time provided the boarding passenger to adapt to escalator before the steps articulate. The exiting passenger is also alerted two to three seconds sooner of the approaching stationary surface at the portal.

2.3.2 Standing

Standing passengers can fall due to a sudden emergency stop of the escalator, or because of the accentuation of postural sway caused by the angular movement of the treadway. Postural sway is the normal shifting of weight from one foot to the other to alleviate stress on leg muscles, and also to equalize blood circulation. Postural sway has been shown to be a significant cause of falling among the elderly. (2.6) Age increases the degree of postural sway and decreases the ability to react when leaning too far. Since most people are not consciously aware of postural sway, they may not compensate for the added motion effects on escalators.

Falls while standing on escalators can also be caused by “blood pooling.” Blood pooling occurs when there is a sudden stop or start of an activity before normal blood circulation can accommodate it. (2.3) This results in unexpected dizziness and loss of balance. Blood pooling effects, like postural sway, increase with age. Transit passengers could experience blood pooling if a long walk precedes the use of the escalator, or when quickly boarding the escalator after a seated train ride.

2.3.3 Exiting

Passengers exiting from an escalator must step off the moving treadway onto a stationary surface. If the feet are not lifted off the tread quickly enough, they will make contact with the stationary endcombplate. When this happens pliable footware can be momentarily caught in the combplate, causing a tripping incident. Additional problems are caused by passengers who do not move quickly away from the escalator exit. Following passengers may be unintentionally forced into these slower pedestrians by action of the escalator. There are reports of such falls with the victim stating that a “bump” or “push” from behind knocked them down.

Multiple passenger accidents can sometimes occur if an escalator is not stopped quickly after a fall at the exit portal. A fall at the exit of a moving walkway during the 1970 Japanese Exposition resulted in a pile-up and non-fatal injury to 42 persons. (2.7)

2.4 ANTHROPOMETRIC CONSIDERATIONS

The design of stairs and other facilities to reduce falls must consider human body dimensions or anthropometrics. Stair treads large enough to accommodate the foot, stair risers low enough to minimize energy expenditure, leg movement, and balance problems, and stair widths sufficient to adequately accommodate passing pedestrians, can reducing falling risks. Handrail graspability, or conformance to the optimal human grip, can affect handrail use and the ability to arrest a fall.

Body measurement data is typically organized in percentiles for males and females. A 95th percentile dimension indicates that 95 percent of the population measured less, and a 50th percentile dimension a median value, with half of the population measuring less and half greater. The fifth percentile would mean only 5 percent measured less.

Selected body measurements for males and females in the 95th and 5th percentile categories compiled from a number of sources are shown in Sections A-1 and A-2 of the Appendix. The dimensions are based on nude body measurements and therefore must be adjusted for addition of clothing and footwear. (2.8, 2.9)

2.4.2 Height (H)

Height (H) is the universal figure of reference for comparing body measurements in the different percentile groups and from various data sources. Its primary use for designers of pedestrian facilities would be to evaluate vertical clearances for doors, stairs, and escalators. All vertical heights require additions for footwear.

2.4.2 Eye Level (E)

Eye level (E) heights are useful for determining human sight lines, as for example, in locating signs.

2.4.3 Knuckle Height (K)

Knuckle height (K) should be considered in determining handrail heights, location of door hardware, and hand activated buttons or controls. Desirable heights for a handrail on stairs and ramps are greater than the knuckle height dimension because the normal pedestrian footprint or "walking line" is horizontally displaced from the handrail about 10 to 12 in. (250-300 mm). Additionally, the most powerful grip on the handrail is obtained with the arm in a slightly bent position, further increasing optimum heights. Footwear allowances must also be added.

From a human factors standpoint, handrails higher than now commonly specified in building codes are desirable, particularly when considering descent on stairs, the more dangerous direction of movement. Handrails higher than current standards would be slightly less comfortable for the general population in ascent, but far fewer and less serious stair accidents occur in that direction. The added height for ascent would be useful for less capable pedestrians who pull themselves by the handrail for added lift because of fatigue, lack of body strength, or other disabilities.

A biomechanical assessment of handrail heights suggested an optimal design range of 36 to 38 in. (914 to 965 mm) above the step as compared to the more common building code maximum of 34 in. (864 mm). (2.10) A 5th percentile 6 year old female child, with an average height of 42.6 in. (1080 mm), would still be able to effectively grasp the higher handrail.

2.4.4 Shoulder Breadth (B)

Shoulder breadth (B) dimensions are of value in determining minimum desirable widths for corridors and stairs. In addition to adding allowances for clothing, an allowance of 3-4 in. (75-100) must be added for body sway. Stairways should provide clear widths of 50-54 in. between handrails to allow passage for two persons moving in opposite directions without brushing contact with each other.

2.4.5 Body Depth (D)

Body depth (D) measurements become significant in combination with shoulder breadth to develop the body ellipse, a simulated plan of view of a standing pedestrian. The body ellipse has been used to determine the standing capacity of subway cars and platform areas. The body depth measurement shown is measured at the chest. Allowances for clothing must be added to these dimensions, as well as 1 in. (25 mm) to include the buttocks.

2.4.6 Foot Length (F)

Foot length (F) measurements are useful in understanding the stair tread dimensions requirements. Stair treads deep enough for the full length of the foot plus allowance for footwear and movement clearances for the shoe would have to be 14 in. (356 mm) to accommodate all users. However, practical tread depths for the 95th percentile male would be between 11 and 11-1/2 in. (280 and 290 mm). This allows for some overhang of the shoe but would accommodate the ball of the foot, which is necessary for proper descent.

2.4.7 Body Center of Gravity (CG)

Body center of gravity (CG) is the height of the center of distribution of human weight. This dimension is needed to determine the desirable height of protective guard rails. The location of the center of gravity in the passive standing position is approximately 54 to 57 percent of total body height for the typical adult male population and 53 to 56 percent for women. Based on the average body center of gravity for the 95th percentile adult male, with the addition of 1-1/2 in. (38 mm) for shoes, protective guard rails should be at least 42 in. (1067 mm) high. This conforms with OSHA standards for such railings. The free fall distance of the center of gravity has also been used as a predictor of probable severity of a falling accident as measured on the abbreviated injury scale. (2.11) Section 2.7 discusses this in greater detail.

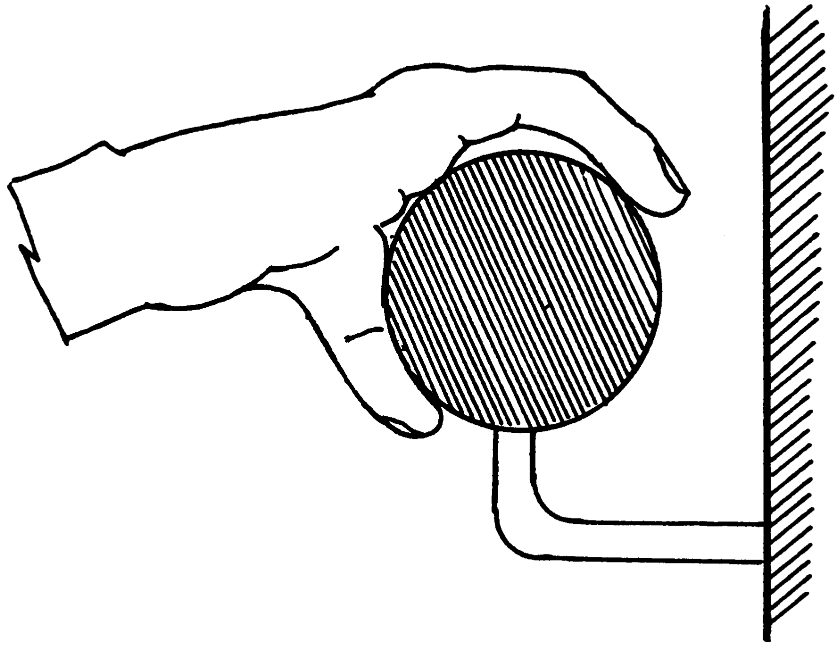
2.4.8 Handrail Graspability

Handrails have important roles in maintaining pedestrian balance, and in potentially arresting a misstep and fall. For the latter role, the handrail should have a cross-sectional geometry that is easy for the user to grasp and exert a “power grip”, or maximum resisting force (see Figure 2-4). Although not covered in most building codes, human factors research has shown that handrail sections having a circumference of no less than 4.4 in. (112 mm) and no greater than 5.2 in. (132 mm) allow the maximum power grip. For cylindrical handrails this translates into a diameter of 1.4 to 1.65 in. (3.6 to 42 mm). (2.11)

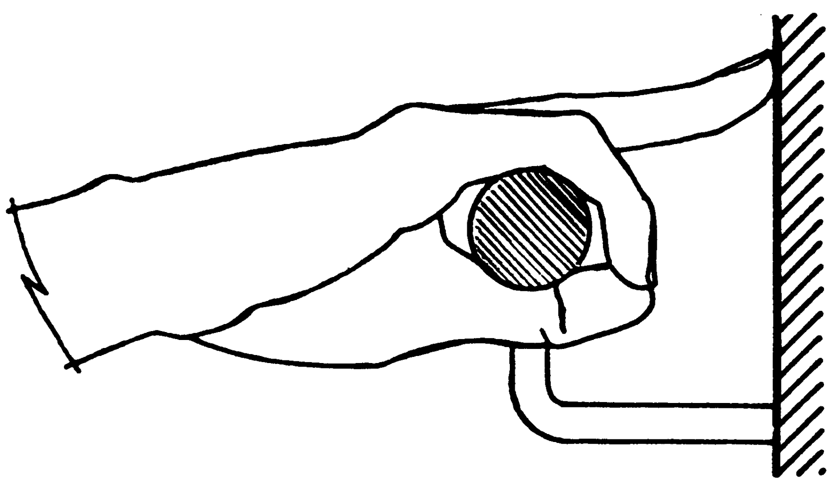
Another aspect of handrail graspability to arrest a fall is wall clearance. In a falling event the victim may have to make a quick open-handed grab for the handrail. A handrail that is too close to a wall surface could interfere with this “last effort” grabbing reflex. Many building codes specify a 1-1/2 in. (38 mm) clearance from walls, but OSHA human factors show that up to 4.62 in. (117 mm) clearance may be required, depending on the aspect of the accident victim from the handrail in the falling sequence. The OSHA wall clearance standard is 3 in. (76 mm). (2.12)

2.5 ENVIRONMENTAL FACTORS AND FALLS

Weather effects and lighting can be a factor in falls. In outdoor station environments rain and icing can reduce surface friction and increase the probability of slipping. Winds above 25 mph (40 kph) can cause falls due to sudden gusts, particularly for the elderly or disabled. The combination of wind and precipitation can significantly increase falling risks. (2.13) Lighting effects such as shadows or other sharp changes in lighting intensity can momentarily confuse pedestrians and may contribute to missteps.



Large handrail geometry does not allow a wrap-around of hand for a power grip.



Handrails set too close to the wall can interfere with a "last effort" grab.

FIGURE 2-4. HANDRAIL GRASPABILITY

2.6 EXPECTANCY FACTOR

Unexpected changes in surface friction, the “banana peel” experience, or the sudden patch of ice, are commonly recognized as a cause of slipping accidents. Differentials in floor finishes, even where the floors have relatively high surface friction values, have been found to cause falls. Changes in floor finishes at points where there is also a change in a pedestrian’s movement direction increase the susceptibility to falls, because of the shift in balance required by the turn. Surprisingly, workers in a factory having a uniformly “slippery” floor experienced relatively few falls because of acclimation to the low surface friction. (2.14)

Expectancy can also become a factor in stair falls where there is a step riser lower or higher than others in the series. Apparently after negotiating the first few steps the stair pacing pattern becomes so ingrained that even relatively small variations in riser height can result in a misstep.

2.7 FALLING ACCIDENT SEVERITY

The injury location and severity of a falling accident depends on the height of the fall and the part of the body that sustains the initial impact. Other factors include the rigidity of the surface on which the fall occurred and whether it was an unimpeded free fall, or attenuated in some way. Falls down stairs can increase the height of a fall and thus its potential impact, but some of the energy of the fall can be dissipated by body contact on the inclined surface of the stair, as compared to an unimpeded free-fall.

A comprehensive system of injury classification called the Abbreviated Injury Scale (AIS) has been developed by the American Medical Association, the Society of Automotive Engineers, and the American Association for Automotive Engineering to establish a uniform means of rating the damage of individual injuries. Multiple injuries are classified using the Overall Abbreviated Injury Scale (OAIS), to provide an indication for the severity of combined injuries. The AIS severity rating for a single body segment or organ is an integer scale from 0 to 6. The OAIS for combined injuries is based on the same scale, but uses a formula approach since the summation of the AIS codes of individual injuries does not double in severity. (2.15)

The AIS scale is briefly summarized as follows:

CODE	SEVERITY CATEGORY
0	No injury
1	Minor
2	Moderate

3	Severe (Not Life-Threatening)
4	Serious (Life-Threatening, Survival Probable)
5	Critical (Survival Uncertain)
6	Maximum (Currently Untreatable)

Injuries in the AIS Code 1 include most abrasions, contusions, shallow lacerations, soft tissue injuries, sprains and mild fractures such as a nose, or finger. Code 2 injuries include generally reversible conditions such as deeper lacerations into joints or muscle tissue, dislocation or fracture of minor joints such as a finger or toe, and head injuries involving unconsciousness for less than 15 minutes and no other complications. Code 3 injuries involve major joint dislocations and fractures, (ankle, knee, shoulder, wrist), head injuries with associated unconsciousness of 15-59 minutes, contusions of vital organs such as the kidney or liver, and a dislocated or ruptured spinal disc. At Code 4, the borderline of life-threatening but survivable events, few injuries to the extremities are included. Head injuries would involve unconsciousness of 1-24 hours, with more severe but survivable injuries to vital organs. Code 5 involves critical injuries to vital organs with uncertain survivability.

A study of free-fall forces showed that the threshold level AIS Code 1 head injury involved a body center of gravity fall of 3.5 feet (1.1 m). From this height the head impact velocity would be 15 ft/sec (4.6 m/sec), and peak head acceleration of 240 “g”s. A CG to CG fall height of 7 ft (2.1 m) was the borderline of an AIS Code 2 head injury, Code 3, 9.5 ft (2.9 m), and Code 4, about 13 to 14 ft (4 to 4.3 m). (2.16) Head injuries are the typical barometer of falling accident severity since trunk injuries are not as common.

Most falling accidents in transit station environments are in the AIS Code 1-3 category, and a Code 4 accident is an extremely rare occurrence. The injury relationships to height of fall do stress the importance of reducing the potential for accidents on stairs or escalators.

3.0 FALLING ACCIDENT CHARACTERISTICS

Transit patron falling accident characteristics have been established by analysis of slightly more than 1000 accident reports for the period 1976-1980. Data for the analysis was obtained from a standard system accident reporting form, shown as Appendix Section A-5. The study involved accidents in 13 stations, 11 subway and 2 elevated. Three of the subway stations are served by combinations of stairs and escalators and the remainder only by stairs.

The accident report forms used in the study are typically filled out by transit police, which tends to introduce some bias in the number and type of recorded falling accidents. Permanent police posts are established only at the busiest stations, making it likely that more minor accidents are observed and recorded at these stations. Also, these stations are typically served by escalators, which could increase the ratio of reported falls for this facility type. Other stations are covered by police on a rotating bases or in response to calls for assistance.

Additionally, the information requested on the form is not always provided by the victim, and sometimes not fully recorded by the police. Other factors that should be considered in interpreting the data is that neither the victim nor the police can accurately diagnose the extent and the severity of injuries at the accident scene. However, the summoning of an ambulance does provide a more probable indication of accident severity and therefore ambulance aided cases are shown for comparison purposes in most of the data summaries in the report. Ambulance aided cases are also of value in comparing results of this study with other accident statistics, such as the National Electronic Injury Surveillance System (NEISS), the U.S. Consumer Product Safety Commission program for monitoring national accident trends. This program uses hospital emergency room admissions data to develop estimates of the national experience.

Considering the above caveats about the raw data, the accident reports provide a good statistical base for showing incident rates for the facility type involved, age and sex of the victim, accident causes, body locations of injuries and temporal patterns of accidents. The data can also be compared with reasonable reliability with transit traffic patterns and passenger characteristics.

3.1 ACCIDENT INCIDENT RATES

Transit systems have an advantage that patron accidents can be generally related to turnstile entries to provide approximate passenger exposure rates. However, turnstile data for an originating station would not account for system transfers or movement through the destination station. At stations where escalators and stairs are used in combination their relative use can only be estimated on the basis of station configuration and observed preferences for the different facility types.

For the purpose of this analysis pedestrian exposure rates for total station use and for walking surfaces in terminals have been based on two times the turnstile entry count, representing both entering and exiting passengers. Exposure rates for stairs and escalators have been based on turnstile entries and estimated use of station stairs and/or escalators. These rates are also doubled to account for two way passenger movement.

During the period 1976-1981, 250 million turnstile entries were recorded for the stations studied, representing approximately 500 million station uses. Stair flight uses were estimated at 600 million during this time, and escalator flight uses 430 million. The total reported pedestrian falling accidents and ambulance aided cases, for walking surfaces, stairs, and escalators, along with their related exposure rates are summarized on Table 3-1.

Table 3-1 shows that escalators and walking surfaces have about the same accident rates per passenger exposure, and stairs about half that rate. The lower rate for stairs may be partially explained by statistics contained later in the report indicating that stair falls are predominantly in the downward direction. Considering this fact, there appears almost an equal likelihood per exposure of a reported transit passenger fall on station walking surfaces, for an escalator flight use or stair flight descent.

TABLE 3-1. TRANSIT PASSENGER FALLING ACCIDENTS: EXPERIENCE BY FACILITY TYPE AND ESTIMATED EXPOSURE

FACILITY	ESTIMATED PASSENGER EXPOSURES (1) (MILLIONS)	REPORTED FALLING ACCIDENTS (3) NO.	REPORTED FALLING ACCIDENTS (3) AMB.	RATIO PER TEN MILLION PASSENGER EXPOSURES NO.	RATIO PER TEN MILLION PASSENGER EXPOSURES AMB.
Escalators (Flight uses)	430	359	116	8.3	2.7
Stairs (Flight uses)	600	261	115	4.4	1.9
Walking Surfaces (Station uses) (2)	500	414	168	8.3	3.4
TOTALS PER STATION USE:		1034	399	20.7*	8.0*

(1) Based on turnstile counts, station configuration, assumed rates of utilization and 2-way use.

(2) Includes platforms, other station areas (turnstile entries x 2).

(3) NO. is total reported in each category, AMB. is ambulance called.

* Based on 250 million turnstile entries, 2 station uses per entry.

3.2 RELATION WITH OTHER TYPES OF EXPOSURES

Comparison of transit falling accident experience with other types of exposures is difficult because of differences in reporting methods and development of incident rate statistics. However, some broad comparisons can be made to indicate general relationships with this other data.

A National Bureau of Standards study of stair accidents reported that for an estimated 1.953 trillion annual stair flight uses in the United States, there are 31 million minor accidents, 2.66 million disabling accidents, 540,000 hospital treatments and 3800 deaths. (3.1) Converting these rates to the same passenger exposure base used in Table 3-1, a minor stair accident occurs 159 times in 10 million flight uses, a disabling accident 13.6 times, and a hospital treatment 2.8 times. The latter two indices are within the range of 4.4 reported stair accidents and 1.9 ambulance aided cases per 10 million flight uses shown in Table 3-1. This indicates that as far as stair accidents are concerned, transit experience is less than the general norms.

Non-fatal escalator accidents were estimated in UMTA Report R1-06-0005-75-3 to average 3.6 per 10 million passengers carried for the period 1970-1972, based on data supplied by the Otis Elevator Company. (3.2) This statistic also generally agrees with the range of 8.3 reported accidents and 2.7 ambulance aided cases per 10 million transit passengers shown in Table 3-1.

A study of employee falling accidents for a recent National Institute for Occupational Safety and Health Study (NIOSH contract 210-76-0150) reported incident rates for a 100 worker year base, representing about 200,000 hours of work-place exposure. (3.3) Occupational uses covered in this study included local government, hospitals, colleges, a fast food restaurant chain, ship construction and repair, and vehicle and telecommunications manufacturers. Incident rates in the study varied between 0.4 to 3.7, with most ranging between 2 to 3 per 200,000 hours of exposure. These data can be roughly compared with transit incident rates by assuming an average time spent by a passenger in a transit station.

Based on an average time of six minutes for each passenger using a station, 10 million passenger exposures would be the equivalent of one million exposure hours, or five times the NIOSH base. If the NIOSH employee incident rate is compared with the transit exposure base of 10 million station uses, the employee rate would be 10 to 15, as compared to the total 20.7 total reported accidents and 8.0 ambulance cases shown in Table 3-1. This rough comparison again supports the premise that transit experience is not significantly different than general norms for other types of exposure.

3.3 AGE AND SEX PATTERNS

Transit users are not representative of an average cross-section of the general population, but are comprised more of employed working age persons, predominantly male and potentially more active than the norm because of the demands of employment and transit travel. Patterns of reported transit passenger falling accidents by age, sex and facility type patterns are shown graphically on Figures 3-1 and 3-2 and in greater statistical detail in Appendix Sections A-4, A-5 and A-6.

Figure 3-1 is a plot of the percentage of reported falling accidents by sex of the victim and different age groups compared to the percentage of passengers in the group. The passenger sex and age distributions were obtained from a 1980 transit passenger origin and destination survey. The comparison shows that there are higher proportional rates of falling accidents for both sexes in the under 18 and 61 and over age groups, and that the male accident rate is less than the female in other age groups. A higher rate of female accidents has been reported for office workers in a study of Workmen's Compensation cases in California. (3.4 However, it is suspected that males are less likely to report a minor fall than females. This hypothesis is somewhat confirmed by data in Appendix Sections A-5 and A-6 which show a higher proportion of more serious accidents requiring an ambulance for males in every age group.

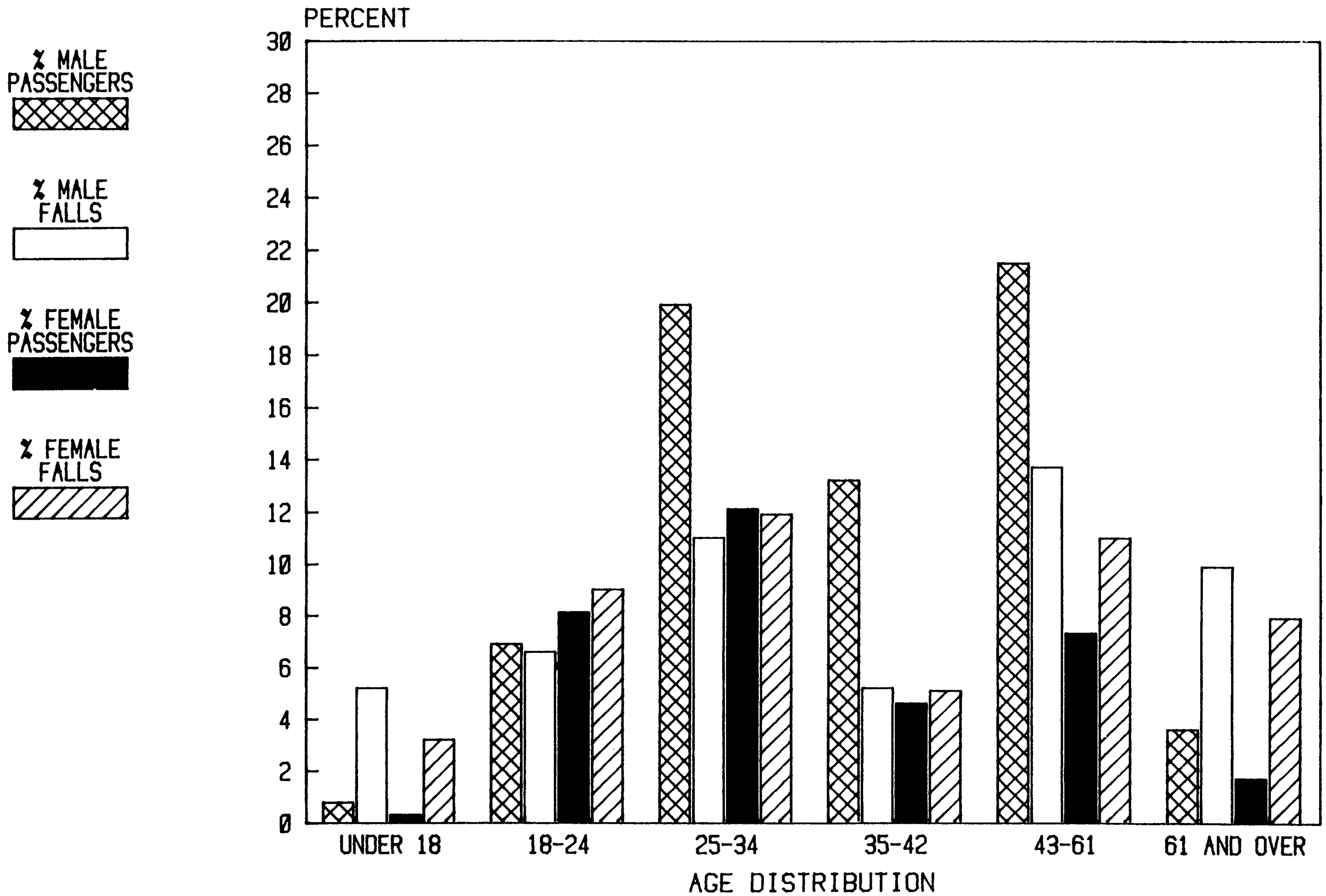


FIGURE 3-1. TRANSIT FALLING ACCIDENTS: PASSENGER AGE AND SEX DISTRIBUTION

Figure 3-2 is a distribution of combined male and female accidents by age group, passenger traffic, and escalator, stair and walking surface pedestrian facility types. The previous patterns of higher rates compared to traffic in young and old groups naturally repeat, but escalators are shown to have a higher incident rate for these groups than stairs and walking surfaces. Children are often observed using escalators in play, walking in the reverse direction, riding on handrails, and other actions which contribute to their higher incident rate. Increased use of medication, slower reaction times, perceptual problems, postural sway, and other aging effects accented by the movement of the escalator contribute to the greater escalator incident rate for the elderly.

Stairs show a proportionately higher incident rate in the age categories 25-42, the population segment with the largest proportion of workers. The greater experience could be associated with faster stair speeds observed for this group. Walking surface fall patterns show high incident rates in young adult and elderly age groups. Data presented later in the report indicates that alcohol influence is a significant causal factor in walking surface accidents, which could account for the higher incident rate for young adults.

3.4 ALLEGED CAUSE OF FALL

The alleged cause of the fall as reported by the victim has been tabulated, with the exception that where symptoms of alcohol involvement were noted, this was listed as the primary accident cause. The number of accidents by cause and facility types are shown on Figure 3-3. A more detailed statistical summary of accident cause summarized by facility and victim sex appears on Appendix Section A-7. Figure 3-3 shows that alcohol involvement is the most significant cause of falling accidents on walking surfaces, and is also a primary cause of accidents on escalators and stairs. Lost balance accidents are shown as the next most significant category for escalators and walking surfaces. Slipping and tripping accidents are the most significant cause for stairs. The foreign object category refers to materials under foot contributing to an accident, such as spilled liquids, grease, newspapers, etc.

The more detailed summary of accident causes in Appendix Section A-7 shows that alcohol involvement is a causal factor in 29 percent of all falling reported accidents. For males, alcohol was involved in 49.4 percent of all reported accidents and 55 percent of all ambulance calls. Removal of alcohol related incidents from the totals results in falling accidents becoming more predominantly female, with 62.6 percent of non-alcohol related falls, and males with 37.4 percent. Female transit riders are about 1/3 of total system passengers as shown in the age and sex comparisons. On a passenger exposure basis, the non-alcohol related falling rate for females would be more than three times that for males. Removal of the alcohol related incidents from the total provides a better correlation with other studies based on job related accidents, since most alcohol use occurs after working hours. Higher female office worker incident rates were noted previously.

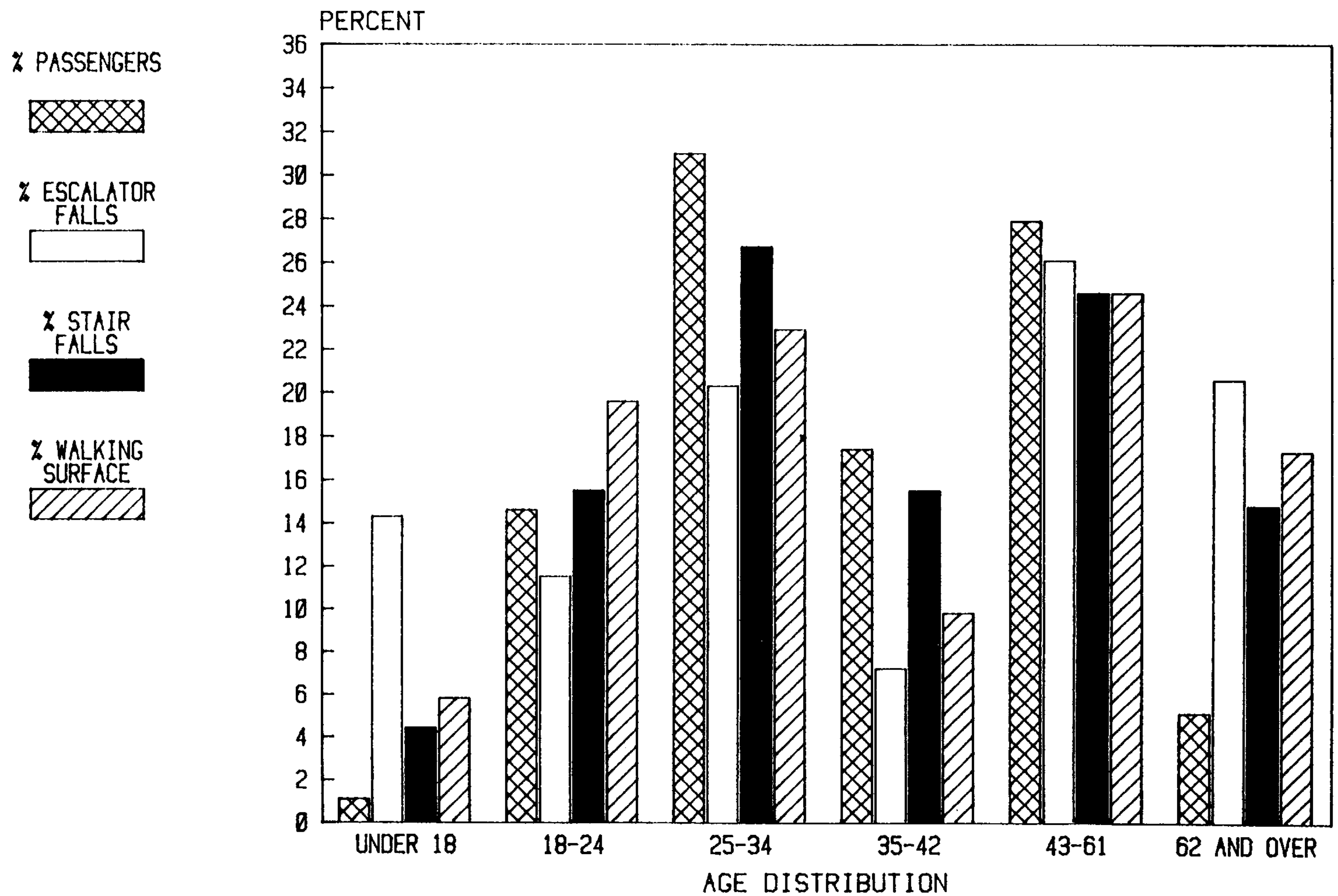


FIGURE 3-2. TRANSIT FALLING ACCIDENTS: AGE, TRAFFIC, FACILITY TYPE

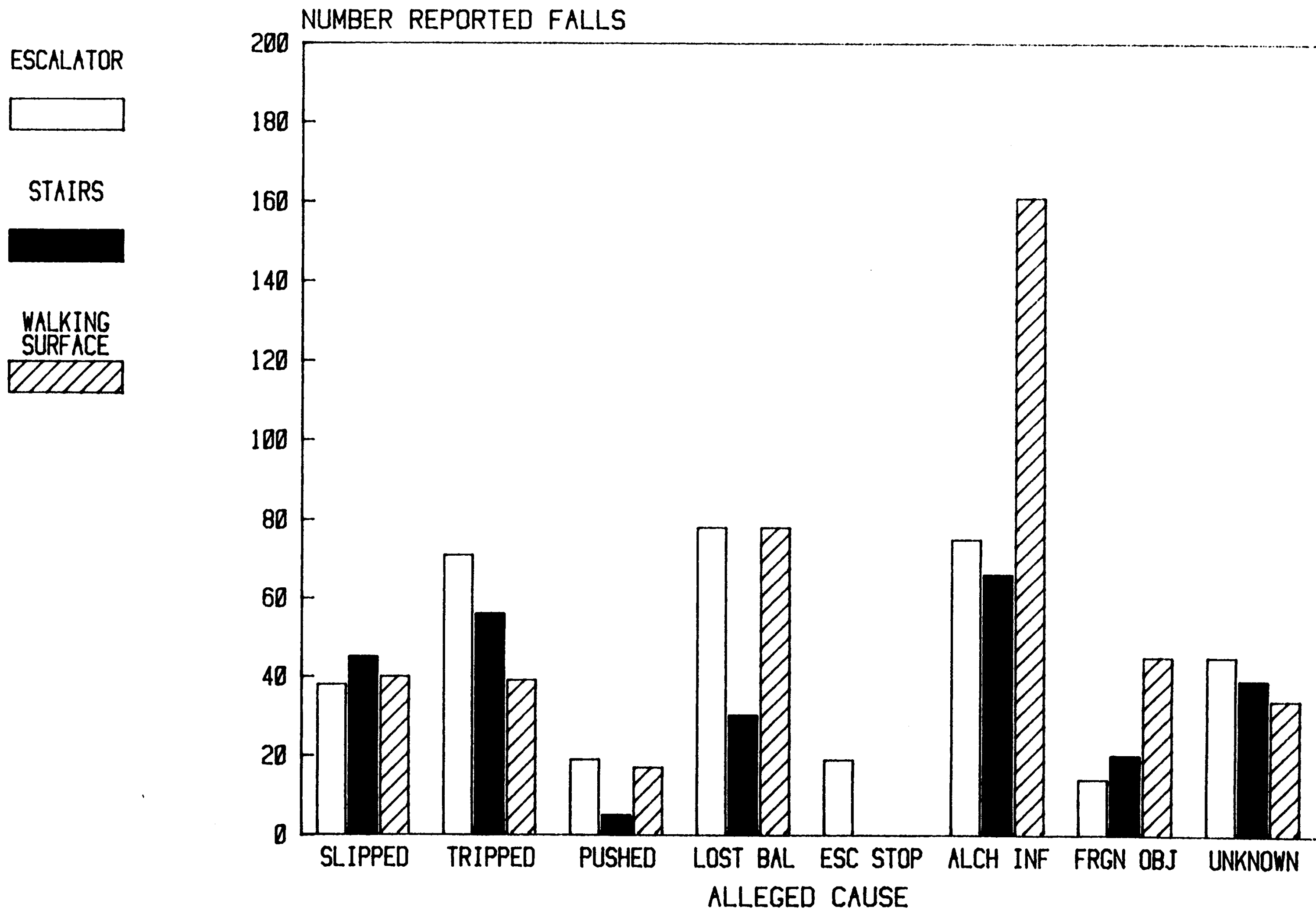


FIGURE 3-3. TRANSIT FALLING ACCIDENTS: FACILITY TYPE AND CAUSE

3.5 TEMPORAL PATTERNS OF FALLS

The time, date and day of the week of falling accidents is reliably reported on accident forms. These temporal patterns of accidents can be compared with transit passenger activity to provide added insight into the factors that may be involved in the falling accident.

Monthly patterns of falling accidents as compared to transit activity and accident cause appear in Appendix Section A-8. The three highest months for falling accidents and ambulance calls are February, July and December, with the latter about double the average month in reported falls and ambulance calls. Alcohol influence significantly increases the December totals.

Daily patterns of falling accidents are illustrated on Figure 3-4 and summarized in Appendix Section A-9. The graph shows that in comparison to passenger activity, weekend accidents are significantly higher, and that Monday is the lowest weekday. The larger number of occasional passengers on weekends unfamiliar with facilities accounts for its higher proportional accident rate. The lower rate on Mondays is surprising, considering the commonly expressed negative psychological attitudes of the public towards “blue Mondays” and the return to work.

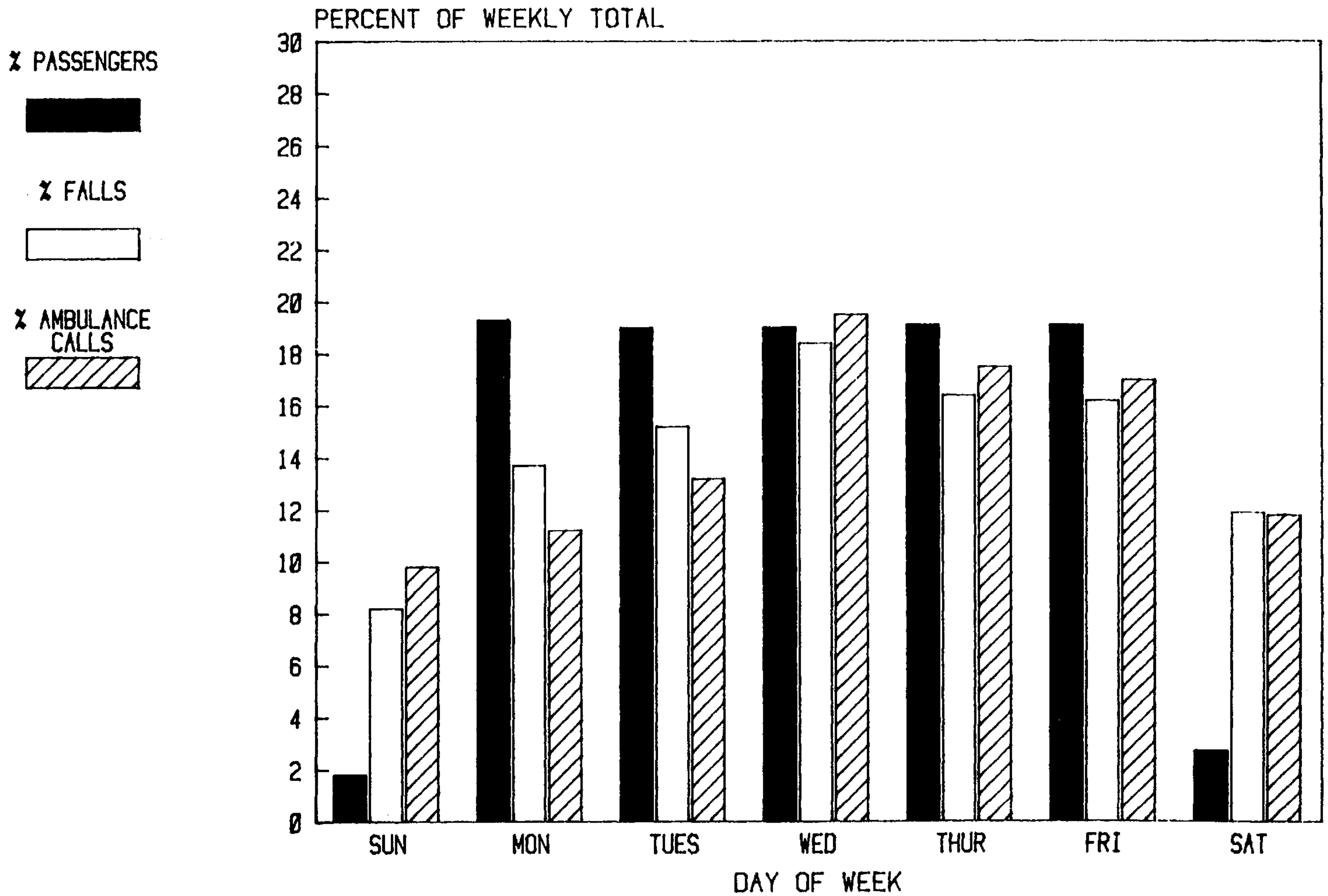


FIGURE 3-4. TRANSIT FALLING ACCIDENTS: TRAFFIC, ACCIDENT BY DAY OF WEEK

The data summary Appendix Section A-9 shows that Wednesday has the highest number of female falls and ambulance calls, although the rate on weekends is proportionally higher compared to traffic. Wednesday is a traditional theater matinee and luncheon day in the system service area, which brings additional female users unfamiliar with the system. Some alcohol use may also be associated with the higher female rate on Wednesdays.

(1) Time of Day accident patterns and causes for weekdays by time of day in three hour intervals related to system traffic are illustrated in Figures 3-5 and 3-6. (2) Additional data showing time patterns and victim sex is provided in Appendix Section A-10. (3) Figure 3-5 shows that most falls occur during off hour periods and not during commuter rush hours. More than 70 percent of system traffic occurs during the peak periods 6-9 A.M. and 3-6 P.M., but only 44 percent of the falls and 35 percent of the ambulance calls. The fall incident rate for the 30 percent of off hour passengers remaining is therefore about twice that of commuters.

Figure 3-5 also shows that evening commuter peak period falls are almost double that of the morning peak. Alcohol influenced falls partially account for this difference, but Figure 3-6 shows that falls from the other major causes, slipping, tripping and loss of balance, also increase in the evening. Fatigue may also partially account for the higher evening incident rate.

3.6 ESCALATOR FALLS

Escalators account for 35 percent of recorded transit passenger falls and 29 percent of all ambulance aided cases (see Appendix Section A-5). Escalators have the lowest rate of ambulance calls and related severity of the three facility types. Female passengers experienced about 55 percent of escalator falls, but had the lowest rate of ambulance calls of any of the facility types studied. In relation to patron exposure, females are almost 2-1/2 times more likely to have an escalator fall than males, but with much lower accident severity.

Appendix Section A-11 shows that the leading causes of escalator falls are loss of balance, alcohol influence, and tripping. Alcohol influence is the predominant accident cause for males, and loss of balance for females. The reported location of the fall on the escalator shown in Appendix Section A-11 is not considered to be statistically reliable because of possible confusion in interpretation of the accident form for both the interrogator and the responding victim. It is the general belief that most escalator falls occur in the boarding and exiting zones where there is a transition between stationary and moving surfaces, and where the escalator step configuration varies. This casts doubt on the high number of accidents reported to occur while “riding”.

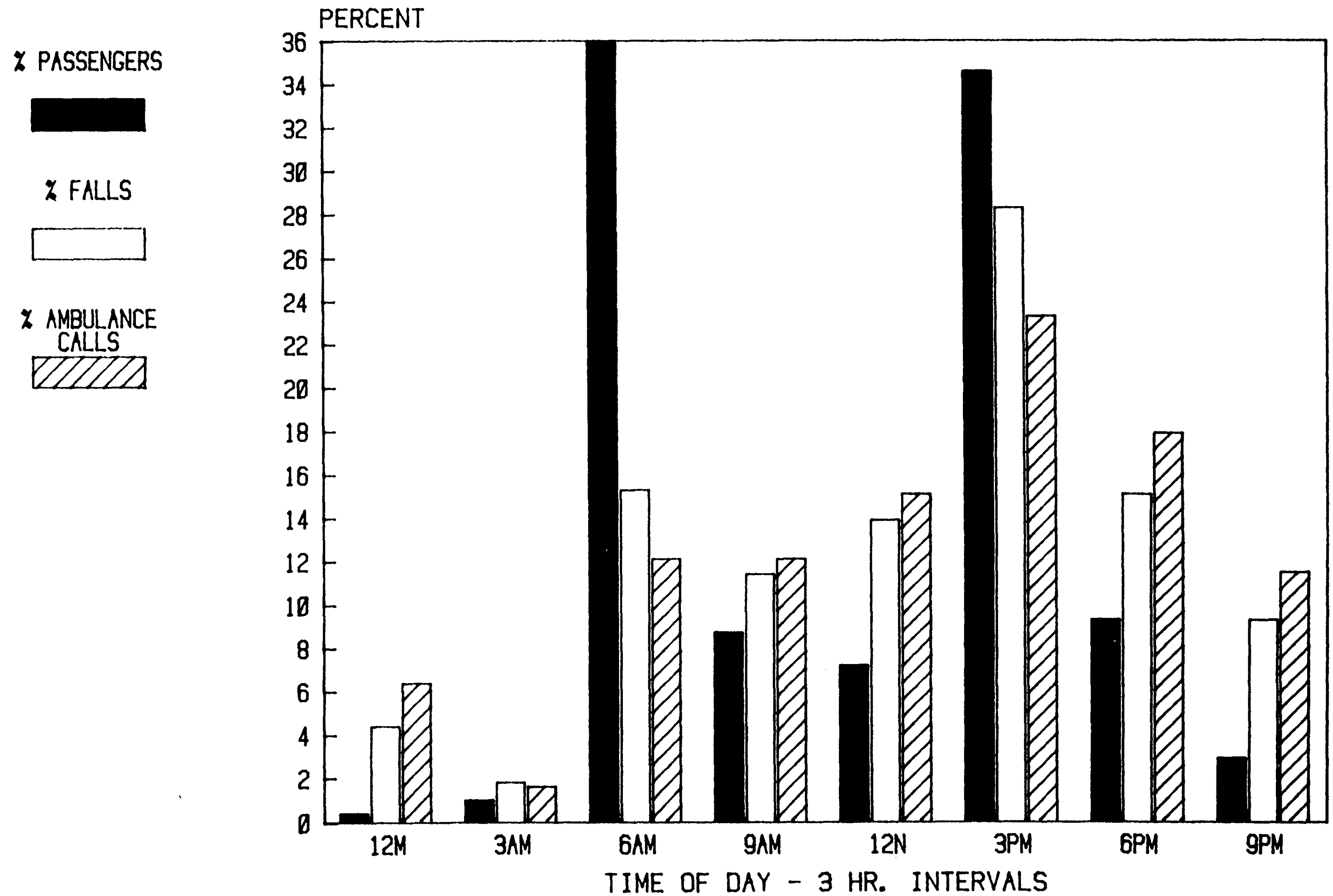


FIGURE 3-5. TRANSIT FALLING ACCIDENTS: WEEKDAY TRAFFIC AND ACCIDENTS

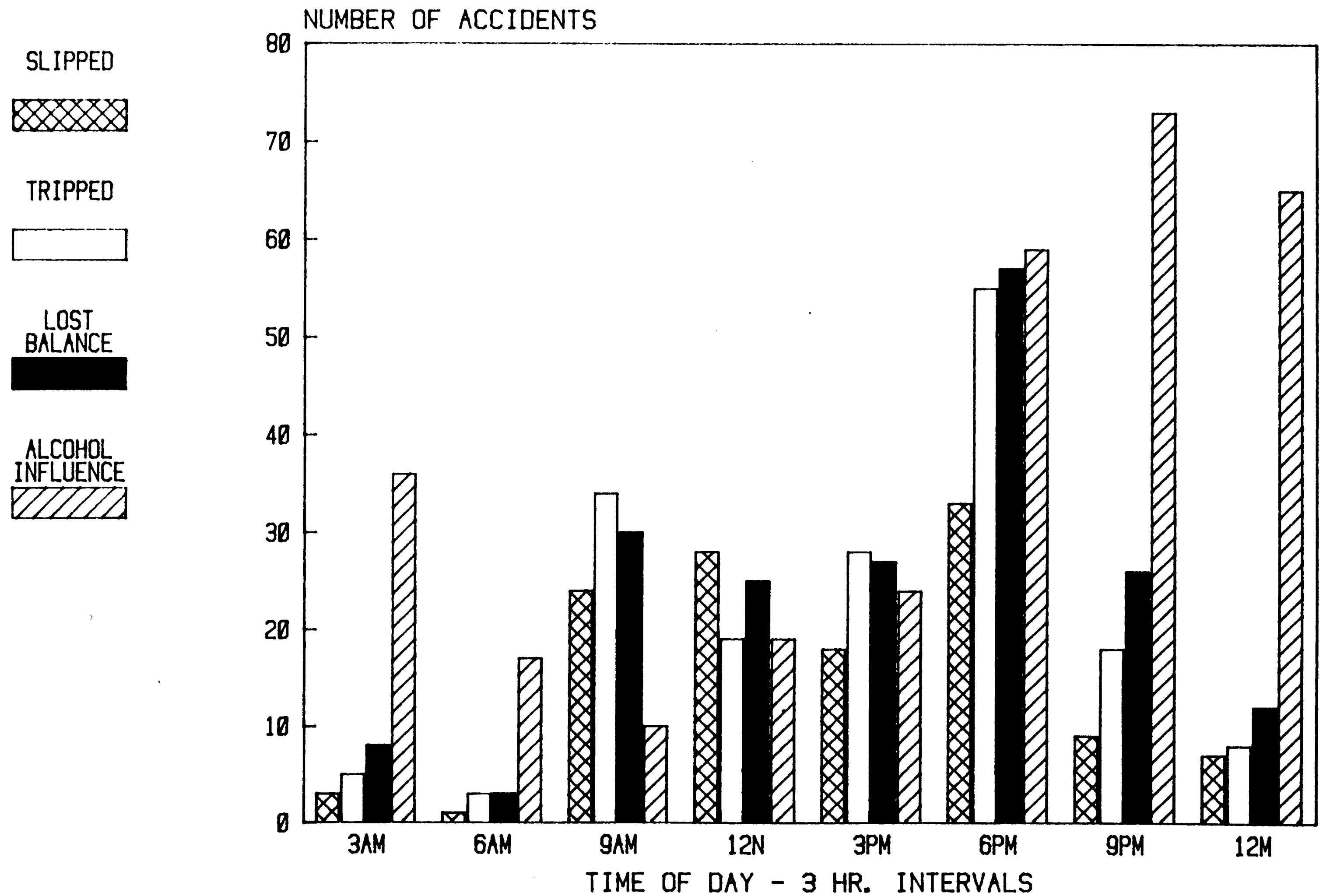


FIGURE 3-6. TRANSIT FALLING ACCIDENTS: ACCIDENT CAUSE BY TIME OF DAY

3.7 STAIR FALLS

Stairs account for 25 percent of the recorded transit passenger falls and 29 percent of the ambulance aided cases. (Appendix Section A-4.) Appendix Section A-12 summarizes the alleged cause, victim sex, and movement direction for 236 stair falls where the accident cause has been recorded. The summary shows that 87.2 percent of all stair falls and 94.1 percent of ambulance cases occur in the down direction. Female victims are involved in 58.5 percent of the falls and 49 percent of ambulance aided cases. The incident rate among females is therefore almost three times that of males, since females represent about one third of system users. As shown on Appendix Section A-12, stair falls for female victims exceed males for every accident cause except alcohol influence. If alcohol is not considered as an accident cause, stair accidents become even more predominantly female, accounting for more than 72 percent of non-alcohol related stair falls, an incident rate about five times the male. This higher experience occurs despite the fact that women are observed to be much more cautious than men on stairs, with a 20 percent lower average speed of descent as noted in Section 2.0.

3.8 WALKING SURFACES

Walking surface related accidents account for 40 percent of recorded transit passenger falls and 42 percent of all ambulance aided cases, the highest severity ratio for all three facility types. Walking surface falls are more predominantly male, representing almost half of all male falls and ambulance aided cases. Appendix Section A-7 shows that alcohol influence was the cause of 55 percent of male walking surface falls and 58 percent of ambulance aided cases. Lost balance is the next largest cause of walking surface falls for males, and is the largest accident cause for females.

Walking surfaces may have a higher number of alcohol involved falls because of the longer times of exposure on transit platforms as compared to the time spent negotiating stairs and riding escalators. Additionally, both stairs and escalators have handrails which can be used by the alcohol impaired to maintain stability. As a point of interest, lost balance accidents on stairs are significantly less than on walking surfaces, which could be attributed to more common use of the handrail for stability. Lost balance accidents on escalators are about the same rate as that for walking surfaces, but with less severity in terms of ambulance calls.

3.9 LOCATION OF INJURY

The body location of falling injuries is illustrated graphically on Figure 3-7 and shown in more statistical detail in Appendix Section A-13. Where more than one injury location was reported, the two most severe are included in the summary, resulting in multiple listing of data in Figure 3-7 and Appendix Section A-13. The most common fall injury locations are the head and leg, accounting respectively for 33 and 24 percent of all reports. Head injuries account for 52 percent of all ambulance aided cases, reflecting the greater concern for increased severity associated with this injury. Leg injuries account for 16 percent of ambulance calls.

Head injuries to males represent 76 percent of all the reports and 81 percent of ambulance aided cases for this body injury location. Males represent 2/3rds of passengers in the study group. Male head injuries are greatest for walking surfaces, followed by escalators and stairs. However, head injuries on stairs show the highest proportion of ambulance aided cases of the three pedestrian facility categories. The larger ratio of male head injuries in falling accidents may be associated with the males' higher center of gravity and greater body mass. These two factors would tend to increase momentum of the male fall, making it more difficult to arrest before a head impact. The greater alcohol involvement in male falls tend to increase head injuries by reducing reaction times and the ability to arrest a fall before a head impact.

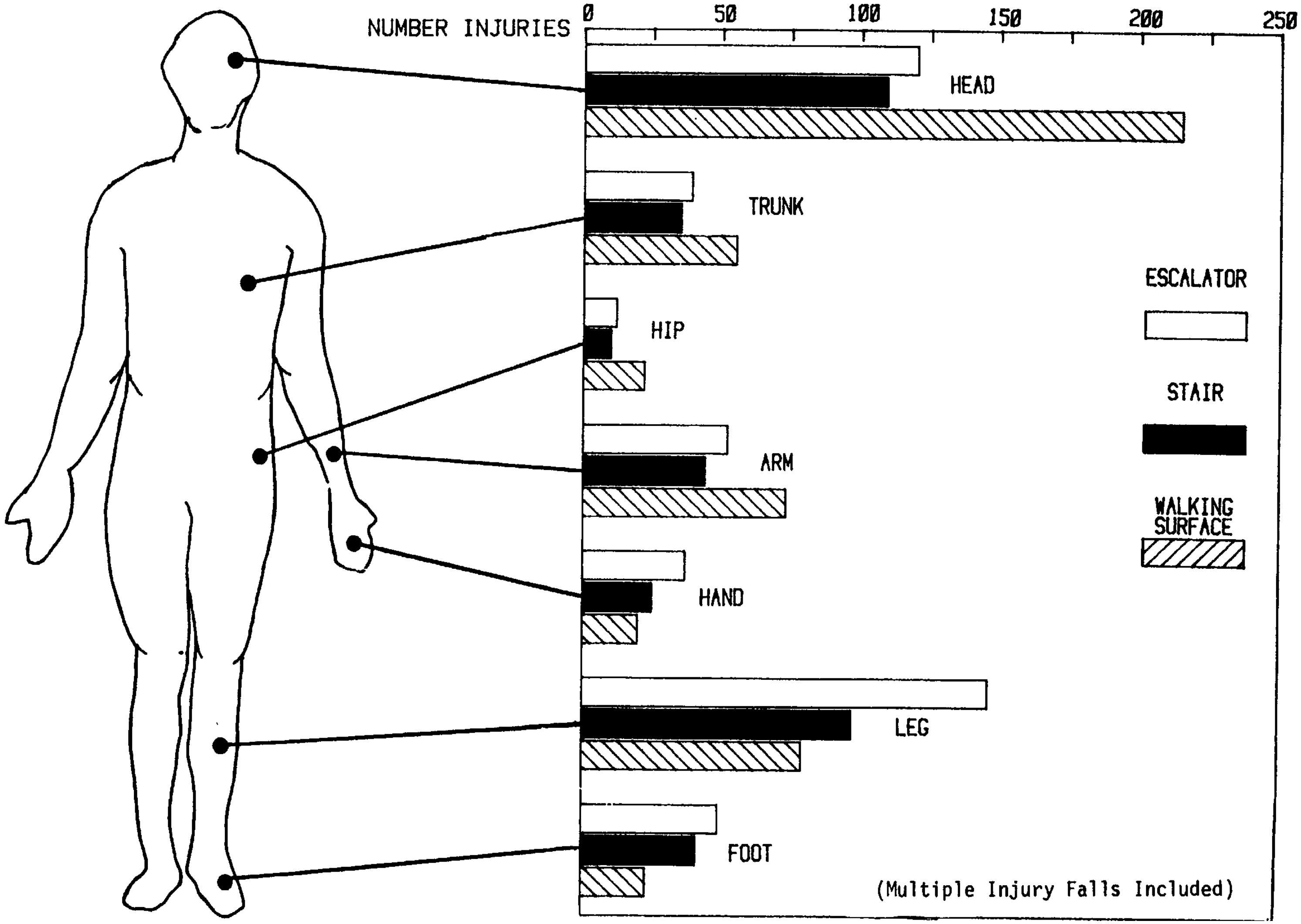


FIGURE 3-7. TRANSIT FALLING ACCIDENTS: INJURY BY BODY LOCATION

Leg injuries predominate in female falls, accounting for 74 percent of all reports and 78 percent of all ambulance aided cases for this body injury location. Female leg injuries are greatest on escalators, followed by stairs and walking surfaces. Stair accidents involving leg injuries result in the largest ratio of ambulance calls for females, followed by escalators and walking surfaces. The lower ratio of female transit passengers further accentuates the difference in body location of injuries between males and females. In relation to passenger traffic, females are six times more likely to sustain a leg injury in a falling accident than males.

4.0 RISK AND CLAIMS MANAGEMENT

It is axiomatic that even in the best designed and most efficiently operated transit systems that falling accidents will occur, and that some patrons will seek compensation for their injuries because of alleged negligence. The primary role of a risk management program is to evaluate transit facility accident and claims experience, identify possible factors contributing to this experience, and develop programs to reduce patron accidents and associated costs. The claim manager works in conjunction with the risk manager to further identify causal factors based on the allegations of victims, and to process claims against the transit property in ways that will minimize settlement costs.

4.1 ELEMENTS OF A RISK MANAGEMENT PROGRAM

The organizational structure of a risk management program can vary, but typical programs include:

- Evaluation and analysis - Maintain accident records, analysis of accident experience by location and facility type, frequency, severity and victim characteristics; identify hazards, causal relationships; report experience data to management and regulatory agencies.

- Inspection - Make periodic field inspections to identify hazards; verify compliance with insurance contract provisions and building codes; assure safe operating practices; conduct special investigations of accident locations identified by atypical experience patterns, serious or unusual incidents, or to establish factual evidence in claims cases.

- Facility Design - Review plans for new facilities to assure compliance with building codes, safe building practices and insurance contract provisions; recommend new or retrofitted designs to reduce hazards, accident frequency and severity.

- Communication - Maintain and disseminate information on published codes, standards and practices; prepare reports and publications; develop media campaigns using signs, announcements, leaflets, etc. to increase safety awareness; coordinate safety and claims management activities; provide expert witness testimony; train personnel in recognition and reporting of safety hazards.

- Insurance - Recommend insurance coverages, self-insurance mix, policy terms and limits; develop relationship of costs to accident and claims experience; negotiate with brokers and underwriters for procurement of insurance.

4.2 SYSTEMATIC APPROACH

A well organized risk management program is dependent on the systematic process for the collection and analysis of falling accident reports. (4.1, 4.2) The purpose of this process is to identify falling hazard locations by relating accident frequency and severity to specific pedestrian facilities and station areas. In order to accomplish this it is necessary that all system stairs and escalators be key numbered, and station areas be divided into zones. These key numbers and zone designations can be stenciled on the stairs and escalators, on columns, and shown on maps at station attendant booths, at police call boxes or other similar locations. All accident reports must reference these numbers along with other data describing the accident. Facility personnel should be trained in filling out accident reports and the use of key codes.

With the transition into computer coding and analysis of accident data, it has become possible to more quickly establish accident trends and to examine these trends in much greater detail. Most transit systems currently monitor only general trends, such as the frequency of accidents on all platforms, stairs, and escalators, as related to total system traffic. Accident severity and claims costs have not usually been directly related to specific facility types and locations. However, in a systematic risk assessment this type of data is essential for the development of cost-benefit evaluations of potential remedial measures. Accident severity has a very significant relationship to claims costs, with the settlement of one serious accident potentially costing more than all others combined in a single year.

A systematic risk assessment analysis of this type could be applied to the recent transit industry trend of reducing escalator speeds from 120 fpm (.6 m/sec) to 90 fpm (.45 m/sec). The lower speed is reported to reduce maintenance costs and the frequency of escalator accidents. This is an illustration of the type of action that should be evaluated not only in terms of reduced accident frequency and maintenance costs, but particularly in terms of accident severity and claims costs. Relative passenger service and the different speeds should also be considered in this evaluation.

4.2.1 Uniform Reporting

Uniform reporting is an essential element in making statistical comparisons of accident experience within the transit industry, with other types of industries and exposures, or with national trends. A review of falling accident data voluntarily reported to the FRA indicates that these reports are not being made on a uniform and consistent basis. The reasons for this are that there are differing interpretations of the guidelines for reporting this data, and because different internal accident report forms and procedures are being used. Added to this, the majority of falling accidents result in minor injuries, many of which are not considered serious enough to report to others.

The lack of statistical uniformity can invalidate comparison of accident experience, and potentially result in misleading conclusions. As an example, the current industry trend in speed reduction of escalators has been partially justified by comparing the accident experience of different properties who are not using the same criteria for collecting and reporting data.

A means of establishing a uniform statistical base for the transit industry is to report only those incidents in which an ambulance is required, either at the request of the victim, or as determined by a police officer or other transit employee at the scene. These cases are typically those where there are obvious injuries requiring further diagnosis and possible hospital treatment. Ambulance aided incidents account for the majority of all the negligence claims filed against transit operators, and particularly the more severe incidents that result in larger claim settlements. At least one major transit property sends an accompanying police officer to the hospital with all ambulance aided cases. Others do this where the injury is apparently severe and it is obvious that the victim will require hospitalization. This can provided added useful information if claims for damages are filed at a later date.

A significant advantage of establishing ambulance aided falling accidents as the uniform index for industry reporting is comparability of the data with statistics compiled by the U.S. Consumer Products Safety Commission.

4.2.2 The National Electronic Injury Surveillance System (NEISS)

The NEISS is an activity of the Consumer Products Commission which provides information on the national accident experience by sampling emergency room admissions at almost 6000 hospitals. NEISS collects two levels of injury data, surveillance and investigation. (4.3) The surveillance data consists of general information about the accident, victim age and sex, injury diagnosis, disposition, accident location, and product related information. Stairs, escalators, and walking surfaces are product categories, but the data does not provide for the direct extraction of slipping and tripping types of accidents.

The second level of NEISS activity is comprised of accident investigations which provide detailed information derived by contacting the victims and witnesses to the incident. Although most of these investigations are not necessarily statistically representative of all reported injuries in a particular product category, they do provide details concerning the accident sequence and the cause of injury. The Commission also investigates reports of injuries from sources other than NEISS. These sources include consumer complaints, newspaper accounts, and answers to requests by government agencies.

Comparability of the transit property data with these national statistics as well as consistent and uniform reporting of accidents among transit systems is a significant industry objective. This objective can be attained by developing a uniform accident report form for internal use by the industry, and by establishing ambulance aided cases as a consistent threshold at which accident experience data is reported to others.

4.3 CLAIMS MANAGEMENT

Some difficulty was experienced in obtaining definitive and detailed information from transit properties on their methods of handling claims, and on settlement costs. A questionnaire survey was sent to a number of properties and returns were received from eight. Many of the returns were incomplete in area of claims practices and costs. Claims managers are understandably “defensive” about the information they supply to others because of the adversary nature of the legal process they are involved in, and the possibility that such information could be misused. The claims settlement techniques of individual claims managers may be likened more to an art than an objective management technique, with manager’s intuition playing a large part in the process.

The legal doctrine of “ordinary care” generally applies to claims for falling accidents in stations, with the victim required to provide evidence of negligence on part of the transit property as a basis for filing a claim for damages. However, the common practice, even in cases where no negligence on the transit property is indicated, is to settle smaller claims out of court, simply because court costs would exceed the costs of a settlement. These “nuisance” settlements are cases where there has been a small incidental medical expense or minor property damage, such as torn clothing. Many settlements in these categories are $100 or less, and seldom exceed $500.

4.3.1 Litigated Cases

Settlement costs for other cases brought to litigation can vary considerably based on a number of factors including severity of the accident, amount of medical expenses, extent of permanent disability if any, lost earnings, establishment of negligence by the plaintiff, and sympathy of the jury for the victim. Transit industry falling accident cases generally have a lower than average settlement cost compared to those reported by others. This is attributable to the industry’s better standards of design and higher levels of maintenance and housekeeping.

Falling accidents involving no treatment or minor first aid without an ambulance call typically do not require any financial settlement. The majority of ambulance aided cases involving some minor hospital treatment but immediate release of the victim also do not usually involve a settlement. About 1 to 3 percent of all cases involve a hospital stay of one or more days and can lead to more costly claims. Accidents involving a permanent disability of the victim are a rare occurrence, but these accidents substantially increase claims costs, and can result in a single large settlement which can exceed the costs of all other cases combined for a typical year.

The majority of transit falling litigations are settled before the actual trial, and large settlements are very rare. Based on the limited information available, the average settlement cost for a falling accident claim is about $1000 to $1500. In contrast, a review of approximately 50 claims awards in falling accident litigations listed by the National Law Reporters in 1982-83 showed that the median settlement was $32,300 and the average settlement was a high $71,000. (4.4) The awards ranged from $2000 for an ankle sprain to $450,000 where permanent partial paralysis of the victim was involved. These awards were not consistent, with wide variations in awards for roughly the same accident scenario and injury syndrome.

4.3.2 Industry Costs

Because of the absence of definitive claims settlement cost data for falling accidents in stations, only an approximate estimate can be developed for total industry cost. The 11 properties included in this study carried a combined total of 7.25 billion passengers in the period 1976-1980, and reported about 10,000 patron falling accidents in stations during this same period. This is equivalent to one falling accident for each 725,000 trips, or assuming two station uses for each trip, one fall for each 1.5 million station exposures. On the statistical basis used in Chapter 3, this is a rate of about seven falling accidents per 10 million exposures. This rate is not in agreement with the statistical analysis in this study, which showed 20.7 falls per 10 million station exposures. Allowing for variations in reporting by using the study data, rather than industry reports, the projected number of transit station falling incidents during 1976-1980 was 30,000, and ambulance aided cases 11,600.

Limited information obtained in this study indicated that negligence claims are filed for one in every 4 to 5 falling accident cases. This would equate to 6000-7500 claims for the study period or an average of about 1350 claims per year. At the present estimated average settlement cost of about $1000 to $1500 per claim, the current annual industry cost of claims settlements is approximately $1.7 million. This is the equivalent of about a tenth of a cent per passenger ride. The administrative costs connected with settling these claims in all likelihood exceeds the actual costs of settlement by a significant amount.

4.3.3 Societal Costs

A 1975 study of hospital experience in falling accidents showed that of 1740 victims examined, 283 or 16 percent were admitted to the hospital and stayed an average of 6.6 days. (4.5) Victims over age 60 comprised 62.5 percent of the admissions, and had an average hospital stay of 8.5 days. The average 1975 hospital stay for the 1740 emergency room admissions and those hospitalized for those falling accidents was 1.07 days and cost $283. The study also showed that 60 percent of the accidents occurred at home, and 40 percent in public places.

The falling accident experience reported by this study would tend to be more extreme than that of the transit industry because it includes the more severe injuries that typically occur in the home. However, extrapolation of the data would indicate that the 30,000 estimated falls and 11,600 emergency room examinations estimated by this study for the transit industry in the period 1976-1980 would result in about 12,400 person days of hospitalization worth about $1.2 million in lost time, assuming wages and overheads at $100 per day, and approximately $3.7 million in hospital costs, at $300 per day. Current wage and hospitalization costs would be higher.

4.3.4 Future Costs

The increasing average age of the general population, increased costs of medical treatment and hospitalization, and increasing awareness of the possibilities of filing claims for damages, even in cases where personal negligence is involved, will increase transit industry falling accident claim costs. Trends shown in the 1970 and 1980 census indicate that the median age of the U.S. population increased from 27.3 to 30.0 years. The percentage of persons over age 55 increased from 19.2 to 20.9, and over age 65 from 10.0 to 11.3 percent in 1970-1980 period. (4.6) Elderly transit patrons tend to have more accidents than average, and with slightly greater severity. The cost of medical treatment is also increasing steadily, and at a rate greater than general economic trends. The national average daily hospital room charges doubled between 1976 and 1982. (4.7)

4.3.5 Insurance Coverage

The survey of transit properties showed that eight respondents were all self-insured for amounts ranging from $.5 to $2 million, with $1 million the most common amount. Excess coverage ranged from $20 million to $100 million.

5.0 DESIGN AND OPERATING STRATEGIES TO REDUCE FALLS

In general, few transit passenger falls are caused by design or operating deficiencies. The very low frequency of falling accidents, large percentage of alcohol involved accidents (29 percent), higher incident rates in non-rush hours, as well as other temporal patterns unrelated to passenger activity levels, show that the majority of patron falling accidents are caused by behavioral factors, pre-existing medical conditions, or personal actions of the victim rather than the transit facility design or operation. This suggests that increasing public awareness of fall avoidance is an important objective in any accident reduction program. However, design and operating practices demand attention because of the higher liability costs associated with accidents where factors such as inappropriate walking surface treatment or poor housekeeping contribute to the fall.

5.1 WALKING SURFACE DESIGN

All walking surfaces should be designed to provide a uniform slip-resistant finish that will maintain its characteristics under heavy foot traffic, cleaning processes and the environmental conditions on the transit facility. Wearing effects, and accumulations of cleaning materials or oil and grease can result in reduced slip resistance. Uneven wear, surface cracking, “spalling”, or “heaving” caused by weathering or the type of materials selected, and pavement settlement, can create surface irregularities that contribute to tripping incidents and can result in falls or wrenched joints.

5.1.1 Wear Patterns

The characteristics of pedestrian movement can be more important than total traffic volume in determining surface wear. Experience has shown that surface abrasion and wear is minimal where pedestrians walk freely, but becomes significant in transitional areas where pedestrians must stop momentarily, shuffle due to crowding, or pivot and turn. Core samples of 3/4 in. (19 mm) thick terrazzo surface over a concrete sub-base in a large transportation terminal showed little wear in “free flow” areas after 15 years service and use in some sections by up to 1 billion passengers. However, this same terrazzo surface had been repeatedly worn down to the concrete sub-base at transitional areas such as doorways, upper and lower landings of stairs and escalators, at newsstands, and other stop-and-go locations. For this reason, travertine and other soft surfacing materials which are subject to wear should not be used for transit facility walking surfaces. (5.1) The design approach in transitional traffic areas requires not only the initial use of durable abrasion resistant materials, but provision for convenient and economic replacement.

5.1.2 Environmental Conditions

Exposure to moisture, freezing, wide changes in temperature, deicing and cleaning chemicals, and other environmental factors naturally affect floor surfaces. Concrete and masonry materials are best suited for transit environments, but still may have problems. For example, terrazzo finishes can become slippery when wet or when polished too smooth in initial finishing or later by wear. Abrasive materials should be included in the initial mix to reduce this problem. Brick, pavers, stone, slate tile, and similar paving materials require a level, well compacted, and well drained supporting subgrade or these materials can become dislodged or break, provide an uneven walking surface, and create tripping hazards. This problem is more severe in areas where there is a freeze-thaw cycle. (5.2)

5.1.3 Slip Resistance

As measured by both dry and wet surface friction factors, slip resistance is an important consideration in falling accidents. The friction coefficient is defined as the ratio of the limit of horizontal force without slippage required to move the contacting surface over the floor, to the vertical force or weight acting on the floor, or:

$$\text{Coefficient of Surface Friction (COF)} = \frac{\text{Horizontal Force}}{\text{Vertical Force}}$$

Measurement of slip resistance of walking surface materials is complicated because it is also dependent on the friction characteristics of the interfacing shoe sole materials. (5.3) The slip resistance of leather-soled shoes can actually improve on some wetted surfaces whereas a synthetic sole with excellent dry surface characteristics can become unusually slippery when wet.

Another problem that makes the standardization of slip resistance ratings of flooring materials difficult is that the available mechanical measuring devices give differing results for the same surface and interacting shoe materials. However, reasonably consistent results, particularly when making comparative evaluations of different materials against each other, have been obtained with a simple arrangement of a weight, a shoe material interface, and a spring scale to measure the horizontal force component. (5.4)

The slip resistance of existing walking surfaces has been improved by saw-cutting the floor and adding epoxy-based abrasive materials in the grooves. Abrasive coatings and abrasive strips can also be applied. Abrasive strips, mats, or other walking surface add-ons must be carefully done and routinely inspected to assure that they don't loosen and create *a* slip or trip hazard. Abrupt changes in surface friction due to add-ons or differences in finishes should be avoided, particularly where passengers must turn and change direction. (2.14)

5.1.4 Slip Resistance Values

The minimum COF required to avoid slipping is the resistive force necessary to maintain the stability of the heel strike and push-off in the walking cycle, or 15-20 percent of the applied force. This is the equivalent of a COF value of 0.15 to 0.20. However, a floor COF in this range does not allow a sufficient margin of safety to allow for variability in footwear and environmental conditions, and therefore would be considered slippery. A floor surface COF in the range of 0.25 to 0.40 would be considered only fair, and 0.50 has been set as the standard for a non-slip surface by a number of sources. (5.5) Measured COFs for different floor materials from various sources vary depending on measurement devices, experimental conditions, and shoe materials. Some representative values are shown on Appendix Section A-14. An excessively high surface friction value, say 1.0 or more, may provide too much slip resistance and potentially result in a tripping hazard.

The concrete floor surfaces used in most transit facilities have a high slip resistance (COF 0.5 - 0.7), but can create problems where there may be an abrupt transition to terrazzo (COF 0.25 - 0.40), or similar flooring materials with lower relative COFs. Polishing with non-skid wax can temporarily improve the COF for many materials, but surface characteristics may change with wax build-up and aging of the wax finish. Waxing also requires continuing maintenance.

5.1.5 Sloping Floors

Higher COFs are necessary on ramped walking surfaces to allow for the increased resistance required for the heel strike and push-off on the slope. This can be obtained by increased roughening of concrete finishes or the addition of slip resistant coatings or strips on the sloped floor. Sloped surfaces can cause an “expectancy” type of accident hazard if the ramp has a lower COF than the intersecting level surface, as for example where there is a carpeted level floor, and a terrazzo finished ramp. The slipping problem occurs at the heel strike when moving from the carpeted area to sloped surface.

5.1.6 Floor Mats

Floor mats are sometimes used in transportation terminals to reduce tracked in mud, snow and other materials that might make floors slippery. (5.6) Typical locations would be doorways, escalator, and stair approaches. Because mats are easily replaced, they may also be used in high wear transitional traffic areas. The floor mat can provide a walking surface with a good coefficient of friction and potentially reduce falls if properly installed and maintained. When possible, mats should be recessed to provide a level walking surface. Care must be taken that mats don’t ripple or curl up at the ends and create a tripping hazard. Mats that are not firmly fixed in place can also shift underfoot and cause a slipping hazard.

To be effective, mats should be long enough to get both feet on the mat at least once. This requires a mat 6 ft (1.8 m) long to accommodate the pace of a 95th percentile male. Mats are made of a wide variety of materials, patterns, and thicknesses. Materials include rubber, vinyl, neoprene, aluminum in the form of chain-like linkages, and coco-fibers. Patterns include ribbed corrugations, perforated, “nubby,” or basket weave surfaces, and open linkage configurations in metal or wire-reinforced rubber designs. Open linkage types are effective in removing grit and providing a non-slip surface, but can catch women’s small diameter heels.

5.2 STAIR DESIGN

The dimensions to be determined in designing stairs include height of riser and length of tread, the width of the stair, configuration of handrails, and the location and size of intermediate landings. Other dimensional details include the nosing or overhang and rounding of the step edge, and for outdoor stairs, the slope of the tread or “wash” required for drainage purposes. Because of heavy pedestrian traffic on most transit facility stairs and the resulting tread wear patterns, stair surfacing materials are an important consideration. As an example, complete replacement of travertine stair treads in one busy transit terminal was required after only a few years service because of excessive wear.

Different tread wearing patterns can be observed on the “up” and “down” side of stairs because of differences in the movement of the foot in ascent and descent. In ascent there is an abrasive rolling and sliding of the foot which results in the dishing out or concave depression of the tread. In descent there is less abrasion but the rolling over the ball of the foot on the tread edge tends to round and “polish” the nosing.

5.2.1 Dimensioning Treads and Risers

For many years architectural handbooks and building codes have used a formula approach for proportioning riser and treads. One such formula, twice the riser plus the width of the tread equals an assumed constant allegedly based on the human pace length ($2R + T = K$), has been found to have its origins in non-scientific observations made more than 300 years ago. (5.7) The pace length constant of 24 inches used in the original equation remained unchanged for hundreds of years despite redefinition of the standard “inch” dimension, and increases in the average human pace. Current anthropometric research, observations of patterns of stair use, and relationships of stair accidents to design characteristics, have shown a more limited range for desirable riser and tread dimensions. (5.8)

5.2.2 Tread Width

Tread width is directly related to the length of the human foot. Where treads are too narrow, pedestrians will be observed moving sideways on the stair to obtain adequate step width for stability. For proper balance and a stable push-off, pedestrians prefer to place the ball of the foot on the step nosing in descent and to have a firm platform for the full length of the foot in ascent. Narrow steps force either awkward sideways movement or an excessive overhanging of the feet which increases the possibilities of a misstep.

Anthropometric measurements discussed in Section 2.0 and shown on Appendix Section A-1 indicate the 95th percentile, male adult foot length is 11.4 in. (290 mm). The dimension from the heel to the metatarsal heads or “ball” of the foot for the 94th percentile male is 8.4 in. (210 mm). Considering allowance for shoes and a 1/4 to 1/2 in. (6 to 13 mm) clearance for heel, the required tread dimension, with the minimum shoe and foot overhang would be 11 in. (280 mm). A tread length of 14 in. (360 mm) would be necessary to fully accommodate the largest male adult foot without an overhang. While treads of this size are not common, the Pennsylvania Railroad Stations in New York and Philadelphia have had 6 in. (150 mm) riser, 14 in. (360 mm) tread stairs under heavy use for more than 50 years.

Although human pace lengths are not a factor within the 11 to 14 in. (280 to 365 mm) range of recommended tread dimensions, tread lengths beyond 14 in. (365 mm) can affect the stair pacing pattern and rhythm, potentially causing safety problems. As an example, an awkward gait pattern is experienced when a stopped escalator with its 8 in. by 16 in. (216 mm/400 mm) riser-tread combination is used as a stair. Normal routine use of a stopped escalator as a stair is not recommended for this reason. Stairs with very long treads, sometimes sloped or ramped by designers, or other atypical riser and tread combinations should be avoided in transit applications because they do not fit normal pacing patterns, and because of the “expectancy” accident factor. It is also advisable to avoid short, abrupt stair flights of one or two risers in open plazas because of the difficulties pedestrians have in perceiving grade changes in this type of visual environment. (5.9)

In summary, dimensional regularity and designs consistent with common experience are emphasized as a very significant aspect of stair design, with even small variations in these factors increasing the probabilities of missteps.

5.2.3 Riser Heights

Riser heights affect the amount of energy and degree of hip and knee joint motion required for stair ascent and descent. Excessive joint rotation caused by high step risers is a problem for the elderly and disabled, but also causes missteps for others. Fatigue from using stairs is a problem for those with heart and lung disabilities, or strength limitations. Studies of human energy expenditure, the probability of missteps, and stair accidents show that the preferred range of riser heights is between 5 and 7 in. (127-178 mm). Open risers having no closed face at the back edge of the step should be avoided because of the possibilities of extensions of the foot into the open space, creating a tripping hazard in ascent. The recommended combinations of tread and riser dimensions based on human factors studies of stairs are shown on Section A-15 of the Appendix. Local codes may require different dimensions than shown by this study. As-built differences in riser heights under normal construction tolerances should not exceed 3/16 in. (5 mm). (3.1)

5.2.4 Nosings

Nosings are the leading edge of the tread, typically rounded and extended beyond the rear of the step below. Projected and extended nosings are thought to increase effective tread length while conserving the amount of horizontal space occupied by the stair. However, based on observations of the movement of the foot in stair locomotion, extended nosings do not functionally increase the tread area for pedestrians. Excessive projection of the nosing can cause missteps by catching the toe in ascent or the heel in descent. Catching of the heel in descent can cause a more severe accident by pitching the pedestrian forward and down the stairs. A protruding, overhanging extension of the nosing is not generally recommended because of this. However, a more acceptable tread extension can be accomplished by sloping or “raking” the back of the riser on an angle from the nosing edge to the intersection with the tread below. The recommended maximum extension or rake of the tread in this configuration would be 1 in. (25 mm).

Rounded nosings can assist in the rotation of the foot around the edge of the stair in descent, and when used on concrete stairs help reduce uneven wear and breakage of the tread edge. The rounded nosing is also considered safer than the sharp right angle edge, which can increase accident severity if impacted during a fall. The recommended radius of rounding is 1/4 to 1/2 in. (6-12 mm).

5.2.5 The Wash

The wash is a downward slope of the stair tread usually used on exterior stairs to promote drainage off the stairway and avoid puddling and icing. Medieval architects believed that the wash reduced the effort of stair climbing, but there is no evidence to support this. Where a wash is employed, the downward slope of the tread should be approximately 1/8 in. per foot (1:100 mm). Strict controls during stair construction are necessary when the wash is used to assure uniformity of riser height dimensions.

5.2.6 Handrails

Handrails provide stability during stair movement, act as a climbing assist for the physically impaired, and help arrest or reduce the potential energy and impact of stair falls. The handrail also provides a tactile guide for the sight impaired and most other users. Handrail design factors include its “graspability” in terms of its shape and wall clearances, the railing height above the step, its structural support, and lastly, the avoidance of ornamentation or other types of details which could contribute to accident severity if impacted during a fall. As discussed in report section 2.4.8, handrail shape, wall clearance, and height are important factors in determining the pedestrian's ability to arrest a fall.

Handrail Shape is determined by the bio-mechanics of the maximum gripping force that can be exerted to resist a fall. When falling, a pedestrian will try to forcefully grasp the handrail, with the hand wrapping around and assuming the handrail shape. The most powerful grasp is obtained with circular and oblong shapes where the circumference of the handrail is between 4.4 and 5.2 in. (110-130 mm). For the circular handrail, this is the equivalent of a diameter of about 1.5 in. (40 mm). Gripping power drops sharply for larger circumferences. The larger oversize or decorative handrail shapes can reduce accidents by providing added stability in normal stair use, but offer little help in arresting a fall in progress. Sharp edges, protrusions, or other handrail design details which could increase impact injuries must be avoided.

Handrail Clearance from walls to allow a "last grasp" effort to arrest a fall should be 3 in. (76 mm) in accordance with OSHA standards. (2.12) This clearance, which is greater than specified in most local building codes, is especially needed where there are rough wall finishes and where pedestrians are likely to have the additional encumbrance of heavy winter clothing. Handrails in recessed alcove arrangements are to be avoided because of the impedance to the quick grasping effort.

Handrail Height is determined by human body dimensions and requirements for stability in descent, the most hazardous direction. For descent the handrail must be high enough so that tall users do not have to bend sideways toward the handrail or trail the hand behind the body to use it. Handrail heights set for taller people are also favorable for others because the added height results in a forward extension of the grasp in descent, increasing stability and resistance to falls. In open stairwells where there is a danger of a fall to a lower level, the handrail must be designed as a guardrail and set higher above the normal body center of gravity to help prevent falls over the railing.

Recent studies indicate that stair handrail heights as high as 36 to 38 in. (914 to 965 mm) would be more bio-mechanically efficient than the common maximum of 34 in. (864 mm) shown in most building codes. (5.10) The height of guard rail type railings should be at least 42 in. (1070 mm) in accordance with OSHA standards to be above the normal body center of gravity for the largest adult male population. Additional railings, vertical balusters, or other types of protective barriers must be provided below the top railing of guard rails to prevent falling beneath it. Protective balusters or other types of barriers are horizontally spaced at 4 in. (100 mm) or less, to be smaller than children’s head dimensions.

Handrail Extensions of a minimum of 12 in. (305 mm) measured horizontally beyond the top landing of the stair, and 12 in. (305 mm) plus the width of the tread at the bottom landing, are recommended. The horizontal extension provides a tactile guide to assist the disabled and sight impaired on these stair approaches.

Handrail Supports must be capable of withstanding the forces caused by normal patterns of use as well as the unusual force of a fall. Most building codes have requirements for handrail strength based on both uniform load and point load criteria. Handrails should be designed to withstand bending moments due to a 250 lb. (113 kg) horizontal concentrated load. Fasteners and mountings of supports should withstand sheer and tensile loads of 250 lbs. (113 kg).

5.2.7 Stair Widths

Stair widths are determined by expected pedestrian traffic volumes and building code requirements. Building code width criteria are intended primarily for establishing the emergency egress requirements and not the aspect of human convenience. The so called pedestrian “lane” dimension, or unit exit width of 22 in. (560 mm) contained in virtually all building codes has resulted in some inadequately designed transit facility stairs. In some transportation terminals 44 in. (1120 mm) wide stairs have been used on the assumption that this provides two effective pedestrian lanes. This 22 in. dimension is approximately equal to an adult male shoulder width, but does not allow for body sway, or for convenient two-way movement and passing where pedestrians are carrying packages and are heavily clothed. The recommended width between handrail centerlines for stairs to allow convenient two way movement without brushing against others and for bypassing slower moving pedestrians is 50 to 54 in. (1270 to 1372 mm).

Photographic studies of pedestrian movement on stairs and careful evaluation of a number of building evacuations show that traffic capacity on stairs increases proportionately with the effective stair width. (5.11) The effective width as determined by photographic analysis is about 7 in. (180 mm) less than the centerline to centerline spacing of handrails. The relationships of various traffic volumes, densities, and levels of pedestrian convenience on stairs are shown on Appendix Section A-16.

5.2.8 Stair Landings

Stair landings at intermediate levels can help reduce the probability of longer extended falls and potentially more severe injury. Intermediate landings also break the monotony and fatigue associated with using long flights of stairs. Upper and lower landings have a function in providing a space for queuing pedestrians. Where possible these landings should be large enough for this purpose and separated from other pedestrian traffic movements to avoid conflicts. Traffic conflicts at the tops of stairs should be particularly avoided, since pedestrian contact could cause a loss of balance and a serious fall.

Traditionally, most flights are broken with intermediate landings at mid-story height, or usually about each 10 to 12 risers, depending on the height selected. Straight run stairs should normally not exceed 18 risers without a landing. The recommended minimum length for an intermediate landing for straight run stairs is 4 ft (1.2 m), and for return run “wrap around” stairs no less than the stair width. Doors should not be located on or near landings because of the possibility of impacting pedestrians and causing a fall, and also because an opened door could block emergency egress.

5.2.9 Stair Lighting

Stair lighting must be adequate for users to clearly differentiate the leading edge of the tread for proper placement of the foot. Studies show that lighting uniformity is probably more significant than intensity. Shadows, glare, and step finishes or carpet patterns that would tend to obscure, “camouflage” or otherwise confuse the differentiation between step edges are to be avoided. A minimum uniform lighting as low as 3 FC (32 lux) is shown in many codes but higher lighting levels, up to 20 FC (215 lux), in transit uses are desirable. More than one light source should be provided to allow for bulb failure.

5.3 ESCALATOR DESIGN

Since escalators are almost an “off-the-shelf” item, there are only a few features that the designer can change. All the major equipment design aspects of escalators are determined by the provisions of the ASME - ANSI A17.1 code. (5.12) Within the constraints of the code the designer can select escalator width, operating speeds, power options, the number of level running steps at entrances and exits, and balustrade materials. Probably the most important factor under designer control is the environmental context in which the escalator is placed - such as its relationship to pedestrian traffic flows, area lighting, and signs.

5.3.1 Escalator Speeds

Escalator speeds are generally set at two norms in the United States, 90 and 120 fpm (.5-.6 mps). Faster speeds are used in other countries, up to a maximum of 200 fpm (1.2 mps) reported in the Soviet Union. (5.13) Although manufacturers rate the capacity of an escalator in direct proportion to speed, studies have shown that the highest practical capacity occurs at about 145 fpm (.7 mps), and that a 25 percent reduction in escalator speed from 120 fpm to 90 fpm (.6 - .5 mps) results in only a 12-15 percent reduction in effective capacity.

(2.5) There is a growing trend in the United States to use the slower 90 fpm (.45 mps) speed, reportedly because of reduced maintenance. The lower speed also tends to reduce the overall number of accidents, particularly for those persons who have perception and reaction problems which can be accentuated at the higher speeds. Some transit properties with dual speed units have followed an alternative practice of using the faster speed in peak periods when escalator trip times and capacity are a desirable passenger service factor, and the slower speed in off-peaks. The lower falling accident experience during peak periods shown in this study appears to support this type of compromise between patron service and relative pedestrian accident exposure.

5.3.2 Level Step Runs

Level step runs at the entrances and exits of escalators are another area where there is no controlled study of the relative advantages of different configurations. The standard escalator used in department stores and older transit properties varies from approximately 1/2 to 1-1/2 level steps, at both the bottom and top landing of the escalators. Newer designs, particularly in high-rise applications, have approximately 3 to 3-1/2 step level run at top and bottom landings. It is believed that the extended level runs allow the passenger more time to adjust to the movement of the escalator when boarding, and to prepare for the transition from the inclined movement of the escalator to a stationary level surface when exiting. It is also believed that level step runs increase the utilization of the escalator by reducing passenger hesitation upon boarding. This latter effect is not significant if true, since level moving walkways with the same entrance dimensions of escalators have been observed to have virtually the same capacity. (2.2)

Additional level steps beyond the standard normally supplied by the manufacturer increase the cost of the escalator because of added structural requirements at escalator ends and because of the greater length of the unit. An alternative to the extended level steps, which also could benefit those having perception and balance problems, might be an increase in the radius of curvature of the guideway tracks which support and articulate the escalator steps. This would produce a more gradual articulation of the steps and allow more time for the passenger to adjust in entrance and exit transition zones, and also reduce the vertical acceleration forces on the passenger. Based on the current understanding of the level run feature, 2 flat steps in transit applications is desirable, with 3 used for faster units or in high-rises.

5.3.3 The Environmental Context

The escalator’s environmental context can be a falling accident factor. Escalator approaches should provide sufficient area to accommodate waiting pedestrians and be separated from other cross-flow pedestrian traffic. Since the boarding and exiting of the escalator involves the visual perception of relative speeds and demarcation between stationary and moving surfaces, as well as pace coordination, sufficient light should be provided for these tasks. Minimum lighting of escalators should be 5 horizontal FC (54 lux), and higher lighting levels up to 20 FC (215 lux) are desirable. Under-the-tread lighting to delineate tread edges and tread illumination by lights set in the balustrades at entrances and exits to increase the contrast between stationary and moving surfaces, is of value.

To allow the eye to adjust, a gradual transition to higher values of lighting at the escalator is preferable. Sharp changes in lighting levels, shadows across the escalator treadway, and glare from highly polished surfaces can confuse the user. Large open spaces with “busy” visual environments and many distractions in the rider’s field of view can potentially cause an accident hazard. Optical affects caused by movement past repetitively patterned wall finishes, such as horizontally placed tiles, have also been observed to disorient escalator riders, particularly on high-rise installations.

5.3.4 Skirt Lubricants

A potentially serious accident sometimes occurs on escalators with children wearing soft footwear such as sneakers. The child places the sneaker-clad foot at the side of the escalator step near the skirt panel, and because of the pliability of the footwear and small size of the foot, the foot is caught between the skirt panel and the moving step, and may also be dragged under the combplate. This entrapment type of accident can result in crushing or even amputation of part of the foot, with an associated high claims settlement cost.

One preventative of this type of accident is the provision of a shut-down switch behind the skirt panel which will stop the escalator when there is pressure against the panel. The shut-down switch on the escalator can also help reduce the severity of the entrapment. Another recent design innovation is the addition of a stepped or raised cleat on the sides of the tread adjacent to the skirt to guide the foot away from the skirt panel. (5.13)

Skirt lubrication to cause the foot to slip away from the skirt and the closing step is also used to prevent entrapment accidents. A study of various types of lubricating materials found that a silicone aerosol spray was about the best for this purpose. (5.14) However, the study also established that lubricants must be very carefully applied because overspraying and wetting of treads can cause a significant slipping hazard. According to this study, the aerosol should be sprayed through a paper cone shield to localize the application of the lubricant on a smaller area of the skirt panel. Other measures to minimize the entrapment involve markings on the treads and signs.

5.3.5 Signs and Markings

A standard sign has been developed by the escalator industry to encourage proper use of escalators by the public. This sign, suggested for use in the latest ANSI-A-17 code is shown on the following page (Figure 5-1). Transportation terminal operators have also put markings such as a red or yellow stripe at tread edges to alert passengers to the danger of standing too close to the skirt panel. Additionally, the National Aeronautics and Space Museum in Washington, DC and several department stores have stenciled the outline of feet on the tread to encourage children to stand on these markings rather than near the skirt. Colored circle or diamond shaped markings spaced periodically along handrails have been used to assist passengers in judging the speed of the handrail and escalator when boarding.

5.4 OPERATIONAL STRATEGIES

Operational techniques to reduce falls on walking surfaces, stairs and escalators are mostly related to careful housekeeping and alerting patrons of potential hazardous conditions. Media campaigns, a method used successfully in other industries for many years, can make transit patrons more aware of falling hazards and encourage them to avoid unsafe practices.

5.4.1 Housekeeping

Loose papers, spilled beverages or food, or similar foreign materials on floors and stairs can present unexpected changes in surface friction to the unwary pedestrian and cause the expectancy type of slipping accidents. (5.15) Restrictions against eating on trains and in stations, media campaigns to reduce littering, and provision of litter baskets can help reduce this problem. Foreign substances and spills on walking surfaces should be removed or covered as quickly as possible to reduce falling hazards. Walking surfaces wetted for cleaning processes should be cordoned off until dry. Caution signs are necessary in areas being cleaned and where there are temporary low profile tripping hazards associated with maintenance and repair procedures such as stretched out electrical cord.

FIGURE 5-1. ESCALATOR CAUTION SIGN

Since housekeeping personnel are exposed to station areas on a periodic basis, they should have the responsibility of reporting falling hazards such as surface cracking, dislodged or broken expansion joint and paving materials, and surfaces that are frequently wet due to inadequate drainage. A checklist approach is useful for this type of inspection.

5.4.2 Use of Media

Public address system announcements on trains and in stations, leaflets, and signs can make transit passengers more safety conscious and help reduce falls. On-board train announcements when there are outside winds above 25 mph (40 kph), or when there are snow and ice conditions on platforms, should be used to alert patrons of falling hazards. This addresses the expectancy factor in the avoidance of falls.

For many years the National Safety Council has distributed posters and leaflets to general industry advocating safe practices. This technique has not been widely applied in the transit industry, but at least one major transit operator has developed and used a safety leaflet for distribution to passengers. This operator is also currently developing a safety poster campaign called “Subway Smarts” for possible use in subway car and station displays.

6.0 FALLING ACCIDENT SEMINAR/WORKSHOP

A meeting of invited Transit Industry representatives to discuss the results of the falling accident study was held on April 25, 1984, at the Journal Square Transportation Center, One PATH Plaza, Jersey City, New Jersey. A roster of attendees is contained in Appendix Section A-18. Seven different rail properties and the American Public Transit Association (APTA) were represented at the meeting. Safety engineering, risk management, claims management, insurance, maintenance, and design and planning disciplines were represented in this group.

The meeting consisted of an extensive slide presentation of the results of the falling accident study, and presentations on PATH claims and risk management procedures and experience. Written comments are summarized in Appendix Section A-19.

6.1 MEETING SUMMARY

There was good participation by attendees in the workshop discussions following the presentation of study results. The discussions and written comments contained in the Appendix focused on the following issues.

6.1.1 Uniform Accident Report Form

There appeared to be a consensus that a uniform internal transit industry accident report form would be of value to the properties in comparing accident experience, and in evaluating the effectiveness of design innovations and differences in operating practices. This data would also be of value in recommending changes in building codes to improve the design of escalators, stairs, and walking surfaces. It was noted that there is a lack of scientific information and accident data on escalators and other pedestrian facilities.

6.1.2 Computer Coding of Accident Data

There appeared to be a reluctance to get involved with computer analysis of accident reports. Some of the disadvantages cited were the costs and difficulties of coding, the tendency to over-complicate the accident evaluation process, and the development of voluminous data which may not have a useful purpose. On the other hand, it was recognized that the computer can provide new dimensions to accident analysis through quick access to long-term experience trends, data base information on the design configuration of stairs and escalators, and other valuable information.

6.1.3 Ambulance Incidence Report Threshold

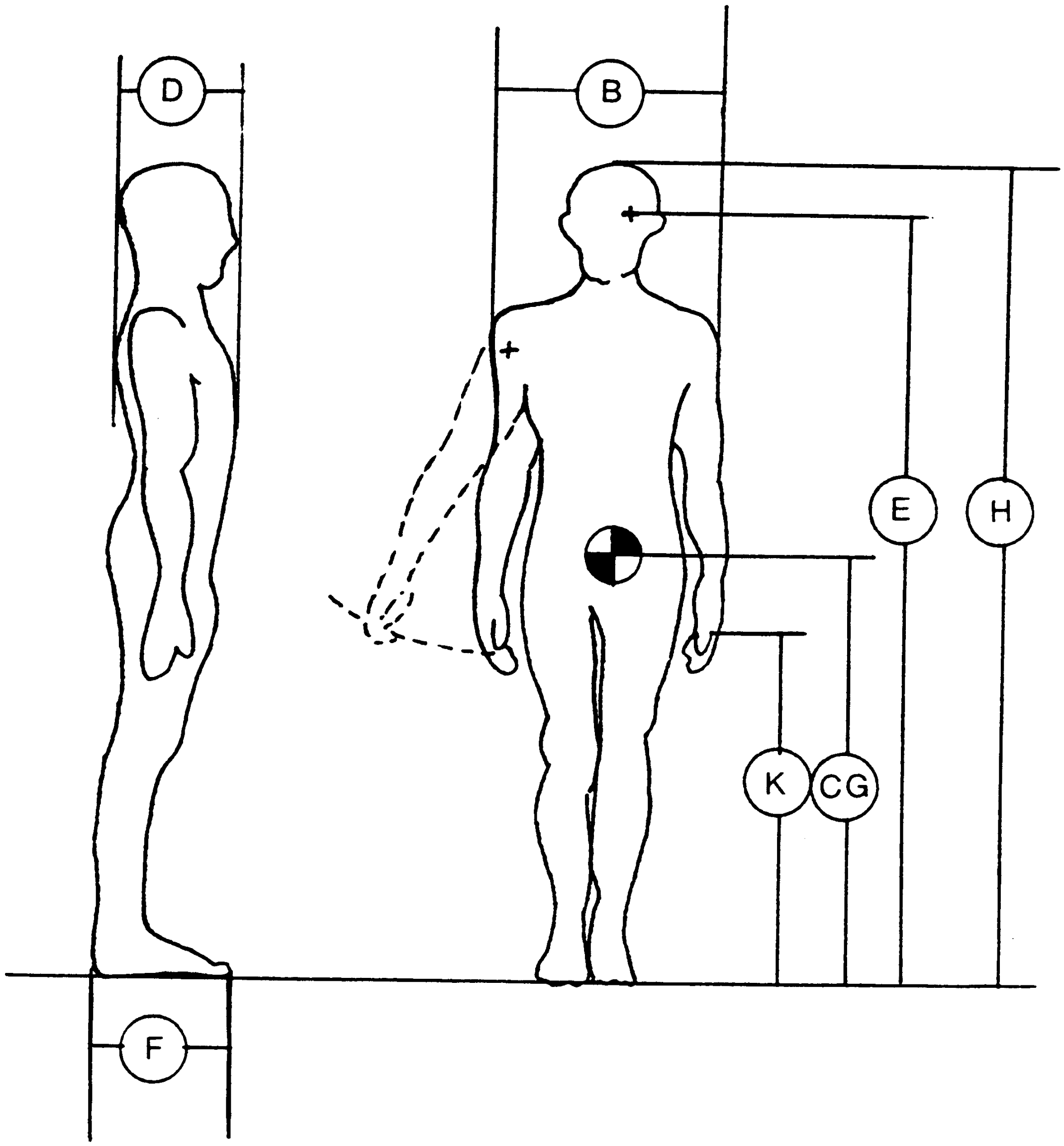
There was some disagreement on the use of ambulance aided accident cases as a uniform threshold for voluntary reports to UMTA.

It was pointed out that many ambulance aided cases involve only minor first aid treatment, which really cannot be classified as "medical" treatment. The industry may not readily accept this recommendation, unless it is developed through APTA as a means of establishing uniformity in industry reporting. It was noted that the Consumer Products Safety Commission budget was cut, and that their National Accident Reporting function was reduced.

6.1.4 Media Campaigns

Interestingly, it was noted that media campaigns to increase the public's awareness of using stair and escalator handrails and other safe practices to avoid falls could help reduce accident liability costs by putting patrons "on notice" about safe practices. Use of media (posters) to advise patrons of emergency evacuation procedures, to keep off tracks, etc. was cited as a precedent for media campaigns to help reduce falls.

APPENDIX CONTENTS



LEGEND:

(H) Height
(E) Eye Level
(K) Knuckle Height
(B) Shoulder Breadth
(D) Body Depth
(F) Foot Length
(CG) Body Center of Gravity
(Standing Upright)

A-1. ANTHROPOMETRICS

A-2. APPROXIMATE HUMAN BODY MEASUREMENTS, UNCLOTHED

PERCENTILES		(H) Height *2*		(E) Eye Level 2		(K) Knuckle Height 2	
		in.	mm.	in.	mm.	in.	mm.
95	MEN	73	1850	69	1750	32	810
	WOMEN	68	1730	64	1630	30	760
5	MEN	65	1650	61	1550	28	710
	WOMEN	60	1520	56	1420	26	660
PERCENTILES		(B) Shoulder Breadth 3		(D) Body Depth 4		(F) Foot Length 5	
		in.	mm.	in.	mm.	in.	mm.
95	MEN	20	510	11	280	11.4	290
	WOMEN	17	430	9	230	10.2	260
5	MEN	17	430	8	200	9.8	250
	WOMEN	14	360	7	180	8.8	220

NOTES:

1 Compiled from a number of sources, allowances for clothing must be added
2 Add 1-1.5 in. men’s footwear, 1-3.0 in. women’s footwear.
3 Add .75-1 in. men’s suit, .50-.75 in. women’s dress.
4 Measured at chest, add 1 in. for buttocks, .5 in. men’s suit, .25-.5 in. women’s dress.
5 Add 1.25-1.5 in. men’s footwear, .50-.75 in. women’s footwear.

PATRON ACCIDENT OR PROPERTY DAMAGE REPORT

INSTRUCTIONS:

☐ Patron Accident - (Send original copy to Inspection & Safety Division).

☐ Property Damage - (Send original copy to Insurance Division).

COPY TWO IS RETAINED BY ORIGINATING UNIT. IF ACCIDENT INVOLVING PATRON, ALSO INCLUDES PROPERTY DAMAGE, SEND COPIES TO BOTH INSPECTION & SAFETY & INSURANCE DIVISION.

FACILITY	EXACT LOCATION OF ACCIDENT. (ATTACH A DIAGRAM TO THIS FORM. WHEN POSSIBLE)	MAINT. H.O.?? NO.
☐ ☐		JOB NO.

ACCIDENT DATE	DAY OF WEEK	TIME	DATE REPORTED	TIME	OCCUPATION	AGE
/ /		A.M. P.M.	/ /	A.M. P.M.	☐ MALE ☐ FEMALE	

	GOING		GETTING		RIDING	STAIR NO.	MOTOR STAIRS STOPPED?	BY WHOM?	HOW LONG AFTER FALL?
☐ STATIONARY STAIRS	UP	DOWN	OFF	ON					
☐ MOTOR STAIRS							☐ YES ☐ NO		

TIME RESTARTED	CONDITION OF AREA
A.M. P.M.	

☐ NO TREATMENT ☐ FIRST AID AT SCENE	IF RENDERED FIRST AID ELSEWHERE. STATE WHERE	AMBULANCE CALLED ☐ YES ☐ NO

NATURE AND EXTENT OF INJURY (INCLUDE PART INJURED).	WEATHER CONDITION ☐ WET ☐ DRY ☐ SNOW ☐ RAIN

ANY APPARENT DISABILITY OTHER THAN FROM FALL?

WHAT DID INJURED ALLEGE CAUSED THE FALL?

KIND OF SHOES WORN BY INJURED:
HIGH HEELS ☐ MEDIUM HEELS ☐ FLAT HEELS ☐ GALOSHES ☐ OTHER:

WHAT DID INJURED CARRY?

ANY EVIDENCE OF ALCOHOL?

YES ☐ NO ☐ IF YES, DESCRIBE: ☐ SPEECH ☐ ODOR ☐ GAIT?? ☐ OTHER

DID YOU. WITNESS ACCIDENT	YES	NO	FOR PROPERTY DAMAGE. DESCRIBE DAMAGE AND GIVE CAUSE OF DAMAGE IF KNOWN

DAMAGE ESTIMATE	DAMAGE INVOLVED ☐ ☐ TENANT ☐ CONTRACTOR ☐ OTHER (EXPLAIN)

REPORTED BY	TIME	DATE	FACILITY MGR' S. SIGNATURE	DATE
		/ /		/ /

A-3. FACSIMILE OF PATRON ACCIDENT REPORT

A-4. TRANSIT PASSENGER FALLING ACCIDENTS: FACILITY TYPE AND SEX OF VICTIM

No. = total in category Amb. = Ambulance called

	Escalators			Stairways			Walking Surfaces			Total All Falls		Ambulance Calls	
	No.	Amb.	Amb. %	No.	Amb.	Amb. %	No.	Amb.	Amb.%	No.	% Tot.	Amb.	% Tot. No.
Males	162	70	43.2	112	61	54.5	267	114	42.6	541	52.3	245	61.4
Females	197	46	23.4	149	54	36.2	147	54	36.7	493	47.7	154	38.6
TOTALS	359	116	x	261	115	x	414	168	x	1034	100.0	399	100.0
Amb. as % Category			32.3			44.1			40.6				
Category as % of falls	34.7			25.2			40.1			100.0			
Amb. as % all falls			29.1		28.8			42.1				100	

Note: One third of all system passengers are females, two thirds male.

A-5. TRANSIT PASSENGER FALLING ACCIDENTS: SEX, AGE DISTRIBUTIONS, ALL FACILITY TYPES

AGE GROUP	MALES					FEMALES				
	FALLS	AMB.	% ALL*	% AMB.	% PSGRS.**	FALLS	AMB.%	ALL*	% AMB.	% PSGRS.*
Under 18	52	19	5.2	5.0	0.8	32	10	3.2	2.6	0.3
18 - 24	66	33	6.6	8.7	6.9	90	32	9.0	8.4	8.1
25 - 34	110	46	11.0	12.1	19.9	119	37	11.9	9.7	12.1
35 - 42	52	22	5.2	5.8	13.2	51	16	5.1	4.2	4.6
43 - 61	136	56	13.7	14.7	21.5	110	32	11.0	8.4	7.3
62 and over	99	52	9.9	13.7	3.6	79	25	7.9	6.6	1.7
TOTALS	515	228	51.6	60.0	65.9	481	152	48.1	39.9	34.1

NOTE: * 996 accidents, 380 ambulance aided cases where ages were reported.

** Based on reported ages, 1980 passenger origin and destination survey.

A-6. TRANSIT PASSENGER FALLING ACCIDENTS: FACILITY TYPE, VICTIM AGE, AND SEX DISTRIBUTION PASSENGERS

MALE = number of male accidents, FEM. = Female, AMB. = Ambulance called

	ESCALATORS				STAIRWAYS				WALKING SURFACES				ROW TOTALS				
AGE GROUP	MALE	AMB.	FEM.	AMB.	MALE	AMB.	FEM.	AMB.	MALE	AMB.	FEM.	AMB.	TOTAL	% ALL	AMB.	% AMB.	% PSGRS. GROUP
Under 18	28	11	22	5	8	0	3	2	16	8	7	3	84	8.4	29	7.6	1.1
18-24	15	8	25	9	7	4	31	6	44	21	34	17	156	15.7	65	17.1	14.6
25-34	19	7	52	13	24	10	43	11	67	29	24	13	29	23.0	83	21.8	31.0
35-42	10	1	15	1	18	13	21	9	24	8	15	6	103	10.3	38	10.0	17.4
43-61	46	18	44	10	27	19	31	14	63	19	35	8	246	24.7	88	23.2	27.9
62 & over	38	21	34	7	20	8	17	11	41	23	28	7	178	17.9	77	20.3	5.1
TOTALS	156	66	192	45	104	54	146	53	255	108	143	54	996	100.0	380	100.0	97.1%*

*Age distributions of passengers based on 1980 origin and destination survey replies, 2.9% no response. Minor under-reporting of below age 18 group likely due to nature of survey.

Note: One third of all passengers are female, two thirds male.

A-7. TRANSIT PASSENGER FALLING ACCIDENTS: FACILITY TYPE, SEX OF VICTIM, ALLEGED CAUSE

CAUSE	ESCALATORS				STAIRWAYS				WALKING SURFACES				ROW TOTALS			
	MALE	AMB.	FEM.	AMB.	MALE	AMB.	FEM.	AMB.	MALE	AMB.	FEM.	AMB.	TOTAL	% ALL	AMB.	% AMB
1. Slipped	11	4	27	6	14	4	31	10	16	2	24	7	123	11.9	33	8.3
2. Tripped	26	8	45	3	14	1	42	12	15	3	24	10	166	16.1	40	10.0
3. Pushed	5	4	14	2	1	0	4	1	6	1	11	4	41	4.0	12	3.0
4. Lost Balance	28	11	50	17	8	6	22	10	39	18	39	24	186	18.0	86	21.6
5. Sudden Stop Escalator	5	3	14	3	-	-	-	-	-	-	-	-	19	1.8	6	1.5
6. Alcohol Inf.	65	33	10	3	55	36	11	4	147	66	14	3	302	29.2	145	36.3
7. Foreign Object	6	3	8	2	5	2	15	5	17	5	28	4	79	7.6	21	5.3
8. Unknown	16	4	29	10	15	9	24	12	27	19	7	2	118	11.4	56	14.0
TOTALS	162	70	197	46	42	61	149	54	267	114	147	54	1034	100.0	399	100.0

Note: One third of all system passengers are female, two thirds male.

A-8. TRANSIT PASSENGER FALLING ACCIDENTS: MONTHLY PATTERNS AND ALLEGED CAUSE

NO. = Number accidents

MONTH	SLIPPED	TRIPPED	PUSHED	LOSS OF BALANCE	SUDDEN ESCALAT OR STOP	ALCOHOL INFLUEN CE	FOREIGN OBJECTS	UNKNOWN	ROW TOTALS				
	NO.	NO.	NO.	NO.	NO.	NO.	NO.	NO.	NO.	AMB.	% ALL	AMB. % ALL	% PSGRS.
JAN.	15	10	4	14	1	20	4	7	75	29	7.2	2.8	8.4
FEB.	10	10	5	17	5	37	6	15	105	39	10.1	3.7	7.8
MAR.	9	14	3	20	3	26	2	10	87	31	8.3	3.0	7.8
APR.	6	15	5	11	0	32	5	7	81	29	7.8	2.8	9.2
MAY	8	18	6	15	0	21	8	12	88	29	8.4	2.8	8.9
JUNE	4	23	5	10	0	16	5	11	74	24	7.1	2.3	8.2
JULY	10	18	1	16	2	23	12	13	95	32	9.1	3.1	7.2
AUG.	11	5	2	21	2	15	10	8	74	29	7.1	2.8	7.4
SEPT.	7	14	3	13	0	23	9	1	70	24	6.7	2.3	8.7
OCT.	11	12	1	14	2	27	6	15	88	39	8.4	3.7	9.0
NOV.	14	15	2	16	3	18	5	7	80	30	7.7	2.9	8.6
DEC.	18	16	4	21	1	45	8	13	126	67	12.1	6.4	8.8
TOTAL	123	170	41	138	19	303	80	119	1043	402	100.0	38.6	100.0

Note: July and August as shown are slightly lower than average due to system strike.

A-9. TRANSIT PASSENGER FALLING ACCIDENTS: DAY OF WEEK, SEX OF VICTIM, DAILY TRAFFIC

NO. = day total; AMB. = ambulance called; % AMB. = percent week

DAY	MALES				FEMALES				COMBINED				PSGR. TRAFFIC
	NO.	AMB.	NO. % WK.	% AMB.	NO.	AMB.	NO. % WK.	% AMB.	NO.	AMB	NO. % WK.	% AMB.	%
Sunday	54	29	9.9	11.8	31	10	6.3	6.5	85	39	8.2	9.8	1.8
Monday	66	24	12.2	9.8	76	21	15.3	13.5	142	45	13.7	11.2	19.3
Tuesday	70	27	12.9	11.0	88	26	17.8	16.8	158	53	15.2	13.2	19.0
Wednesday	83	41	15.3	16.7	108	37	21.8	23.9	191	78	18.4	19.5	19.0
Thursday	91	47	16.8	19.2	79	23	15.9	14.8	170	70	16.4	17.5	19.0
Friday	92	45	16.9	18.4	76	23	15.4	14.8	168	68	16.2	17.0	19.1
Saturday	87	32	16.0	13.1	37	15	7.5	9.7	124	47	11.9	11.8	2.7
TOTALS	543	245	100.0	100.0	495	155	100.0	100.0	1038	400	100.0	100.0	100.0

NOTE: One third of all system passengers are female, two thirds male.

A-10. TRANSIT PASSENGER FALLING ACCIDENTS: FACILITY TYPE, TIME OF DAY, SEX OF VICTIM, WEEKDAY PASSENGER TRAFFIC

MALE = number of male accidents, FEM. = female, AMB. = Ambulance called

	ESCALATORS				STAIRWAYS				WALKING SURFACES				ROW TOTALS				% PSGRS.
TIME OF DAY	MALE	AMB.	FEM.	AMB.	MALE.	AMB.	FEM.	AMB.	MALE	AMB.	FEM.	AMB.	TOTAL*	% ALL	AMB.	% AMB.	TRAFFIC
(AM) 12 - 3	5	4	2	0	6	4	2	0	17	11	4	1	36	4.4	20	6.4	0.4
3 - 6	4	1	2	0	1	1	2	0	5	2	1	1	15	1.8	5	1.6	1.0
6 - 9	6	1	29	6	4	3	41	11	15	6	31	11	126	15.3	38	12.1	35.9
9 - 12	18	9	17	3	5	2	16	4	24	13	18	7	98	11.9	38	12.1	8.7
(PM) 12 - 3	15	8	29	10	16	4	15	8	20	6	20	11	115	13.9	47	15.1	7.2
3 - 6	36	15	61	13	21	11	39	11	43	14	34	9	234	28.3	73	23.3	34.6
6 - 9	23	8	17	4	21	13	13	8	38	18	13	5	125	15.1	56	17.9	9.3
9 - 12	18	9	12	4	10	8	3	0	30	13	4	2	77	9.3	36	11.5	2.9
TOTALS	125	55	169	40	84	46	131	42	192	83	125	47	826	100.0	313	100.0	

*Total combined male and female.

A-11. TRANSIT PASSENGER FALLING ACCIDENTS: FALLS ON ESCALATORS, ALLEGED CAUSE, SEX OF VICTIM, LOCATION

ALLEGED CAUSE	BOARDING								EXITING													
	UP				DOWN				UP				DOWN				RIDING				ROW	
	MALE		FEMALE		MALE		FEMALE		MALE		FEMALE		MALE		FEMALE		MALE		FEMALE		TOTALS	
	NO.	AMB.	NO.	AMB.	NO.	AMB.	NO.	AMB.	NO.	AMB.	NO.	AMB.	NO.	AMB.	NO.	AMB.	NO.	AMB.	NO.	AMB.	NO.	AMB.
SLIPPED	2	0	4	1	1	0	1	0	0	0	1	0	2	1	4	2	5	3	17	3	37	10
TRIPPED	1	1	3	0	1	0	3	0	4	1	8	1	4	1	9	0	14	5	21	2	68	11
PUSHED	1	1	1	0	0	0	0	0	1	1	1	1	1	0	1	0	2	2	9	1	17	6
LOSS BALANCE	5	1	5	3	1	1	5	1	2	0	3	1	4	1	6	1	16	8	31	11	78	28
SUDDEN STOP	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	5	3	11	3	18	6
ALCOHOL INF.	4	1	0	0	9	4	0	0	5	0	0	0	7	4	4	1	36	22	6	2	71	34
FOREIGN OBJECTS	0	0	0	0	1	0	1	0	0	0	2	1	1	1	1	0	4	2	4	1	14	5
UNKNOWN	0	0	0	0	0	0	0	0	3	3	5	1	2	0	4	0	8	1	19	9	41	14
TOTALS	13	4	13	4	13	5	11	1	15	5	20	5	21	8	30	4	90	46	118	32	344	114

Note: One third of all system passengers are female, two thirds male.

A-12. TRANSIT PASSENGER FALLING ACCIDENTS: FALLS ON STAIRS, ALLEGED CAUSE, SEX OF VICTIM, MOVEMENT DIRECTION

MALE = number of male accidents, FEM. = female, AMB. = Ambulance called

ALLEGED CAUSE	UP				DOWN				ROW TOTALS			
	MALE	AMB.	FEM.	AMB.	MALE	AMB.	FEM.	AMB.	ALL	% ALL	AMB.	% AMB.
SLIPPED	2	1	4	0	10	2	24	9	40	17.0	12	11.8
TRIPPED	3	0	7	1	11	4	34	11	55	23.3	16	15.7
PUSHED	0	0	1	0	1	0	3	1	5	2.1	1	0.9
LOST BALANCE	0	0	0	0	7	5	19	8	26	11.0	13	12.7
ALCOHOL INFLUENCE	4	2	2	1	45	31	9	3	60	25.4	37	36.3
FOREIGN OBJECTS	2	1	3	0	3	1	9	4	17	7.2	6	5.9
UNKNOWN	1	0	1	0	9	5	22	12	33	14.0	17	16.7
TOTALS	12	4	18	2	86	48	120	48	236	100.0	102	100.0
					DOWN RELATION TO TOTALS				206	87.2	96	94.1

Note: One third of all system passengers are female, two thirds male.

A-13. TRANSIT PASSENGER FALLING ACCIDENTS: FACILITY TYPE, SEX OF VICTIM, BODY LOCATION OF INJURY

MALE = Number of accidents in category, FEM. = female, AMB. = ambulance called

(Multiple injury locations included*)

BODY AREA	ESCALATORS**				STAIRWAYS***				WALKING SURFACES†				ROW TOTALS			
	MALE	AMB.	FEM.	AMB.	MALE	AMB.	FEM.	AMB.	MALE	AMB.	FEM.	AMB	TOTAL	% ALL	AMB.	AMB . % TOTAL
Head	111	51	50	6	78	45	31	14	161	76	54	20	485	36.4	212	53.7
Arm	25	4	27	5	26	4	53	13	43	7	31	7	205	15.4	40	10. 1
Hand	-	-	-	-	-	-	-	-	8	2	8	3	16	1.2	5	1.3
Hip	27	7	25	5	13	2	23	3	20	4	23	4	131	9.8	25	6.3
Leg	33	4	118	22	15	3	85	20	36	7	47	7	334	25.0	63	16.0
Mid-body	9	1	30	6	13	6	24	3	29	13	27	9	132	9.9	38	9.6
Unknown	5	3	5	2	2	1	2	1	12	3	4	2	30	2.3	12	3.0
TOTALS	210	70	255	46	147	61	218	54	309	112	194	52	1333	100.0	395	100.0

*In multiple injuries ambulance is coded for primary injury location.

**Includes 58 multiple injuries for males, 74 females.

***Includes 36 multiple injuries for males, 74 females.

† Includes 69 multiple injuries for males, 56 females.

1. Static Coefficient of Friction (COF) Selected Floor Materials

Leather and Rubber Soles

	Leather Sole		Rubber Sole	
Floor Material	Dry	Wet	Dry	Wet
Concrete	0.54		0.74	
Vinyl Tile	0.46	0.30	0.58	0.63
Rubber	0.45	0.43	0.44	0.87
Sheet Vinyl	0.43	0.78	0.48	0.82
Cork Tiles	0.42	0.78	0.53	1.00
Linoleum	0.27		0.42	
Terrazzo	0.25		0.38	
Limestone, Honed	0.10		0.15	

Source: Schjodt, R., “Measurement of Human Reaction to Hardness of Floor Covering,” ASTM Bulletin No. 247, July 1960.

2. Static Coefficient of Friction (COF) for Selected Walkway Materials

	Material	Leather (Dry)	Neolite* (Dry)
1.	Brushed Concrete (new against the brush)	.75	.90
2.	Asphalt Tile (waxed heavy use area)	.56	.47
3.	Asphalt Parking Lot (old)	.53	.64
4.	Quarry Tile (unglazed 6” x 6” tiles)	.49	.60
5.	Brick Pavers on Stairs (new, no finish)	.43	.73
6.	Exposed Aggregate Pea Gravel (heavy traffic)	.41	.57
7.	Granite Stairs (old, exterior well used)	.40	.66
8.	Plywood “A” Side (with grain, no finish)	.39	.75

*Neolite was sanded smooth and flat.

Source: Templer, J., “Design Guidelines to Make Crossing Structures Accessible to the Physically Handicapped.” (unpublished)

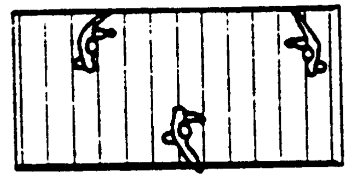
A-15. RECOMMENDED TREAD AND RISER RELATIONSHIPS*

Risers	**Treads (inches)**						
7	11						
6 1/2	11	11 1/2	12	12 1/2			
6	11	11 1/2	12	12 1/2	13	13 1/2	14
5 1/2	11	11 1/2	12	12 1/2	13		
5	11	11 1/2	12				
Risers	**Treads (millimeters)**						
178	280	290					
165	280	290	305	320			
152	280	290	305	320	330	340	355
240	280	290	305	320	330		
127	280	290	305				

Source: Templer, J., “Development of Priority Accessible Networks,” US DOT-FHWA-1P-80-8, Jan. 1980, 224 pp.

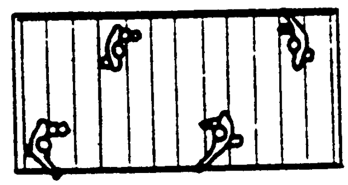
*Local building codes may specify riser and tread combinations which do not agree.

STAIRWAY LEVEL OF SERVICE A



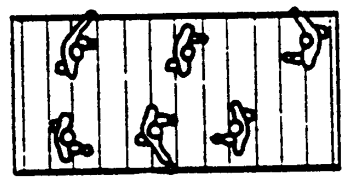
Average Flow Volume: 5 PFM* or less
Average Speed: 125 ft/min, or more
Average Pedestrian Occupancy Area: 20 sq. ft./person
Description: unrestricted choice of speed: relatively free to pass: no serious difficulties with reverse traffic movements; flow is approximately 30% of maximum capacity.

STAIRWAY LEVEL OF SERVICE B



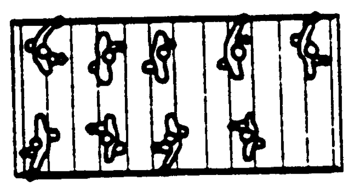
Average Flow Volume: 5-7 PFM
Average Speed: 120-125 ft/min.
Average Pedestrian Occupancy Area: 15-20 sq.ft./person
Description: restricted choice of speed: passing encounters interference: reverse flows ??create occasional conflicts: flow is approximately 34% of maximum capacity

STAIRWAY LEVEL OF SERVICE C



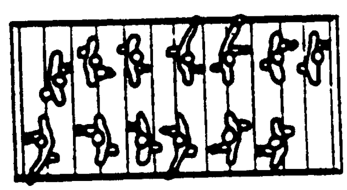
Average flow volume: 7-10 PFM
Average Speed: 115-120 ft/min.
Average Pedestrian Area Occupancy: 10-15 sq. ft./person
Description: speeds are partially restricted: passing is restricted: reverse flows are partially restricted: flow is approximately 50 percent of maximum capacity.

STAIRWAY LEVEL OF SERVICE D



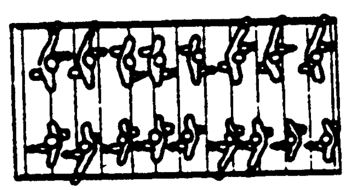
Average Flow Volume 10-13 PFM
Average Speed: 105-115 ft/min.
Average Pedestrian Area Occupancy: 7-10 sq.ft./person
Description: speeds are restricted: passing is virtually impossible: reverse flows are severely restricted: flows are approximately 50-65% of maximum capacity.

STAIRWAY LEVEL OF SERVICE E



Average Flow Volume: 13-17 PFM
Average Speed: 85-115 ft/min.
Average Pedestrian Area Occupancy: 4-7 sq.ft./person
Description: speeds are severely restricted: passing is impossible: reverse traffic flows are severely restricted: ??intermittent stoppages of flow are likely to occur: flows are approximately 66-85% of maximum capacity.

STAIRWAY LEVEL OF SERVICE F



Average Flow Volume: 17 PFM or greater
Average Speed: 0 . 85 ft./min.
Average Pedestrian Area Occupancy. 4 sq.ft./person or less
Description: speed is severely restricted: flow is subject to complete breakdown with many stoppages: passing as well as reverse flows are impossible.

*PFM - Pedestrians per root width of stairway, per minute.

Source: Fruin. John J., Pedestrian Planning and Design. MAUDEP Inc., 1971.

A-16. STAIR TRAFFIC AND WIDTH RELATIONSHIPS

A-17. SUMMARY OF DESIGN FACTORS

Walking Surfaces

- wear is more significant in transitional areas where there is “stop and go” traffic, requiring design that considers replacement;
- pavers require a well compacted and drained sub-base to avoid uneven settlement or dislodgement;
- wide variations in surface friction should be avoided because of the “expectancy” factor;
- floor mats should be recessed, if possible, and periodically inspected for curling of ends.

STAIRS

Risers - uniform closed risers 6-7 in. (150-180 mm), Min. vertical tolerance 3/16 in. (5mm);

nosing - rounded 1/4 to 1/2 in. (6-12 mm) radius, raked riser Max. horizontal extension 1 in. (25 mm).

Treads - 11-14 in. (280-350 mm) abrasion resistant materials, replaceable elements. Appendix A-16, riser/tread dimension;

wash - outdoor for drainage, slope down 1:100.

Handrails - graspable design, avoid protrusions and details that could be impacted in fall;

grip circumference - 4.4-5.2 in. (110-130 mm);

height - max. allowable under code usually 34 in. (864 mm) guard rail type 42 in. (1067 mm);

horizontal extension - upper landing 12 in. (305 mm), lower landing 12 in. (305 mm) plus one tread length;

clearance - 3 in. (76 mm) from wall in accordance with OSHA Standard;

widths - transit applications min. 50-40 in. (1270-1372 mm) clear distance between handrails.

Landings - typical at 10-12 risers, 18 max., 4 ft (1.2 m) min, length.

Lighting - uniform, no shadows or glare Min. 3 FC (32 lux), up to 20 FC (215 lux).

ESCALATORS

- level runs at entrance and exit 2-3 steps;
- lighting minimum 5 horizontal FC diffused, avoid shadow and glare affects;
- use skirt lubrications with care because of possible slipping hazards due to over spray.

A-18. PEDESTRIAN FALLING ACCIDENTS IN TRANSIT TERMINALS

Workshop/Seminar -- April 25, 1984

ROSTER OF
-- ATTENDEES --

	NAME	ORGANIZATION	TITLE
1.	Robert A. Olmsted	Metropolitan Transportation Authority (NY)	Asst. Director, Planning
2.	Bob LaRosa	Long Island Rail Road	Oper. Planning Engr.
3.	Jessie Wetjen	Long Island Rail Road - Safety Dept.	Safety Inspector
4.	Lauren Gregory	Long Island Rail Road - Insurance Dept.	Insurance Agent
5.	Laura Radin	Port Authority of NY & NJ, Risk Mgmt.	Hazardous Materials Spec.
6.	Raymond DiPiero	Port Authority of NY & NJ, Risk Mgmt.	Maint. Eval. Engr.
7.	Thomas Buttling	Port Authority of NY & NJ, Risk Mgmt.	Maint. Eval. Engr.
8.	Howard Silfin	Port Authority of NY & NJ, Risk Mgmt.	Admin., Maint. Eval Engr.
9.	Walter Coupland	Port Authority Trans-Hudson, Claims	Principal Claims Rep.
10.	Thomas P. Maher	Port Authority of NY & NJ	Claims Rep.
11.	Carmelo Simeti	New York City Transit Authority	Safety Dept.
12.	J. D. Graziano	New York City Transit Authority	Safety Dept
13.	Karel Heidweiller	Port Authority of NY & NJ, Risk Mgmt.	Maint. Eval. Engr.
14.	Henry Brochhagen	Port Authority of NY & NJ, Risk Mgmt.	Acting Supv., Safety Engr.

15.	Harry Woods	Port Authority of NY & NJ, Risk Mgmt.	Maint. Eval. Engr.
16.	Dilip Guha	Port Authority of NY & NJ, Eng. R&D	Research Engineer
17.	George M. Burgess	Washington Metro. Area Transit Authority	System Safety Eng.
18.	Donald D. Dzinski	American Public Transit Association	Mgr. Safety & Prog. Development
19.	C. R. Guenther	Port Authority Transit Corp.	Supv., Safety & Risk Mgmt.
20.	J. P. Bardzilowski	Port Authority Trans-Hudson	Safety Supv.
21.	Robert Davidson	Port Authority of NY & NJ	Architect
22.	Kenneth Kuhn	Southeastern Pennsylvania Transit Authority	Risk/Loss Control Mgr.
23.	John O'Reilly	Port Authority of NY & NJ, Risk Mgmt.	Staff Safety Engr.
24.	Anthony Slowe	Massachusetts Bay Transit Authority	System Safety, Asst. Mgr.
25.	Robert M. Dorer	U.S. D.O.T. Transportation Systems Center	Project Engineer
26.	Michael J. Lynch	Port Authority Trans-Hudson, Claims	Supv. Claim Rep.
27.	Frank J. Mirovsky	Port Authority of NY & NJ, Bus Terminal	Maint. Unit Supv.
28.	John S. Pavlovich	NY Metropolitan Transportation Council	Mgr., Planning Div.
29.	John J. Fruin	Port Authority of NY & NJ, Eng. R&D	Research Engineer

A-19. SUMMARY OF COMMENTS BY WORKSHOP PARTICIPANTS

Uniform Accident Report Form:

1) Feasibility of standard industry accident form should be determined through evaluation of forms currently in use. (Safety Engineer)

2) Would like to see standard form, but industry adoption would be difficult. (Manager System Safety)

3) Standardization of accident reporting forms and computerization seems like a very desirable program. (Maintenance Supervisor)

4) Uniform accident reporting form would assist in developing better building codes, design standards. (Maintenance Engineer)

5) Uniform accident report form only of value if all properties agree to use it. (Claims Representative)

6) Standardized accident form could help in developing better design standards geared for transit. (Safety Manager)

7) There is need for standard measurement rates, and accident definitions for transit industry. (Risk Manager)

8) Complexities of “notice”, as related to claims and liability must be addressed by future seminars/workshops. (Safety Manager)

9) Complete standardization of accident form is believed to be unobtainable, but uniformity of certain key data is possible. (Safety Manager)

10) Agree with need for simple standard industry report form and system. It would help establish industry standards. (Safety Supervisor)

11) A standard accident form would be good for loss control programs and for comparison of industry experience. (Insurance Agent)

12) Standard accident form could be extremely useful, but transit properties would have differing priorities and interests in data. (Claims Representative)

Ambulance-Aided Reporting Threshold

1) Whole issue of reporting accidents has to be addressed by industry before applicability of ambulance-aided report threshold can be addressed. (Safety Manager)

2) Ambulance call threshold for reporting accidents is not realistic. (Risk Manager)

3) Standardized reporting and uniform threshold would be of value, but ambulance aided cases is not viable threshold based on our experience. (Safety and Risk Management Supervisor)

4) Ambulance aided cases are a suitable reporting threshold. (Safety Supervisor)

5) Ambulance aided accident report threshold is not ideal, but may be best available. (Maintenance Engineer)

6) Ambulance aided cases is poor criteria for accident reporting since transit facilities differ greatly in facilities and practices. (Claims Representative)

7) The varying accessibility of hospitals from different facilities may affect a patron's desire to seek treatment. (Claims Representative)

8) Inflated data could be generated since many ambulance cases are false alarms. (Planning Manager)

9) Only 30-40 percent ambulance calls involve medical treatment. (Safety Engineer)

Design

1) Design standards should be established for new systems recognizing human factors and its relationship to falls. (Safety Engineer)

2) Would like to see similar workshops directed at Engineering and Architectural staff. (Maintenance Supervisor)

3) Study should be done of impact of requiring standees to keep right on escalator. (Anonymous)

4) Up and down lane positions on stairs should be clearly defined. (Anonymous)

5) Issue of labeling or non-labeling of emergency stop buttons should be evaluated. (Anonymous)

6) Determine relationship of frequency and severity of accidents to vertical rise of stairs and escalators. (Manager, Planning)

7) Is fatigue on stairs and optical effects on escalators an accident cause? (Manager, Planning)

8) Determine affects of escalator speed on frequency and severity of accidents. (Manager, Planning)

9) Determine affects of lighting on use of pedestrian assist devices. (Manager, Planning)

Media Campaign - Safety Awareness

1) Agree with “subway smarts” media campaign on industry-wide basis to reduce accidents. (Safety Supervisor)

2) Media campaign has value in defending claims because patrons are advised of hazards. (Maintenance Engineer)

3) Our property is currently working on a passenger awareness program, with a positive emphasis approach, to bring attention to accident hazards. (Insurance Agent)

4) Good idea that has cost/benefit; good to advise public of hazards; “how to” use system has merit. (Planning Manager)

5) No reasons against - if local policy permits. (Safety Engineer)

REFERENCES

1.0 Introduction

1.1 National Safety Council, "Accident Facts," 1981.

1.2 Snyder, R. G., "Occupational Falls," NIOSH, avail. NTIS, PB-299 286 177, 104 pp.

2.0 Human Factors and Falls

2.1 Murray, M.P., "Gait as a Pattern of Total Movement," American Journal Phsy. Med., 1967, pp. 290-333.

2.2 Fruin, J., "Pedestrian Planning and Design," MAUDEP Press, 1971, 206 pp.

2.3 Ayoub, M.M., and G.M. Bakken, "An Ergonomic Analysis of Walking and Working Surfaces," OSHA, PB-293-283, Aug. 1978, 238 pp.

2.4 Hawkins, N.M., et al., "Behavioral Observations of Passengers Boarding a Slow Speed Conveyor," Loughborough Univ. Eng., Nov. 1974, 57 pp.

2.5 Zimmerman, W. E., et al., "Escalator Design Features Evaluation Jet Propulsion Lab.," UMTA-MA-06-0023-81-3, May 1982, 53 pp.

2.6 Overstall, P.W., et al., "Instability and Falls in the Elderly - Age and Ageing," 1978, pp. 92-96.

2.7 New York Times, Moving Walk Accident - Japanese Exposition, April 6, 1970.

2.8 Panero, J., "Human Dimension and Interior Space, Whitney Library Design," 1979, 320 pp.

2.9 U.S. Dept. Defense, "Human Factors Engineering Design for Army Material," Mil-HDBK-759, March 1975, 442 pp.

2.10 Maki, B.E., et al., "Biomechanical Assessment of Handrail Parameters," West Park Research Council, Canada, May 1983, 90 pp.

2.11 Armstrong, T., et al., "An Ergonomic Basis Recommended OSHA Standard 29 CRF, Part 1910, Subpart D, Walking and Working Surfaces," PB-284-370, March 1978, 179 pp.

2.12 OSHA Standards General Industry (209 CFR, 1910 Subpart D, - Walking, -Working Surfaces)," Stock No. 029-015-00054-6, Nov. 1978, 820 pp.

2.13 Cohen, H., et al., “Pedestrians and Wind in the Urban Environment, U.S. Department of Commerce, PB-279-134, Dec. 1977, 124 pp.

2.14 “Safety Sciences - Collection and Analysis of Work Surface Accident Profile Data,” NIOSH, PB 80-191505, Dec. 1977.

2.15 “The Abbreviated Injury Scale AIS-80,” Amer. Assoc., Automotive Medicine, 1980, 56 pp.

2.16 Snyder, R.G., et al., “Study of Impact Tolerance Through Free-Fall Investigation,” Insurance Inst. Highway Safety, PB 277-537, Dec. 1977, 130 pp.

<u>3.0 Falling Accident Characteristics</u>

3.1 Archea, J., et al., “Guidelines for Stair Safety,” National Bureau of Standards, pub. NBS-BBS 120, May 1979, 129 pp.

3.2 Cheaney, E.S., et al., “Safety in Urban Mass Transportation,” UMTA-R1-0005-73-3, Battelle Labs., March 1976, 101 pp.

3.3 Cohen, H.H., and D.M.J. Compton, “Fall Accident Patterns,” Professional Safety Mag., June 1982, pp. 16-22.

3.4 “Accident Facts,” National Safety Council, 1981, 97 pp.

<u>4.0 Risk and Claims Management</u>

4.1 Fedor, O.H., et al., “RMS - The Risk Management System,” Mechanical Engineering Mag., Nov. 1976, pp. 21-25.

4.2 Cantilli, E., “Transportation Systems Safety - A Methodology,” Polytechnic Institute of N.Y., Contract DOT-05-05241, Jan. 1977, 154 pp.

4.3 Consumer Products Safety Commission, National Injury Information Clearninghouse, “Accident Investigations;” and “The National Injury Clearinghouse.” Pamphlets. No date.

4.4 “Verdicts and Settlements - Litigation Research Group - National Law Reporters,” var. issues 1982-1983.

4.5 Hongladarom, G.C., et al., “Analysis of the Causes and Prevention of Injuries Attributed to Falls,” U.S. Public Health Services, Contract No. 200-76-0635, 305 pp.

4.6 Spungin, Ray, “Regional Age Distribution of a Population in NY/NJ Metropolitan Region,” PANYNJ, June 1982, 9 pp.

4.7 “Statistical Abstract of the United States - Vital Statistics, Hospital Expenses,” 1983, p. 113.

<u>5.0 Design and Operating Strategies to Reduce Falls</u>

5.1 Wolfe, W.C., “Durability and Maintenance as Related to the Selection of Flooring,” NBS Tech. Note 783, 1973, 68 pp.

5.2 Progressive Architecture Technics, “A Move Afoot, Plaza, Lobby Flooring,” 59, No. 12, Dec. 1978, pp. 86-91.

5.3 Brungraber, R. J., “An Overview of Floor Slip Research,” NBS Tech. Note 85, Jan. 1976, 113 pp.

5.4 Cohen, H. H., et al., “Fall Accident Patterns,” Professional Safety, June 1982, pp. 16-22.

5.5 Rosen, S., <u>The Slip and Fall Handbook</u> (Hanover Press, 1983), 138 pp.

5.6 National Safety Council, “Floor Mats and Runners,” Data Sheet 1-595-81 (reprint April 1981 Safety News, pp. 59-62).

5.7 Fitch, J.M., J. Templer, and P. Corcoran, “The Dimensions of Stairs,” Scientific American, 231, 1974, pp. 82-90.

5.8 Templer, John, “Provisions for Elderly and Handicapped Pedestrians,” FHWA-1P-80-8, US Govt. Print., Jan. 1980, 224 pp.

5.9 Thul, R.F., “Engineering to Prevent Falling Accidents,” National Safety News, Nov. 1964, pp. 26, 27, 89, 90.

5.10 Maki, B.E., et al., “Biomechanical Assessment of Handrail Parameters,” Cont. No. OSX82-00180, National Research Council, Canada, Hay 1983, 90 pp.

5.11 Pauls, J.L., “Recommendations for Improving the Safety of Stairs,” Ottawa, National Research Council, Division of Building Research, Building Practice Note 35, June 1982.

5.12 American Society of Mechanical Engineers, “American Standard Safety Code for Elevators,” ANSI-A17.1, 1965.

5.13 Strakosch, G., <u>Vertical Transportation, Elevators and Escalators</u>, (New York, Wiley, 1982).

5.14 Irvine, C.H., “Evaluating Escalator Skirt Panel Lubricants,” Elevator World, April 1982, pp. 32-36.

5.15 <u>Oakland CA Daily Review</u>, “Three Persons Slip and Fall in Escalator due to Spilled Beer and Chicken,” April 18, 1983.