# STATION EMERGENCY EXITING

## HOW IT WAS SOLVED AT THE SOUTHERN CALIFORNIA RAPID TRANSIT DISTRICT

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# FORWARD

Transit systems are placing an increased emphasis on the expedient evacuation of patrons from stations in an emergency. This has created a problem in determining the proper number of egress units required for emergency evacuation. Additionally, a reasonable period of time to egress from station platforms to a point of safety had to be established.

An in-depth study of this problem clearly indicated that there is no single standard and/or code presently available which totally satisfies the needs of a subway-type transit system.

The Southern California Rapid Transit District (SCRTD) Fire/Life Safety Committee, consisting of representatives from the Southern California Rapid Transit District, the City and County of Los Angeles Fire Departments and the General Consultants, analyzed existing and proposed codes and standards and found that a combination of attributes from the several codes and standards, in conjunction with variation in exiting criteria, provided the most appropriate and cost effective approach toward determining exiting needs for postulated emergencies.

The Fire/Life Safety Committee believes that the station emergency exiting criteria developed for the Metro Rail Project are an appropriate solution to the emergency exiting problem.

This paper discusses the analysis performed, and the approach used, in establishing the SCRTD Emergency Egress Requirements.

# INTRODUCTION

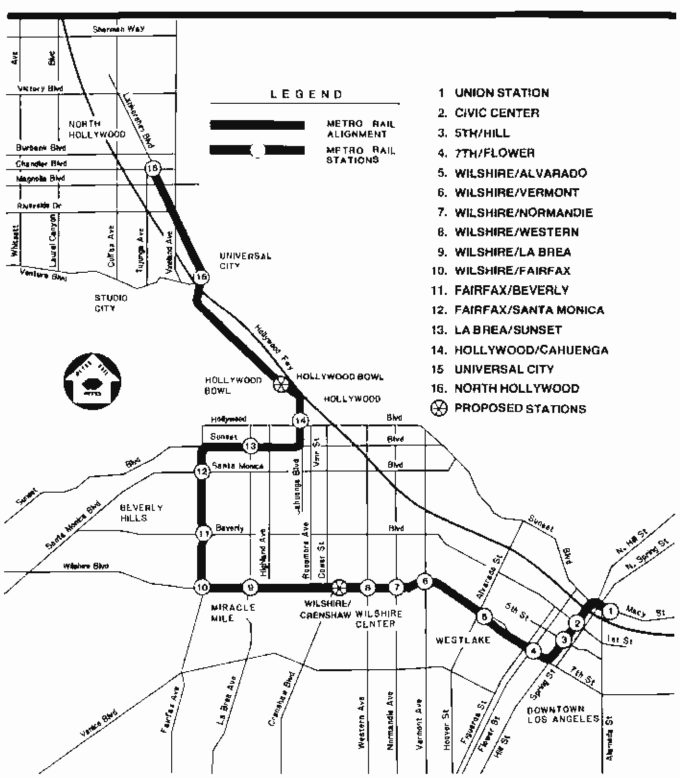
Since June 1980, the Southern California Rapid Transit District (SCRTD) has been engaged in the preliminary engineering phase of the Metro Rail Project. The project is an 18-mile underground rail line, which will be the initial segment of Southern California's ultimate rapid transit network. As part of the 1976 Regional Transportation Development Program, Metro Rail is designed to help solve the increasing transportation problems of Los Angeles' high-density urban center--the regional core.

Before Metro Rail goes into operation, it will have passed through the five conventional stages of rapid transit development: (1) planning and alternatives analysis; (2) preliminary engineering/environmental impact analysis; (3) final design; (4) construction; and (5) operational testing. The SCRTD completed the first phase in 1980. The preliminary engineering phase is nearing completion after an intensive two-and-a-half-year program, during which the key elements of the Metro Rail Project were defined.

Following approval of the Environmental Impact Statement, the final design phase will commence, followed by a 4- to 6-year construction period, and a system inspection, startup, and testing period. Figure 1 indicates the alignment of the Metro Rail line and the station locations.

RTD

Southern California Rapid Transit District
Metro Rail Project
FIGURE 1



Of great importance during the design phase of the Metro Rail system are fire and life safety considerations. Providing for egress from stations in the event of an emergency is one of the most significant safety design considerations that needs to be addressed. The proper number of station stairs, escalators, and normal and emergency exits must be specified; and emergency ventilation and fire suppression systems must be provided. Additionally, well-defined and unobstructed exit paths and procedures for evacuation must be established. This paper discusses only the issue related to emergency exits, units of exiting width and egress time constraints.

To properly address these issues, the SCRTD Fire/Life Safety Committee performed an in-depth study of present and proposed codes, standards and guidelines to determine the most appropriate application of them in the development of egress criteria. Specifically, the codes, standards and guidelines used for the study were:

- NFPA 101, Life Safety Code, 1981 Edition
- NFPA 130 (Proposed), Standard for Fixed Guideway Transit Systems
- Uniform Building Code, 1979 and 1982 Editions
- APTA Guidelines for Design of Rapid Transit Facilities, June 1981

The review of the above codes indicated that there was no single code or standard which could be applied in its entirety to satisfy the unique SCRTD's exiting needs in an efficient and cost effective manner.

The SCRTD Fire/Life Safety Committee then proceeded to develop a specific criteria for emergency egress from stations. An important ingredient in the development of the criteria was the "Station Emergency Egress Study Report" performed by the Fire/Life Safety Committee, with assistance from the station general consultant. The approach used to formulate the report is presented in the following sections:

- Metro Rail System Characteristics
- Review of Codes, Standards and Guidelines
- Application of Criteria to Metro Rail Stations
- Results and Conclusions

## 1.0 METRO RAIL SYSTEM CHARACTERISTICS

Emergency exiting criteria are an integral part of the total Fire/Life Safety program for Metro Rail stations. It is essential that criteria be developed with an understanding of station characteristics.

All stations will be underground with top of rail elevations varying from 40 to 80 feet below grade. The stations are of a center platform configuration. Fare collection areas are at the mezzanine level and located at the center or end of the station. Two exits are provided off each mezzanine.

Emergency stairs are located at the ends of each platform providing unobstructed access to the surface. Escalator and stair elements for normal use in stations were sized to accommodate peak 15 minute patronage. The ratio of normal use stair-to-escalator exiting provisions is greater than one at all stations.

Automatic sprinkler protection is provided in station ancillary spaces, truss spaces of escalators and elevator machine rooms. A three-zoned under vehicle water spray extinguishing system is located on each area trackway at the stations. Actuation of the system is provided for each trackway at the platform level.

A wet standpipe system will be installed to enable the fire service to reach all areas in the station. The train control room will be protected by a Halon extinguishing system. An emergency ventilation system is provided throughout the Metro Rail system. It is based on a push-pull concept of fan operation, some of which are drawing air while others are exhausting air. Normal ventilation augments the emergency ventilation system, providing additional capability for:

- Increasing fresh air supply;
- Maintaining acceptable air temperatures; and
- Removing smoke or toxic fumes in the event of fire.

## 2.0 REVIEW OF CODES, STANDARDS AND GUIDELINES

At the initiation of the Preliminary Engineering Phase of the Metro Rail Project, there were several adopted and proposed codes, standards, and guidelines that addressed the subject of exit width requirements and quantities as it applies to transit stations. The dilemma that faced the Fire/Life Safety Committee was "which code, if any, is the most appropriate for the requirements of the SCRTD Metro Rail Project?" It was decided that a comparative analysis was necessary which would:

- Determine the emergency exiting provisions of the respective codes and

- Apply the code provisions to selected Metro Rail Stations.

The consensus of the Fire/Life Safety Committee was that the analysis and the comparison of results would enable the Committee to properly assess the merits of the respective codes and to prescribe the Metro Rail criteria. The specific codes, standards and guidelines investigated were:

- Uniform Building Code, 1979 and 1982 Edition,
- Life Safety Code, NFPA 101, 1981 Edition
- Proposed Standard for Fixed Guideway Transit Systems, NFPA 130, and
- APTA Guidelines for Design of Rapid Transit Facilities, June 1981.

The following summarizes the approach used in determining exit width requirements under the various code provisions. Initial discussions will focus on occupant load determinants followed by an explanation of the SCRTD exit capacity calculation.

## 2.1 Uniform Building Code

Under the Uniform Building Code (UBC), occupant load of a building is determined according to its intended use. A Metro Rail station would fall under the category of 'Group A - Occupancy', which includes 'Assembly Buildings'. The occupant load for an assembly building is determined by dividing the floor area of the assembly by an 'occupant load factor' of 7 square feet per person. The capacity of exits required is measured in feet of exit width. This capacity is calculated by dividing the occupant load by 50 persons per foot of exit width.

Metro Rail station exit requirements under the UBC were calculated by:

- Identifying the net platform area equal to gross platform area minus areas usable for normal circulation, e.g., platform edge strips and areas occupied by vertical circulation devices.
- Calculating occupant load--equal to net platform area divided by 7 square feet per person.
- Calculating required exit capacity equal to occupant load divided by 50 persons per required foot of exit width.

The effect of applying a 4 square feet per person load factor was also investigated, because as the analysis proceeded the Fire/Life Safety Committee was interested in the comparative results of operationally limiting the platform load. The 4 square feet threshold was selected so that space would be available to accept an emergency incident train load. This combined platform load would then approximate the "waiting space" level of density as defined in the Life Safety Code.

Figure 2 summarizes the U.B.C. requirements.

**FIGURE 2**

## UNIFORM BUILDING CODE
## EMERGENCY EXITING REQUIREMENTS

I BASIS FOR EXITING PROVISIONS

- BUILDING CLASSIFICATION - GROUP "A" ASSEMBLY
- OCCUPANT LOAD FACTOR - 7 SF/PERSON AND 4 SF/PERSON
- UNIT OF EXIT WIDTH - NO PROVISION
- OCCUPANT CAPACITY PER UNIT OF EXIT WIDTH - 50 PERSONS/FOOT OF TOTAL EXIT WIDTH

II SPECIFYING EXIT REQUIREMENTS

- USING PLATFORM AREA AS BASIS
  - TRANSFORM GROSS TO NET AREA
  - CALCULATE OCCUPANT LOAD = $\frac{\text{NET AREA}}{\text{7 SF/PERSON}}$
  - CALCULATE REQUIRED CAPACITY = $\frac{\text{OCCUPANT LOAD}}{\text{50 PERSONS/FOOT}}$

2.2 National Fire Protection Association (NFPA) 101 - Life Safety Code

Under NFPA 101, occupant load of a building is determined according to its intended use. The classification of occupancy for a Metro Rail station would be 'place of assembly'. Occupant load for a 'new place of assembly' is determined by dividing net floor area of the assembly by the appropriate occupant load factor. For an assembly area of concentrated use without fixed seats, the occupant load factor is 7 square feet per person (as for UBC (the 4 square feet per person factor was also analyzed). The capacity of exits is measured in 'units of exit width' of 22 inches per unit. Fractions of a unit comprising 12 inches or more are counted as 1/2 unit of exit width.

For Metro Rail stations, the capacity of exits required was calculated by dividing the occupant load by a factor of 75 persons per unit of exit width.

Metro Rail station exit requirements under NFPA 101 were determined by:

- Identifying the net platform area.
- Calculating the occupant load equal to net platform area divided by 7 square feet per person.
- Calculating the required exit capacity equal to occupant load divided by 75 persons per unit of exit width.

Figure 3 provides a summary of NFPA 101 requirements.

**FIGURE 3**

**NFPA 101**
**EMERGENCY EXITING REQUIREMENTS**

**I BASIS FOR EXITING PROVISIONS**

- BUILDING CLASSIFICATION - ASSEMBLY
- OCCUPANT LOAD FACTOR - 7 SF/PERSON AND 4 SF/PERSON
- UNIT OF EXIT WIDTH - 22 INCH EXIT LANE
- OCCUPANT CAPACITY PER UNIT OF EXIT WIDTH - 75 PERSONS/UNIT OF EXIT WIDTH

**II SPECIFYING EXIT REQUIREMENTS**

- USING PLATFORM AREA AS BASIS
  - TRANSFORM GROSS TO NET AREA
  - CALCULATE OCCUPANT LOAD $= \dfrac{\text{NET AREA}}{\text{7 SF/PERSON}}$
  - CALCULATE REQUIRED EXIT CAPACITY $= \dfrac{\text{OCCUPANT LOAD}}{\text{75 PERSONS/ EXIT LANE}}$

## 2.3 Proposed National Fire Protection Association (NFPA) 130 - Standard for Fixed Guideway Transit Systems

Under proposed NFPA 130, the occupant load is based upon peak period link loads and on entraining loads at a station. Occupant load thus varies from station to station according to changes in the number of entraining passengers at a station and in the 'link loads' (line volume) on inbound and outbound trains entering the station.

A station's 'inbound link' refers to the number of passengers on trains entering a station on the inbound track. A station's 'outbound link' load, in this discussion, is the number of passengers on trains entering a station on the outbound track. 'Inbound' and 'outbound' in this discussion refer to the train's direction of travel relative to the Union Station. All link loads are based on volumes on board trains entering the station.

The occupant load is the sum of the 'Calculated Train Load' and the station entraining load. The calculated train load represents the passenger volume on trains entering a station that would have to be off-loaded in an emergency. The calculated train load is determined for one train on the inbound and outbound track of a station during the peak 15 minute period. It is assumed that the number of persons on each train will be twice the normal peak 15 minute levels to allow for one missed headway. Thus, the number of persons on a train is calculated by multiplying twice the peak 15 minute link load by the scheduled headway in minutes divided by 15.

The maximum number of persons on any train can not exceed the 'maximum practical capacity' for the train. (For Metro Rail service, a maximum capacity of 1,200 persons was assumed.) It is further assumed that trains on each track will arrive and off-load simultaneously. The calculated train load is, thus, the sum of persons on an inbound and an outbound train.

The station entraining load represents the peak 15 minute passenger accumulation on the station platform awaiting a train.

Occupant loads were calculated for both the AM and PM peaks. The higher occupant load, AM or PM, was designated as 'worst case' and was the basis for determining the evacuation times and emergency exiting requirements.

Emergency exit capacity was measured in units of exit width equal to 22 inches per unit. Occupant capacity per unit of exit width varies by circulation element. The required exit capacity was determined to allow (1) evacuation of the passengers from the station platform in 4 minutes and (2) evacuation of passengers from the most remote part of the platform to a point of safety in 6 minutes.

Figure 4 summarizes the NFPA 130 requirements.

FIGURE 4

NFPA 130

EMERGENCY EXITING REQUIREMENTS

I BASIS FOR EXITING PROVISIONS

- BUILDING CLASSIFICATION - UNDERGROUND STATION
- OCCUPANT LOAD FACTOR - BASED ON PLATFORM ENTRAINING LOAD AND DESIGN TRAIN LOAD(S) THAT MAY OFF-LOAD IN AN EMERGENCY
- UNIT OF EXIT WIDTH - 22 INCH EXIT LANE
- OCCUPANT CAPACITY PER UNIT OF EXIT WIDTH - VARIES BE EGRESS ELEMENT

II SPECIFYING EXIT REQUIREMENTS

- STATION OCCUPANT LOAD
  - 15 MINUTE ENTRAINING LOAD PLUS SIMULTANEOUS OFF-LOAD OF TRAINS ENTERING STATION DURING PEAK 15 MINUTE PERIOD WITH A MISSED HEADWAY
- CALCULATE EXIT CAPACITY SUCH THAT:
  - OCCUPANT LOAD IS EVACUATED FROM STATION PLATFORM IN <u>4 MINUTES</u>
  - EVACUATION FROM MOST REMOTE POINT ON PLATFORM TO A POINT OF SAFETY IN <u>6 MINUTES</u>

## 2.4 <u>SCRTD Criteria for Emergency Egress from Stations</u>

A set of criteria, referred to as "Metro Rail Fire/Life Safety Committee Criteria (F/LS Criteria)" was developed. It was evolutionary and only the final version is discussed in this paper. The following describes the Metro Rail F/LS Criteria.

Exiting provisions for the Metro Rail F/LS Criteria are similar in many respects to the methodology already discussed under NFPA 130. Both criteria rely on a dynamic modelling approach. For both criteria, the exit capacity required is determined to allow evacuation of the passengers from the platform and evacuation of passengers from the most remote point on the platform.

Where the F/LS Criteria differs from NFPA 130 is in defining the occupant load and, thus, in the manner of calculating the occupant load. Under the F/LS Criteria, occupant load is the sum of the 'Calculated Train Load' and the entraining load. As in NFPA 130, the calculated train load in the F/LS Criteria represents the passenger volume on trains entering a station that would have to be off-loaded in an emergency.

The calculated train load in both criteria is determined for one train on each track in the station during the peak 15 minute period. However, under the F/LS Criteria, the number of persons on each train is assumed to be what would normally occur during the peak 15 minutes, if schedules were maintained (not twice the normal load as provided in proposed NFPA 130). The number of persons on a train is calculated by multiplying the peak 15 minute link load by the scheduled headway and dividing by 15.

Under the F/LS Criteria, the maximum number of persons on any train can not exceed the maximum practical capacity of the train. It is further assumed that trains on each track arrive and off-load simultaneously. The calculated train load is, thus, the sum of loads on an inbound and an outbound train. Additionally, the calculated train load can be no less than the maximum capacity of a single train.

The entraining load was defined as the number of passengers that would accumulate on the platform in the time period equivalent to four headways during the peak 15 minute operating period. A further constraint was that the entraining load could not exceed the net platform area divided by 4 square feet per person. This constraint reflects a commitment by Metro Rail to limit access to the station platform through operational measures whenever accumulations of entraining passengers bring the net platform area per passenger to 4 square feet per person.

Once the occupant load was determined under the F/LS Criteria, the remainder of the methodology followed the exiting requirements in the same manner as the procedure for NFPA 130.

Emergency exit capacity for the F/LS Criteria was measured in units of exit width equal to 22 inches per unit. Occupant capacity per unit of exit width varies by circulation element. Exit capacity required is determined to allow: (1) evacuation of the passengers from the station platform in 4 minutes; and (2) evacuation of passengers from the most remote part of the platform to a point of safety in 6 minutes.

Figure 5 summarizes the Metro Rail Fire/Life Safety Committee Criteria requirements.

FIGURE 5

METRO RAIL FLS CRITERIA
EMERGENCY EXITING REQUIREMENTS

I BASIS FOR EXITING PROVISIONS

- BUILDING CLASSIFICATION — UNDERGROUND STATION
- OCCUPANT LOAD FACTOR — BASED ON ENTRAINING AND DESIGN TRAIN LOAD(S) THAT MAY OFF-LOAD IN AN EMERGENCY
- UNIT OF EXIT WIDTH — 22 INCH EXIT LANE
- OCCUPANT CAPACITY PER UNIT OF EXIT WIDTH — VARIES BY EGRESS ELEMENT

II SPECIFYING EXIT REQUIREMENTS

- STATION OCCUPANT LOAD
  - ENTRAINING LOAD EQUAL TO PLATFORM ACCUMULATION OF 4 HEADWAY TIME PERIOD. PLATFORM VOLUME LIMITED TO 4 SF/PERSON.
  - LINK LOAD EQUAL TO SIMULTANEOUS OFF-LOAD OF TRAINS CARRYING DESIGN LOAD DURING PEAK 15 MINUTE PERIOD. MINIMUM TRAIN OFF-LOAD EQUAL TO ONE TRAIN OF MAXIMUM CAPACITY.
- EXIT CAPACITY TEST
  - EVACUATE OCCUPANT LOAD FROM PLATFORM IN 4 MINUTES.
  - EVACUATE OCCUPANT LOAD FROM MOST REMOTE POINT ON PLATFORM TO A POINT OF SAFETY IN 6 MINUTES.
- MINIMUM EXIT REQUIREMENTS
  - SUFFICIENT WIDTH TO ACCOMMODATE 7 SF/PERSON BASED ON NET PLATFORM AREA.

## 3.0 APPLICATION OF CRITERIA TO METRO RAIL STATIONS

The next step in the process was to compare the exit width requirements of the respective code provisions for three representative stations. The stations selected for analysis were:

- 5th/Hill,
- Wilshire/Western,
- Hollywood/Cahuenga.

The objective was to test the sensitivity of the codes to varying patronage characteristics and station configurations along the line, and the stations listed above appeared to offer the best cross-section of station patronage.

5th/Hill is a downtown high patronage station, with among the highest forecasted link loads. The station is of a double-end mezzanine configuration.

Wilshire/Western is a moderate volume mid-line station, and at the time of the analysis was a single-end mezzanine configuration.

Hollywood/Cahuenga is an outlying low volume station, and at the time of the analysis, it also was designated as a single-end mezzanine configuration.

Exiting requirements and evacuation times were projected separately for two distinct patronage levels. The first level was the year 2000 peak 15 minute patronage. The second level was a '1.6 contingency,' or ultimate design year level. This represented a patronage level 60 percent higher than the base year 2000 levels. It was assumed that scheduled peak hour headways in the year 2000 would be 3-1/2 minutes. At the time patron demand reaches 1.6 contingency levels, peak hour headways are assumed to be 2 minutes. An interesting point surfaced during the exiting analysis; it gave an indication that headways closer than the assumed 3-1/2 minutes may be necessary by the year 2000.

The next step was to evaluate the patronage and headways against the various requirements of the Codes and Standards.

## 3.1 UBC and NFPA 101 Exit Width Requirements

A review of UBC and NFPA 101 exit width provisions reflects that these two codes are insensitive to changes in patronage levels since occupant load is based on the physical dimensions of the platform. Therefore, the occupant load and the exit width requirements will be constant over the life of the Metro Rail System, logically assuming no change in the platform width or length.

For the three stations in question, the procedures for prescribing UBC and NFPA 101 exit width requirements are straightforward. Following the steps outlined in Sections 2.1 and 2.2 resulted in exit width requirements as follows:

| STATION | EXIT WIDTH REQUIRED (In Exit Units of 22 Inches) UBC | NFPA 101 |
|---|---|---|
| 5th/Hill | 18.0 | 22.0 |
| Wilshire/Western | 16.5 | 20.0 |
| Hollywood/Cahuenga | 16.5 | 20.0 |

As stated previously, these exit capacities do not change as patronage levels grow. The implications of this constant condition are discussed and graphically portrayed later in this paper.

## 3.2 Application of NFPA 130 and F/LS Committee Criteria

NFPA 130 and the Metro Rail F/LS Committee Criteria are sensitive to changes in patronage levels. Both are considered a dynamic approach to specifying exit width requirements for a station since exit capacity varies when either station configuration or the patronage level changes. For purposes of illustration in this paper, only the procedures specified by the F/LS Criteria will be applied to the 5th/Hill Station. Patronage levels at the ultimate design year will be used. The study and tables herein also reflect the results for NFPA 130.

Station configuration and occupant load are the primary determinants of exit width requirements and evacuation times for the two dynamic approaches. It should be noted that the development of the station configuration to satisfy the criteria was an iterative process, and only the final configuration is related in this paper. The patronage data used in this analysis was issued on March 14, 1983. Minor refinements in patronage estimates have been made since that date, which do not adversely affect the results of the analysis.

The station occupant load is based on patronage during the peak period and on the operating headway. The patronage characteristics for 5th/Hill are shown in Figure 6. Forecasts for both the "AM" and "PM" peak periods are shown since both conditions must be investigated in determining a worst case or maximum occupant load.

As discussed in Section 2.4, the occupant load is comprised of an entraining load and a summed inbound and outbound link load. Since the system will be operating on two minute headways at the ultimate patronage design level, the entraining load will equal eight minutes of platform accumulation. It is essential to note that by relating the entraining load to headway interval, it is possible to have about the same value for the entraining load during both base year and ultimate design period operations. This result is possible since 4 headways of accumulation at 3-1/2 minute intervals were approximately equal to four headways at 2 minute intervals during the respective time periods. This recognized about a 60 percent improvement in operational efficiency to accommodate the 60 percent patronage increase. In effect, this approach enables the SCRTD to set an acceptable risk level and maintain it through operational procedures.

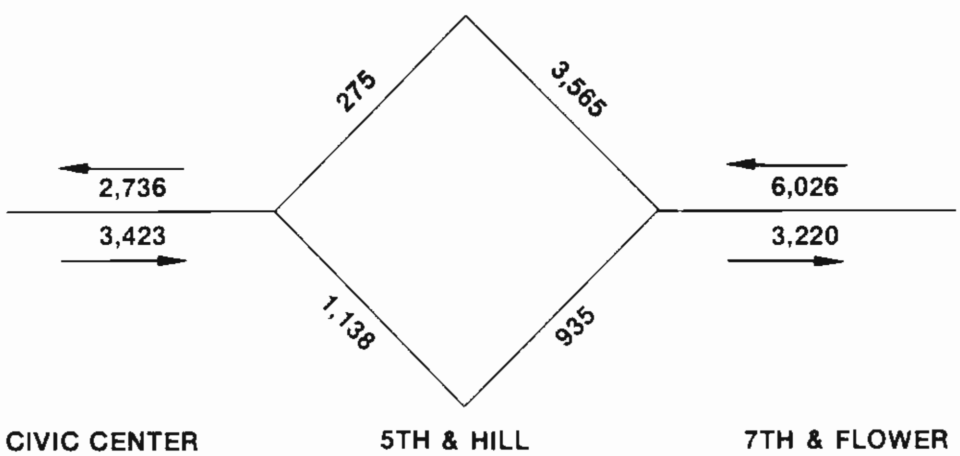
FIGURE 6

PEAK PERIOD PATRONAGE CHARACTERISTICS

5TH/HILL STATION

ULTIMATE DESIGN YEAR

- AM PERIOD
  - PEAK HOUR PATRONAGE: 15,768
  - PEAK 15 MINUTE CHARACTERISTICS:




- PM PERIOD
  - PEAK HOUR PATRONAGE: 19,531
  - PEAK 15 MINUTE CHARACTERISTICS:

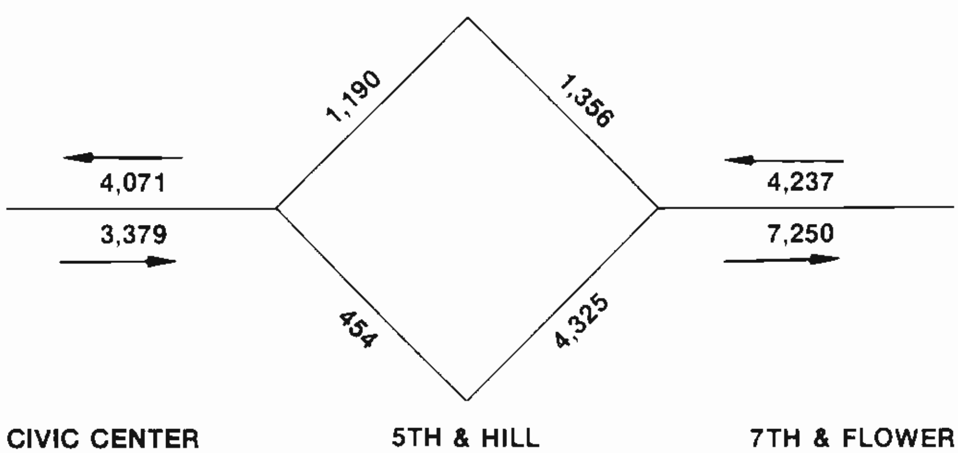


Figure 7 derives the occupant load for the 5th/Hill Station, and details the calculation for both entraining and link load contributions. The figure indicates that the 4 square feet per person entraining load limitation is applicable as well as the 1200 patron "floor" on link load contribution.

**FIGURE 7**

## OCCUPANT LOAD CALCULATION

### 5TH/HILL STATION

- CONDITIONS
  - YEAR — ULTIMATE DESIGN
  - HEADWAY — 2 MINUTES
  - CRITERIA — METRO RAIL FIRE/LIFE SAFETY

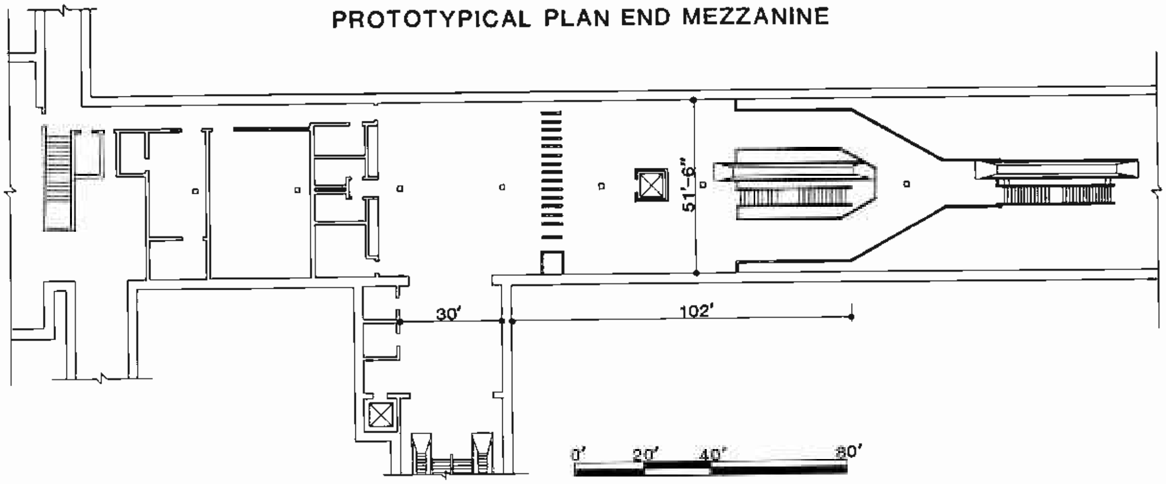
- <u>AM PEAK PERIOD</u>
  - ENTRAINING LOAD
    - (275 + 935) X 8/15 = 646
  - LINK LOAD CONTRIBUTIONS
    - LINK OUTBOUND — 3,423 X 1/7 = 489
    - LINK INBOUND — 6,026 X 1/7 = 861
  - TOTAL STATION LOAD
    - 646 + 489 + 861 = 1,996

- <u>PM PEAK PERIOD</u>
  - ENTRAINING LOAD
    - (1,190 + 4,325) X 8/15 = 2,942
    (USE 2,877 - 4 SF/PERSON LIMIT)
  - LINK LOAD CONTRIBUTION
    - LINK OUTBOUND - 3,379 X 1/7 = 483
    - LINK INBOUND - 4,237 X 1/7 = 605
    1,088 USE 1,200
  - TOTAL STATION LOAD
    - 2,877 + 1,200 = 4,077

With the occupant load derived, the next step was to define the station configuration. 5th/Hill is a double-end mezzanine station. Figure 8 is a prototypical plan of an end mezzanine and shows general relationships among vertical circulation elements, fare collection devices, and entrances. The relative locations are critical since they affect travel distances and evacuation times for the station occupant load.

FIGURE 8

PROTOTYPICAL PLAN END MEZZANINE




The number of vertical elements from the platform to the mezzanine level and from the mezzanine to grade level are depicted in Table 1.

TABLE 1

EMERGENCY EXITING ANALYSIS

STATION: 5TH & HILL
VERTICAL CIRCULATION ELEMENTS

| ELEMENT | NUMBER OF ELEMENTS | WIDTH PER ELEMENT | UNITS OF EXIT WIDTH PER ELEMENT | TOTAL WIDTH (FEET) | TOTAL UNITS OF EXIT WIDTH |
|---|---|---|---|---|---|
| PLATFORM TO MEZZANINE | | | | | |
| - STAIRS | 7 | 5'-8" | 3 | 39.67 | 21 |
| - ESCALATOR | 5 | 4'-0" | 2 | 20 | 10 |
| - TOTAL | | | | 59.67 | 31 |
| EMERGENCY EXITS | | | | | |
| PLATFORM TO SURFACE | | | | | |
| - STAIRS | 1 | 7'-4" | 4 | 7.33 | 4 |
| MEZZANINE TO SURFACE | | | | | |
| - STAIRS | 2 | 3'-6" | 2 | 7 | 4 |
| MEZZANINE TO SURFACE | | | | | |
| - STAIRS | 6 | 5'-8" | 3 | 34 | 18 |
| - ESCALATOR | 6 | 4'-0" | 2 | 24 | 12 |
| - TOTAL | | | | 58 | 30 |

Since the exit capacity between the respective levels affects the movement of patrons, it is necessary to convert the vertical devices to a passenger flow capacity. Figure 9 shows this conversion for 5th/Hill. It should be noted that exit capacities per lane of egress were adopted from NFPA 130.

## FIGURE 9
## EMERGENCY EXIT CAPACITY CALCULATIONS

STATION 5TH/HILL

OCCUPANCY LOAD 4,077

### EXIT LANES AND CAPACITY PROVIDED

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **PLATFORM TO CONCOURSE** | | | | | | | | |
| STAIRS | 7 | X | 3 | LANES X | 35 | PPM = | 735 PPM |
| ESCALATORS | 5 | X | 2 | LANES X | 35 | PPM = | 350 PPM |
| EMERGENCY STAIRS | 1 | X | 4 | LANES X | 35 | PPM = | 140 PPM |
| | | | | | | TOTAL | 1225 PPM |
| **THROUGH FARE BARRIER** | | | | | | | |
| FARE GATES | 26 | X | 1 | LANES X | 50 | PPM = | 1300 PPM |
| SERVICE GATES | 4 | X | 2 | LANES X | 50 | PPM = | 400 PPM |
| EMERGENCY GATES | | X | | LANES X | | PPM = | PPM |
| | | | | | | TOTAL | 1700 PPM |
| **FARE BARRIER TO SAFE AREA** | | | | | | | |
| STAIRS | 6 | X | 3 | LANES X | 35 | PPM = | 630 PPM |
| ESCALATORS | 6 | X | 2 | LANES X | 35 | PPM = | 420 PPM |
| EMERGENCY STAIRS | 1 | X | 4 | LANES X | 35 | PPM = | 140 PPM |
| | | | | | | TOTAL | 1190 PPM |

Application of the test criteria was the final step in analyzing a station's emergency exiting characteristics. Figure 10 illustrates the procedures to test the evacuation of station occupant load from the platform and to test occupant load evacuation from the most remote point on the platform to a point of safety. 5th/Hill evacuation times are 3.33 and 5.98 minutes, respectively, for the two tests.

**FIGURE 10**

**EMERGENCY EXIT CAPACITY TESTS**

**TEST 1**

EVACUATE STATION OCCUPANT LOAD FROM STATION PLATFORM(S) IN 4 MINUTES OR LESS.

$$W_1 \text{ (WAITING TIME AT PLATFORM EXITS)} = \frac{\text{W (OCCUPANCY LOAD)}}{\text{EXIT CAPACITY}}$$

$$W_1 = \frac{\text{4,077 PERSONS}}{\text{1,225 PPM}} = \text{3.33 MINUTES}$$

**TEST 2**

EVACUATE STATION OCCUPANT LOAD FROM THE MOST REMOTE POINT ON THE PLATFORM TO A POINT OF SAFETY IN 6 MINUTES OR LESS.

WALKING TIME FOR LONGEST EXIT ROUTE =

$$T = T_1 + T_2 + T_3 + T_4 + T_5$$

| | |
|---|---|
| $T_1$ (PLATFORM) | 55 FEET/ 200 FPM = 0.28 MINUTES |
| $T_2$ (PLATFORM TO CONCOURSE) | 15 FEET/ 50 FPM = 0.30 MINUTES |
| $T_3$ (CONCOURSE TO FARE BARRIER) | 206 FEET/ 200 FPM = 1.03 MINUTES |
| $T_4$ (FARE BARRIER TO SAFE AREA) | 127 FEET/ 200 FPM = 0.64 MINUTES |
| $T_5$ (GRADE) | 34 FEET/ 50 FPM = 0.68 MINUTES |
| | T = 2.93 MINUTES |

• ADDITIONAL WAITING TIME AT PLATFORM EXITS

$3.33\ (W_1) - 0.28 (T_1) = 3.05$ MINUTES

• ADDITIONAL WAITING TIME AT FARE BARRIER

OCCUPANT LOAD AT CONCOURSE =
OCCUPANT LOAD - EMERGENCY STAIR CAPACITY

= 4077 - 467 = 3610 PATRONS

$W_2$ (CONCOURSE OCCUPANT LOAD GATE CAPACITY)

= 3610 PERSONS/1700 PPM = 2.13 MINUTES

$2.13\ (W_2) - 3.33\ (W_1) = 0$ MINUTES

• ADDITIONAL WAITING TIME AT CONCOURSE EXITS

$$W_3 = \frac{\text{CONCOURSE OCCUPANT LOAD}}{\text{EXIT CAPACITY}}$$

$$W_3 = \frac{3610 \text{ PERSONS}}{1190 \text{ PPM}} = 3.04 \text{ MINUTES}$$

$3.04\ (W_3) - 3.3\ (W_1) = 0$ MINUTES

• TOTAL EXIT TIME

$(T)\ 2.93 + (W_1 - T_1)\ 3.05 + (W_2 - W_1)\ 0 + (W_3 - W_1)\ 0$

= 5.98 TOTAL MINUTES

Both NFPA 130 and the F/LS Criteria were applied to all three stations. The occupant loads and evacuation times for the respective stations are depicted in Table 2.

TABLE 2

EMERGENCY EXITING ANALYSIS
EVACUATION TIMES

| STATION | OCCUPANT LOAD | | EVACUATION TIME (MINUTES) TO CLEAR PLATFORM | | EVACUATION TIME (MINUTES) TO POINT OF SAFETY | |
|---|---|---|---|---|---|---|
| | NFPA 130 | METRO RAIL F/LS | NFPA 130 | METRO RAIL F/LS | NFPA 130 | METRO RAIL F/LS |
| 2000 (3½ MIN. HEADWAY) | | | | | | |
| 5TH/HILL | 5,704 | 4,077 | 4.66 | 3.33 | 7.31 | 5.98 |
| WESTERN | 2,995 | 2,334 | 4.76 | 3.71 | 6.77 | 5.72 |
| HOLL/CAHUENGA | 2,073 | 1,815 | 3.30 | 2.89 | 5.66 | 5.25 |
| ULTIMATE DESIGN YEAR (2 MIN. HEADWAY) | | | | | | |
| 5TH/HILL | 7,681 | 4,077 | 6.28 | 3.33 | 8.93 | 5.98 |
| WESTERN | 3,524 | 2,089 | 6.00 | 3.32 | 8.01 | 5.33 |
| HOLL/CAHUENGA | 2,318 | 1,726 | 3.68 | 2.74 | 6.04 | 5.10 |

## 3.3 Comparison of Alternative Criteria

Upon completion of the above, a comparison was made of the respective code requirements over the Metro Rail's entire planning period (Year 2000 and a 1.6 contingency). To accomplish this comparison, it was necessary to derive occupant loads following the respective code provisions and then determine the number of exit units that would be required to satisfy the criteria. This task was accomplished for both the base year and for the ultimate design year to account for projected changes in patronage levels and operating characteristics. A qualifying assumption is necessary at this point prior to portraying the results.

Initial capital costs and operating characteristics for any transportation system are based on patronage forecasts, and subsequent modifications of the system are based on actual patronage levels and refined projections. It is understood that the modifications are not based on a specific year, but on attaining a specific patronage level. However, in order to graphically compare the results, a base year of 2000 and an ultimate design year of 2020 were assumed.

The results of determining the respective exit width requirements are shown in tabular format in Table 3. Particular attention should be devoted to the variations in exit unit requirements as one proceeds from a high-volume to low-volume station.

TABLE 3

EMERGENCY EXITING ANALYSIS
EXITING CAPACITY REQUIREMENTS

| STATION | OCCUPANT LOAD | | | | EXIT WIDTH REQUIRED (IN EXIT UNITS OF 22 INCH @) | | | | EXIT WIDTH PROVIDED (EXIT UNITS) |
|---|---|---|---|---|---|---|---|---|---|
| | U.B.C. | NFPA 101 | NFPA 130 | METRO RAIL F/LS | U.B.C. | NFPA 101 | NFPA 130 | METRO RAIL F/LS | |
| 2000 (3½ MINUTE HEADWAY) | | | | | | | | | |
| 5TH/HILL | 1,644 | 1,644 | 5,704 | 4,077 | 18.0 | 22.0 | 49.0 | 35.0 | 35 |
| WESTERN | 1,490 | 1,490 | 2,995 | 2,334 | 16.5 | 20.0 | 21.5 | 17.0 | 18 |
| HOLL/CAHUENGA | 1,490 | 1,490 | 2,073 | 1,815 | 16.5 | 20.0 | 16.5 | 14.0 | 18 |
| ULTIMATE DESIGN YEAR (2 MIN. HEADWAY) | | | | | | | | | |
| 5TH/HILL | 1,644 | 1,644 | 7,681 | 4,077 | 18.0 | 22.0 | 65.5 | 35.0 | 35 |
| WESTERN | 1,490 | 1,490 | 3,524 | 2,089 | 16.5 | 20.0 | 25.5 | 15.0 | 18 |
| HOLL/CAHUENGA | 1,490 | 1,490 | 2,318 | 1,726 | 16.5 | 20.0 | 18.0 | 13.5 | 18 |

Upon completing the above, two conclusions were evident:

- Both of the dynamic approaches are sensitive to changes in station patronage volumes and are reflected in the occupant load calculation.

- The UBC and NFPA 101 occupant load calculations show sensitivity only as it relates to changes in platform dimensions, which are minimal.

The data in Table 3 have also been presented in graphical format in Figures 11, 12, and 13 on a station-by-station basis to more clearly show the wide variation in exit width requirements. For the dynamic approaches, additional data points were calculated to show exit width requirements for each of the operating headways throughout the planning period.

FIGURE 11

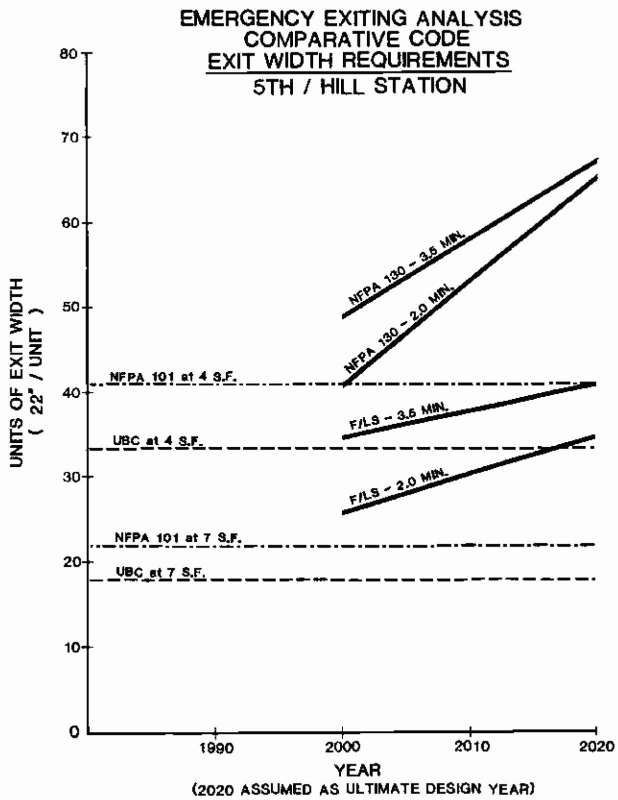



FIGURE 12

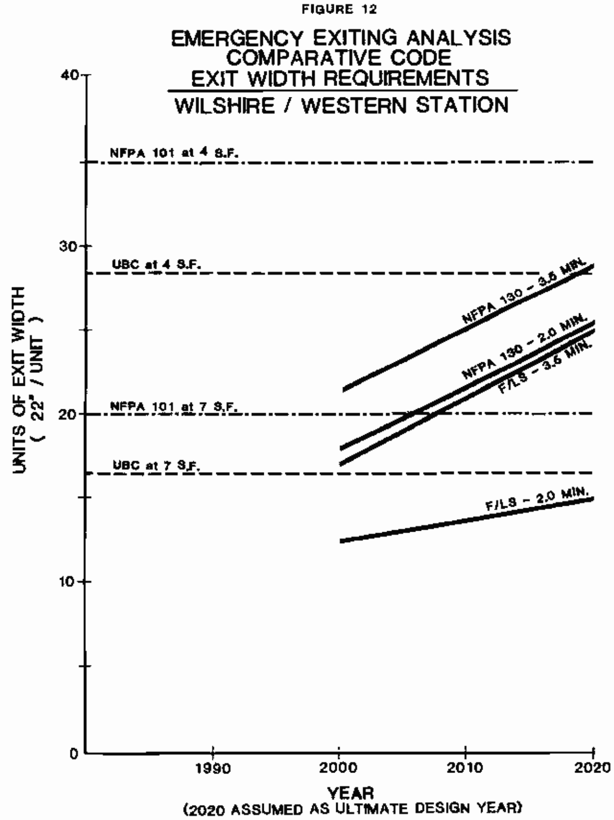
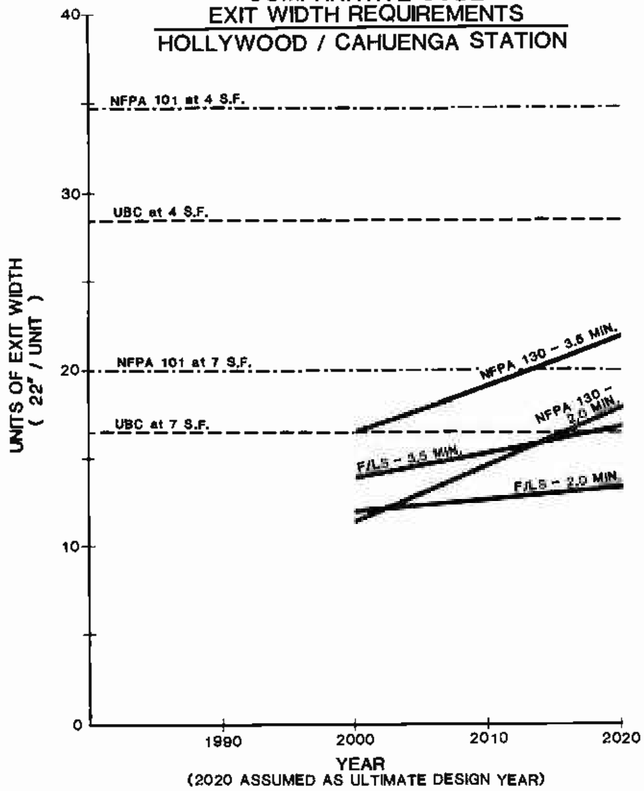


FIGURE 13

EMERGENCY EXITING ANALYSIS
COMPARATIVE CODE
EXIT WIDTH REQUIREMENTS
HOLLYWOOD / CAHUENGA STATION




## 4.0 RESULTS AND CONCLUSIONS

In reviewing the analysis, the Fire/Life Safety Committee identified a number of apparent weaknesses in existing code provisions as they applied to transit station requirements. A number of these are listed below:

- UBC and NFPA 101 provisions do not consider actual patron loads which may be in the station.
- At high volume stations, UBC and NFPA 101 provisions appear to provide insufficient exiting width and, at low volume stations, more than may be needed.
- NFPA 130 does not recognize physical limitations of the platform in deriving entraining load.
- UBC, NFPA 101 and NFPA 130 do not adequately recognize transit system operational procedures which may be instituted to intervene and limit occupant loading during potential emergency conditions.
- NFPA 130 uses a static period for determining entraining loads and does not recognize the effect that variations in headway interval may have on platform accumulation.

The analysis clearly indicated that occupancy load and, thereby, exit width requirements, were a function of patronage levels, operational characteristics of the system, and station configuration. None of the existing codes appeared to encompass all of these factors. Thus, the Fire/Life Safety Committee developed a set of criteria to satisfy the unique requirements of the Metro Rail System. This criteria was previously described in Section 2.0.

The F/LS Criteria combine the merits of a patronage-based dynamic approach and the constraint that platform accumulation is limited by physical dimensions. This joint consideration dictates that operational measures are an integral part of the station emergency egress characteristics. In addition, by tying entraining loads to an accumulation of headways, the criteria assert that:

- The time-lapse for identification of an emergency condition is not static and is a function of system operation which varies during the day and throughout the life of the system and that

- The entraining portion of the station occupant load will vary as the headway is shortened or lengthened.

These two characteristics imply that actual operations directly affect the volume of patrons that may have to be evacuated during an emergency condition. They also imply that, as operational effectiveness improves, the element of risk is reduced and Fire/Life Safety response capabilities are enhanced. Likewise, if operations are not achieving the intended objectives, the increased risk will also be apparent.

For criteria to be appropriate, this flexibility to respond to and accurately assess the actual conditions is mandatory. The Metro Rail F/LS Criteria possess this flexibility.

The adopted emergency exiting criteria for the Metro Rail System provide a realistic answer to the dilemma of specifying the appropriate exit width requirements for the Metro Rail Stations. By integrating the factors of patronage, operational characteristics, and station configuration, the criteria enable the SCRTD to monitor and report actual conditions and to assess the emergency egress characteristics of the respective stations.

It can therefore be concluded that each transit system has to clearly understand the physical characteristics of its system, (this applies to new and old transit systems) to provide sufficient emergency exiting. These characteristics should include:

- Selection of the most appropriate requirements from applicable codes and standards.
- Developing operational procedures to intervene and/or mitigate platform overcrowding.
- Provide sufficient emergency exits and exit paths to meet its needs in an efficient and cost effective manner.

# BIOGRAPHIES OF THE AUTHORS

## Biography of Roger W. Wood Jr.

Roger W. Wood Jr. is Supervisory Engineer, Safety, Security and System Assurance for the Southern California Rapid Transit District (SCRTD). In this capacity he is responsible for Safety, Fire/Life Safety, Security and System Assurance activities on the Metro Rail Project. He received his B.S. degree (1965) in Mechanical Engineering from Northeastern University and a B.A. degree (1966) in Business Administration from College of the Holy Cross. Prior to joining the SCRTD he was an associate with Booz, Allen and Hamilton on assignment as Deputy Program Manager to the Maryland Mass Transit Administration for the Reliability, Maintainability and Safety Program during the development of the Baltimore Region Rapid Transit System. Prior to joining BA&H he was employed by the David Clark Company, ILC Industries and was president of his own safety consulting firm.

Mr. Wood has 22 years of safety and systems assurance experience in aerospace and transportation. He was instrumental in the development of a special fire survival suit for auto racing and for the U.S. Army, Navy, and Air Force. He has specialized in the evaluation of materials and application programs for hostile environments.

## Biography of Robert G. Cutlip

Robert G. Cutlip is a Senior Project Engineer for Tippetts-Abbett-McCarthy-Stratton (TAMS) and is Program Control Manager and Project Engineer for station siting and preliminary design for the Southern California Rapid Transit District Metro Rail Project. His responsibilities include ensuring proper integration of Fire/Life Safety requirements into station design and preparing civil engineering site plans for select stations. Mr. Cutlip received a B.S. degree from the U.S. Air Force Academy (1971), an M.S. degree from Vanderbilt University (1973), and is pursuing MBA studies at the University of Southern California. He is a registered professional engineer. Mr. Cutlip's varied experience includes participation in a passenger and cargo forecast analysis and engineering development studies for the New Lisbon Airport Master Plan; identification of design and construction technologies and facilities programming requirements for a phased one billion dollar new town development; and preparation of numerous environmental studies ranging from electric generating stations to military base realignments. Prior to joining TAMS, Mr. Cutlip was a Corporate Vice President for The Benham Group, where, in addition to project engineer duties, he was responsible for directing a technical information resource center and developing a business development plan for the 10 nationwide offices.

# Biography of Allen Simon

Mr. Simon is a Transportation Planner for Tippetts-Abbett-McCarthy-Stratton (TAMS). He was the lead analyst investigating station exiting requirements for the SCRTD Metro Rail Project.

Mr. Simon received a Masters of Science in City Planning and a Masters of Science in Civil Engineering from the University of Pennsylvania in 1974. He received a Bachelor of Science in Humanities and Science from Massachusetts Institute of Technology in 1969. He is a member of The American Planning Association.

Mr. Simon was overseas Project Manager for TAMS for the Master Planning and Preliminary Engineering of three airports in Portugal. Before joining TAMS, Mr. Simon served as transit analyst for Metropolitan Boston's Central Transportation Planning staff. In this capacity, he developed surface transit plans in conjunction with programmed MBTA Rail Rapid Transit extensions.