

CHAPTER 3 DESIGN GUIDELINES

- 3.1 Introduction, 25
- 3.2 American Public Transit Association, 25
 - 3.2.1 Wayside Noise Limits, 25
 - 3.2.1.1 Community Categories, 25
 - 3.2.1.2 Measurement of Wayside Passby Noise, 25
 - 3.2.1.3 Relation to Equivalent Levels— L_{eq} , 27
 - 3.2.2 Ancillary Facility Noise, 27
 - 3.2.3 Station Platform Noise Levels, 27
 - 3.2.4 Transit Vehicle Noise Limits, 27
- 3.3 Federal Transit Administration, 27
 - 3.3.1 Transit System Projects, 28
 - 3.3.1.1 Basis, 30
 - 3.3.1.2 Land Use Categories, 30
 - 3.3.1.3 Levels of Impact, 31
 - 3.3.1.4 Mitigating Adverse Impact, 31
- 3.4 Local Ordinances, 31
- 3.5 Preparation of Noise Specifications, 31
- 3.6 References, 32

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CHAPTER 3

DESIGN GUIDELINES

3.1 INTRODUCTION

Environmental impact analysis and design guidelines are discussed in this chapter. Included are (a) the design guidelines published by APTA and (b) the guidelines recently published by the FTA for environmental assessment and design of rail transit projects and highway/transit corridor projects. The FTA provides criteria for assessing and comparing noise impacts of various transportation modes, including bus as well as ancillary facilities of transit systems. Also discussed in this chapter are local ordinances and the preparation of noise specifications for transit equipment.

3.2 AMERICAN PUBLIC TRANSIT ASSOCIATION

APTA provides design guidelines for noise produced by transit trains. These guidelines are comprehensive; they include limits for vehicle interior, exterior, station platform, and fan and vent shaft noise levels (*I*). (Noise level limits are also provided for fan noise and substation noise.)

3.2.1 Wayside Noise Limits

Wayside noise limits are recommended by APTA, based on community categories and building types.

3.2.1.1 Community Categories

Community categories defined by the APTA guidelines are listed in Table 3–1 in terms of description and median L_{50} sound levels. These basic community categories serve as a basis for recommending appropriate noise level limits. Each community category is assigned a range of ambient median sound levels, L_{50} , as part of its description, which forms a basis for assigning rail transit noise limits. The noise limits are intended to limit maximum passby noise to levels consistent with other modes of transportation, such as automobiles passing along streets in front of residential receivers. Design guidelines for maximum rail transit noise are then selected for the type of community.

Design guidelines for maximum passby noise levels are provided in Table 3–2 for various types of communities and occupancies. The APTA guidelines place a limit on maxi-

imum sound levels so that they are comparable to other sources of noise, such as automobiles and light trucks. These limits are applied to nighttime operations, because the sensitivity to noise is greater at night than during daytime hours. In practice, wheel/rail noise will be independent of the time of day. The noise limits apply outdoors at the building or area under consideration, but not closer than 50 ft from the (nearest) track centerline. At locations where the train noise has no particularly annoying or identifiable components, experience with the noise level guidelines given in Table 3–2 has shown that the community will usually accept the resulting noise environment if the maximum noise level design goals are met, in spite of the transient nature of wheel/rail noise. More importantly, the APTA guidelines can be met with practical noise control provisions.

Maximum sound levels for specific types of buildings are indicated in Table 3–3. These limits should be applied regardless of the community area category involved. The designer should be careful in locating surface or aerial transit lines adjacent to auditoria, television studios, schools, theaters, amphitheaters, and churches.

At locations where noise from impacts at jointed track or crossovers, wheel squeal on curves, and so on occur, the noise will be more annoying than usual. The APTA guidelines make no provision for these types of noise.

3.2.1.2 Measurement of Wayside Passby Noise

The maximum sound level is defined as the maximum sound level measured with a sound level meter set to the “fast meter response,” which is similar to an rms averaging time of 0.125 sec. In practice, the rms sound level is often determined by averaging the sound energy over the passby duration to average out minor fluctuations in sound level due to abnormally rough wheels, impacts, etc., as might be done with an integrating sound level meter or real time analyzer. Minor fluctuations of noise level can also be energy averaged using the “slow” sound level meter response characteristic, equivalent to an rms averaging time of 1 sec. The difference between the “slow” sound-level meter measurement and the “fast” sound-level meter measurement for a smoothly varying train passby signature is a fraction of a decibel. A problem may arise, however when measuring the maximum sound level using the slow meter response for very rapidly

TABLE 3-1 GENERAL CATEGORIES OF COMMUNITIES ALONG TRANSIT SYSTEM CORRIDORS (APTA)

| Area Category | Area Description | Typical L_{50} dBA | |
|---------------|---|----------------------|----------------|
| | | Day | Night |
| I | <u>Low Density</u> urban residential, open space, park, suburban | 40-50 | 35-45 |
| II | <u>Average</u> urban residential, quiet apartment and hotels, open space, suburban residential, or occupied outdoor area near busy streets. | 45-55 | 40-50 |
| III | <u>High density</u> urban residential, average semi-residential/commercial areas, parks, museums and non-commercial public building areas. | 50-60 | 45-55 |
| IV | <u>Commercial</u> areas with office buildings, retail stores, etc., primarily daytime occupancy | 60-70 | Not Applicable |
| V | <u>Industrial</u> areas or freeway and highway corridors | >60 | Not Applicable |

L_{50} is the median noise level. The energy equivalent noise level during the day is typically about 3 to 5 dB higher than the L_{50} .

TABLE 3-2 GUIDELINES FOR MAXIMUM AIRBORNE NOISE FROM TRAIN OPERATIONS (APTA)

| Community Area Category | Description | Single Event Maximum Noise Level Design Goal - dBA | | |
|-------------------------|-----------------------------|--|------------------------|----------------------|
| | | Single Family Dwellings | Multi-Family Dwellings | Commercial Buildings |
| I | Low Density Residential | 70 | 75 | 80 |
| II | Average Density Residential | 75 | 75 | 80 |
| III | High Density Residential | 75 | 80 | 85 |
| IV | Commercial | 80 | 80 | 85 |
| V | Industrial /Highway | 80 | 85 | 85 |

Note: These limits apply at the structure or sensitive area, but not closer than 50 feet from the track centerline.

TABLE 3-3 GUIDELINES FOR MAXIMUM AIRBORNE NOISE AT SPECIFIC BUILDINGS FROM TRAIN OPERATIONS (APTA)

| Building Occupancy | Single Event Maximum Noise Design Goal - dBA |
|--|--|
| Amphitheaters | 60 |
| "Quiet" Outdoor Recreation Areas | 65 |
| Concert Halls, Radio and TV Studios, Auditoria | 70 |
| Churches, Theaters, Schools, Hospitals, Museums, Libraries | 75 |

rising passby noise levels, in which case the fast sound-level meter response should be used. Most trains require at least 1 sec to pass a measurement location, a time that is consistent with the slow meter response. The slow meter response is entirely adequate for measuring maximum passby noise from heavy rail transit trains of four or more cars at distances beyond one car length.

3.2.1.3 Relation to Equivalent Levels – L_{eq}

The maximum noise level limits indicated by the APTA guidelines limits may be correlated with energy averaged noise levels for the purpose of assessing community reaction to noise. The following formula by Peters (2) is useful to relate the maximum passby level measured with a sound level meter set to “fast” response (0.125 sec integration time) with the energy averaged L_{eq} over an extended period:

$$L_{eq} = L_{max} + 10 \text{Log}_{10}\{R(1.5D + d)/v\} - 30$$

where:

- R = number of trains per hour
- D = distance of the receiver from the track centerline
- d = average train length in meters
- v = train speed in km/hr.

As an example, if the 70 dBA design limit is just met at a location 60 m from the track, with train speed of 96 km/hr, and average train length of 91 m, then an L_{dn} of 55 dBA would be obtained with an average of 16 trains per hour during the daytime (7:00 AM to 10:00 PM) and 1.5 trains per hour at night.

For the most part, the APTA guidelines for community noise levels due to transit trains agree with the goals of the Environmental Protection Agency (EPA) “Levels Document” (3). Meeting the APTA maximum noise level goals for residential locations will not necessarily guarantee that the Day-Night Levels identified in the “Levels Document” as “requisite to protect the public health and welfare with an adequate margin of safety” will be achieved. Even if the maximum level goals of the APTA guidelines are achieved, the Day-Night Levels will depend on scheduling, especially on the number of trains passing during the nighttime period.

3.2.2 Ancillary Facility Noise

The APTA guidelines provide noise level limits for ancillary facilities, including vent and fan shafts through which wheel/rail noise may propagate and impact normally quiet residential communities. The maximum limits for transient noise emanating from fan and vent shafts due to train operations are listed in Table 3–4. These limits apply at the shorter distance of 50 ft from the ancillary facility or at the setback line of the nearest building.

3.2.3 Station Platform Noise Levels

The APTA guidelines recommendations for station platform noise levels due to trains are summarized in Table 3–5. Trains entering and leaving subway stations should not produce noise levels in excess of 85 dBA. The noise level limits for above grade stations are 80 and 85 dBA for ballast-and-tie and concrete track beds, respectively. Noise levels 5 dB below these limits are desirable. Platform noise levels are normally measured at 5 ft above the platform, roughly midway between the platform edge and rear wall, or 5 ft from the platform edge, whichever is closer to the track. The noise levels apply to the total noise level, including noise due to wheel/rail sources as well as traction motor equipment, vehicle ventilation and air conditioning equipment, and brake systems. (The APTA guidelines also provide limits for continuous noise levels due to station and subway ventilation fans, and recommend station reverberation times to control speech intelligibility of public address systems.)

3.2.4 Transit Vehicle Noise Limits

Interior and exterior vehicle noise generally have separate standards, though the sources are the same. The APTA guidelines recommend limits for vehicle interior and exterior operational maximum A-weighted noise levels at maximum operating speeds on ballast-and-tie and concrete track beds. These limits are listed in Table 3–6. (The APTA guidelines also recommend maximum auxiliary equipment noise levels for stationary vehicles.) These limits are incorporated into many transit vehicle procurement specifications. The goal of the APTA guidelines is that vehicles be constructed to minimize wayside and interior noise levels. Further, the limits given in Table 3–6 apply to the total noise produced by the transit vehicle, not just wheel/rail noise. Much of the noise produced by a transit vehicle on ballast-and-tie track with smooth ground rail is produced by traction motor equipment and aerodynamic turbulence in the truck area. Subjectively, meeting the APTA guidelines for interior noise levels means that the interior noise on ballast-and-tie track at low speeds should be “quiet” while at high speeds in subway the noise may be “intrusive” but not “annoying” (4). These levels are consistent with those of all but the quietest of automobiles at highway speeds.

3.3 FEDERAL TRANSIT ADMINISTRATION

The FTA provides comprehensive guidelines for environmental assessment of proposed transit projects in a report entitled *Transit Noise and Vibration Impact Assessment* (5), referred to informally as the “guidance manual.” The FTA guidelines recommend procedures for assessing transit noise impacts due to all forms of transit, including rail transit. The FTA expects project sponsors to use these guidelines for rail projects which involve funding assistance from the FTA.

The purpose of this section is to introduce and summarize the FTA guidance for environmental noise impact assessment.

TABLE 3-4 GUIDELINES FOR NOISE FROM TRANSIT SYSTEM ANCILLARY FACILITIES (APTA, TABLE 2-7-G)

| Area Category | Area Description | Maximum Transient Noise Level due to Trains - dBA |
|---------------|-----------------------------|---|
| I | Low Density Residential | 50 |
| II | Average Density Residential | 55 |
| III | High Density Residential | 60 |
| IV | Commercial | 65 |
| V | Industrial/Highway | 75 |

TABLE 3-5 PLATFORM NOISE LEVEL LIMITS MEASURED AT 5 FEET ABOVE THE PLATFORM, 5 FEET FROM PLATFORM EDGE OR CENTERLINE, WHICHEVER IS CLOSEST TO THE TRACK (APTA)

| Station Type | Track Type | Maximum Noise Level - dBA |
|--------------|-----------------|---------------------------|
| Subway | Concrete | 85 |
| Above Grade | Concrete | 85 |
| | Ballast-and-tie | 80 |

TABLE 3-6 SUMMARY OF TRANSIT VEHICLE OPERATIONAL NOISE LEVEL DESIGN GOALS (APTA, TABLE 2-7-A)

| Specification | Item | Goal - dBA | | |
|--|--|------------|-------|-------------|
| | | 2-Car | 4-Car | 6- or 8-Car |
| Vehicle Interior Noise Limits | In open (ballast and tie) at maximum speed on welded rail (+5 dBA on jointed rail) | 70 | | |
| | In open (concrete track bed) at maximum speed | 74 | | |
| | In tunnels at maximum speed | 80 | | |
| Exterior Noise Limits (15 m from track centerline in open with no reflecting surface within 100 feet of test location) | Ballast and tie track - 80 mph | 84 | 86 | 87 |
| | Ballast and tie track - 60 mph | 80 | 82 | 83 |
| | Concrete Track bed - 80 mph | 88 | 90 | 91 |
| | Concrete track bed - 60 mph | 85 | 87 | 88 |

The user of this manual should refer directly to the above-referenced report when trying to interpret and apply FTA's noise prediction procedures and impact assessment criteria.

3.3.1 Transit System Projects

The FTA criteria for assessing the environmental noise impact of transit system projects are shown in Figure 3-1 for

categories of land use defined in Table 3-7. The project noise levels are indicated along the ordinate, and the existing ambient, or no-build, noise levels are indicated along the abscissa. Thus, for example, the noise due just to transit operations can be plotted against the ambient noise without transit operations, and if the point falls within the "impact" zone, the transit noise would be deemed to produce an impact, though not a "severe impact."

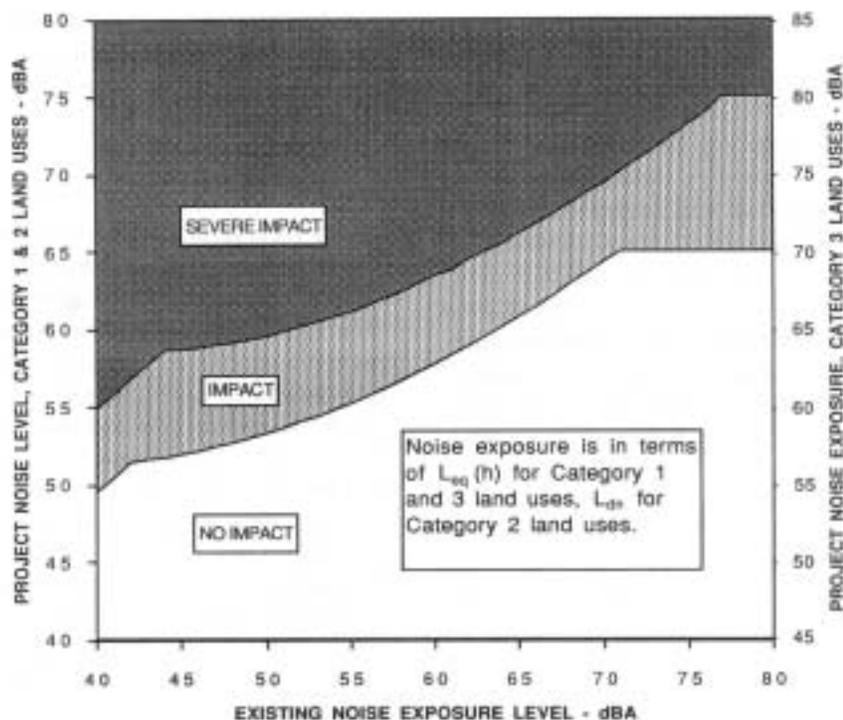


FIGURE 3-1 FTA NOISE IMPACT ASSESSMENT CRITERIA FOR TRANSIT PROJECTS

TABLE 3-7 LAND USE CATEGORIES AND METRICS FOR TRANSIT NOISE AND IMPACT ANALYSIS

| Land Use Category | Noise Metric | Description of Land Use Category |
|-------------------|---------------------|---|
| 1 | Outdoor $L_{eq}(h)$ | Tracts of land where quiet is an essential element in their intended purpose. This category includes lands set aside for serenity and quiet, and such land uses as outdoor amphitheaters and concert pavilions, as well as National Historic Landmarks with significant outdoor use. |
| 2 | Outdoor L_{dn} | Residences and buildings where people normally sleep. This category includes homes, hospitals, and hotels where a nighttime sensitivity to noise is assumed to be of utmost importance. |
| 3 | Outdoor $L_{eq}(h)$ | Institutional land uses with primarily daytime and evening use. This category includes schools, libraries, and churches where it is important to avoid interference with such activities as speech, meditation and concentration on reading material. Buildings with interior spaces where quiet is important, such as medical offices, conference rooms, recording studios, and concert halls fall into this category. Places for meditation or study associated with cemeteries, monuments, museums. Certain historical sites, parks and recreational facilities are also included. |

* L_{eq} for the noisiest hour of transit-related activity during hours of noise sensitivity.

3.3.1.1 Basis

The FTA criteria base the degree of environmental impact in part on existing ambient noise levels. As stated in the guidance manual, they incorporate both absolute criteria, which consider activity interference caused by the transit project alone, and relative criteria, which consider annoyance due to the change in the noise environment caused by the transit project. The level or magnitude of impact is determined by two factors: predicted project noise and existing noise. In the mid-range, the impact criteria allow higher project noise levels as existing noise levels increase. However, there is an absolute limit placed on project noise at the higher ambient levels, as reflected in Figure 3-1, where the ascending curves flatten out.

An important aspect of the FTA noise impact criteria is shown in Figure 3-2. This figure illustrates the cumulative, or total, increase in noise allowed by the impact criteria at different ambient noise levels. As the ambient noise environment gets louder, the increase in cumulative noise allowed by the criteria gets smaller. This aspect recognizes that people already exposed to high ambient noise levels are least able to tolerate increases in noise due to introduction of a new noise source.

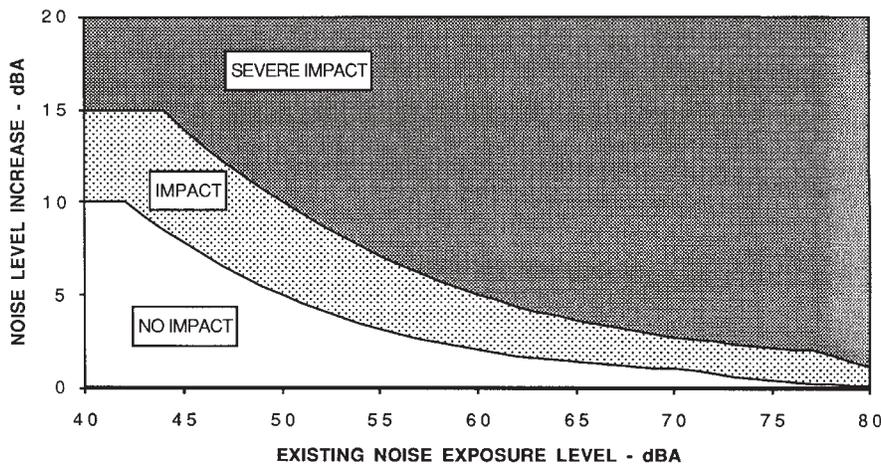
As illustrated in Figure 3-2, areas where existing noise levels are low (L_{dn} less than 40 dBA) may suffer a 10 dBA increase in noise level without being described as being significantly impacted by the project. Conversely, areas with a background level on the order of 70 to 75 dBA (e.g., near a highway) may experience a noise increase of only a few decibels by the project and be described as being impacted by the project. A very attractive feature of the FTA criteria is that they help to reduce “incrementalization” of noise impacts due to multiple projects; adding to already excessively high

noise levels on the order of 80 dBA is not necessarily an appropriate approach. Few criteria for environmental assessment have this desirable feature.

3.3.1.2 Land Use Categories

The FTA criteria are defined separately for three different categories of land use, as defined in Table 3-7. Category 1 includes tracts of land where quiet is a basis for use, such as outdoor pavilions or National Historic Landmarks where outdoor interpretation routinely takes place. The hourly equivalent level, L_{eq} (h) applies to these areas. Category 2 includes residences and buildings where people sleep, for which the Day-Night level, L_{dn} , is to be used. Category 3 areas include schools, libraries, churches, certain parks, and other institutions frequented during the daytime and evening periods, for which the hourly equivalent level, L_{eq} (h), applies. The hourly L_{eq} used for Category 1 and 3 areas is the hourly L_{eq} for the noisiest hour of transit related activity during the hours of land use. As indicated in Figure 3-1, the project noise limits for Category 3 areas may be 5 dB higher than the limits for Category 1 and 2 areas.

The criteria do not apply to industrial or commercial areas which are compatible with high noise levels. However, commercial establishments that require quiet as a basis for use would be subject to the criteria, such as motion picture or recording studios. The application of the criteria to historical structures depends on their use and location. Thus, historical structures used as commercial shops in noisy downtown areas would not be subject to the criteria. Historical transportation structures, such as railroad stations, would not be considered noise sensitive, simply on the basis of their use.



Noise exposure is in terms of L_{eq} (h) for Category 1 land uses, L_{dn} for Category 2 land uses.

FIGURE 3-2 INCREASE IN CUMULATIVE NOISE LEVELS ALLOWED BY FTA CRITERIA FOR LAND USE CATEGORIES 1 AND 2

3.3.1.3 Levels of Impact

The terms “no impact,” “impact,” and “severe impact” may be interpreted as follows:

No Impact. The project, on average, will result in an “insignificant increase in the number of people highly annoyed by new noise.” The term “highly annoyed” is vague, but usually refers to people willing to engage in litigation or, at the very least, complain about the noise to local officials with threat of litigation.

Impact. This is a moderate impact. The change in cumulative noise is noticeable to most people, but may not be sufficient to cause strong, adverse community reactions. Other project-specific factors must be considered to determine the need for mitigation, such as the types and numbers of noise-sensitive land uses.

Severe Impact. A significant percentage of people would be highly annoyed by the noise, perhaps resulting in vigorous community reaction attended by litigation.

Categories 1 and 2 impact criterion curves for “impact” and “severe impact” are constant at project noise levels of 65 and 75 dBA for existing ambient noise levels in excess of 71 and 77 dBA, respectively. Project noise levels greater than 65 dBA or 75 dBA are considered an “impact” or “severe impact,” respectively, regardless of the existing noise level.

The FTA criteria do not apply to most commercial or industrial land uses, unless quiet is a basis for such use. Examples of industries which would fall under the purview of the FTA criteria include sound and motion picture recording studios. A word of caution is appropriate, however. Many motion picture or sound recording studios require very low ambient background sound levels of about 15 dBA to allow use of the facility for modern digital sound mastering. Also, commercial buildings in areas of restricted automobile or truck usage, such as open malls, may be impacted by transit noise.

3.3.1.4 Mitigating Adverse Impact

The FTA noise impact criteria provide a framework for assessing the magnitude of impact from proposed projects. The criteria are based on human response to noise and do not incorporate considerations of feasibility, practicality or cost of reducing adverse noise levels. Once the magnitude of impact has been established during the environmental review process, FTA works in cooperation with the project sponsor to determine the need for noise mitigation. The guidance manual does not establish a requirement to mitigate noise at any specific impact level, although “severe impact” presents the most compelling case to reduce noise. The manual outlines the project-specific factors that must be considered in determining the need for mitigation. Considerations include the number and types of noise-sensitive sites, the level of existing noise and level of increase due to the project, and the

benefits and cost of mitigation treatments. The reader is referred to the guidance manual for a fuller explanation of how mitigation is addressed.

3.4 LOCAL ORDINANCES

Local noise ordinances may restrict rail transit noise levels. Thus, when planning a new transit facility, or responding to complaints from city or county inhabitants, local noise ordinances should be reviewed to determine if any potential conflicts exist. Often, rail transit noise is not considered in developing a noise ordinance, and the result is that rail transit noise might not be compatible with some noise ordinances if strictly interpreted. In such cases, rail transit systems are asked to meet noise standards that are more restrictive than those for automobiles. For this reason, community understanding of the technical problems facing the transit system designer is important, as is recognition by the designer of local standards for peace and quiet.

When transit corridors are located in residential communities, noise levels invariably exceed the usual limits for continuous noise. This is true for most modern types of transportation including automobiles, buses, and rail transit systems. Recognizing the problem, most modern noise ordinances include specific, but separate, limits on motor vehicle traffic noise levels. If rail transit was not considered when an ordinance was prepared, it may be that the train noise is exempt. However, either a modified ordinance may be required that specifically covers rapid transit systems, or a variance may be required. Without special consideration, the transit system might have to comply with unrealistic noise limits.

Way and structure maintenance such as rail grinding can be very noisy. These operations are most often scheduled at night, a period when residential communities are most sensitive to noise, and when local ordinances are most restrictive. The possibility of local noise ordinances being exceeded by transit maintenance work should be checked. This is particularly relevant to the design of effective rail grinding programs for controlling rail corrugation. A mitigating factor in such maintenance work as rail grinding is the reduction of wheel/rail wayside noise, a long-term benefit achieved with possibly a short-term noise impact. In this case, the community should be made aware of the long-term noise reduction benefits of rail grinding, and, as a result, there should be an increase in the community’s acceptance of maintenance-related noise. Even in this case, efforts should be made to control maintenance-related noise to the extent that is practical.

3.5 PREPARATION OF NOISE SPECIFICATIONS

A comprehensive program for control of wheel/rail noise includes the development of criteria and specifications for new facilities and equipment. Documents for virtually all major purchases of rail transit equipment now include specifications for maximum acceptable limits of noise and vibration.

In developing noise specifications or criteria, one must reach compromise between levels that are technically and economically feasible and levels that will minimize the adverse impact of noise on people and structures. An example specifications for transit vehicle procurements is provided in the *Handbook of Urban Rail Noise and Vibration Control* (see Chapter 2 references).

Of particular interest in the specification for transit vehicles is the designation of a minimum sound transmission loss for each of the characteristic sections of the car body, because most interior noise is generated exterior to the vehicle. This is particularly important for vehicles traveling through subways, where wheel/rail noise is the dominant interior noise. Even on at-grade ballast-and-tie track, inadequate floor sound insulation may result in unnecessarily high interior noise levels.

3.6 REFERENCES

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