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Noise-impact estimates per FTA and APTA criteria

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Abstract

In a recent paper, light-rail line noise exposures were predicted both in terms of maximum pass-by sound levels for comparison to APTA criteria and day–night average sound levels for comparison to FTA criteria. For the local land uses and ambient noise conditions of the project, the distances for the unmitigated pass-by noise exposures to attenuate to the APTA and FTA criteria limits were estimated and the numbers of included dwellings counted. The results found that the FTA impact-onset (i.e., "some-impact") criterion curve yielded significantly greater noise exposed areas while the APTA criteria yielded results between those of the FTA "some"- and "severe"-impact curves. However, those results only applied to the specific project under evaluation. This paper attempts to extend and generalize the comparison by parametric computation of exposed areas using both the FTA and APTA procedures. Predicted exposures in this paper are compared as a function of background ambient sound levels, type of land use impacted, numbers of daytime and nighttime operations, and train pass-by maximum sound levels. At very low background ambient sound levels, FTA tended to predict the greatest exposure, while in very noisy environments, APTA predicted more exposure. APTA predicted more exposure with low numbers of daily and/or nighttime operations, and FTA predicted more exposure with high numbers, but the comparative exposures were strongly dependent upon background ambient sound level and land use. For train pass-by maximum sound levels, APTA tended to show more exposure for very quiet pass-bys and to be intermediate to FTA/some and FTA/severe for noisier events—with the comparative exposures strongly dependent upon background ambient and land use.

1. Introduction

Over the last 20 years, many transit systems in North America have been designed using guidelines sponsored by an industry association, the American Public Transit Association (APTA). In 1995, an agency of the US Department of Transportation, the Federal Transit

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Administration (FTA), published impact assessment procedures to be used for Federally funded transit projects; the FTA procedures now are used widely in the US. These guidelines take different approaches to accomplish very similar goals. The APTA Guidelines are intended as a guide for the design of transit systems. On the other hand, the FTA Manual is directed explicitly to impact assessment. This paper examines the consequences on transit system design from the use of the alternative procedures by comparing the extent of noise impacts predicted with each method.

2. Transit system noise criteria

Because of their purpose, which is to assist the design and specification of transit systems, the APTA Guidelines are most suitable for the specification of vehicle performance such as may be contractually required of equipment manufacturers. However, they can be, as they are in this paper, applied as criteria for defining environmental noise impacts. The FTA Guidance Manual is inherently better suited to noise-impact assessment since it quantifies noise exposures in terms of noise metrics which include factors (i.e., number and duration of events) found in noise-effects studies to have important influences on human adverse response to noise.

The APTA procedures are based upon the maximum A-weighted sound level (L_{Amax}) of a single vehicle pass-by. The FTA methods are based upon the cumulative effect of the pass-by maximum sound level, pass-by duration, number of pass-bys, and times of day of the pass-bys in terms of the nighttime-weighted, day–night average sound level (L_{dn}). The single-event L_{Amax} metric describes the highest sound level that a person experiences as a transit vehicle passes. The L_{dn} metric has been found to predict more accurately public annoyance from noise.

2.1. APTA guidelines

The American Public Transit Association developed noise and vibration design goals for community exposures as part of its 'Guidelines for Design of Rail Transit Facilities' [1]. The APTA Guidelines consider the effect of noise and vibration on the community because of its importance in public acceptance of transit systems. The Guidelines include recommendations for noise and vibration exposure to transit property patrons, employees and the neighbouring community. They provide specifications for vehicle interiors and exteriors, vehicle component equipment, and other auxiliary equipment. Exposures are addressed from both line operations and ancillary facilities (such as, in stations, tunnels and shop areas, and in the community adjacent to the transit-system corridor).

In defining appropriate community-noise design sound levels, adjacent land uses and existing ambient sound levels are considered. For the purpose of establishing the design goals, general community-area categories are differentiated, as described in Table 1. Noise guidelines for train operations are specified for the land-use categories in terms of train pass-by maximum sound levels for single- and multi-family dwellings (SFD and MFD), and commercial buildings, as given in Table 2. In addition to the design goals for general types of buildings, recommendations for noise exposures near specific building types are also provided. Note that while the APTA design

Table 1
General categories of communities along rail system corridors per APTA guidelines

Community area		Typical ambient noise (dB(A))
Category	Description	L_{50} [a]
I	*Low-density* urban residential, open space park, suburban residential or recreational area; no nearby highways or boulevards	40–50 day; 35–45 night
II	*Average* urban residential, quiet apartments and hotels, open space, suburban residential, or occupied outdoor areas near busy streets	45–55 day; 40–50 night
III	*High-density* urban residential, average semi-residential/ commercial areas, urban parks, museum, and non-commercial public building areas	50–60 day; 45–55 night
IV	*Commercial* areas with office buildings, retail stores, etc., primarily daytime occupancy; central business districts	60–70
V	*Industrial* areas or *freeway* and *highway corridors*	>60

[a] The 50th-percentile sound level (L_{50}) is the sound level exceed 50% of the time.

Table 2
APTA guidelines for maximum airborne noise from train operations—near general types of buildings

Community area		Maximum pass-by sound level (dB(A))		
Category	Description	Single-family dwellings	Multi-family dwellings	Commercial buildings
I	Low-density residential	70	75	80
II	Average residential	75	75	80
III	High-density residential	75	80	85
IV	Commercial	80	80	85
V	Industrial/highway	80	85	85

The design-goal sound levels are generally applicable at the near side of the nearest dwelling or occupied building or in residential areas at 15 m from the track centerline, whichever is *farther*.

goal maxima are not intended to apply at distances <15 m, in this analysis the computed distances to the specified sound level limit will be reported.

2.2. FTA guidance manual

The FTA developed criteria to be used in evaluating noise impact from mass transit projects [2]. These criteria apply to all rail projects, including line operations as well as fixed facilities such as storage and maintenance yards, passenger stations and terminals, parking facilities, and substations. Also included are certain bus facilities, particularly those using separate roadways built exclusively for buses.

The FTA criteria are based upon comparison of the existing outdoor ambient noise to the future outdoor sound levels from the proposed project. They incorporate both absolute criteria,

Table 3
FTA land-use categories and metrics for transit noise impact criteria

Land-use category	Noise metric (dB(A))	Description of land-use category
1	Outdoor $L_{eq}(1)$[a]	*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 building 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 $L_{eq}(1)$[a]	*Institutional land uses with primarily daytime and evening use*—this category includes schools, libraries and churches where it is important to avoid interference with activities such as speech, mediation 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.

[a] $L_{eq}(1)$ for the noisiest hour of transit-related activity *during hours of noise sensitivity* (also given as L_{Aeq1hr}).

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. An absolute criterion caps the noise exposure from the proposed project regardless of any other considerations, while the relative criterion limits the extent to which the ambient sound levels may be elevated by a proposed action. The noise criteria and the sound level descriptors used by the criteria are a function of land use, as defined in Table 3. Depending upon land-use category, the recommended noise metric is either the average A-weighted sound level for the noisiest hour of transit-related activity during hours of noise sensitivity, L_{Aeq1hr}, or the nighttime-weighted, 24-h average provided by the day–night average sound level, L_{dn}. In most assessments, residences and buildings where people sleep are the greatest concern. Thus, L_{dn} is the noise metric usually evaluated.

These criteria were based upon surveys of human response to community noise. In public opinion surveys polling community annoyance, subjective verbal descriptions of the noise environment were related to objective measurements of the day–night average sound levels in the canvassed area to define a dose–response relationship.

The noise-impact criteria are defined by two curves, which allow increasing project noise with increasing existing ambient noise up to a point, beyond which impact is determined based upon project noise alone. These noise-impact criteria are shown in Fig. 1. The lower curve defines the limit up to which the sound levels for the proposed project are considered to have no impact, i.e., the exposure above which *some* impact occurs. The upper curve defines the noise exposure above which *severe* impact occurs. The lower curve, defining the onset of noise impact, increases up to 65 dB(A) [L_{dn}] for residential land uses which is a common limit for an acceptable living environment defined by a number of US Government agencies. The upper curve increases to a limit of 75 dB(A) [L_{dn}] for residential land uses which is a level generally associated with an unacceptable

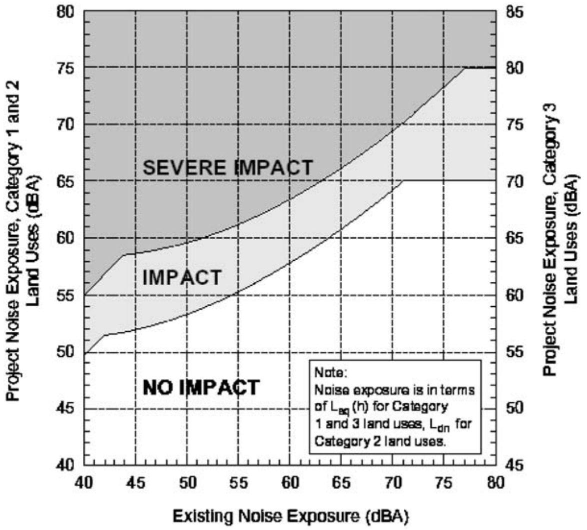


Fig. 1. FTA noise-impact criteria for transit projects.

living environment. Between the two curves, the proposed project is judged to have an impact, although it is not severe. At these intermediate exposures, the change in the cumulative noise exposure is described as noticeable to most people but may not be sufficient to cause strong adverse reactions from the community. In this noise exposure zone, FTA recommends that "*other project-specific factors must be considered to determine the magnitude of the impact and the need for mitigation, such as the predicted level of increase over existing noise levels and the types and numbers of noise-sensitive land uses affected*". The significance of each of the exposure regions is highlighted in Table 4.

A project exposure which is less than the existing community noise exposure can still fall within the "impact" region of Fig. 1. For example, the "some-impact" project noise exposure in a residential area is 55 dB(A) [L_{dn}] in a 55-dB(A) [L_{dn}] ambient environment, and 60 dB(A) [L_{dn}] in a 65-dB(A) [L_{dn}] environment. As the existing level of ambient noise increases, the allowable level of transit noise increases; but the amount by which the community noise exposure is allowed to increase is reduced. While no increase in noise is allowed in areas with existing ambient noise of 75 dB(A) [L_{dn}], an exposure increase of 7 dB(A) is allowed where the ambient noise is currently 45 dB(A) [L_{dn}]. This is justified by the presumption that people who are already exposed to high levels of noise will notice, and be annoyed by, only a small increase in the amount of noise in their community. However, if existing sound levels are low, a greater change in community noise will be required for the equivalent increase in annoyance. Note that the FTA criteria are qualified by a note that they are based upon community annoyance reactions to noise at various levels that have been reported in the scientific literature, but do not account for any specific community attitudinal factors that may exist.

3. Comparative impacts—case study

A Transitway was proposed that would link the Bethesda and Silver Spring, Md. central business districts, which would be developed by the Maryland Mass Transit Administration

Table 4
FTA noise exposure ranges

Exposures up to impact-onset curve
Insignificant increase in numbers of persons highly annoyed
Generally considered an acceptable environment
Exposures above severe impact curve
Significant increase in numbers of persons highly annoyed
Generally considered an unacceptable environment
Project proceeds only in absence of more desirable alternative
Mitigation measures for substantial noise reduction desired
Exposures in region between curves
Some increase in numbers of persons highly annoyed
Change may be noticeable but not sufficient for severe adverse reaction
Degree of impact depends upon magnitude of noise increase and types and extent of affected noise-sensitive land uses
Need for mitigation depends upon local values and project-specific factors

Noise exposure ranges for regions defined by upper and lower curves in Fig. 1.

(MTA) together with the Montgomery Co. Department of Transportation [3]. Light-rail and bus alternatives were considered, but only the results for the rail alternative will be discussed in this paper. Because of the history of the project, both the American Public Transit Association Guidelines and the Federal Transit Administration Guidance Manual were used in evaluating noise impacts in a 1996 noise and vibration assessment.

About 17% of the Transitway operations were at night; day–night average sound levels were calculated based upon 191 daytime and 38 nighttime train pass-bys. Vehicle speeds along the route were proposed to vary between 56 and 89 kmph with right-of-way features including at-grade or elevated structure or tunnel, and tie-and-ballast or direct-fixation (embedded) track. A noise-emission relationship as a function of speed for the expected light-rail vehicle was determined by field tests.

The resultant noise exposures at 15 m from the track centreline for operations at the varying route speeds for individual train pass-bys and cumulative noise exposures were calculated for the evaluated noise metrics (both L_{Amax} and L_{dn}) by longitudinal location. The appropriate APTA or FTA criteria sound levels for the Transitway in the vicinity of each longitudinal location were identified and the distances from the track for the vehicle noise to reduce to the criterion value were computed. These predictions are conservative since attenuation due to existing topography or buildings was not incorporated into the computations.

These distances can be considered impact-zone contours and may fall within the right-of-way. The width of the zone will be twice the setback distance to the criterion value if the land uses are the same on both sides of the track.

3.1. Comparative impacts

The line-operation sound levels along the alignment varied with vehicle speed and track features. The predicted magnitudes at 15 m from the right-of-way centreline were L_{Amax}, 61–87 dB(A), and L_{dn}, 51–69 dB(A). For the study area corridor, the criteria sound levels were $L_{Amax} = 70-85$ dB(A) for APTA and $L_{dn} = 55-65$ dB(A) for FTA "some impact". The sound levels predicted for unmitigated line operations indicated significant noise exposures above the criteria at some locations. The distances from the track centreline required to reach the criteria values are:

- APTA, 3–67 m (average, 19 m);
- FTA "some impact", 9–143 m (average, 51 m);
- FTA "severe impact", 3–58 m (average, 21 m).

A rough pattern was suggested by the results. The average width of the impact zone defined by the APTA criteria was only about 95% of that defined by the FTA/"severe" criteria. However, APTA includes more land uses (that is, commercial), extending the affected area but narrowing the average width. The width of the FTA/"some" zone was about 2.5 times that of the FTA/ "severe" or that of APTA.

When the evaluation focused upon the actual numbers of structures defined by the criteria as adversely affected, a slightly different pattern appeared. Based upon numbers of structures, the APTA criteria showed about 50% more impacts than FTA/"severe". The FTA/"some" criteria gave about three times as many impacts as FTA/"severe" and about twice as many impacts as APTA. Note that the comparative noise impacts in terms of affected structures apply only to the actual land development within the Transitway study area.

Thus, the FTA "some-impact" (impact-onset) criterion was most restrictive, i.e., extended further from the track. For the evaluated Transitway project with about 17% night operations, the FTA "some-impact" criterion curve yielded significantly greater noise-exposed areas and impacts while the APTA criteria produced results intermediate to those from the FTA "some"- and "severe"-impact curves.

4. Comparative impacts—parametric evaluation

The findings for the Transitway project apply with certainty only to that evaluated proposal. The unanswered question is 'How representative is the proposed project?' To answer the question, key noise exposure variables were evaluated parametrically. Three variables were considered:

- *background ambient sound level*—in terms of day–night average sound level,
- *effective number of operations*—the nighttime-weighted total number of train pass-bys,
- *train pass-by maximum sound level.*

For each analysis, a two-car train of 29-m long light-rail vehicles travelling at 72 kmph on at-grade tie-and-ballast track with welded rails was assumed. Unless otherwise varied, the train pass-by maximum sound level was assumed to be 80 dB(A) at 15 m, the daily effective number of operations was assumed to be 400, and the background ambient sound level was assumed to be either 55 or 65 dB(A) [L_{dn}]. Impacts using the APTA procedures were assessed for both SFD and MFD. Impacts using FTA were assessed for both 'some' and 'severe' exposures. Propagation was assumed over flat, soft ground, with unshielded wheel–rail noise to a receptor standing at track elevation. As for the case study, the distances from the track for the vehicle noise to attenuate to the APTA and FTA criterion values were computed.

4.1. Background noise

Impacts were considered over a background sound level range of 40–80 dB(A) [L_{dn}]. The APTA community area categories, which are functions of ambient noise in terms of 50th-percentile sound levels as in Table 1, were *estimated* to correspond to ambient day–night average sound levels as:

(I) *low-density urban residential*: $L_{dn} \leqslant 55$ dB(A),
(II) *average urban residential*: $55 \leqslant L_{dn} < 60$ dB(A),
(III) *high-density urban residential*: $60 \leqslant L_{dn} < 65$ dB(A), and
(IV) *commercial area*: $L_{dn} > 65$ dB(A).

Over the background noise evaluation range, the computed range of distances to the criterion levels are, as shown in Fig. 2:

- APTA/SFD: 16–39 m,
- APTA/MFD: 16–25 m,
- FTA/some: 10–105 m, and
- FTA/severe: 2–46 m.

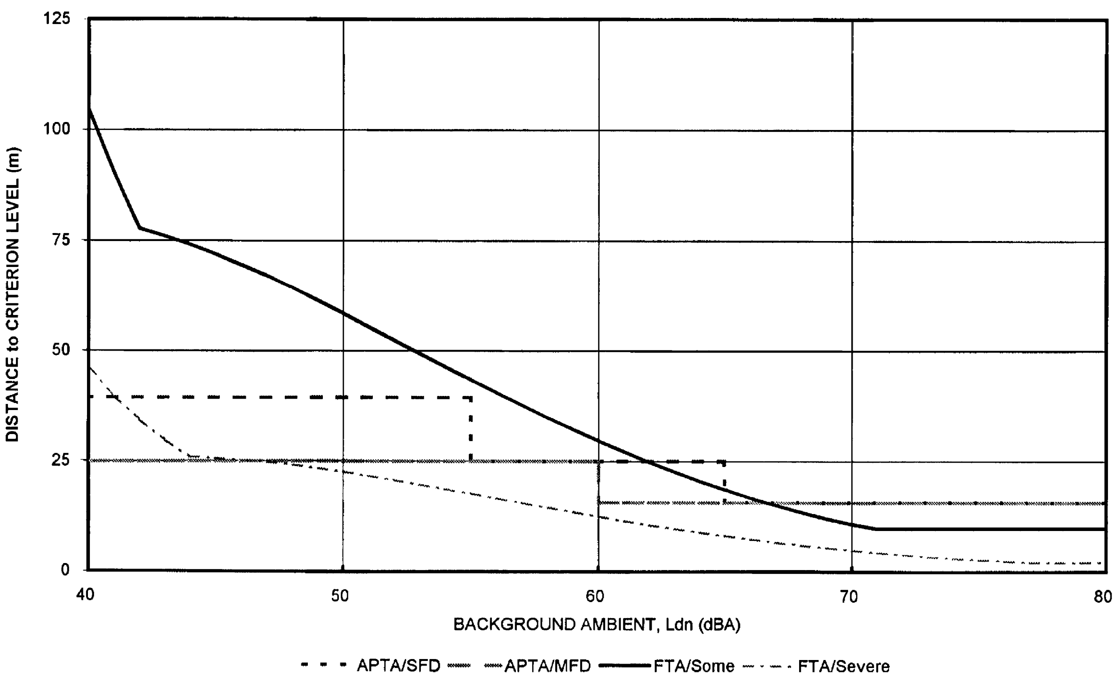


Fig. 2. Effect of background ambient sound level on predicted impacts (2 × 29-m light-rail cars at 72 kmph on at-grade, welded, tie-and-ballast track with 15-m $L_{Amax} = 80$ dB(A) and $N_{eff} = 400$).

At very low background ambient ($L_{dn} \leqslant 45$ dB(A)), the rank order of decreasing impact was FTA/some, FTA/severe, and APTA. At low background ambient ($45 < L_{dn} \leqslant 55$ dB(A)), the order of decreasing impact was FTA/some, APTA, and FTA/severe. At intermediate background ambient ($55 < L_{dn} \leqslant 65$ dB(A)), the order was still FTA/some, APTA, and FTA/severe, but converging with increasing ambient. At high background ambient ($L_{dn} > 65$ dB(A)), the order of decreasing impact was APTA, FTA/some, and FTA/severe.

4.2. Effective operations

Since the day–night average sound level has a 10 dB(A) nighttime weighting, one pass-by at night effectively is equivalent to 10 pass-bys during daytime. Thus, the effective number of operations is defined as

$$N_{eff} = N_d + 10N_n,$$

where N_d is the daytime operations, N_n is the nighttime operations, and night is defined as 2200 to 0700 h. Over an evaluation range of 20–2000 effective operations, the computed range of distances to the criterion level with a 65-dB(A) [L_{dn}] ambient are, as shown in Fig. 3a:

- APTA/SFD: 25 m,
- APTA/MFD: 16 m,
- FTA/some: 2–54 m, and
- FTA/severe: 1–24 m.

The range of distances with a 55-dB(A) [L_{dn}] ambient are, as shown in Fig. 3b:

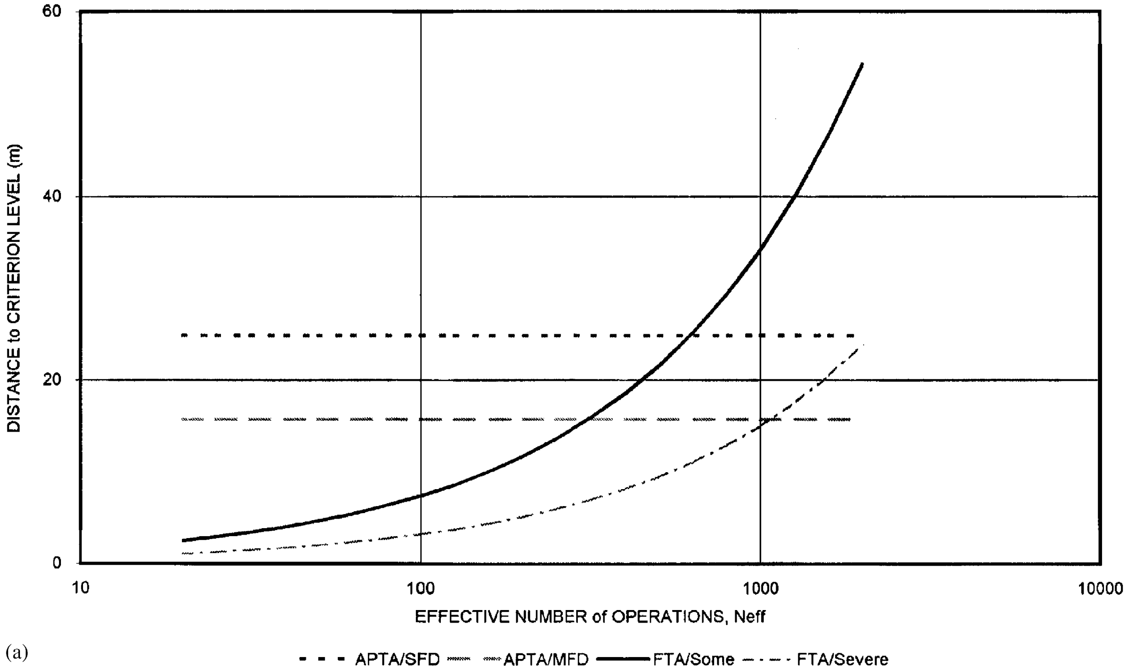
- APTA/SFD: 39 m,
- APTA/MFD: 25 m,
- FTA/some: 6–127 m, and
- FTA/severe: 2–51 m.

Although the comparative impacts are strongly dependent upon background ambient sound level and land use, APTA yields a greater impacted area for low numbers of operations while FTA gives greater impact for high numbers.

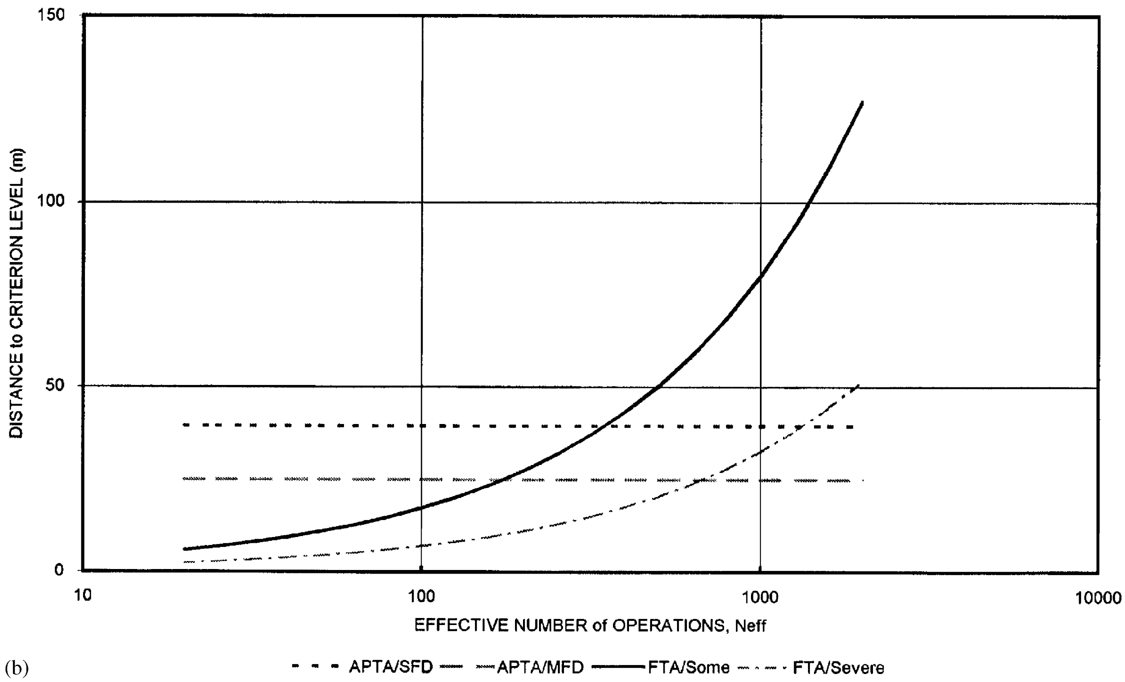
4.3. Train pass-by maxima

The 15-m train pass-by maximum sound levels were varied from 70 to 90 dB(A) while holding the train length and speed constant so that the pass-by sound exposure level, L_{AE}, was directly related to the L_{Amax}. Over the maximum sound level evaluation range, the range of distances to the criterion level with a 65 dB(A) [L_{dn}] ambient are, as shown in Fig. 4a:

- APTA/SFD: 10–61 m,
- APTA/MFD: 6–38 m,
- FTA/some: 4–82 m, and
- FTA/severe: 2–36 m.

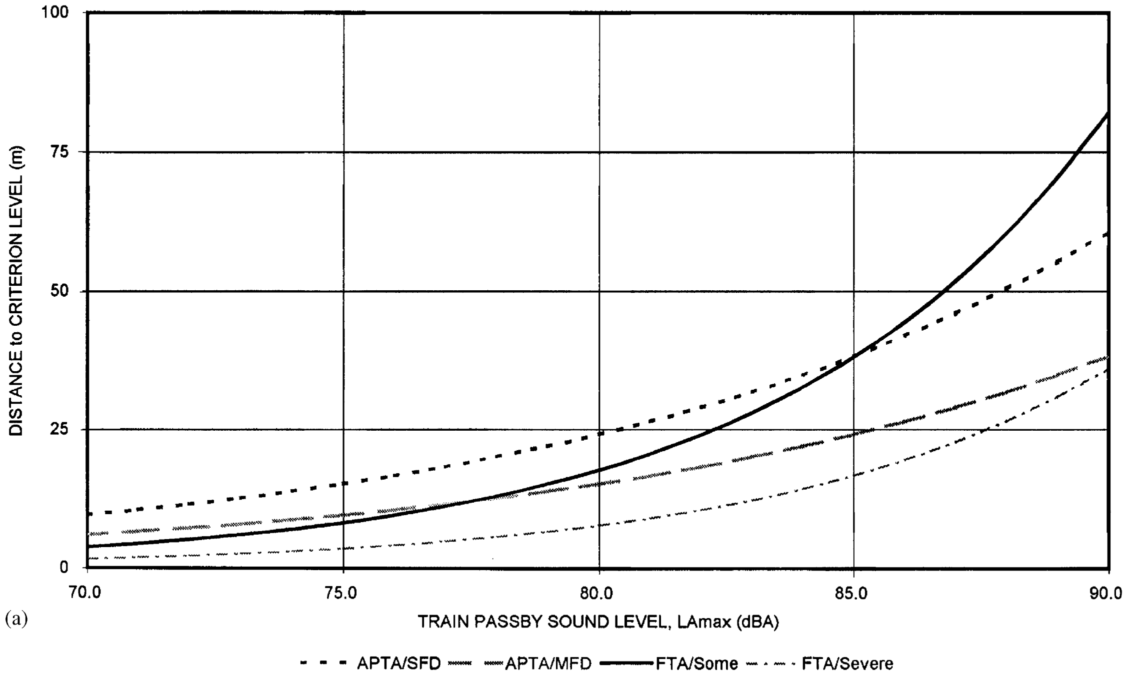


(a)

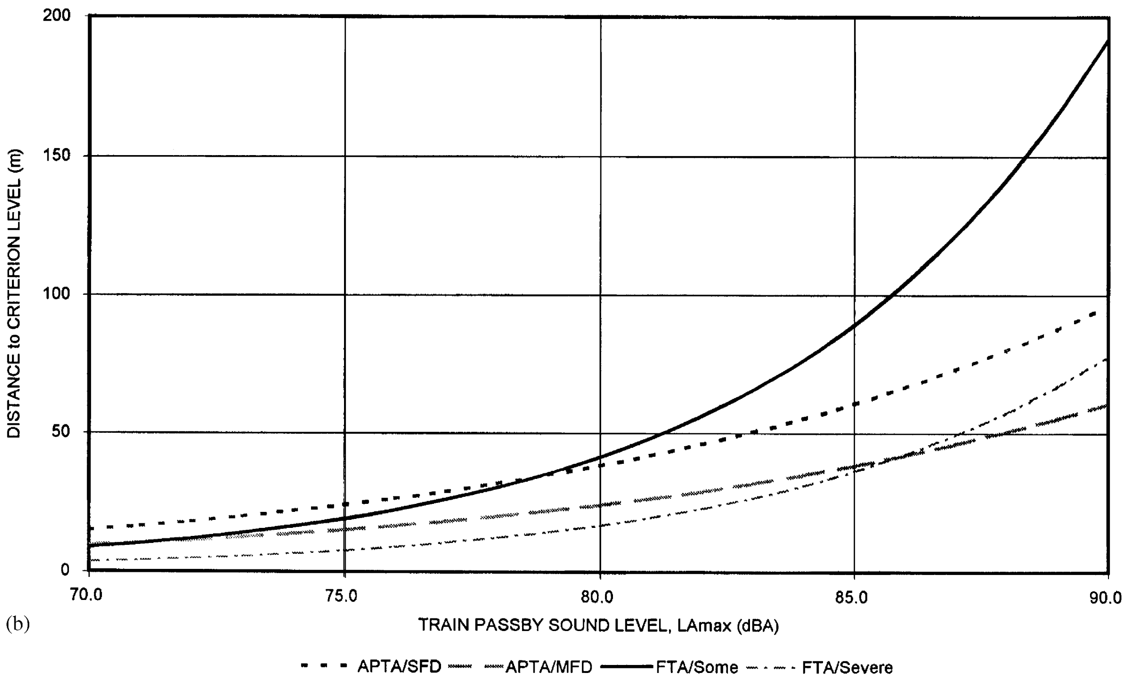


(b)

Fig. 3. Effect of effective number of operations on predicted impacts: (a) 65-dB(A) $[L_{dn}]$ ambient sound level; (b) 55-dB(A) $[L_{dn}]$ ambient sound level (2×29-m light-rail cars at 72 kmph on at-grade, welded, tie-and-ballast track with 15-m $L_{Amax} = 80$ dB(A)).



(a)



(b)

Fig. 4. Effect of train pass-by maximum sound level on predicted impacts: (a) 65-dB(A) [L_{dn}] ambient sound level; (b) 55-dB(A) [L_{dn}] ambient sound level (2×29-m light-rail cars at 72 kmph on at-grade, welded, tie-and-ballast track with $N_{eff} = 400$).

The range of distances with a 55-dB(A) [L_{dn}] ambient are, as shown in Fig. 4b:

- APTA/SFD: 15–96 m,
- APTA/MFD: 10–61 m,
- FTA/some: 9–192 m, and
- FTA/severe: 4–78 m.

At very low train emission levels, APTA indicates greater noise impacts. Otherwise, APTA tends to be between FTA/some and FTA/severe with the comparative impacts strongly dependent upon ambient noise and land use.

5. Conclusions

The relative noise exposures predicted by the FTA and APTA criteria depend upon the characteristics of the evaluated project and the affected communities. APTA Guidelines are more protective in noisy locations, for lightly used lines, or for quiet vehicles. In contrast, the FTA Manual is more restrictive for quiet environments, busy routes, or noisy vehicles. Both FTA and APTA criteria can be used effectively to guide transit system design. However, if the APTA L_{Amax} specification is used, cumulative exposures should be examined in the design process to help to guide the selection of suitable design sound levels. Since the FTA criteria incorporate noise-effects considerations, they presumably are more accurate in predicting community satisfaction, while APTA may be overly restrictive in some situations and too permissive in others.

References

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