

8. VIBRATION IMPACT CRITERIA

Because of the relatively rare occurrence of annoyance due to ground-borne vibration and noise, there has been only limited sponsored research of human response to building vibration and structure-borne noise. However, with the construction of new rail rapid transit systems in the past 20 years, considerable experience has been gained as to how communities will react to various levels of building vibration. This experience, combined with the available national and international standards,⁽¹⁾⁽²⁾ represents a good foundation for predicting annoyance from ground-borne noise and vibration in residential areas.

The criteria for environmental impact from ground-borne vibration and noise are based on the maximum levels for a single event. The criteria presented in Table 8-1 account for variation in project types as well as the frequency of events, which differ widely among transit projects. Most experience is with the community response to ground-borne vibration from rail rapid transit systems with typical headways in the range of 3 to 10 minutes and each vibration event lasting less than 10 seconds. It is intuitive that when there will be many fewer events each day, as is typical for commuter rail projects, it should take higher vibration levels to evoke the same community response. This is accounted for in the criteria by distinguishing between projects with frequent and infrequent events where *Frequent Events* is defined as more than 70 events per day. Most commuter rail projects will fall into the infrequent event category, although some commuter rail lines serving major cities are in the frequent event category.

The criteria are primarily based on experience with passenger train operations with only limited experience from freight train operations. The difference is that passenger train operations whether rapid transit, commuter rail, or intra-city create vibration events that last less than about 10 seconds. A typical line haul freight train is about 5000 feet long. At a speed of 30 mph, it will take a 5000-foot freight train approximately two minutes to pass. Even though the criteria are primarily based on experience with shorter vibration events and this manual is oriented to transit projects, there will be situations where potential impacts from freight train ground-borne vibration will need to be evaluated. The prime example is when freight train tracks must be relocated to provide space for a transit project within a railroad right-of-way. Some guidelines for applying these criteria to freight train operations are given later in this chapter.

The criteria for acceptable ground-borne vibration are expressed in terms of rms velocity levels in decibels and the criteria for acceptable ground-borne noise are expressed in terms of A-weighted sound level. The limits are specified for the three land use categories defined below:

Vibration Category 1: High Sensitivity – Included in Category 1 are buildings where low ambient vibration is essential for the operations within the building, which may be well below levels associated with human annoyance. Concert halls and other special use facilities are covered separately in Table 8-2. Typical land uses covered by Category 1 are: vibration-sensitive research and manufacturing, hospitals with vibration-sensitive equipment, and university research operations. The degree of sensitivity to vibration will depend on the specific equipment that will be affected by the vibration. Equipment such as electron microscopes and high resolution lithographic equipment can be very sensitive to vibration, and even normal optical microscopes will sometimes be difficult to use when vibration is well below the human annoyance level. Manufacturing of computer chips is an example of a vibration-sensitive process.

The vibration limits for Vibration Category 1 are based on acceptable vibration for moderately vibration-sensitive equipment such as optical microscopes and electron microscopes with vibration isolation systems. Defining limits for equipment that is even more sensitive requires a detailed review of the specific equipment involved. This type of review is usually performed during the final design phase and not as part of the environmental impact assessment. Mitigation of transit vibration that affects sensitive equipment typically involves modification of the equipment mounting system or relocation of the equipment rather than applying vibration control measures to the transit project.

Note that this category does not include most computer installations or telephone switching equipment. Although the owners of this type of equipment often are very concerned about the potential of ground-borne vibration interrupting smooth operation of their equipment, it is rare for computer or other electronic equipment to be particularly sensitive to vibration. Most such equipment is designed to operate in typical building environments where the equipment may experience occasional shock from bumping and continuous background vibration caused by other equipment.

Vibration Category 2: Residential – This category covers all residential land uses and any buildings where people sleep, such as hotels and hospitals. No differentiation is made between different types of residential areas. This is primarily because ground-borne vibration and noise are experienced indoors and building occupants have practically no means to reduce their exposure. Even in a noisy urban area, the bedrooms often will be quiet in buildings that have effective noise insulation and tightly closed windows. Hence, an occupant of a bedroom in a noisy urban area is likely to be just as sensitive to ground-borne noise and vibration as someone in a quiet suburban area.

Vibration Category 3: Institutional – Vibration Category 3 includes schools, churches, other institutions, and quiet offices that do not have vibration-sensitive equipment, but still have the potential for activity-interference. Although it is generally appropriate to include office buildings in this category, it is not appropriate to include all buildings that have any office space. For example, most industrial buildings

have office space, but it is not intended that buildings primarily for industrial use be included in this category.

Table 8-1 Ground-Borne Vibration and Noise Impact Criteria				
Land Use Category	Ground-Borne Vibration Impact Levels (VdB re 1 micro inch/sec)		Ground-Borne Noise Impact Levels (dB re 20 micro Pascals)	
	Frequent¹ Events	Infrequent² Events	Frequent¹ Events	Infrequent² Events
Category 1: Buildings where low ambient vibration is essential for interior operations.	65 VdB ³	65 VdB ³	-4	-4
Category 2: Residences and buildings where people normally sleep.	72 VdB	80 VdB	35 dBA	43 dBA
Category 3: Institutional land uses with primarily daytime use.	75 VdB	83 VdB	40 dBA	48 dBA
Notes: <ol style="list-style-type: none"> "Frequent Events" is defined as more than 70 vibration events per day. Most rapid transit projects fall into this category. "Infrequent Events" is defined as fewer than 70 vibration events per day. This category includes most commuter rail systems. This criterion limit is based on levels that are acceptable for most moderately sensitive equipment such as optical microscopes. Vibration sensitive manufacturing or research will require detailed evaluation to define the acceptable vibration levels. Ensuring lower vibration levels in a building often requires special design of the HVAC systems and stiffened floors. Vibration-sensitive equipment is not sensitive to ground-borne noise. 				

There are some buildings, such as concert halls, TV and recording studios, and theaters, that can be very sensitive to vibration and noise but do not fit into any of the three categories. Because of the sensitivity of these buildings, they usually warrant special attention during the environmental assessment of a transit project. Table 8-2 gives criteria for acceptable levels of ground-borne vibration and noise for various types of special buildings.

The criteria in Tables 8-1 and 8-2 are related to ground-borne vibration causing human annoyance or interfering with use of vibration-sensitive equipment. It is extremely rare for vibration from train operations to cause any sort of building damage, even minor cosmetic damage. However, there is sometimes concern about damage to fragile historic buildings located near the right-of-way. Even in these cases, damage is unlikely except when the track will be very close to the structure. Damage thresholds that apply to these structures are discussed in Section 12.2.2.

Table 8-2 Ground-Borne Vibration and Noise Impact Criteria for Special Buildings				
Type of Building or Room	Ground-Borne Vibration Impact Levels (VdB re 1 micro-inch/sec)		Ground-Borne Noise Impact Levels (dB re 20 micro-Pascals)	
	Frequent¹ Events	Infrequent² Events	Frequent¹ Events	Infrequent² Events
Concert Halls	65 VdB	65 VdB	25 dBA	25 dBA
TV Studios	65 VdB	65 VdB	25 dBA	25 dBA
Recording Studios	65 VdB	65 VdB	25 dBA	25 dBA
Auditoriums	72 VdB	80 VdB	30 dBA	38 dBA
Theaters	72 VdB	80 VdB	35 dBA	43 dBA
Notes: 1. "Frequent Events" is defined as more than 70 vibration events per day. Most transit projects fall into this category. 2. "Infrequent Events" is defined as fewer than 70 vibration events per day. This category includes most commuter rail systems. 3. If the building will rarely be occupied when the trains are operating, there is no need to consider impact. As an example consider locating a commuter rail line next to a concert hall. If no commuter trains will operate after 7 pm, it should be rare that the trains interfere with the use of the hall.				

One factor not incorporated in the criteria is how to account for existing vibration. In most cases, the existing environment does not include a significant number of perceptible ground-borne vibration or noise events. The most common example of needing to account for the pre-existing vibration is when the project will be located in an existing rail corridor. Following are methods of handling representative scenarios:

1. *Infrequently-used rail corridor:* Use the standard vibration criteria when the existing rail traffic consists of at most one or two trains per day.
2. *Moderately-used rail corridor:* If the existing traffic consists of more than about 10 trains per day and the train vibration substantially exceeds the impact criteria, there is no impact as long as the project vibration levels estimated using the procedures outlined in either Chapter 10 or 11 are at least 5 to 10 decibels less than the existing vibration. The existing train vibration can be either measured or estimated using the General Assessment procedures in Chapter 10. It is usually preferable to measure vibration from existing train traffic.
3. *Heavily-used rail corridor:* If the project will not significantly increase the number of vibration events, there will not be additional impact unless the project vibration, estimated using the procedures of Chapters 10 or 11, will be higher than the existing vibration. Approximately doubling the number of events is required for a significant increase. An example of this case would be a new commuter rail line sharing part of a corridor with an existing rapid transit system with both systems carrying similar volumes of traffic. When the project will cause vibration higher than the existing, the existing source can be ignored and the standard vibration criteria applied to the project.
4. *Moving existing tracks:* Another scenario where existing vibration can be significant is when a new project will use an existing rail right-of-way and result in shifting the location of existing tracks. The track relocation and reconstruction can result in lower vibration levels, in which case this aspect of the project represents a benefit not an adverse impact. If the track relocation will cause higher vibration

levels at sensitive receptors, then the projected vibration levels must be compared to the appropriate impact criterion to determine if there will be impact. Most freight lines have two to six trains per day, but each train may take several minutes to pass by. For typical freight trains, the locomotive vibration is 5 to 10 decibels higher than vibration from the rail cars.

Although the impact thresholds given in Tables 8-1 and 8-2 are based on experience with vibration from rail transit systems, they can be applied to freight train vibrations as well. A dual approach is recommended with separate consideration of the locomotive and rail car vibration. Because the locomotive vibration only lasts for a few seconds, the infrequent event limit is appropriate. However, for a typical line-haul freight train where the rail car vibration lasts for several minutes, the frequent event limits should be applied to the rail car vibration. Some judgment must be exercised to make sure that the approach is reasonable. For example, some spur rail lines carry very little rail traffic (sometimes only one train per week) or have short trains, in which case the infrequent limits are appropriate.

REFERENCES

1. Acoustical Society of America, "American National Standard: Guide to Evaluation of Human Exposure to Vibration in Buildings," ANSI S3.29-1983 (ASA 48-1983).
2. International Standards Organization, "Evaluation of Human Exposure to Whole-Body Vibration, Part 2: Continuous and Shock-Induced Vibrations in Buildings (1-80Hz)," ISO-2361-2, 1989.

