

APPENDIX 3.4-A

Noise and Vibration Mitigation Guidelines

Proposed California High-Speed Train Project Noise and Vibration Mitigation Guidelines

1.0 Purpose

The California High-Speed Rail Authority (Authority) and Federal Railroad Administration (FRA) conducted a noise and vibration impact analysis consistent with FRA methods for the proposed California High-Speed Train (HST) System. Adverse noise impacts and vibration impacts are anticipated in several areas along the alternatives. To reduce these potential impacts, mitigation measures such as constructing sound barriers or insulating affected buildings could be implemented. To the extent that mitigation measures are feasible and reasonable, they may be applied at the source, along the alignment, or at the receiving building. Criteria for implementing noise mitigation include balancing effectiveness, physical feasibility, cost, and density and proximity of sensitive receptors.

This memorandum presents the Authority's noise and vibration mitigation guidelines and incorporates by reference the guidelines, definitions, and technical manuals recognized by FRA as being consistent with FRA noise and vibration mitigation requirements. The guidelines are subject to revision.

2.0 Regulatory Requirements

The National Environmental Policy Act (NEPA) and California Environmental Quality Act (CEQA) establish a mandate for federal and state agencies to incorporate environmental protection and enhancement measures into their proposed programs and projects. The FRA encourages noise abatement for HST projects where severe noise impacts are identified by using the methods in the FRA guidance manual (FRA 2005). The guidance manual includes noise criteria and guidelines to determine the need for mitigation. Noise criteria are stated in terms of outdoor exposure to project-related noise compared with existing noise levels. The manual defines three levels of impact: (1) No Impact, (2) Moderate Impact, and (3) Severe Impact. Project-related noise in the No Impact range is not likely annoying and is considered acceptable by FRA without mitigation. Moderate Impact means project-related noise would be noticeable and may result in some complaints from affected sites, but that impacts are not considered significant under CEQA and mitigation would not be required. Project-related noise in the Severe Impact range represents the most compelling need for mitigation and indicates a high level of annoyance from project noise at affected sites; these impacts are considered to be significant in the context of NEPA, Section 106 of the National Historic Preservation Act, and CEQA.

3.0 Noise Mitigation Guidelines

In general, feasible and effective noise mitigation is required when severe or significant impacts are identified. Mitigation guidelines for the three impact categories identified by FRA are as follows:

- No Impact: No mitigation required.
- Moderate Impact: Mitigation not required but may be considered at the discretion of the Authority.
- Severe Impact: Consideration of feasible and effective mitigation is required if impacts cannot be avoided. The Authority will take steps to reduce noise substantially through mitigation measures that are reasonable, physically feasible, practical, and cost-effective.

Potential noise impact is assessed and mitigation will be considered for undeveloped lands where sensitive receptors will be if there is substantial physical progress (e.g., laying the building foundation) toward the construction of the property by the time the notice of intent of the project has been issued.

3.1 Mitigation of Severe Noise Impacts

The Authority has examined different mitigation measures to avoid, minimize, or mitigate severe noise impacts. If severe noise impacts cannot be avoided through project design changes, then the Authority will take steps to reduce severe noise substantially through mitigation measures that are reasonable, physically feasible, practical, and cost-effective.

The following criteria will be used for evaluating the reasonableness of any particular potential noise barrier as mitigation for severe noise impacts:

- Project noise-related increase over existing noise levels.
- Number of noise sensitive sites affected. Generally, at least 10 sites would have to be affected to justify a sound barrier.
- Sound barriers less than 800 feet long generally should not be considered.
- Barrier heights above 14 feet will not be recommended. Mitigation options for areas that require barriers over 14 feet tall will be studied on a case by case basis.
- Is the cost range for the noise barrier within \$45,000 (2010 dollars) per benefited residence?
- Does a substantial majority of the community approve of implementation?

Section 4(f) and Section 106 properties with severe or moderate noise impacts may require mitigation, may not be subject to these guidelines, and will be evaluated on a case-by-case basis.

3.1.1 Substantial Noise Reduction

A sound barrier should be constructed only if it would result in a minimum outdoor noise reduction of 5 decibels (dB).

3.1.2 Physically Feasible

Noise mitigation measures must be designed, constructed, installed, or implemented in compliance with structural requirements related to ground conditions, wind loading, seismic risk, safety considerations, accessibility, material maintainability and longevity, and applicable engineering design practices and technology.

Sound barriers are the most common noise mitigation measure. The maximum sound barrier height would be 14 feet for at-grade sections; however, all sound barriers should be designed to be as low as possible to achieve a substantial noise reduction. Berm and berm/wall combinations are the preferred types of sound barriers where space and other environmental constraints permit.

On aerial structures, the maximum sound barrier height would also be 14feet, but barrier material would be limited by engineering weight restrictions for barriers on the structure. Sound barriers on the aerial structure should still be designed to be as low as possible to achieve a substantial noise reduction.

3.1.3 Visual Effects

Sound barriers could consist of solid, semitransparent, and transparent materials. Barriers could have visual effects, depending on their location and height. Sound barriers could be treated to reduce visual impacts.

3.1.4 Cost-Effectiveness

The cost of any particular sound barrier as mitigation cannot exceed \$45,000 per benefitted building. This cost is determined by dividing the total cost of the mitigation measure by the number of affected noise-sensitive buildings that receive a substantial (i.e., 5-dB or greater) outdoor noise reduction. This calculation will generally limit the use of sound barrier mitigation in rural areas that have few and/or isolated residential buildings. If the density of residential dwellings is insufficient to make a sound barrier cost-effective, then other noise abatement measures, such as sound insulation, will be considered on a case-by-case basis. If sound insulation is identified as an alternative mitigation measure, the treatment must provide a substantial increase in noise reduction (i.e., 5 dB [A-weighted scale] or greater) between the outside to inside noise levels for the interior rooms exposed to HST-related noise. If sound insulation is not possible, feasible, or cost-effective, then the Authority will consider other measures, such as purchasing a noise easement.

3.1.5 Reasonable

The above factors will have to be balanced to accomplish a package of noise mitigation measures that are effective but reasonable. Reasonableness implies that good judgment and common sense have been applied during the decision-making process. Reasonableness is determined on the basis of several factors regarding the individual circumstances and the specific needs of affected receivers.

4.0 Vibration Mitigation Guidelines

Reactions to vibration impacts depend on the maximum levels for an average repeated train pass-by event. The frequency of events is a consideration in the FRA vibration impacts criteria. The FRA guidance manual provides vibration criteria. The FRA distinguishes between *frequent* and *infrequent* vibration events, defining frequent as more than 70 vibration or train pass-by events per day.

An HST may operate within close proximity to existing freight or passenger rail trains where ground vibration already may be present. In such cases, the impact of new HST service is assessed as follows:

- Infrequently Freight or Passenger Rail Services: Four or fewer freight and/or passenger trains per day; HST impact is assessed using the FRA vibration criteria.
- Moderate Freight or Passenger Rail Services: If up to 12 freight and/or passenger trains per day and FRA impact criteria are already exceeded, then HST is considered to cause no impact if its vibration is 5 dB lower than the existing freight and passenger rail operations. If not, HST impact is assessed using the FRA vibration criteria.
- Heavy Freight or Passenger Rail Services: If HSTs pass by at less than half as often as freight and passenger trains, then no impact exists unless the HST vibration exceeds the vibration levels of the freight and passenger operations.

Where the HST track is closer to vibration sensitive receivers than an existing rail corridor, impact will be assessed if the existing train vibration levels are increased significantly. A significant increase is 3 vibration dB (VdB) or more.

Potential vibration impact is assessed and mitigation will be considered for undeveloped lands where sensitive receptors will be if there is substantial physical progress (e.g., laying the building foundation) toward the construction of the property by the time the notice of intent of the project has been issued.

4.1 Vibration Mitigation

Vibration mitigation will be considered whenever the criterion is exceeded as determined by detailed analysis. If found feasible and reasonable, mitigation measures will be included as part of the HST projects.

4.2 Vibration Guidelines

To the extent they are feasible and reasonable, vibration mitigation measures may be applied at the source, along the path, or at the receiving building. However, the most effective measures are generally those that are applied at the source.

The Authority will use the following cost-benefit criteria to determine the reasonableness of implementing vibration mitigation:

- The minimum length of track mitigated must be determined from calculations based on the FRA detailed analysis methods.
- The vibration mitigation treatment must provide a minimum of 3-VdB reduction for every impacted receiver to be considered effective.
- The Authority will apply the following formula to determine if the mitigation is cost-effective: Length x cost/foot divided by VdB reduction divided by the number of buildings benefitted. If this dollar amount exceeds \$45,000, the treatment is not considered to be cost-effective.

The cost-benefit criteria are designed to ensure that vibration mitigation is installed in areas where receivers would benefit significantly but not in areas where they would do little or no good.

5.0 References Cited

Federal Railroad Administration (FRA). 2005. *High-Speed Ground Transportation Noise and Vibration Impact Assessment*. Final report. October.

Federal Transit Administration (FTA). 2006. *Transit Noise and Vibration Impact Assessment*. FTA-VA-90-1003-06. May.

Mitigation Measures

Mitigation Measures

Mitigation Measures for Construction Noise and Vibration

Construction Noise Mitigation Measures

Monitor construction noise to verify compliance with the limits. Provide the contractor the flexibility to meet the FTA construction noise limits in the most efficient and cost-effective manner. The contractor would have the flexibility of either prohibiting certain noise-generating activities during nighttime hours or providing additional noise control measures to meet the noise limits. To meet required noise limits, the following noise control mitigation measures will be implemented as necessary, for nighttime and daytime:

- Install a temporary construction site sound barrier near a noise source.
- Avoid nighttime construction in residential neighborhoods.
- Locate stationary construction equipment as far as possible from noise-sensitive sites.
- Re-route construction-related truck traffic along roadways that will cause the least disturbance to residents.
- During nighttime work, use smart back-up alarms, which automatically adjust the alarm level based on the background noise level, or switch off back-up alarms and replace with spotters.
- Use low-noise emission equipment.
- Implement noise-deadening measures for truck loading and operations.
- Monitor and maintain equipment to meet noise limits.
- Line or cover storage bins, conveyors, and chutes with sound-deadening material.
- Use acoustic enclosures, shields, or shrouds for equipment and facilities.
- Use high-grade engine exhaust silencers and engine-casing sound insulation.
- Prohibit aboveground jackhammering and impact pile driving during nighttime hours.
- Minimize the use of generators to power equipment.
- Limit use of public address systems.
- Grade surface irregularities on construction sites.
- Use moveable sound barriers at the source of the construction activity.
- Limit or avoid certain noisy activities during nighttime hours.

To mitigate noise related to pile driving, the use of an augur to install the piles instead of a pile driver would reduce noise levels substantially. If pile driving is necessary, limit the time of day that the activity can occur.

Construction Vibration Mitigation Measures

Building damage from construction vibration is only anticipated from impact pile driving at very close distances to buildings. If piling is more than 25 to 50 feet from buildings, or if alternative methods such as push piling or augur piling can be used, damage from construction vibration is not expected to occur.

Other sources of construction vibration do not generate high enough vibration levels for damage to occur. When a construction scenario has been established, preconstruction surveys will be conducted at locations within 50 feet of piling to document the existing condition of buildings in case damage is reported during or after construction. Damaged buildings would be repaired or compensation paid.

Mitigation Measures for Operational Noise and Vibration

Operational Noise Mitigation Measures

Various options exist to address the potentially severe noise effects from HSTs. The mitigation measure or suite of mitigation measures for severe noise impacts shall be designed to reduce the noise level from HST operations from "severe" to "moderate" according to the provisions of the FRA noise and vibration manual (FRA 2005). With input from local jurisdictions and balancing technological factors, such as structural and seismic safety, cost, number of affected receptors, and effectiveness, mitigation measures would be selected and implemented from among the following:

- **Install sound barriers.** Depending on the height and location relative to the tracks, sound barriers can achieve between 5 and 15 dB of noise reduction. The primary requirements for an effective sound barrier are that the barrier must (1) be high enough and long enough to break the line-of-sight between the sound source and the receiver, (2) be of an impervious material with a minimum surface density of 4 pounds per square foot, and (3) not have any gaps or holes between the panels or at the bottom. Because many materials meet these requirements, aesthetics, durability, cost, and maintenance considerations usually determine the selection of materials for sound barriers. Depending on the situation, sound barriers can become visually intrusive. Typically, the sound barriers style is selected with input from the local jurisdiction to reduce the visual effect of barriers on adjacent lands uses. For example, sound barriers could be solid or transparent, of various colors, materials, and surface treatments.

The maximum sound barrier height would be 14 feet for at-grade sections; however, all sound barriers would be designed to be as low as possible while still achieving a substantial noise reduction. Berm and berm/wall combinations are the preferred types of sound barriers where space and other environmental constraints permit. On aerial structures, the maximum sound barrier height would also be 14 feet, but barrier material would be limited by engineering weight restrictions for barriers on the structure. Sound barriers on the aerial structure should still be designed to be as low as possible while still achieving a substantial noise reduction. Sound barriers on aerial structures and at-grade could consist of solid, semitransparent, and transparent materials.

- **Install building sound insulation.** Sound insulation of residences and institutional buildings to improve the outdoor-to-indoor noise reduction is a mitigation measure that can be provided when the use of sound barriers are not feasible in providing a reasonable level (5 to 7 dB) of noise reduction. Although this approach has no effect on noise in exterior areas, it may be the best choice for sites where sound barriers are not feasible or desirable and for buildings where indoor sensitivity is of most concern. Substantial improvements in building sound insulation (on the order of 5 to 10 dB) can often be achieved by adding an extra layer of glazing to windows, by sealing holes in exterior surfaces that act as sound leaks, and by providing forced ventilation and air conditioning so that windows do not need to be opened. Establish performance criteria to balance existing noise events and ambient roadway noise conditions as factors for determining mitigation measures.
- **Acquire easements on properties severely affected by noise.** Another option for mitigating noise impacts is to acquire easements on residences likely to be impacted by HST operations by paying the homeowners to accept the future noise conditions. This approach is usually taken only in isolated cases where other mitigation options are infeasible, impractical, or too costly.
- **Vehicle noise specification.** In the procurement of an HST vehicle technology, the Authority will require bidders to meet the federal regulations (40 CFR Part 201.12/13) at the time of procurement for locomotives (currently a 90 dB level standard) and rail cars (currently a 93 dB level standard for

cars operating at speeds of greater than 45 mph). Depending on the available technology, this could significantly reduce the number of impacts throughout the corridor.

- **Special trackwork at crossovers and turnouts.** Because the impacts of HST wheels over rail gaps at turnouts increases HST noise by approximately 6 dB over typical operations, turnouts can be a major source of noise impact. If the turnouts cannot be moved from sensitive areas, the project can use special types of trackwork that eliminate the gap.
- **Additional noise analysis during final design.** If final design of the track base or final vehicle specifications results in changes to the assumptions underlying the noise analysis, reassess noise impacts and recommendations for mitigation and provide supplemental environmental documentation, as required by CEQA and NEPA.
- **Heavy maintenance facilities measures.** In order to reduce the noise from the heavy maintenance facility, the following noise mitigation measures are available:
 - Enclose as many of the maintenance activities within the facility as possible.
 - Eliminate windows in the maintenance building that would face toward noise sensitive land uses adjacent to the facility. If windows are required to be located on the side of the facility facing noise-sensitive land uses, they should be the fixed type of windows with a sound transmission class (STC) rating of at least 35. If the windows must be of operable design, they should be closed during nighttime maintenance activities.
 - Close maintenance facility doors where the rails enter the facility during nighttime maintenance activities.
 - Maintenance tracks that cannot be located within the maintenance facility should be located on the far side of the facility from adjacent noise-sensitive receivers.
 - For maintenance tracks that cannot be installed away from noise-sensitive receivers, install noise barrier along the maintenance tracks in order to protect the adjacent noise-sensitive receivers.
 - All mechanical equipment (compressors, pumps, generators, etc.) should be located within the maintenance facility structure.
 - Any mechanical equipment located exterior to the maintenance facility (compressors, pumps, generators, etc.) should be located on the far side of the facility from adjacent noise-sensitive receivers. If this is not possible, this equipment should be located within noise enclosures to mitigate the noise during operation.
 - All ventilation ducting for the maintenance facility should be pointed away from the adjacent noise-sensitive receivers.

Operational Vibration Mitigation Measures

Implement Project Vibration Mitigation. Mitigation for operational vibration impacts can take place at the source, sensitive receiver, or along the propagation path from the source to the sensitive receiver. Measures include:



Vibration Mitigation Procedures and Descriptions

Mitigation Procedure	Location of Mitigation	Description
Location and Design of Special Trackwork	Source	Careful review of crossover and turnout locations during the preliminary engineering stage. When feasible, relocate special trackwork to a less vibration-sensitive area. Installation of spring frogs eliminates gaps at crossovers and helps reduce vibration levels.
Vehicle Suspension	Source	Rail vehicle should have low unsprung weight, soft primary suspension, minimum metal-on-metal contact between moving parts of the truck, and smooth wheels that are perfectly round.
Special Track Support Systems	Source	Floating slabs, resiliently supported ties, high resilience fasteners and ballast mats all help reduce vibration levels from track support system.
Building Modifications	Receiver	For existing buildings, if vibration-sensitive equipment is affected by train vibration, the floor upon which the vibration-sensitive equipment is located could be stiffened and isolated from the remainder of the building. For new buildings, the building foundation should be supported by elastomer pads similar to bridge bearing pads.
Trenches	Along Vibration Propagation Path	A trench can be an effective vibration barrier if it changes the propagation characteristics of the soil. It can be open or solid. Open trenches can be filled with materials such as styrofoam. Solid barriers can be constructed with sheet piling, rows of drilled shafts filled with either concrete or a mixture of soil and lime, or concrete poured into a trench.
Buffer Zones	Receiver	Negotiate a vibration easement from the affected property owners or expand rail right-of-way.