4.3 NOISE AND VIBRATION

This section analyzes the potential noise and vibration impacts of the No Action Alternative and the Plan Alternative and Options. The noise discussion in this section has been updated from the 1993 Final EIS to include polices and criteria addressing the Federal Transit Administration's (FTA) 1995 guidance and information from project-level environmental documents for Sound Transit light rail, commuter rail, and regional express bus projects. In addition, the discussion of criteria has been updated to reflect current federal, state, and local noise guidelines and regulations.

4.3.1 Background

4.3.1.1 Noise

The human ear can perceive a large range of noise levels. Noise levels are typically expressed on a logarithmic scale in units called decibels (dB). Magnitudes of typical noise levels are presented in Table 4.3-1. The commonly used frequency weighting for environmental noise is A-weighting (dBA), which simulates how an average person hears sound.

Table 4.3-1
Typical Noise Levels

Transportation Sources	Noise Level (dBA)	Other Sources	Description
Jet takeoff (200 feet)	130		painfully loud
	120		
Car horn (3 feet)	110		maximum vocal effort
	100	shout (0.5 feet)	very annoying
Heavy truck passby (50 feet)	90	jack hammer (50 feet)	loss of hearing with
		home shop tools (3 feet)	prolonged exposure
Train on a structure passby (50 feet)	85	backhoe (50 feet)	
City bus passby (50 feet)	80	bulldozer (50 feet)	annoying
		vacuum cleaner (3 feet)	
Train passby (50 feet)	75	blender (3 feet)	
City bus at stop (50 feet)			
Freeway traffic (50 feet)	70	lawn mower (50 feet)	
		large office	
Train in station (50 feet)	65	washing machine (3 feet)	intrusive
	60	TV (10 feet)	
Light traffic (50 feet)		talking (10 feet)	
Light traffic (100 feet)	50	refrigerator (3 feet)	quiet
	40	library	
	30	soft whisper (15 feet)	very quiet

Sources: FTA (1995); EPA (1971, 1974).

Noise levels from traffic and transit sources depend on volume, speed, and the type of vehicle. Generally, an increase in volume, speed, or vehicle size increases traffic noise levels. Vehicular noise is a combination of noises from the engine, exhaust, and tires. Other conditions affecting traffic noise include defective mufflers, steep grades, terrain, vegetation, distance from the roadway, and shielding by barriers and buildings.

Noise levels decrease as distance increases from the noise source. For a line source such as a roadway or railway, noise levels decrease 3 dBA over hard ground (e.g., concrete, pavement) or 4.5 dBA over soft ground (e.g., grass) for every doubling of distance between the source and the receptor. For a point source such as a transit center, noise levels will decrease between 6 and 7.5 dBA for every doubling of distance from the source.

A common noise descriptor for environmental noise is the equivalent sound level (L_{eq}), which is a measure that sums all sounds during a period of time. An L_{eq} measured over a 1-hour period is the hourly L_{eq}, denoted $L_{eq}(h)$. The day/night level (L_{dn}) describes the daily noise environment and adds a penalty for high noise levels at night. L_{max} is the highest noise level that occurs during a measurement period. $L_{eq}(h)$ and L_{dn} are used in environmental noise assessments because they account for the number of loud events that occur, rather than just the maximum level from a single event.

Applicable noise regulations and guidelines provide a basis for evaluating potential noise impacts. For federally funded transit projects, the FTA has established impact criteria. The applicable noise impact criteria depend on the specific project type. For fixed guideway and transit facilities, FTA project exposure criteria apply. For busways, access ramps, and other projects that connect to the roadway system, the Federal Highway Administration (FHWA) highway traffic noise criteria are applicable.

Under the FTA transit criteria, noise impacts occur when predicted $L_{eq}(h)$ or L_{dn} noise levels caused by the project increase the overall noise by between 1 and 10 dBA, depending on the land use and existing noise level (FTA 1995). In general, the higher the existing noise level, the less a project may increase the overall noise level without causing a noise impact under the FTA criteria. There are three categories of sensitive land use (Table 4.3-2) that may be impacted by noise. Other uses, such as retail and industrial, are generally not noise sensitive.

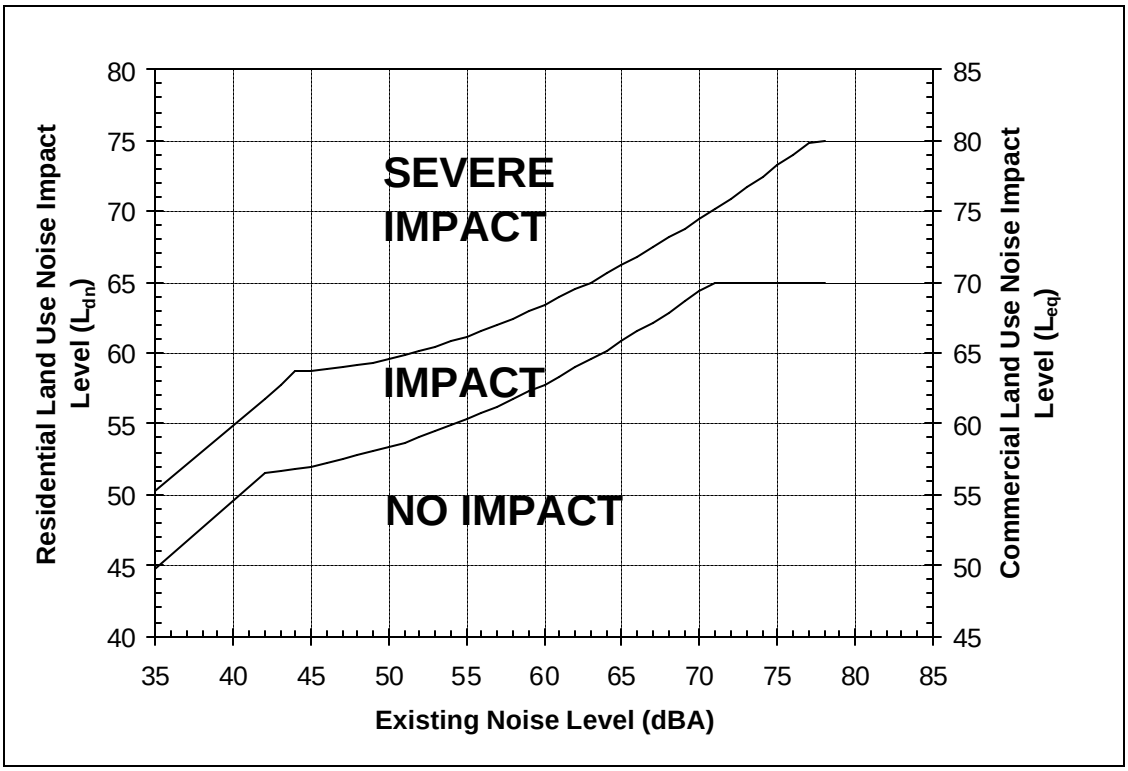
Table 4.3-2
Noise-Sensitive Land Uses

Category	Description
1	The most sensitive land uses. This category includes land where quiet is essential, such as outdoor amphitheaters and concert pavilions.
2	Places where people sleep, including homes, apartments, hotels, and hospitals.
3	The least sensitive of the three categories. This category includes schools, libraries, medical offices, concert halls, and other similar uses.

The noise exposure levels that define impacts from transit facilities under the FTA criteria are presented in Figure 4.3-1. The noise exposure levels shown in Figure 4.3-1 include only noise generated by a specific project and not other noise sources that contribute to the overall noise level in the project area. For example, if a project is located in a residential area with an average L_{dn} of 50 dBA, the project can generate up to 54 dBA L_{dn} without causing any impact and up to 59 dBA L_{dn} without causing a severe impact. For noise-sensitive commercial areas, impacts are determined by peak-hour L_{eq}, so if the average L_{eq} is 50 dBA, the project can generate up to 59 dBA L_{eq} without causing any impact and up to 64 dBA L_{eq} without causing a severe impact. Severe impacts generally meet the definition of a significant adverse impact under the National Environmental Policy Act (NEPA) (FTA 1995).

For roadway projects, traffic noise impacts occur when predicted $L_{eq}(h)$ traffic noise levels exceed the FHWA's established noise abatement criteria or substantially exceed existing noise levels (23 CFR 772.5). Mitigation is considered when $L_{eq}(h)$ traffic noise levels approach or exceed the FHWA criteria. The FHWA criteria, along with Washington State Department of Transportation (WSDOT) guidance, are applied to portions of Sound Transit projects that affect the highway system. Although "substantially exceed" is not defined, WSDOT considers an increase of 10 dBA or more to be a substantial exceedance.

Figure 4.3-1. Project Noise Exposure Impact Criteria for Transit Projects



Source: FTA (1995).

The FHWA noise abatement criteria specify exterior $L_{eq}(h)$ noise levels for various land activity categories (Table 4.3-3). For receptors where serenity and quiet are of extraordinary significance, the noise criterion is 57 dBA. For residences, parks, schools, churches, and similar areas, the noise criterion is 67 dBA. For developed lands, the noise criterion is 72 dBA. WSDOT considers a noise impact to occur if predicted $L_{eq}(h)$ noise levels approach within 1 dBA of the noise abatement criteria in Table 4.3-3. Thus, if a noise level were 66 dBA or higher, it would approach or exceed the FHWA noise abatement criterion of 67 dBA for residences.

WSDOT defines severe noise impacts as traffic noise levels that exceed 75 dBA outdoors in Category B areas or 60 dBA indoors in Category E areas. Severe noise impacts also occur if predicted future noise levels exceed existing levels by 15 dBA or more in noise-sensitive locations as the result of a project (WSDOT 2004c).

The Washington State Department of Ecology (Ecology) regulates noise levels at property lines of neighboring properties (WAC Chapter 173-40). Traffic and transit noise is exempt from the property line noise limits, but the limits apply to construction noise during certain hours and to other operations, such as park-and-ride facilities. The maximum permissible noise levels depend on the land uses of both the source noise and receiving property (Table 4.3-4). Construction noise from projects within the state of Washington must meet Ecology property line regulations during nighttime hours. In many jurisdictions, allowable nighttime noise levels for residential areas are 10 dBA less than the daytime levels shown in Table 4.3-4. The noise levels in Table 4.3-4 apply to construction equipment at residential receiving properties only between 10 p.m. and 7 a.m. Most jurisdictions within Sound Transit's service area have adopted the Ecology property line regulations with minor amendments. In Seattle, construction noise is allowed to exceed the property-line noise limits by 20 to 25 dBA, and impact equipment may produce levels as high as 99 dBA for short time periods during daytime hours, which are defined as between 7 a.m. and 10 p.m. on weekdays and 9 a.m. and 10 p.m. on weekends.

Table 4.3-3
FHWA Noise Abatement Criteria

Activity Category	L_{eq}(h) (dBA)	Description of Activity Category
A	57 (exterior)	Lands on which serenity and quiet are of extraordinary significance and serve an important public need and where the preservation of those qualities is essential if the area is to continue to serve its intended purpose; may include National Parks, National Monuments, and other lands of significance
B	67 (exterior)	Picnic areas, recreation areas, playgrounds, active sports areas, parks, residences, motels, hotels, schools, churches, libraries, and hospitals
C	72 (exterior)	Developed lands, properties, or activities not included in Categories A or B above
D	none	Undeveloped lands
E	52 (interior)	Residences, motels, hotels, public meeting rooms, schools, churches, libraries, hospitals, and auditoriums

Source: 23 CFR Part 772.

Table 4.3-4
Maximum Permissible Environmental Noise Levels by Environmental Designation

EDNA of Noise Source	Maximum Permissible Environmental Noise Levels		
	EDNA of Receiving Property		
	Residential	Commercial	Industrial
Residential	55 dBA	57 dBA	60 dBA
Commercial	57 dBA	60 dBA	65 dBA
Industrial	60 dBA	65 dBA	70 dBA

Source: WAC (1989).
EDNA = environmental designation for noise abatement

4.3.1.2 Vibration

There are two applicable sets of vibration criteria established by FTA: disturbance criteria and damage criteria. Disturbance criteria are used to establish impact from project operation, while building damage criteria are used to establish the likelihood of damage to nearby fragile buildings during construction activities. Operational disturbance criteria are shown in Table 4.3-5. Vibration levels can also be discussed in terms of decibels, which in this document are represented by the notation VdB. The FTA guidance on vibration damage threshold covers *fragile buildings* (100 VdB) and *extremely fragile historic buildings* (95 VdB).

Table 4.3-5
Transit Vibration Impact Criteria

Land Use Category	Vibration Impact Level	
	Frequent Events	Infrequent Events
Buildings where low ambient vibration is essential for interior operations	65 VdB	65 VdB
Residences and buildings where people normally sleep	72 VdB	80 VdB
Institutional land uses with primarily daytime use	75 VdB	83 VdB

Source: FTA (1995).

4.3.2 Affected Environment

4.3.2.1 Noise

Background environmental sound levels vary widely in different environments. The United States Environmental Protection Agency (EPA) evaluated L_{dn} sound levels at various locations and has developed qualitative descriptions of the sound environments that experience various sound levels (Table 4.3-6). The L_{dn} level is a measure of 24-hour environmental sounds and is often lower than the peak 1-hour sound levels that are evaluated for roadway noise.

Table 4.3-6
Typical Outdoor Sound Levels in Various Environments

Qualitative Description	L_{dn} (dBA)
City Noise (Downtown Major Metropolis)	80
	75
Very Noisy Urban	70
Noisy Urban	65
Urban	60
Suburban	55
Small Town and Quiet Suburban	50
	45

Source: EPA (1974).

Because transportation sources contribute most of the ambient noise in urban to suburban areas, ambient noise levels generally can be estimated based on distance to transportation sources. Typical L_{dn} noise levels as a function of distance from highways, arterials, and rail lines are shown in Figure 4.3-2. L_{dn} noise levels measured in the Puget Sound region tend to be consistent with the values in Table 4.3-6 and Figure 4.3-2. Seattle urban-area levels were measured as ranging between 61 and 76 dBA L_{dn} in the *Central Link EIS* (Sound Transit 1999a). Measurements taken for the *I-405 Corridor Program EIS* (WSDOT 2002a) ranged between 56 and 68 dBA L_{dn} along the existing Burlington Northern rail line along the east side of Lake Washington.

Existing transit noise sources in the Central Puget Sound region include buses, light rail, and commuter rail. Noise from buses depends on the bus sizes and types. There are also slight variations depending on engine type and coach size and weight. Electric buses are quieter than diesel buses. Diesel engines often produce more noise than equivalent gasoline engines; however, newer hybrid buses are substantially quieter under certain operating conditions.

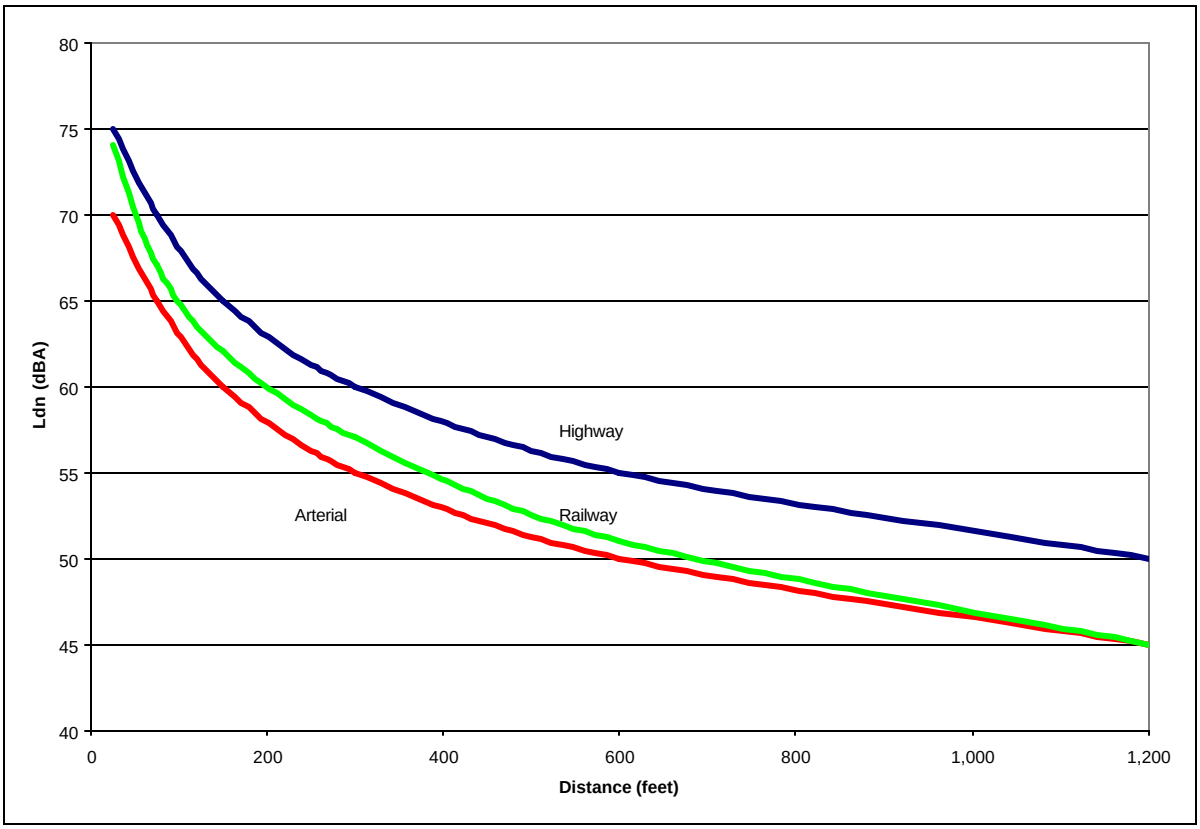
The peak accelerating noise (L_{max}) produced by the diesel coaches operated by King County Metro range from about 80 to 83 dBA at a distance of 50 feet. Peak cruising noise, even at high speeds, is somewhat less than peak accelerating noise. The significance of transit noise depends on background traffic and the mix of vehicle types. On heavily traveled roadways, the contribution of bus noise to total traffic noise is generally very limited.

4.3.2.2 Vibration

There are almost constant background vibrations within most urban environments, most of which are imperceptible except to extremely sensitive monitoring equipment. Ground vibration is generally only of concern if it annoys people or damages structures. At some locations, such as those with very sensitive laboratory equipment, sensitivity to ground vibration may be much greater.

Low-level ground vibration is generated in all transportation corridors, but is generally below the threshold of human perception. Peak vibration levels caused by very heavy vehicles may be perceptible within 5 to 10 feet of traffic lanes. Even the strongest traffic-induced vibrations generally diminish to levels that are imperceptible to humans within 20 feet of roadways (PSCOG 1983).

Figure 4.3-2. Typical Ldn Noise Levels Near Transportation Facilities



Source: FTA (1995).

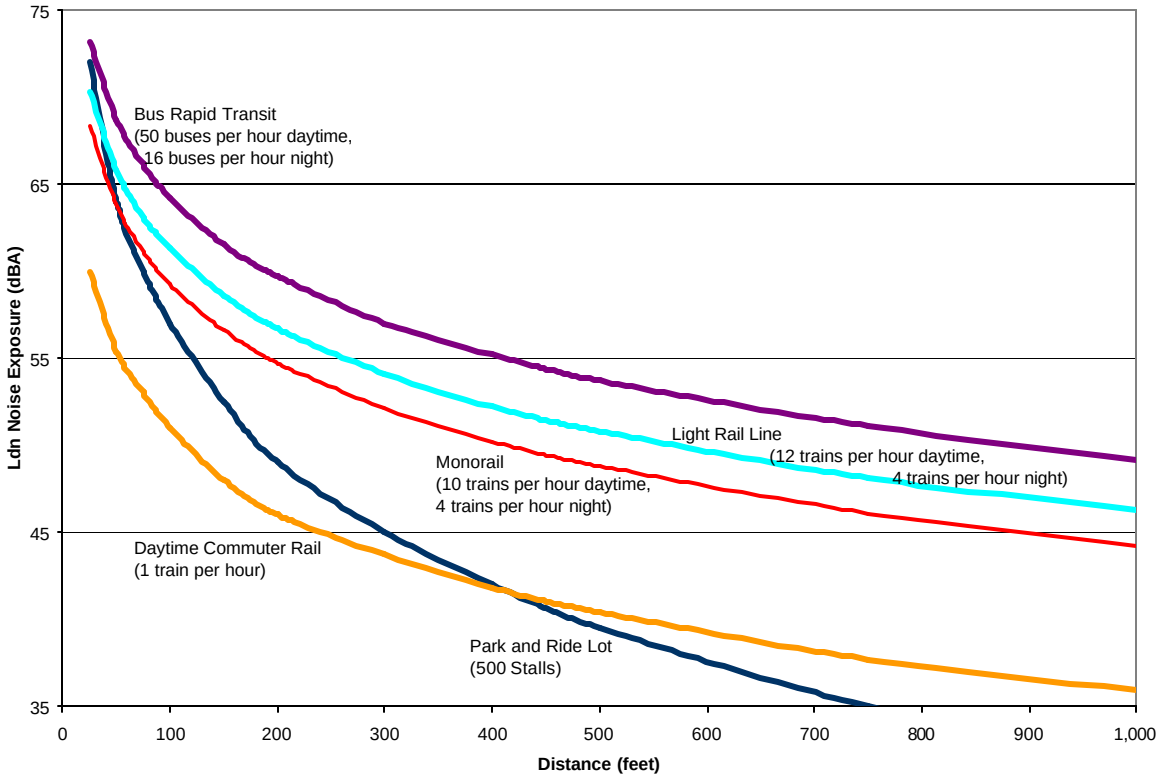
4.3.3 Long-Term Impacts

4.3.3.1 Regional Transit Long-Range Plan Alternative

Under the Plan Alternative, Sound Transit would expand beyond the current system built with *Sound Move.* The expanded system would result in increased transportation noise sources, including light rail and commuter rail trains, buses, park-and-ride lots, and other transit support facilities. Typical L_{dn} noise exposure levels expected to occur near various transit facilities are shown in Figure 4.3-3. Actual noise exposure levels would depend on operating speed, number of trains per day, local terrain, and the design of a project.

Typical L_{dn} noise exposure levels for a three-car light rail system operating at 40 miles per hour (mph) in two directions with 5-minute headways in each direction during the day and 15-minute headways at night would be approximately 66 dBA L_{dn} at 50 feet from the tracks. Typical noise exposure levels at 150 feet from an at-grade light rail line with 12 trains per hour operating during the daytime and 4 per hour at night would be approximately 60 dBA L_{dn} (Figure 4.3-3). The noise exposure would decrease to approximately 51 dBA L_{dn} at 500 feet from the track. For light rail technology, noise levels adjacent to elevated tracks are commonly 3 to 5 dBA greater than for at-grade tracks. This is similar to the projected noise levels reported in Sound Transit's environmental documents for Central Link and Tacoma Link, as discussed under the No Action Alternative. Different operating conditions affect noise levels, with the highest levels projected at 72 dBA, when frequencies and train speeds are higher.

Figure 4.3-3. Typical Ldn Noise Exposure Levels Near Transit Facilities



Source: Parsons Brinckerhoff (2005).

Typical L_{dn} noise exposure levels for a commuter rail system consisting of a locomotive and two rail cars, operating one train per hour during the day at 50 mph, would be approximately 55 dBA at 50 feet from the track. The noise exposure would decrease to approximately 40 dBA at 500 feet from the track. If trains idle for long periods of time at stations, the L_{dn} noise exposure levels in the vicinity of the stations would be greater than the levels shown for commuter rail in Figure 4.3-3.

A 500-stall surface-level park-and-ride lot operating with 10 buses per hour between 5 a.m. and 10 p.m. would generate an L_{dn} noise exposure level of approximately 64 dBA at 50 feet from the lot. The noise exposure level would decrease to approximately 40 dBA at 500 feet from the lot.

Noise impacts would depend both on the noise exposure level experienced at a location (Figure 4.3-3) and the existing noise level (Figure 4.3-1). In urban areas with existing L_{dn} noise levels in the 60 to 70 dBA range, noise impacts from light rail lines would occur at noise-sensitive locations (such as residences) within 50 to 100 feet of the tracks, depending on local conditions. In suburban areas with existing L_{dn} noise levels in the 50 to 60 dBA range, noise impacts would occur within approximately 100 to 150 feet of park-and-ride lots, and impacts would occur within approximately 25 to 50 feet of commuter rail lines with one commuter train per hour.

Vibration from buses and other rubber-tired vehicles is typically less than perceptible levels at distances greater than approximately 10 feet from the vehicle. Rail transit generates higher levels of vibration than buses because the vehicles are heavier and have less dampening, or dissipation of vibrating energy. Typical vibration levels for light rail and commuter rail vehicles operating at 50 mph are shown in Figure 4.3-4. Actual vibration levels would depend on vehicle type, track condition, and soil type. Assuming that light rail operations result in frequent events (more than 70 pass-bys per day), vibration impacts generally could occur at residences within about 60 feet of the tracks. Commuter rail operations are generally less frequent; therefore, a higher maximum vibration level would be acceptable than for light rail operations. Vibration impacts, such as rattling of windows

and perceptible floor movement, from commuter rail operations generally could occur at residences within about 80 feet of the tracks, but would be unlikely to cause physical damage. The corridors being considered for commuter rail operations are currently in use for other rail operations, which also generate vibrations to nearby residences. Vibration levels from commuter rail operations would generally be less than levels from existing freight rail on tracks currently used by freight rail because the weight of commuter trains is less than of freight trains. No substantial vibration impacts are expected at distances greater than 60 feet from light rail and 80 feet from commuter rail tracks.

If regional express bus/BRT is used to provide the same passenger capacity as light rail, noise levels would be greater than for light rail operations. Typical L_{dn} noise exposure levels for an average of 50 buses per hour operating at 40 mph in each direction during between 7 a.m. and 10 p.m. and an average of 16 buses per hour at other times would be approximately 69 dBA L_{dn} at 50 feet from the bus lanes. This level of operations would provide passenger capacity similar to a light rail system. Typical noise exposure levels at 150 feet from the bus lanes would be approximately 62 dBA L_{dn} (Figure 4.3-3).

4.3.3.2 Plan Alternative Options

Various options to the Plan Alternative would result in noise levels similar to those discussed for the Plan Alternative. The specific locations where plan elements are constructed or the operational hours or frequency of plan elements would differ between the options, resulting in changes in location or small changes in magnitude of elevated noise levels that would result from the Plan Alternative.

If monorail technology is used, noise levels near the monorail would be similar to those documented in the Seattle Monorail Project Green Line Final EIS (Seattle Monorail Project 2004). Typical L_{dn} noise exposure levels for a two-car monorail system operating in two directions between 5 a.m. and midnight with 4-minute headways in each direction during peak periods and 8-minute headways during off-peak periods at 40 mph would be approximately 64 dBA L_{dn} at 50 feet from the track. Typical noise exposure levels at 150 feet from a monorail line with these operations would be approximately 57 dBA L_{dn} (Figure 4.3-3). The evaluated monorail operations were based on published typical operating assumptions for the Seattle Monorail Project Green Line, while the light rail system operations were typical of proposed Sound Transit Central Link operations, which would include higher-capacity trains operating more frequently during the daytime than the monorail system. While the noise levels shown in Figure 4.3-3 for a monorail system are lower than those for a light rail system, the monorail system evaluated would serve fewer daily passengers than the light-rail system.

4.3.3.3 No Action Alternative

Services provided under *Sound Move* would continue to operate under the No Action Alternative. The system would not be expanded beyond the *Sound Move* plan. Existing and currently planned transit services and facilities would create noise levels similar to those discussed under the Plan Alternative. As documented in the *Central Link EIS* (Sound Transit 1999), light rail operation would generate noise exposure levels between 57 and 72 dBA L_{dn} at analyzed locations between 40 and 170 feet from the tracks. Along the Tacoma light rail alignment, a noise exposure level of 61 dBA L_{dn} was predicted at the only residential location (Winthrop Apartments, near Commerce Street and S. 9th Street) modeled along the corridor. Commuter rail noise exposure levels of between 47 and 55 dBA L_{dn} were predicted at noise-sensitive sites along the Tacoma-to-Seattle alignment.

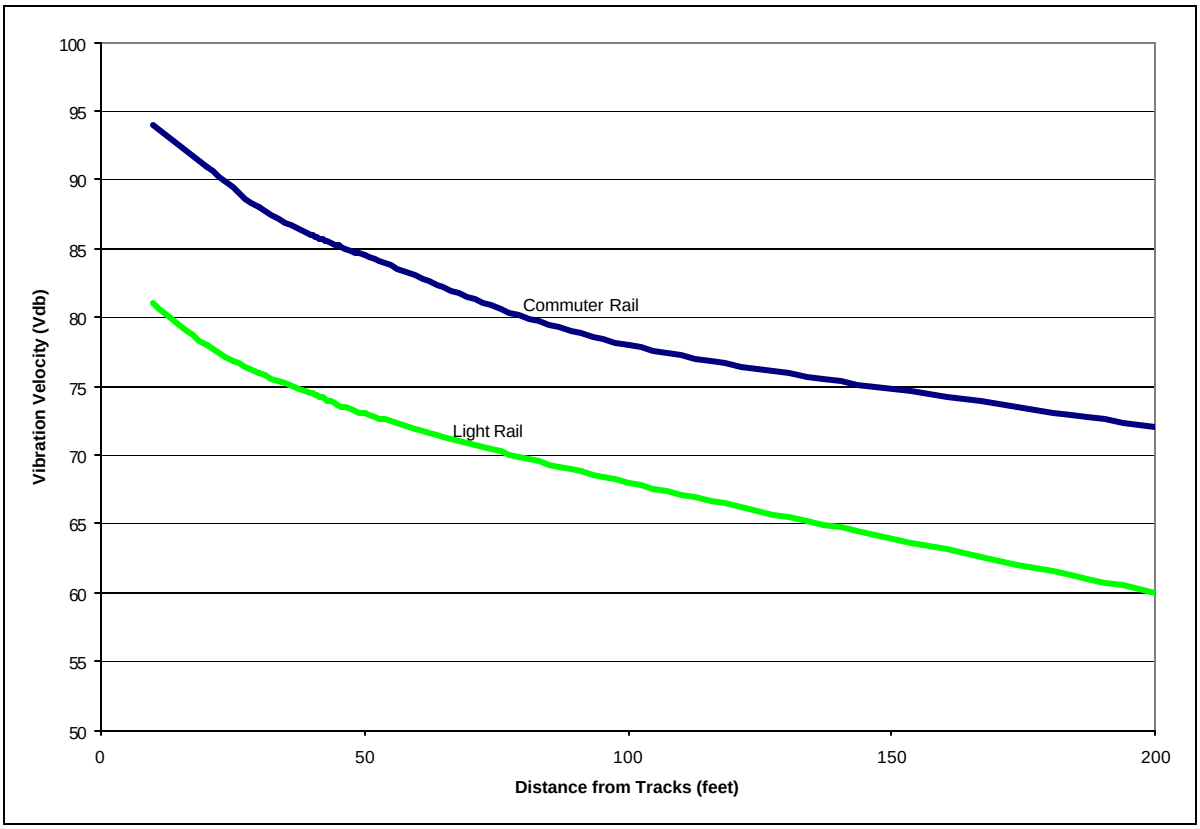
Vibration levels along existing and planned rail facilities would be similar to the levels discussed under the Plan Alternative.

4.3.4 Construction Impacts

4.3.4.1 Regional Transit Long-Range Plan Alternative

Noise during construction could be bothersome to nearby residents and businesses. Construction workers also would be subject to construction noise while working on the site. Construction noise would vary widely both in its range and hours over the course of implementation of the program. Individual projects constructed as part of the Plan Alternative would generate disturbances in the vicinity during the construction of the individual projects. Specific impacts would be determined during future project-level planning and environmental review.

Figure 4.3-4. Typical VdB Vibration Levels Near Rail Transit Lines



Source: FTA (1995).

The most prevalent noise source at most construction sites would be internal combustion engines. Earth-moving equipment, material-handling equipment, and stationary equipment are all engine-powered. Mobile equipment operates at sound levels that vary in a cyclic fashion, but stationary equipment (e.g., pumps, generators, and compressors) operates at sound levels that are fairly constant over time. Because trucks would be present during most phases and would not be confined to the project site, noise from trucks could affect more receptors. Other noise sources would include impact equipment and tools such as pile drivers. Impact tools could be pneumatic, hydraulic, or electric.

Construction noise associated with any project element would be intermittent, occurring at different times during the construction and at various locations in the project area. Construction noise levels would depend on the type, amount, and location of construction activities. The maximum noise levels of construction equipment for individual projects would be similar to the typical maximum construction equipment noise levels presented in Figure 4.3-5.

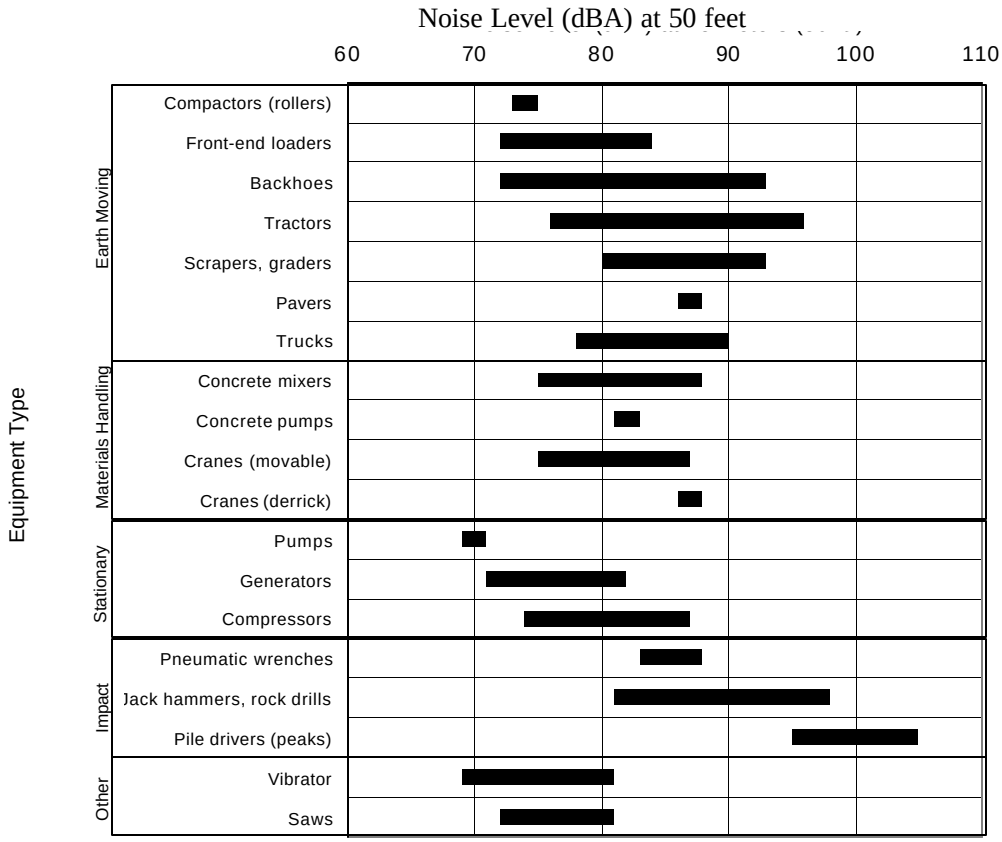
As shown in Figure 4.3-5, maximum noise levels from construction equipment would range from 69 to 106 dBA L_{max} at 50 feet. Construction noise at locations farther away would decrease at a rate of 6 to 8 dBA per doubling of distance from the source. Because various pieces of equipment would be turned off, idling, or operating at less than full power at any given time and because construction machinery is typically used to complete short-term tasks at any given location, average L_{eq} daytime noise levels would be less than the maximum noise levels presented in Figure 4.3-5.

Construction noise is allowed to exceed Ecology property-line noise limits during daytime hours (7 a.m. to 10 p.m. on weekdays and 9 a.m. to 10 p.m. on weekends). In some jurisdictions, such as the City of Seattle, the property-line regulations are somewhat different. In Seattle, construction noise is allowed to exceed the property-line noise limits by 20 to 25 dBA and impact equipment may produce levels as high as 99 dBA for short periods

during daytime hours. Nighttime construction would be required for some of the projects included in the programs. Nighttime construction is likely to exceed the nighttime noise limits. To accommodate nighttime exceedances of property-line noise limits, nighttime noise variances would be required from local jurisdictions.

The construction activities that would result in the highest levels of ground vibration are demolition, tunneling, and impact pile driving. The use of jackhammers and hoe rams would result in the highest levels of vibration during demolition activities. Demolition activities conducted 100 feet or more from existing structures generally would not exceed the damage risk criteria for older extremely fragile buildings. During impact pile driving, the ground vibration level at 25 feet is expected to be in the range of 104 to 112 VdB inches/second depending on the size and force exerted by the pile driver. At distances of 400 feet or greater, the damage risk from pile driving would be much lower and is expected not to exceed 95 VdB. Other techniques that do not require impact driving are also available for pile driving, which would result in lower vibration levels. Analysis of construction vibration impacts would be determined in conjunction with future project-level environmental review for those projects where vibration damage would be likely.

Figure 4.3-5. Typical Construction Equipment Noise Levels



Source: EPA (1971) and WSDOT (1991).

4.3.4.2 Plan Alternative Options

Construction impacts for the Options would be similar to those discussed for the Plan Alternative. Options that would increase the magnitude and duration of construction activities in any specific area would also increase the construction noise disturbance to nearby residents. As documented in the Seattle Monorail Project Final EIS (Seattle Monorail Project 2004), noise associated with construction of a monorail line would be similar to the levels shown in Figure 4.3-5 because the same types of equipment would be used.

4.3.4.3 No Action Alternative

Construction impacts under the No Action Alternative would occur near *Sound Move* projects, along with a limited number of other committed improvements to the regional transportation system that would be constructed. The construction noise impacts and mitigation measures associated with most of these projects are addressed in the project-specific environmental documentation for the various projects and are expected to be similar to the Plan Alternative.

4.3.5 Potential Mitigation Measures

Noise can be controlled at three locations: (1) at the source (e.g., with mufflers and quieter engines), (2) along the noise path (e.g., with barriers such as noise walls, shielding, or increased distance), and (3) at the receptor (e.g., with insulation such as windows, doors, or increased insulation in walls). Implementation of noise mitigation at the receptor (location 3) would not be consistent with FHWA or WSDOT noise abatement policy in most instances. Noise abatement is necessary only where frequent human use occurs and where a lower noise level would have benefits (23 CFR Part 772).

4.3.5.1 Long-Term Impacts

A variety of mitigation methods could be implemented, to the extent feasible, to reduce transit system noise impacts. For example, noise impacts from long-term operation of individual projects could be reduced with the following measures:

- Apply traffic management measures for bus and HOV projects.
- Acquire land as buffer zones or for construction of noise barriers or berms.
- Realign roadways or tracks further from noise-sensitive receptors.
- Design and treat tracks and wheels to reduce squeal, flats, rail corrugations, and gaps.
- Maintain transit vehicles and use engine compartment treatments to reduce engine noise.
- Construct noise barriers or berms.
- Use welded track instead of joined track.
- Install noise insulation in buildings.

Future project-level planning and environmental review would evaluate individual project impacts and the need for these measures as they apply to each project. The project-level analysis would also examine system components and facility locations where vibration could be a particular concern to determine where more analysis and mitigation may be required. Vibration simulation techniques could be used to evaluate potential vibration impacts, if appropriate and feasible. Facilities and equipment could then be designed to achieve appropriate ground-borne vibration limits. The following measures could be used to reduce vibration impacts, to the extent feasible:

- Realign tracks further from vibration-sensitive receptors.
- Design track support systems to reduce the transmission of vibration.
- Follow vehicle specifications to eliminate vibration from vehicle suspension resonance.
- Maintain vehicles and tracks to prevent vibration levels increasing over time.

4.3.5.2 Construction Impacts

Construction noise could be reduced by using enclosures or walls to surround noisy equipment, installing mufflers on engines, substituting quieter equipment or construction methods, minimizing time of operation, and locating equipment farther from sensitive receptors. Construction activities would meet requirements established in local noise ordinances or require a temporary noise variance from local jurisdictions. Temporary noise variances would establish requirements during construction. To reduce construction noise and vibration at nearby

receptors along the proposed corridors, the following mitigation measures could be incorporated into construction plans and contractor specifications of individual projects, to the extent feasible:

- Erect noise berms and barriers as early as possible to provide noise shielding.
- Limit construction activities to daytime hours to reduce construction noise levels during sensitive nighttime hours. This option may extend construction duration. This measure may not be feasible for all projects since some nighttime construction may be necessary.
- Equip construction equipment engines with adequate mufflers, intake silencers, and engine enclosures to reduce their noise.
- Specify the quietest equipment available to reduce noise by 5 to 10 dBA.
- Turn off construction equipment during prolonged periods of nonuse to eliminate noise from construction equipment during those periods.
- Require contractors to maintain all equipment and train their equipment operators to reduce noise levels and increase efficiency of operation.
- Locate stationary equipment away from receiving properties to decrease noise from that equipment in relation to the increased distance.
- Construct temporary noise barriers or curtains around stationary equipment that must be located close to residences to decrease noise levels at nearby sensitive receptors.
- Use construction techniques (such as augured or vibrated instead of driven piles) to reduce noise and vibration impacts.
- Use passive measures (trenching, sheet piling, and screening) to modify the propagation paths of ground-borne vibrations.
- Monitor vibration levels at sensitive receptors.

4.3.6 Significant Unavoidable Adverse Impacts

Some significant unavoidable adverse impacts from noise and vibration are expected under the No Action Alternative and Plan Alternative and Options. Temporary noise impacts during construction may be unavoidable and could be considered significant, especially where construction is required during nighttime hours. Future project-level environmental documentation would determine if applicable noise standards are exceeded at specific locations in a particular project area or corridor. Where this occurs, potential mitigation for such impacts would be evaluated and implemented as appropriate to address the impact.