9.0 Noise and Vibration

9.1 Introduction

A noise and vibration assessment was conducted to identify the potential for impacts for the proposed alternatives of the Columbia Pike Transit Initiative proposed between Pentagon City (Arlington County) and Leesburg Pike (Fairfax County). The noise and vibration assessment was prepared in accordance with the National Environmental Policy Act (NEPA) and the guidelines set forth by the Federal Transit Administration's (FTA) *Transit Noise and Vibration Impact Assessment*[1]. The results of the noise and vibration assessment are described in the following sections.

9.1.1 Human Perception of Noise and Vibration

Noise

Noise is "unwanted sound" and, by this definition, the perception of noise is a subjective process. Several factors affect the actual level and quality of sound (or noise) as perceived by the human ear and can generally be described in terms of loudness, pitch (or frequency), and time variation. The loudness, or magnitude, of noise determines its intensity and is measured in decibels (dB) that can range from below 40 dB (the rustling of leaves) to over 100 dB (a rock concert). Pitch describes the character and frequency content of noise, such as the very low "rumbling" noise of stereo subwoofers or the very high-pitched noise of a piercing whistle. Finally, the time variation of noise sources can be characterized as continuous, such as with a building ventilation fan; intermittent, such as trains passing by; or impulsive, such as pile-driving activities during construction.

Various sound levels are used to quantify noise from transit sources, including a sound's loudness, duration, and tonal character. For example, the A-weighted decibel (dBA) is commonly used to describe the overall noise level because it more closely matches the human ear's response to audible frequencies. Because the A-weighted decibel scale is logarithmic, a 10 dBA increase in a noise level is generally perceived as a doubling of loudness, while a 3 dBA increase in a noise level is just barely perceptible to the human ear. Typical A-weighted sound levels from transit and other common sources are shown in **Figure 9-1**.

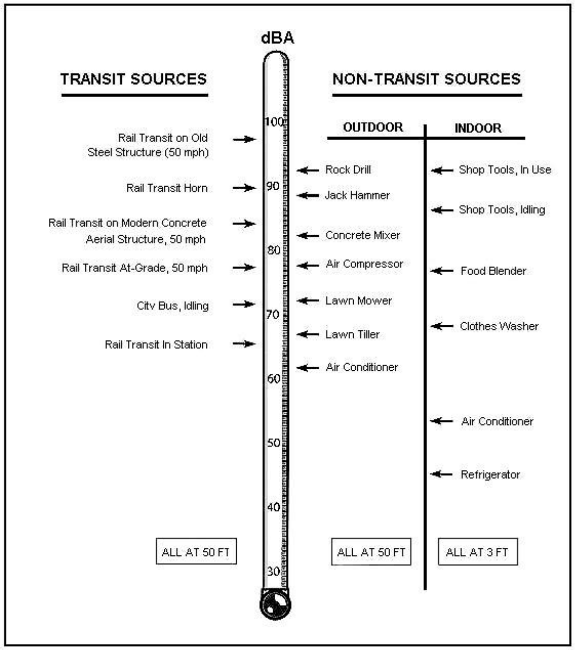
Several A-weighted noise descriptors are used to determine impacts from transit related sources including the L_{max}, which represents the maximum noise level that occurs during an event such as a bus or train passby; the L_{eq}, which represents a level of constant noise with the same acoustical energy as the fluctuating noise levels observed during a given interval, such as one hour; and the L_{dn}, or the 24-hour day-night noise level, which includes a 10-decibel penalty for all nighttime activity between 10:00 p.m. and 7:00 a.m.

Vibration

Ground-borne vibration associated with vehicle movements is usually the result of uneven interactions between wheels and the road or rail surfaces. Examples of such interactions (and subsequent vibrations) include train wheels over a jointed rail, an untrue rail car wheel with "flats," and a motor vehicle wheel hitting a pothole, a manhole cover, or any other uneven surface.

Unlike noise, which travels in air, transit vibration typically travels just below the surface of the ground. Depending on the geological properties of the surrounding terrain and the type of building structure exposed to transit vibration, vibration propagation can be more or less efficient. Buildings with a solid foundation set in bedrock are "coupled" more efficiently to the surrounding ground and experience relatively higher vibration levels than buildings located in sandier soil. On the other hand, heavier buildings (such as masonry structures) are less susceptible to ground-borne vibration than wood-frame buildings because they absorb more of the vibration.

Figure 9-1: Typical A-Weighted Noise Levels



Source: Transit Noise and Vibration Impact Assessment, Federal Transit Administration, Washington, DC, May 2006.

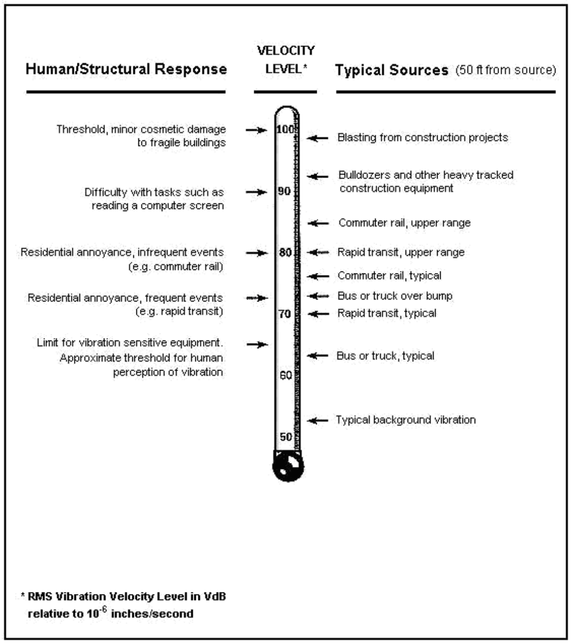
Vibration induced by vehicles passing by can generally be discussed in terms of displacement, velocity, or acceleration. However, human responses and

[1] *Transit Noise and Vibration Impact Assessment*, FTA-VA-90-1003-06, U.S. Department of Transportation, Federal Transit Administration, Office of Planning and Environment, Washington, DC, May 2006.

responses by monitoring instruments and other objects are most accurately described with velocity. Therefore, the vibration velocity level is used to assess vibration impacts from transit projects.

To describe the human response to vibration, the average vibration amplitude (called the root mean square, or RMS, amplitude) is used to assess impacts. The RMS velocity level is expressed in inches per second or vibration decibels (VdB). All VdB vibration levels are referenced to 1 micro-inch per second. Typical ground-borne vibration levels from transit and other common sources are shown in **Figure 9-2**.

Figure 9-2: Typical Ground-Borne Vibration Levels



Source: *Transit Noise and Vibration Impact Assessment*, Federal Transit Administration, Washington, DC, May 2006.

9.1.2 Regulatory Setting

FTA Noise and Vibration Standards

The Federal Noise Control Act of 1972 (Public Law 92-574) requires that all federal agencies administer their programs in a manner that promotes an environment free from noises that could jeopardize public health or welfare. Therefore, the noise and vibration assessment was prepared in accordance with the National Environmental Policy Act (NEPA) and the guidelines in FTA's *Transit Noise and Vibration Impact Assessment* [2] (FTA 2006). These guidelines form the basis for determining the potential noise and vibration impacts associated with light rail transit projects.

The FTA guidelines are specifically used to assess noise and vibration impacts from transit vehicles and facilities (such as buses, trains, and stationary sources such as grade crossings bells and maintenance facilities). FTA assesses impacts at sensitive receivers such as residences, schools, and libraries. Commercial and industrial properties are typically not considered sensitive to transit noise and vibration except laboratories and other facilities that utilize sensitive photographic or imaging equipment. For example, the 24-hour day-night noise level (or L_{dn}) is used to assess impacts particularly at night when sensitivity to transit noise is more enhanced. A detailed description of the FTA evaluation criteria and the modeling methodologies is included in the following section.

WMATA Noise and Vibration Criteria

During the construction and development of the initial Metrorail rapid transit system in the 1970s, design criteria were developed specifically for the WMATA rail system. The most current version of these design criteria are described in WMATA Manual of Design Criteria for Maintaining and Continued Operation of Facilities and Systems[3]. Since these design criteria were primarily intended for heavy rail rapid transit, the WMATA criteria were not used to evaluate impacts from the lighter streetcar or bus vehicles operating on city streets.

9.2 Methodology

FTA's *Transit Noise and Vibration Impact Assessment* guidance manual presents the basic concepts, methods, and procedures for evaluating the extent and severity of noise and vibration impacts from transit projects. Transit noise and vibration impacts are assessed based on land-use categories and these uses' sensitivity to noise and vibration from transit sources as described in the FTA guidelines.

Local noise ordinances were identified for Arlington County "Chapter 15: Noise Control Code" and Fairfax County "Article 4, Section 108: Noise Code".

9.2.1 FTA Noise Criteria

As shown in **Figure 9-3**, the FTA noise impact criteria are defined by two curves that allow increasing project noise levels as existing noise increases up to a point, beyond which the impact is determined based on project noise

[2] *Transit Noise and Vibration Impact Assessment*, FTA-VA-90-1003-06, U.S. Department of Transportation, Federal Transit Administration, Office of Planning and Environment, Washington, DC, May 2006.

[3] *WMATA Manual of Design Criteria for Maintaining and Continued Operation of Facilities and Systems*, Washington Metropolitan Area Transit Authority, Department of Operations Services, Office of Engineering Support Services, May 2008.

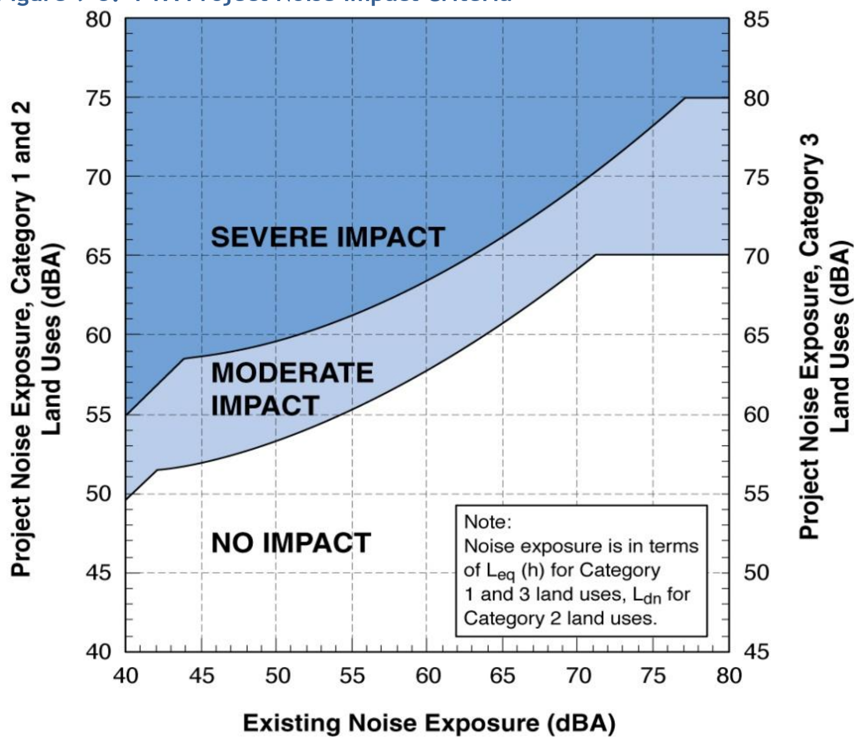
alone. The FTA land-use categories and required noise metrics are described in **Table 9-1** below. The FTA project noise impact criteria is shown in **Figure 9-3** below.

Table 9-1: FTA Land-Use Categories and Noise Metrics

Land-Use Category	Noise Metric	Description
1	$L_{eq}(h)$	Tracts of land set aside for serenity and quiet, such as outdoor amphitheaters, concert pavilions, and historic landmarks.
2	L_{dn}	Buildings used for sleeping such as residences, hospitals, hotels, and other areas where nighttime sensitivity to noise is of utmost importance.
3	$L_{eq}(h)$	Institutional land uses with primarily daytime and evening uses including schools, libraries, churches, museums, cemeteries, historic sites, and parks, and certain recreational facilities used for study or meditation.

Source: FTA, 2006.

Figure 9-3: FTA Project Noise Impact Criteria



As shown in **Figure 9-3**, the FTA transit noise impact criteria define noise impacts in terms of the existing noise levels, the expected noise levels with the proposed project, and the land uses that would be affected. Category 1 and 2 land uses are more sensitive to noise than Category 3 land uses (see **Table 9-1**). For example, a project noise level of 60 dBA might be considered a moderate impact at a Category 1 or 2 land use but no impact at a Category 3 land use.

The FTA noise criteria separate noise impacts into two categories: *moderate impact* and *severe impact*. The *moderate impact* category indicates that the change in noise is noticeable but might not be great enough to cause a strong, adverse community reaction. The *severe impact* category indicates that a significant percentage of the population would be highly affected by the new noise. The degree of impact at any specific location can be determined by comparing the predicted project noise level at the site to the existing noise level.

The average day-night noise level over a 24-hour period, or L_{dn}, was used to characterize noise exposure for residential areas (FTA Category 2). For other noise-sensitive land uses identified along the project corridor, such as schools and libraries (FTA Category 3), the peak hourly noise level, or $L_{eq}(h)$, was used.

9.2.2 FTA Vibration Criteria

The FTA vibration criteria for evaluating ground-borne vibration impacts from transit vehicle passbys at nearby sensitive receptors are shown below in **Table 9-2**. These vibration criteria are related to ground-borne vibration levels that are expected to result in human annoyance and are based on root mean square (RMS) velocity levels expressed in velocity decibels (VdB) referenced to 1 micro-inch per second (μips).

FTA's experience with community response to ground-borne vibration indicates that, when only a few trains pass by per day, it takes higher vibration levels to evoke the same community response that occurs from more frequent trains. This is taken into account in the FTA criteria by distinguishing between projects with *frequent, occasional, and infrequent* vibration events. The *frequent events* category is defined as more than 70 trains per day; the *occasional events* category is defined as between 30 and 70 trains per day; and the *infrequent events* category is defined as fewer than 30 trains per day. To be conservative, the FTA *frequent events* criteria were used to assess ground-borne vibration impacts along the in-street shared right-of-way based on the transit vehicle types and service headways associated with each alternative. .

The vibration criteria levels shown in **Table 9-2** are defined in terms of human annoyance for different land-use categories such as high sensitivity (Category 1), residential (Category 2), and institutional (Category 3). In general, the vibration threshold of human perceptibility is about 65 VdB.

For above-grade transit systems, the FTA ground-borne noise criteria are typically not applied except for buildings that have sensitive interior spaces (such as laboratories and other Category 1 receptors) and that are well insulated from exterior noise (such as optical or medical research laboratories). In general, airborne noise often masks ground-borne noise for above-ground (at-grade or elevated) transit systems such as the system proposed for the rail-build alternative. Therefore, ground-borne noise impacts were not evaluated along the proposed project corridor since no Category 1 sensitive buildings were identified.

Table 9-2: FTA Ground-Borne RMS Vibration Impact Criteria for Annoyance

Receptor Land Use		RMS Vibration Levels (VdB)[1]		
Category	Description	Frequent Events	Occasional Events	Infrequent Events
1	Buildings where low vibration is essential for interior operations	65	65	65
2	Residences and buildings where people normally sleep	72	75	80
3	Daytime institutional and office use	75	78	83
Specific Buildings	TV, recording studios; concert halls	65	65	65
	Auditoriums	72	80	80
	Theaters	72	80	80

1 Ground-borne vibration levels are referenced to 1 x 10^{-6} inches per second (VdB referenced to 1 micro-inch/sec).
Source: FTA, 2006.

9.2.3 Modeling Assumptions

The noise assessment was conducted according to FTA's *Transit Noise and Vibration Impact Assessment* guidelines. Specifically, a general assessment was conducted to model the noise levels from the proposed streetcar transit operations under the Streetcar Build Alternative in the design year (2030). The modeling assumptions and input parameters (such as reference noise levels) used in the noise assessment are summarized below.

- Impacts were assessed for the Streetcar Build Alternative including the three Western Terminus Design Options:
  - Skyline Central Plaza
  - Jefferson Street Transit Center
  - Skyline Route 7
- Total daily operations were determined based on 6-minute headways during all peak and off-peak periods of the day between 6:00 am and 8:30 pm (using the Friday and Saturday WMATA operating plan). Similarly, 12-minute headways are assumed for all other off-peak periods of the day between 5:30 am and 2:00 am including late evening and early morning.
- A one-vehicle train was assumed for both peak and off-peak periods of the day. The default source noise level of 79 dBA SEL (77 dBA L_{max}) was assumed for all streetcar passbys (reference distance of 50 feet and 50 miles per hour [mph]).
- At station stops, an average idling time of 30 seconds was used to account for noise contribution from stationary or vehicle auxiliary equipment noise such as rooftop mechanical systems. The default FTA reference source noise level of 65 dBA L_{max} was assumed for all stationary streetcar events (50 feet).
- Maximum travel speeds of 40 mph were used for all segments of the proposed transit corridor except near stations, where the speed was reduced to 15 mph.
- No warning horns or bells are assumed as part of the normal operating procedure since intersections, including pedestrian-only crossings, will be guided by in street traffic signals. Bells used during emergency situations would not be considered as part of the normal operating procedure.
- The FTA Noise and Vibration Guidelines do not include a noise analysis and vibration profile for the streetcar vehicle type assumed for analsis elsewhere in this AA/EA. In lieu of a streetcar profile, this analysis is based on the operating characteristics and noise and vibration profile of the Siemens S-70 light rail vehicle currently used by Houston Metro and Salt Lake City's Utah Transit Authority.
- According to the FTA Noise and Vibration Guidelines, the potential for wheel squeal for typical light rail operations exists along track curves with a turning radius of less than 100 feet. However, modern streetcar systems are specifically designed for routine operations along curves with radii well below 100 feet. FTA has not issued guidelines specific to assessment of streetcar wheel squeal, and no detailed assessment has been performed for this study.
- The vibration impacts from light-rail transit vehicle operations were predicted using the default FTA ground surface vibration curves for light rail vehicles. These curves were adjusted to reflect local conditions such as changes in train speed and special track work such as switches.
- Continuously welded rail (CWR) embedded track is proposed everywhere along the project corridor where the corridor is shared with vehicular traffic.
- In accordance with the FTA guidance, the streetcar service was treated as a new source of noise along the project corridor. As a result, the existing local traffic and buses were included in the background noise levels, which were used to develop the project impact criteria.
- The FTA screening distances of 350 feet for noise and 150 feet for vibration were applied to the surrounding land uses to determine the population of potential receptor sites included in the modeling analysis. Over 2,500 sensitive receptors were identified for evaluation.
- For the proposed streetcar O&M facility, the default FTA source level of 82 dBA L_{max} (118 dBA SEL) was used in the modeling analysis.

9.3 Existing Conditions

9.3.1 Noise Monitoring

To determine the existing background noise levels at sensitive receptors in the vicinity of the proposed transit corridor, a noise-monitoring program was conducted at five representative locations shown in **Figure 9-4** and described in **Table 9-3**. Hourly equivalent A-weighted noise levels (or L_{eq}(h) in dBA) were measured continuously over a 24-hour period at five representative sites to determine the average ambient conditions during a typical weekday. The representative sites included single-family residences, townhomes and apartment complexes along the project corridor (or FTA Category 2 land-uses). The noise measurements document existing noise sources throughout the project study area such as existing traffic along Columbia and Leesburg Pike. In accordance with FTA guidelines, 24-hour day-night noise levels (or Ldn in dBA) were developed based on the monitoring results. The noise-monitoring program was conducted on June 1-4, 2010.

The intent of the noise monitoring program was not to document the background noise level at every receptor, but to strategically select monitoring sites that were representative of the project corridor's adjacent land uses and closest to the proposed alignment. Existing noise levels observed at these monitoring sites can be adjusted to estimate existing noise levels at sites farther away from the ROW, based on distance.

The sound-level meters that were used to measure current noise conditions (Brüel & Kjær Model 2236 and Larson Davis Model 820) meet or exceed the American National Standards Institute (ANSI) standards for Type I accuracy and quality. The sound-level meters were calibrated using a Brüel & Kjær Model 4231 before and after each measurement. All measurements were conducted according to ANSI Standard S1.13-2005, Measurement of Sound Pressure Levels in Air. All noise levels are reported in dBA, which best approximates the sensitivity of human hearing.

9.3.2 Baseline Noise Conditions

As shown in **Table 9-3**, the measured day-night noise levels along the project corridor are fairly consistent ranging from 65 dBA at Receptors M4 and M5 (residences along Jefferson Street and George Mason Drive, respectively) to 66 dBA at Receptors M1, M2 and M3 (residences along 12th Street South and Columbia Pike). Similarly, measured peak-hour Leq noise levels along the project corridor range from 61 dBA at Receptors M3 and M5 (residences along Colombia Pike and George Mason Drive, respectively) to 64 dBA at Receptor M1 (residences along 12th Street South). These noise levels are generally representative of urban land uses in the study area and reflect the dominance of vehicle traffic noise along Columbia and Leesburg Pike.

Table 9-3: Measured Baseline Noise Levels at Representative Locations along the Project Corridor (in dBA)

Receptor	Description	Land Use	Date	1-Hour L_{eq}	24-Hour L_{dn}
M1	Bennington Apts., 12th St. S.	Res.	9/02/10	64	66
M2	Dorchester Apts., Columbia Pike	Res.	9/01/10	62	66
M3	Oakland Apartments, Columbia Pike	Res.	9/02/10	61	66
M4	Wildwood Towers, S. Jefferson St.	Res.	9/01/10	62	65
M5	Skyline Plaza, George Mason Dr.	Res.	9/01/10	61	65

Source: AECOM, Arlington, VA, October, 2011.

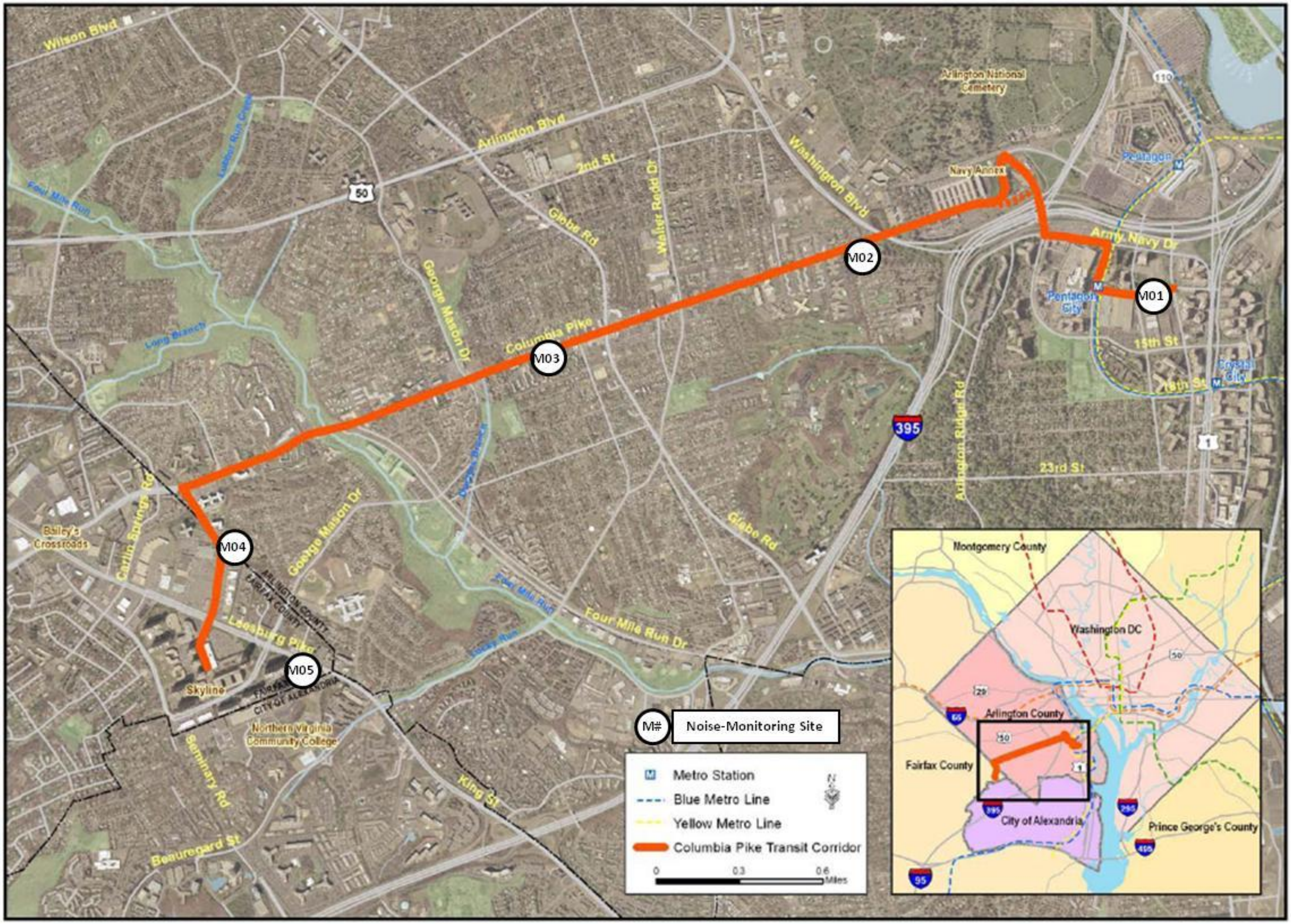
In summary, the current ambient noise environment is generally affected by traffic along the major arterial streets namely Columbia and Leesburg Pike.

9.3.3 Baseline Vibration Conditions

Table 9-2 (*FTA Ground-Borne RMS Vibration Impact Criteria for Annoyance*) previously listed the three categories of land use that FTA considers to be sensitive to vibration. Vibration Category 1 includes research and manufacturing facilities, hospitals with vibration-sensitive equipment and university research operations. Equipment such as electron microscopes and high-resolution lithographic apparatus can be very sensitive to vibration from transit operations. However, no Vibration Category 1 land uses were identified along the project ROW within the vibration screening distance of 450 feet from the existing rail corridor.

Since there is no current rail activity along the Columbia Pike corridor, no existing vibration measurements were conducted. Existing vibration along the project corridor is mainly due to vehicle traffic on local roads. Therefore, current vibration from existing general traffic along the project corridor was not measured. However, the FTA General Assessment was used to determine vibration impacts under the proposed Streetcar Build Alternative using typical ground propagation characteristics for steel-wheeled streetcar vehicles.

Figure 9-4: Representative Baseline Noise Monitoring Sites along the Project Corridor



9.4 Environmental Consequences

9.4.1 No Build Alternative

Noise

Future noise levels under the No Build Condition should be similar to those under the existing conditions. The study area is characterized as a mixture of both urban and suburban communities that include major arterials (such as Columbia and Leesburg Pikes). Irrespective of other projects on the Transportation Improvement Program (TIP), ambient noise under the No Build Condition should be the same as the existing condition without the Columbia Pike Transit Initiative. Therefore, the No Build Condition would not cause any new noise impacts.

Vibration

Future vibration levels under the No Build Condition should also be similar to those under the existing conditions. The study area is characterized as a mixture of both urban and suburban communities that include major arterials (such as Columbia and Leesburg Pikes). Irrespective of other projects on the TIP, ambient ground-borne vibration levels under the No Build Condition should be the same as the existing condition without the Columbia Pike Transit Initiative. Therefore, the No Build Condition would not cause any new vibration impacts.

9.4.2 TSM Alternatives

Noise

Future noise levels in the Study Area under TSM 1 and TSM 2 Alternatives are expected to be similar to those measured under the existing conditions. Similar to the No Build Alternative, changes in noise due to increases in traffic volumes between now and 2035 would be insignificant and would not be perceptible. These alternatives would add efficiencies to local bus service, but the improvements would not result in significant changes to the frequency of bus pass-bys as compared with the No Build Alternative. Therefore, the TSM 1 and TSM 2 Alternatives are not expected to change background noise levels or cause additional operational noise impacts.

Vibration

Future vibration levels in the Study Area under TSM 1 and TSM 2 Alternatives are expected to be similar to those experienced currently under the existing conditions. Similar to the No Build Alternative, changes in vibration due to increases in traffic volumes between now and 2035 would be insignificant and would not be perceptible. These alternatives would add efficiencies to local bus service, but the improvements would not result in significant changes to the frequency of bus pass-bys as compared with the No Build Alternative. Therefore, TSM 1 and TSM 2 Alternatives are not expected to cause any operational vibration impacts.

9.4.3 Streetcar Build Alternative

Since the project would introduce new transit service, noise from the Streetcar Build Alternative was evaluated using the FTA prediction procedures. Additionally, since the proposed streetcar service's greatest impact will likely occur during nighttime at residences and during the peak traffic hours at non-residential receptors, two sets of impact assessment criteria were used. The FTA evaluation criteria were used to assess 24-hour impacts at residences (especially during the most sensitive nighttime period when people are sleeping) and daytime peak-hour impacts at institutional receptors.

FTA Noise Assessment

Since most of the noise-sensitive sites for this project are residential, the L_{dn} descriptor was used to reflect the particularly heightened sensitivity to nighttime noise. Predicted noise levels are shown in **Table 9-4** under the Streetcar Build Alternative. The table compares noise levels for representative receptor locations along the project alignment for existing conditions and the Streetcar Build Alternative. Note that the "Build" levels represent the noise for the Build Alternative only, and not the future level with the project; this approach allows a direct comparison with the FTA criteria to assess the potential for impact. As shown in **Table 9-4**, the L_{dn} day-night noise levels at residences along the proposed Streetcar Build Alternative are predicted to range from 54 dBA at Receptor M3 (residences along Columbia Pike) to 62 dBA at Receptor M1 (apartments along 12th Street South).

Table 9-4: Predicted Noise Levels at Select Receptors under the Streetcar Build Alternative (dBA)

	Receptor	Land	Noise		FTA Criteria		
ID	Description	Use	Existing	Build	Moderate	Severe	Impact
M1	Bennington Apts., 12th St. S.	Res.	66	62	62	67	Yes
M2	Dorchester Apts., Columbia Pike	Res.	66	57	61	67	No
M3	Oakland Apartment, Columbia Pike	Res.	66	54	62	67	No
M4	Wildwood Towers, S. Jefferson St.	Res.	65	57	61	66	No

1 The FTA impact criteria, which are reported as 24-hour Ldn levels for residences and peak-hour Leq for institutions, vary by location based on the existing noise levels.
Source: AECOM, October, 2011.

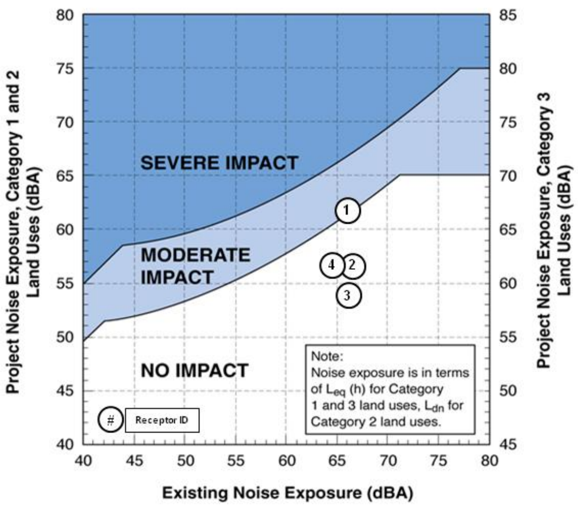
Noise levels at the representative receptor sites described above were used to characterize noise impacts from the Streetcar Build Alternative at all other locations within the project area. Consequently, anticipated project-related effects were evaluated at a total of almost 2,500 noise-sensitive receptors along the proposed Build Alternative alignment. As shown in **Table 9-5**, corridor wide 24-hour day-night noise levels under the Streetcar Build Alternative are predicted to exceed the FTA moderate impact criteria at three residential buildings (Category 2 land-uses) and one office building (Category 3 land-use). The Category 2 land uses that are predicted to exceed FTA moderate impact criteria include the DoubleTree Hotel, the Lenox Club (apartment building), and the Bennington (apartment buiding). The Category 3 land use is the Verizon switch building. No exceedances of the FTA severe impact criteria are predicted. **Figure 9-5** shows the projected-related noise impacts under the Streetcar Built Alternative.

Table 9-5: Overall Project-Related Noise Impacts under the Streetcar Build Alternative

	FTA Category 2[1]		FTA Category 3[1]	
Segment	*Moderate*	*Severe*	*Moderate*	*Severe*
Arlington	3	0	1	0
Fairfax	0	0	0	0
Totals	3	0	1	0

1 The FTA assessment evaluated transit impacts at both Category 2 (residential) and Category 3 (institutional) receptors.
Source: AECOM, October, 2011.

Figure 9-5: Project-Related Noise Impacts under the Streetcar Build Alternative



All of the noise impacts are predicted in Arlington County are due to activities at the proposed Pentagon City O&M facility. No other *moderate* impacts are predicted in Arlington or Fairfax Counties due to streetcar passbys and activities at station stops. The predicted noise levels from the Pentagon City O&M facility are based on worst-case conditions based on the default FTA reference levels. These noise levels may be lower depending on the actual usage and configuration of the actual facility. For this analysis, no shielding or other attenuation effects were applied for onsite buildings. The predicted noise impacts are shown graphically in **Figure 9-6** at the end of this report.

Since streetcars are designed to operate along narrow urban streets, the onset of wheel noise at tight-radius curves is not expected. However, at locations where conceptual design shows curve radii of less than 100 feet, careful attention is required during final design to minimize the potential for wheel squeal. There are three locations where the Streetcar Build Alternative curve radii would be less than 100 feet: Columbia Pike and Jefferson Street (85 feet), Columbia Pike and Joyce Street (94 feet), and access to the O&M facility at 12th and Eads Streets (85 feet). These radii are well above the typical vehicle manufacturer minimums of 60 feet.

The *moderate* noise impacts predicted at the hotel and high-rise apartment and office buildings adjacent to the proposed Pentagon City maintenance facility are located in an urban area with a background level of 66 dBA. Since there are no visible exterior land uses at these locations, interior noise levels would be lower due to the 25-35 dBA noise reduction provided by the windows. Therefore, no adverse interior noise effects are predicted at these locations due to the proposed maintenance facility.

Although L_{max} is used to develop L_{dn} noise levels, L_{max} can be better related to because it is the level that people actually hear. Maximum noise levels from streetcar passbys are predicted to range from 66 dBA at Receptor M1 (residences along South Eads Street) to 74 dBA at Receptor M2 (residences along Columbia Pike). Similarly, the L_{max} levels from stationary streetcars at stations are predicted to range from 43 dBA at Receptor M1 (residences along South Eads StreetColumbia Pike) to 49 dBA at Receptor M2 (residences along Columbia Pike). Maximum noise levels from the proposed O&M facility are predicted to range from below background at Receptors M1-M3 to 62 dBA at Receptor M1 (residences adjacent to the proposed Pentagon City maintenance facility).

9.4.4 FTA Vibration Assessment

Vibration impacts due to streetcar passbys are unlikely given the assumed travel speeds expected along the in-street running rail corridor. Furthermore, streetcars are generally lighter than typical light rail transit vehicles for which the FTA has developed reference ground-surface vibration curves. However, vibration impacts from streetcars due to steel wheel-on-steel rail interactions were evaluated using maximum corridor speeds.

In general, exceedances of the FTA vibration "annoyance" impact criterion of 72 VdB for *frequent* events occur at residences and other FTA Category 2 land-uses less than 5 feet from the proposed track alignment near stations to 45 feet at the maximum speed of 40 mph. However, in the vicinity of switches, vibration impacts occur at residences less than 55 feet near stations to 135 feet at the maximum speed of 40 mph. Track switches used in routine streetcar operations would be located near the terminus stops and at lead tracks to the proposed maintenance facility. Additional track switches used for emergency operations only would be located at one location near the middle of the alignment along Columbia Pike. All of the proposed switches would be used at very slow operating speeds, and no exceedances of the FTA vibration criteria are predicted along the project corridor under the proposed Streetcar Build Alternative.

9.4.5 Summary of Analysis

Based on the results of the noise and vibration modeling assessments, the following findings summarize the predicted impacts along the Columbia Pike Transit Initiative Corridor:

- FTA *moderate* noise impacts are predicted at 3 residential receptors and one office building under the Streetcar Build Alternative near the proposed Pentagon City O&M facility.
- No noise impacts are predicted at any parks or institutions (FTA Category 3 land-uses).
- Due to the urban land-uses along the project corridor, noise impacts are dominated by existing roadway traffic.
- No vibration impacts are predicted at any residences, parks or institutions under the Streetcar Build Alternative.

9.5 Minimization and Mitigation Measures

No *severe* impacts are predicted under the Streetcar Build Alternative. The text below describes measures that will be taken by the project sponsor to minimize and mitigate predicted *moderate* noise impacts and reduce the potential for other noise or vibration impacts.

During subsequent stages of design, efforts to minimize noise and vibration effects will focus on the following:

- Operations and maintenance facility: siting of facility equipment to minimize effects on adjacent uses; timing of heavy maintenance activities to minimize disruption; design of facility building to minimize transmission of noise and vibration.
- Track curves: coordinate track design and vehicle manufacturer requirements to minimize the potential for wheel squeal; during operation employ friction reducing measures.

If the Streetcar Build Alternative is selected as the Locally Preferred Alternative and advanced to implementation and operation, noise and vibration levels will be monitored and any impacts addressed through additional mitigation.

Figure 9-6: Predicted Noise Impacts under the Streetcar Build Alternative