KC Downtown Streetcar

APPENDIX C: NOISE AND VIBRATION TECHNICAL MEMORANDUM

Kansas City Downtown Streetcar Project

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DATE: September 21, 2012

SUBJECT: **Kansas City Downtown Streetcar Project: Noise and Vibration Technical Memorandum**

1. INTRODUCTION

This memorandum presents the results of an assessment of noise and vibration effects that would result from the proposed Kansas City Downtown Streetcar Project. The assessment followed the guidance for a General Noise Assessment and a General Vibration Assessment according to the guidance in *Transit Noise and Vibration Impact Assessment* report (FTA-VA-90-1003-06) adopted by the Federal Transit Administration in 2006.

1.1 The Proposed Action

The Kansas City Downtown Streetcar Project is proposed for the downtown core of Kansas City, Missouri. The project would include new capital improvements necessary to implement streetcar service generally operating northbound and southbound on Main Street. The study area extends from the City Market and Columbus Park areas on the north, through the Central Business District, Power & Light District, and Crossroads Arts District, to Union Station and Crown Center on the south. The City of Kansas City, Missouri anticipates beginning construction of the project in 2013 with streetcar service proposed to begin in April 2015.

1.2 Noise

Noise is unwanted or undesirable sound. Sound travels through the air as waves of tiny air pressure fluctuations caused by vibration. The intensity or loudness of a sound is determined by how much the sound pressure fluctuates. For convenience, sound pressure is expressed in decibel (dB) notation.

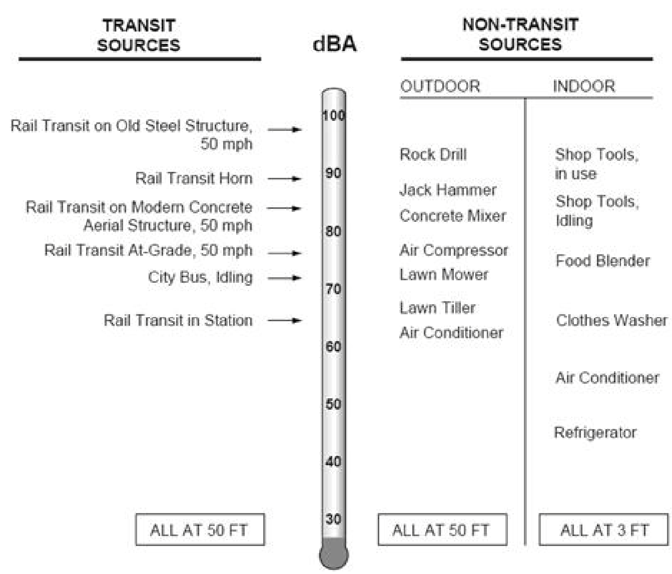


Figure 1, Typical Noise Levels

Most sounds consist of a broad range of sound frequencies, from low frequencies to high frequencies. The average human ear does not perceive all frequencies equally. Therefore, the A-weighting scale was developed to approximate the way the human ear responds to sound levels; it mathematically applies less "weight" to frequencies we do not hear well, and applies more "weight" to frequencies we do hear well. Typical A-weighted noise levels for various types of sound sources are summarized in Figure 1.

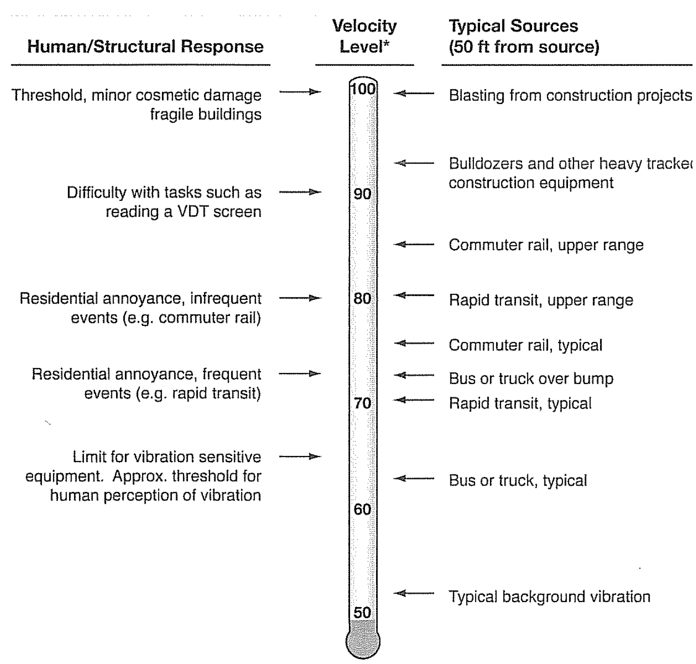
The equivalent average sound level (L_{eq}) is often used to describe sound levels that vary over time, usually a one-hour period. The L_{eq} is often described as the constant sound level that is an equivalent exposure level to the actual time-varying sound level over the period (hour). Using twenty-four consecutive 1 hour L_{eq} values it is possible to calculate daily cumulative noise exposure. A common community noise rating is the Day-Night Average Sound Level (DNL or L_{dn}). The L_{dn} is the 24-hour L_{eq} but includes a 10-dBA penalty on noise that occurs during the nighttime hours (between 10 p.m. and 7a.m.) where sleep interference might be an issue. The 10-dBA penalty makes the L_{dn} useful when assessing noise in residential areas, or land-uses where overnight sleep occurs.

1.3 Vibration

Vibration consists of rapidly fluctuating motions. However, human response to vibration is a function of the average motion over a longer (but still short) time, such as one second. The root mean square (RMS) amplitude of a motion over a one-second period is commonly used to predict human response to vibration. For convenience, decibel notation is used to describe vibration relative to a reference quantity. The FTA has adopted the notation VdB (for vibration decibels), which is decibels relative to a reference quantity of one microinch per second (10^{-6} in/s).

Ground-borne vibration (GBV) can be a serious concern for residents or at facilities that are vibration-sensitive, such as laboratories or recording studios. The effects of ground-borne vibration include perceptible movement of building floors, interference with vibration sensitive instruments, rattling of windows, and the shaking of items on shelves or hanging on walls. Additionally GBV can cause the vibration of room surfaces resulting in ground-borne noise (GBN). Ground-borne noise is typically perceived as a low frequency rumbling sound.

In contrast to airborne noise, ground-borne vibration is not an everyday experience for most people. The background vibration level in residential areas is usually 50 VdB or lower—well below the threshold of perception for humans, which is around 65 VdB. Levels at which vibration interferes with sensitive instrumentation can be much lower than the threshold of human perception, such as for medical imaging equipment or extremely high-precision manufacturing. Most perceptible indoor vibration is caused by sources within a building such as the operation of mechanical equipment, movement of people, or slamming of doors. Typical outdoor sources



* RMS Vibration Velocity Level in VdB relative to 10^{-6} inches/second

of perceptible ground-borne vibration are construction equipment, steel-wheeled trains, and traffic on rough roads, though in most soils GBV dissipates very rapidly. Figure 2 illustrates common vibration sources and the human and structural response to ground-borne vibration.

2. REGULATORY SETTING

2.1 FTA Noise and Vibration Assessment Guidelines

The FTA published guidance in *Transit Noise and Vibration Impact Assessment* (FTA, 2006). The guidance includes noise and vibration assessment methods and impact thresholds.

FTA Noise Evaluation Criteria

The FTA noise impact criteria are used to predict future noise impacts from transit operations. FTA noise impact thresholds are a function of land use and existing noise exposure. The FTA differentiates noise-sensitive land uses into three distinct categories.

- **Category 1:** Tracts of land where quiet is an essential element in their intended purpose.
  - Lands set aside for serenity and quiet
  - Outdoor amphitheaters and concert pavilions
  - National historic landmarks with significant outdoor use
  - Recording studios and concert halls
- **Category 2:** Residences and buildings where people normally sleep.
  - Homes, hospitals, and hotels where a nighttime sensitivity to noise is assumed to be of utmost importance.
- **Category 3:** Institutional land uses with primarily daytime and evening use.
  - Schools, libraries, and churches where it is important to avoid interference with activities such as speech, meditation, and concentration on reading material.
  - Places for meditation or study associated with cemeteries, monuments, museums, campgrounds and recreational facilities.
  - Certain historical sites and parks.

Historic buildings and parks are a special case. For historic buildings, noise-sensitivity is determined by the current land-use, not the historic land-use. For instance, a historic house used as a commercial shop is not considered noise-sensitive, whereas a historic warehouse converted to multi-unit residences is noise-sensitive in Category 2. Parks that are used for passive recreation such as reading, meditation or sedate conversation are noise sensitive Category 3 land-uses, whereas parks used for active recreation such as sporting fields, playgrounds, or areas where social groups gather are not considered noise-sensitive.

The L_{dn} descriptor is used to assess transit-related noise for residential areas and land uses where overnight sleep occurs (Category 2). The L_{eq} descriptor is used to assess transit-related noise at other noise-sensitive land uses (Category 1 and Category 3), specifically during the noisiest hour of transit-related activity concurrent with the receptors' hours of noise sensitivity. The FTA noise impact criteria are shown in Figure 3. The figure illustrates existing noise exposure and project-related noise exposure, and shows how FTA noise impact thresholds vary with existing noise levels.

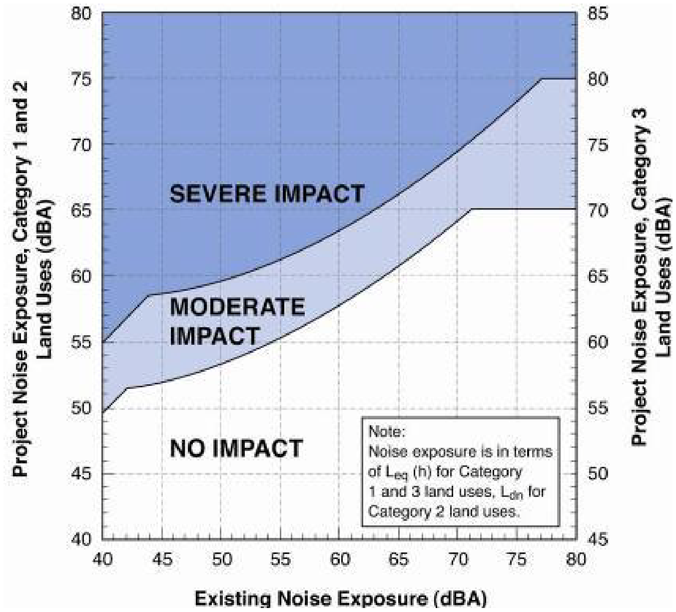


Figure 3, Noise Impact Thresholds

Two degrees of noise impacts are included in the FTA criteria. The degree of impact affects whether noise mitigation is investigated or implemented.

- **Severe Impact:** A significant percentage of people are highly annoyed by noise in this range. Noise mitigation would normally be specified for severe impact areas unless it is not feasible or reasonable (unless there is no practical method of mitigating the impact).
- **Moderate Impact:** In this range, other project-specific factors are considered to determine the magnitude of the impact and the need for mitigation. Other factors include the predicted increase over existing noise levels, the types and number of noise-sensitive land uses affected, existing outdoor-indoor sound insulation, and the cost-effectiveness of mitigating noise to more acceptable levels.

<u>FTA Vibration Evaluation Criteria</u>

The FTA vibration impact criteria are used to predict future vibration impacts from transit operations. FTA identifies separate criteria for both ground-borne vibration (GBV) and ground-borne noise (GBN). Ground-borne noise is often masked by airborne-noise; therefore, ground-borne noise criteria are primarily applied to subway operations in which airborne noise is negligible.

The FTA differentiates vibration-sensitive land uses into three distinct categories; similar but not identical to the noise-sensitive land-use categories. These categories are one factor for setting the vibration impact threshold.

- **Category 1:** High Vibration Sensitivity.
  - Buildings where ambient vibration well below levels associated with human annoyance is essential for equipment or operations within the building.
  - Typically includes vibration-sensitive research and manufacturing facilities, hospitals, and university research operations.
- **Category 2:** Residential.
  - Includes all residential land uses and any building where people sleep, such as hotels and hospitals.

- **Category 3:** Institutional.
  - Schools, churches, other institutions, and quiet offices that do not have vibration-sensitive equipment, but still have the potential for activity interference.
  - Certain office buildings, but not all buildings that have office space.

The Category 1 vibration impact threshold is acceptable for most moderately sensitive equipment; other highly sensitive equipment would each require a detailed analysis to determine the acceptable vibration levels, and the effect of the Project on the equipment. In any case, there are no GBN impact thresholds for these type of Category 1 land-uses because equipment sensitive to GBV is generally not sensitive to GBN. However, there are other special Category 1 land-uses, such as concert halls, television and recording studios, and theaters, which can be very sensitive to both GBV and GBN. The FTA has developed special vibration impact thresholds for these land uses.

The basis for evaluating FTA vibration impact thresholds is the highest expected RMS vibration levels for repeated vibration events from the same source. The thresholds are differentiated between vibration sensitive land uses and the frequency of the events.

- **Frequent Events:** More than 70 vibration events per day. Most rapid transit projects fall into this category.
- **Occasional Events:** Between 30 and 70 vibration events of the same source per day. Most commuter trunk lines have this many operations.
- **Infrequent Events:** Fewer than 30 vibration events per day. This category includes most commuter rail branch lines.

There are 198 expected train pass-by events on weekdays (99 trains each direction). Therefore, only the vibration impact thresholds for "Frequent Events" need be considered for this project. Table 1 shows the GBV and GBN impact thresholds for Categories 1, 2 and 3 experiencing frequent vibration events.

Table 1
Ground-borne Noise and Vibration Impact Thresholds

Land Use Category	GBV Impact thresholds For Frequent Events (VdB re. 1 µin/s)	GBN Impact thresholds For Frequent Events (dBA re. 20 µPa)
Category 1	65 VdB	N/A
Concert Halls	65 VdB	25 dBA
TV Studios	65 VdB	25 dBA
Recording Studios	65 VdB	25 dBA
Auditoriums	72 VdB	30 dBA
Theaters	72 VdB	35 dBA
Category 2	72 VdB	35 dBA
Category 3	75 VdB	40 dBA

2.2 Local Noise Regulations

This analysis assumed that operation of the proposed project is not subject to local noise regulations.

3. NOISE AND VIBRATION ASSESSMENT METHODS

The noise assessment and the vibration assessment were conducted according to the General Assessment methods in *Transit Noise and Vibration Impact Assessment* (FTA, 2006). Receptor identification for both noise-sensitive and vibration-sensitive land uses included a review of land use-related GIS data, windshield surveys and a review of digital aerial photographs. Receptors in the study area were identified and categorized for noise-sensitive land uses and vibration-sensitive land uses according to FTA categories.

3.1 Noise Impact Assessment Methods

In overview, the noise assessment consists of the following general steps:

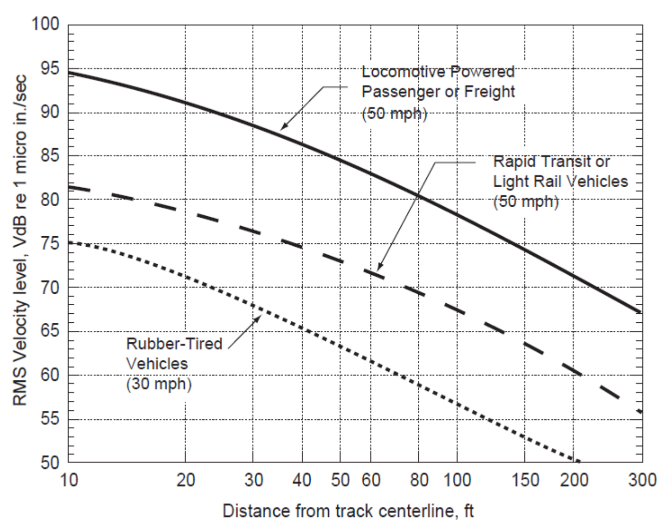
1. Establish the study area and identify noise-sensitive land-uses.
2. Evaluate the existing conditions and set corresponding impact thresholds.
3. Calculate the noise emission levels of project-related sources.
4. Calculate the propagation of noise from the project-related sources to the impact thresholds.
5. Identify receptors anticipated to experience moderate noise impacts or severe noise impacts.

The FTA provides a method for calculating the noise emission of transit-related noise sources and the propagation from the source to a receptor. This assessment for the project-related noise sources included wayside noise from the streetcar, which is a combination of wheel-rail rolling noise and propulsion source, as well as the noise from the streetcar rolling over track turnouts. It also included several alternative locations for Traction Power Substations (TPSS) and three alternatives for the Vehicle Maintenance Facility (VMF). There are no audible crossing signals proposed for this project.

3.2 Vibration Impact Assessment Methods

In overview, the vibration assessment consists of the following general steps:

1. Establish the study area and identify vibration-sensitive land-uses.
2. Evaluate the traffic conditions and set corresponding impact thresholds.
3. Select the base generalized vibration curve and apply appropriate adjustments.
4. Determine the propagation from project-related vibration sources to the impact thresholds.
5. Identify receptors anticipated to experience vibration impacts.



The FTA generalized vibration curve for rapid transit or light rail vehicles was used as the base curve for the GBV and GBN assessments. Figure 4 illustrates the generalized ground surface vibration curves defined by FTA. Adjustments factors used to develop vibration propagation prediction included corrections for speed, track configuration, distance, geologic conditions, and building/foundation type.

Soil and subsurface conditions are known to have a strong influence on the levels of GBV. Vibration propagation is generally more efficient in stiff, clay-type soils than in loose, sandy soils and at-grade track when the depth to bedrock is 30 feet or less. Soil layering and the depth to the water table can also affect GBV, but the effects are not always predictable and are not well established. (FTA/Hanson, et. al 2006). As a conservative assessment, soils in the project area were assumed to be efficient at transmitting vibration.

4. AFFECTED ENVIORNMENT

4.1 Noise-Sensitive Land Uses

The Kansas City Downtown Streetcar Project study area lies along Main Street in Kansas City, Missouri, which is an urban transportation corridor. Land use throughout the project area is largely commercial and retail with residential, mixed use, industrial and other institutional (e.g., medical) land uses scattered throughout the area. Existing data sources were reviewed for the Project study area in order to help identify individual land uses. A windshield survey was conducted on May 30, 2012, to visually assess the existing conditions within the Project study area and to document individual land uses and structures within the study area. The project team identified noise-sensitive land uses in the project area that could potentially be affected by project-related noise. Predominantly urban land uses are typically associated with fairly noisy background noise levels, and that is the case here. Existing noise levels in the project area are dominated by transportation noise (i.e., roadway traffic noise).

4.2 Baseline Noise Conditions

Existing noise levels were measured at six noise-sensitive receptor locations located throughout the project area. These areas are representative of portions of the project area that were expected to be affected by project-related streetcar traffic. The sound level meters were configured to continuously measure ambient noise levels in dBA, and to store data at the end of each hour for 24 continuous hours. Table 2 summarizes the noise monitoring data in the project vicinity.

Table 2
Existing Noise Levels

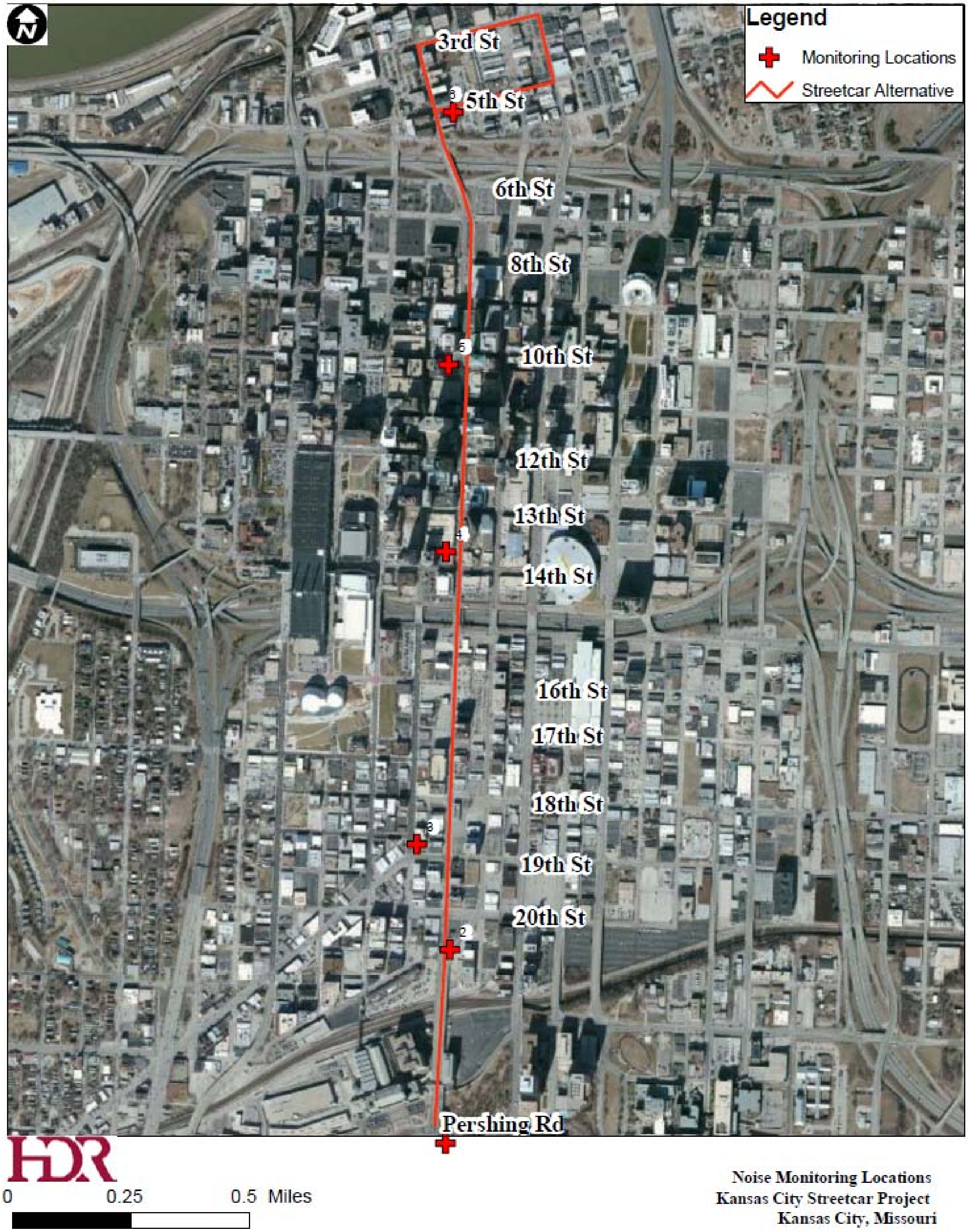
Noise Monitoring Locations	Existing Noise Levels		
	Day-Night Rating (L_{dn}, dBA)	Quietest Hour (L_{eq}, dBA)	Noisiest Hour (L_{eq}, dBA)
1 – Westin Crown Center	59	45	61
2 – Recording Studios	73	57	77
3 – 1819 Lofts	66	53	68
4 – Hilton President Hotel	70	63	67
5 – Hanover Lofts	71	54	70
6 – DE Lofts	57	45	55

Figure 4, Generalized Ground Surface Vibration Curves

Table 3 presents the noise impact thresholds determined based on the existing noise levels measured in the study area. Figure 5 shows the noise monitoring locations and the proposed alignment.

Table 3
Noise Impact Thresholds

Track Segment	Impact Threshold Leq (dBA)					
	Cat 1 Mod	Cat 1 Sev	Cat 2 Mod	Cat 2 Sev	Cat 3 Mod	Cat 3 Sev
1 – Westin Crown Center	58	64	57	63	63	69
2 – Recording Studios	65	75	65	72	70	80
3 – 1819 Lofts	63	68	61	67	68	73
4 – Hilton President Hotel	62	67	64	69	67	72
5 – Hanover Lofts	64	69	65	70	69	74
6 – DE Lofts	55	61	56	62	60	66



HDR

Noise Monitoring Locations
Kansas City Streetcar Project
Kansas City, Missouri

Figure 5, Ambient Noise Monitoring Locations

5. ENVIRONMENTAL CONSEQUENCES

5.1 Projected Noise Effects from the Streetcar Alternative

Projected noise effects were estimated using the FTA's General Noise Assessment methods. The streetcar operational noise was projected from the combination of normal wheel-rail rolling noise plus the noise due to wheels rolling over track turnouts or crossovers. In addition, noise from eight alternative TPSS locations, and three alternative VMF locations was evaluated. All assumptions for noise assessment calculations are based upon FTA methods, with one exception. This analysis assumes that proposed TPSS includes the use of transformers that not to exceed a sound pressure level of 60 dBA as measured at 50 ft from the transformer.

Streetcars would operate in the street and would be controlled by operators using existing and proposed traffic signals. Therefore, audible warning signals were not evaluated in this noise assessment.

The analysis calculated the distance to the noise impact thresholds in accordance with section 5.5 (Determining Noise Impact Contours) in the FTA guidance manual. Using GIS, it was evaluated whether or not there were any noise-sensitive land uses within those calculated distances. Table 4 presents the results of that noise impact assessment for segments that will experience two-way streetcar traffic. Values for the noise impact contours are rounded to the nearest 5 feet.

Table 4
General Noise Assessment Results for Two-way Streetcar Traffic

Track Segment	Unshielded Impact Contour Distance						Impacts inside contour ?
	Cat 1 Mod (ft)	Cat 1 Sev (ft)	Cat 2 Mod (ft)	Cat 2 Sev (ft)	Cat 3 Mod (ft)	Cat 3 Sev (ft)	
1 – Westin Crown Center	10 ft	5 ft	20 ft	10 ft	5 ft	<5 ft	No
2 – Recording Studios	<5 ft	<5 ft	5 ft	<5 ft	<5 ft	<5 ft	No
3 – 1819 Lofts	5 ft	<5 ft	10 ft	<5 ft	<5 ft	<5 ft	No
4 – Hilton President Hotel	5 ft	<5 ft	5 ft	<5 ft	<5 ft	<5 ft	No
5 – Hanover Lofts	<5 ft	<5 ft	5 ft	<5 ft	<5 ft	<5 ft	No
6 – DE Lofts	20 ft	10 ft	20 ft	10 ft	10 ft	<5 ft	No

Table 5 presents the results of the noise impact assessment for the segment that will experience one-way streetcar traffic.

Table 5
General Noise Assessment Results for One-way Streetcar Traffic

Track Segment	Unshielded Impact Contour Distance						Impacts inside contour ?
	Cat 1 Mod (ft)	Cat 1 Sev (ft)	Cat 2 Mod (ft)	Cat 2 Sev (ft)	Cat 3 Mod (ft)	Cat 3 Sev (ft)	
6 – DE Lofts	10 ft	5 ft	15 ft	5 ft	5 ft	<5 ft	No

Table 6 presents the results of the noise impact assessment for segments that will experience noise from the OMF leader track.

Table 6
General Noise Assessment Results for OMF Leader Track

Track Segment	Unshielded Impact Contour Distance						Impacts inside contour?
	Cat 1 Mod (ft)	Cat 1 Sev (ft)	Cat 2 Mod (ft)	Cat 2 Sev (ft)	Cat 3 Mod (ft)	Cat 3 Sev (ft)	
6 – DE Lofts	<5 ft	<5 ft	5 ft	<5 ft	<5 ft	<5 ft	No

Table 7 presents the results of the noise impact assessment for segments that will experience noise from crossovers and turnout frogs.

Table 7
General Noise Assessment Results for Crossovers and Turn-outs

Track Segment	Unshielded Impact Contour Distance						Impacts inside contour?
	Cat 1 Mod (ft)	Cat 1 Sev (ft)	Cat 2 Mod (ft)	Cat 2 Sev (ft)	Cat 3 Mod (ft)	Cat 3 Sev (ft)	
1 – Westin Crown Center	125 ft	75 ft	160 ft	95 ft	80 ft	45 ft	No
6 – DE Lofts	65 ft	25 ft	75 ft	40 ft	40 ft	15 ft	No

Table 8 presents the results of that noise impact assessment for segments that will experience noise from TPSS.

Table 8
General Noise Assessment Results for TPSS

Track Segment	Unshielded Impact Contour Distance						Impacts inside contour?
	Cat 1 Mod (ft)	Cat 1 Sev (ft)	Cat 2 Mod (ft)	Cat 2 Sev (ft)	Cat 3 Mod (ft)	Cat 3 Sev (ft)	
1 – Westin Crown Center	60 ft	35 ft	85 ft	50 ft	40 ft	25 ft	No
2 – Recording Studios	35 ft	15 ft	40 ft	25 ft	20 ft	10 ft	No
3 – 1819 Lofts	40 ft	25 ft	60 ft	35 ft	25 ft	15 ft	No
4 – Hilton President Hotel	40 ft	25 ft	45 ft	30 ft	25 ft	15 ft	No
5 – Hanover Lofts	35 ft	20 ft	40 ft	25 ft	20 ft	15 ft	No
6 – DE Lofts	80 ft	45 ft	95 ft	55 ft	50 ft	30 ft	No

Table 9 presents the results of the noise impact assessment for segments that will experience noise from the proposed OMF.

Table 9
General Noise Assessment Results for OMF

Track Segment	Unshielded Impact Contour Distance						Impacts inside contour ?
	Cat 1 Mod (ft)	Cat 1 Sev (ft)	Cat 2 Mod (ft)	Cat 2 Sev (ft)	Cat 3 Mod (ft)	Cat 3 Sev (ft)	
6 – DE Lofts	<5 ft	<5 ft	225 ft	135 ft	<5 ft	<5 ft	No

General Noise Assessment results indicate there would be no moderate or severe noise impacts at any noise-sensitive receptor due to proposed streetcar operations, TPSS locations, or VMF alternatives C, D or E.

5.2 Projected Vibration Effects from the Streetcar Alternative

Projected GBV effects were estimated using the General Vibration Assessment method based upon FTA guidance. The GBV due to streetcar operation was projected from the combination of normal wheel-rail rolling vibration plus the GBV due to wheels rolling over track turnouts or crossovers. For purposes of the vibration assessment, the operating speed at passenger stations was assumed not to exceed 14 mph. In addition, while substations generate some noise, they do not generate GBV and therefore TPSS locations were not assessed.

General Vibration Assessment results indicate there would be no ground-borne noise or ground-borne vibration impacts at any vibration-sensitive receptor due to proposed streetcar operations.

5.3 Construction Noise and Vibration Levels

The construction of the proposed project could result in temporary noise and vibration increases within and adjacent to the project area. The construction equipment which generate noise and vibration would primarily be heavy machinery and vehicles related to construction activities. Noise and vibration levels during construction vary depending upon the construction phase, the location of the construction activities, and the movement of construction equipment. Construction would likely occur during normal working hours, which are generally considered to be "noise and vibration tolerant" periods. Construction contractors need to be aware of local noise ordinances to assure compliance. Potential noise and vibration effects during the construction phase of the project would be temporary.

6. SUMMARY

6.1 No Build Alternative

There would be no project related noise or vibration effects with the no build alternative because there would be no new construction or operations of transit improvements. Ambient noise levels would likely continue to increase as traffic levels increase in the study area.

6.2 Summary of Noise Analysis for the Streetcar Alternative

Noise impacts from project-related noise sources were evaluated using current FTA General Noise Assessment guidelines. Existing noise levels were measured at representative locations within the project study area. Project-related noise sources were evaluated to determine the potential for noise impacts based on FTA impact thresholds.

The results of the analysis are as follows:

- Existing noise levels in the project area are loud and are dominated by transportation noise (i.e., roadway traffic noise), which is typical of the predominantly urban land uses found in the project area.
- General noise assessment results indicate there would be no noise impacts at any noise-sensitive receptor due to operation of the streetcar alternative.
- Construction noise may affect certain receptors near to the construction activity, but noise effects would be temporary and would normally occur during "noise and vibration tolerant" periods of the day.

6.3 Summary of Vibration Analysis for the Streetcar Alternative

Impacts from project-related vibration sources were assessed using current FTA General Vibration Assessment methods. The vibration propagation was calculated to determine the receptors that would experience an impact, according to FTA impact thresholds.

The results of the analysis are as follows:

- General assessment results indicate there would be no impacts at any noise-sensitive receptor due to GBV from the Streetcar Alternative.
- Construction vibration may affect certain receptors near to the construction activity, but vibration effects would be temporary and would normally occur during "noise and vibration tolerant" periods of the day.

Environmental Assessment

APPENDIX

FTA GENERAL NOISE ASSESSMENT CALCULATIONS