SOUTH FLORIDA EAST COAST
CORRIDOR TRANSIT ANALYSIS STUDY

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Phase 2 Vibration Technical Memorandum

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Date: May 21, 2010

Subject: South Florida East Coast Corridor Transit Analysis (SFECCTA) Study: Vibration Technical Memorandum

This technical memorandum presents analyses based on an initial set of operating assumptions. As the TSM, BRT and rail alternatives were refined, service frequencies were reduced. Since the changes in proposed operations were reductions, we concluded that the vibration analysis as presented remains an accurate assessment by which to support the conclusion of the AA Report's comparative analysis between alternatives.

INTRODUCTION

Purpose

The purpose of this technical memorandum is to outline the methods used to identify resources that could be affected by vibration associated with various alternatives and subsequent results. The results of this analysis were incorporated into the Environmental Screening Model and published in the Draft Detailed Environmental Screening Report (ESR).

Project Description

The Florida Department of Transportation (FDOT) initiated the multi-phased South Florida East Coast Corridor Transit Analysis (SFECCTA) study in December 2005 recognizing that the Florida East Coast (FEC) Railway was and is a unique transportation asset that should be evaluated and developed in the context of regional transportation issues, priorities and needs. The SFECCTA study is designed to evaluate the reintroduction of passenger service along a portion of the FEC Railway corridor from Miami to Jupiter. In its second phase, the SFECCTA study continued the Alternative Analysis (AA) – Early Scoping process that was initiated in Phase 1. A discussion of the Phase 1 AA may be found in the Phase 1 Conceptual Alternatives Analysis/Environmental Screening Report (AA/ESR) on the project website (http://www.sfeccstudy.com/).

Phase 2 of the SFECCTA was initiated in January 2009 and was designed to build upon the Phase 1 AA to refine and further develop through an iterative process the alternatives identified at the conclusion of the first phase. The primary focus of Phase 2 was to identify a locally preferred alternative (LPA) within the study area, in accordance with Federal Transit Administration (FTA) and FDOT project development processes, that could ultimately be submitted to FTA for federal assistance in the form of New Starts funding. The Phase 2 Draft ESR has been prepared to describe the detailed environmental screening approach conducted as part of the Phase 2 AA and is supported by a series of technical memoranda and reports like the one presented here.

Project Area

The SFECCTA project area, illustrated on the Project Location Map (**Figure 1**), is bounded on the south by

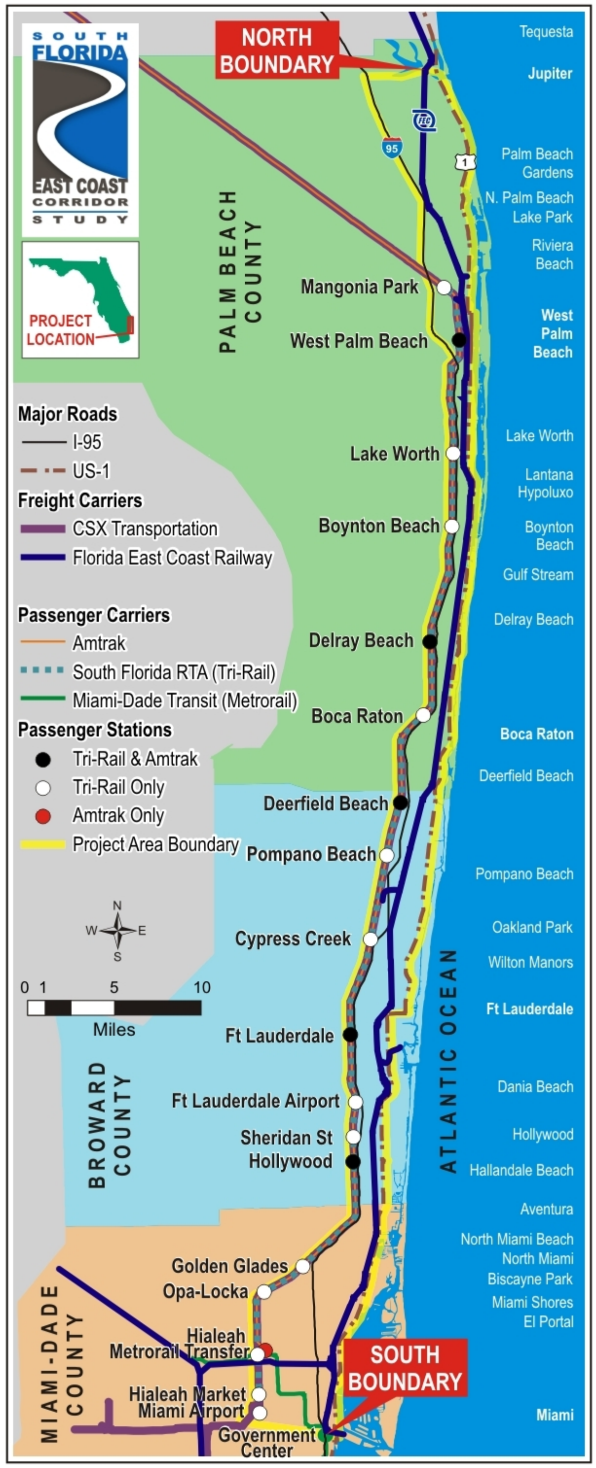
Flagler Street, just south of the Miami-Dade Government Center, in the City of Miami and on the north by the southern shoreline of the Loxahatchee River in the Town of Jupiter.

The western boundary of the project area runs parallel to and 0.5-mile west of the South Florida Rail Corridor (SFRC)/Tri-Rail corridor from the Miami Intermodal Center (MIC) north to Mangonia Park then continues in a northwesterly direction parallel to and 0.5-mile west of I-95 to the southern shoreline of Southwest Fork of the Loxahatchee River (C-18). The eastern boundary of the project area runs parallel to and 0.5-miles east of Highway US-1 from the Central Business District (CBD) of the City of Miami north to the southern shoreline of the Loxahatchee River in Jupiter.

Within the SFECCTA *project area* are several unique *study areas* that were developed specifically to define the affected environment and screen/evaluate the various project alternatives. Generally, the affected environment is a Geographic Information System (GIS) inventory of environmental, social, and cultural resources that could be affected by the proposed improvements. The affected environment and screening process are defined and documented in the Draft ESR.

The primary study area, where most of the improvements are expected to occur, is the FEC Railway corridor that extends from the CBD of the City of Miami north to the Town of Jupiter in Palm Beach County (a linear distance of approximately 83 miles). A detailed description of each study area and environmental screening methodology is provided in Chapter 3 and Appendix A, respectively, of the Draft ESR.

Figure 1: Project Location Map



Ground-Borne Vibration

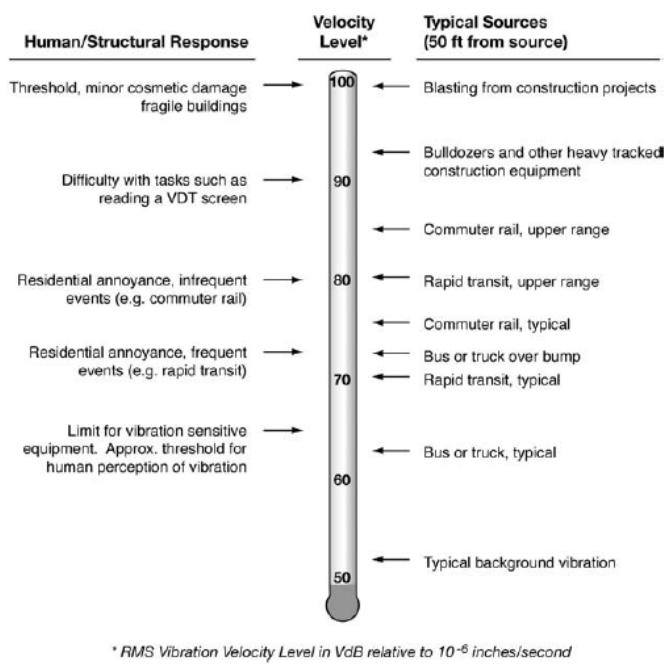
Ground-borne vibration is the oscillatory motion of the ground about some equilibrium position that can be described in terms of displacement, velocity, or acceleration.

Because sensitivity to vibration typically corresponds to the amplitude of vibration velocity within the low-frequency range of most concern for environmental vibration (roughly 5-100 Hz), velocity is the preferred measure for evaluating ground-borne vibration from rail projects.

Vibration consists of rapidly fluctuating motions with an average motion of zero. Several descriptors can be used to quantify vibration amplitude. The most common measure used to quantify vibration amplitude is the peak particle velocity (PPV), defined as the maximum instantaneous peak of the vibratory motion. PPV is typically used in monitoring blasting and other types of construction-generated vibration, since it is related to the stresses experienced by building components. Although PPV is appropriate for evaluating building damage, it is less suitable for evaluating human response, which is better related to the average vibration amplitude. In a sense, the human body responds to average vibration amplitude. Because the net average of a vibration signal is zero, the root mean square (rms) vibration velocity level, in decibels (VdB), is used to describe the "smoothed" vibration amplitude. Thus, ground-borne vibration levels will be stated in units of vibration decibels (VdB). This unit is equivalent to a velocity of one micro-inch per second (10-6 in./sec.). This is not a universally accepted notation. However, it is used throughout the FTA Guidance manual to reduce the possibility of confusion with sound decibels.

Figure 2 illustrates typical ground-borne vibration levels for common sources, as well as criteria for human and structural response to ground-borne vibration. As shown, the range of interest is from approximately 50 to 100 VdB, from imperceptible background vibration to the threshold of damage. Although the approximate threshold of human perception to vibration is 65 VdB, annoyance is usually not significant unless the vibration exceeds 70 VdB.

Figure 2 Typical Ground-Borne Vibration Levels



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

Criteria for Ground-Borne Vibration

The FTA ground-borne vibration impact criteria are based on land use and train frequency, as shown in **Table 1**. Vibration sensitive receptors are classified in three categories. Category 1 receptors are those buildings where interior activities or operations are sensitive to vibration and would be interfered with by any increase above low ambient vibration levels. An example of a Category 1 receptor is a building in which research using electron microscopes is conducted. Category 2 receptors consist of single-family residences as well as apartment or townhouse buildings. Category 3 receptors include churches, schools and other commercial buildings that do not house vibration sensitive equipment. Industrial buildings that are mainly used for manufacturing are not included in this category.

Table 1: Ground-Borne Vibration Impact Criteria

Land Use Category	Ground-Borne Vibration Impact Levels (VdB re 1 micro inch/sec)		
	Frequent Events[1]	Occasional Events[2]	Infrequent Events[3]
Category 1: Buildings where vibration would interfere with interior operations.	65 VdB[4]	65 VdB[4]	65 VdB[4]
Category 2: Residences and buildings where people normally sleep.	72 VdB	75 VdB	80 VdB
Category 3: Institutional land uses with primarily daytime use.	75 VdB	78VdB	83 VdB

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

Notes:

1. "Frequent Events" is defined as more than 70 vibration events of the same source per day. Most rapid transit projects fall into this category.

2. "Occasional Events" is defined as between 30 and 70 vibration events of the same source per day. Most commuter trunk lines have this many operations.

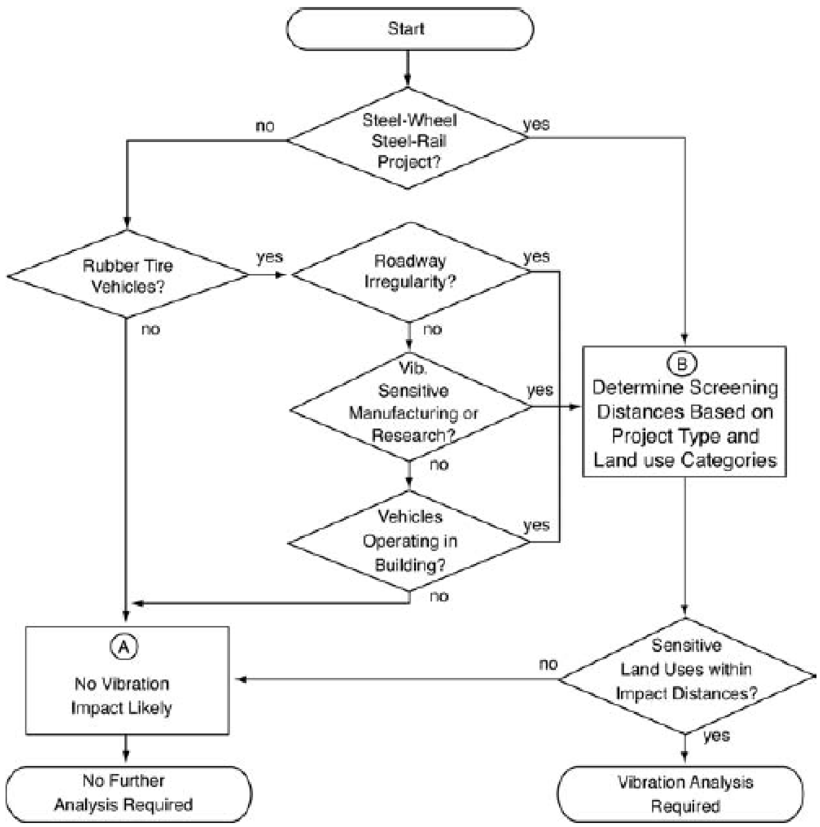
3. "Infrequent Events" is defined as fewer than 30 vibration events of the same kind per day. This category includes most commuter rail branch lines.

4. This criterion limit is based on levels that are acceptable for most moderately sensitive equipment such as optical microscopes. Vibration sensitive manufacturing or research will require detailed evaluation to define the acceptable vibration levels. Ensuring lower vibration levels in a building often requires special design of the HVAC systems and stiffened floors.

Methodology

The FTA recommends the following screening procedure to determine if there is a likelihood of vibration impact from a project. The vibration screening procedure defined by the FTA follows the flowchart shown in **Figure 3**.

Figure 3: Flow Chart of Vibration Screening Process



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

The screening distance referred to in Box B of **Figure 3** is 200 feet for Category 2 receivers (residential), according to the FTA guidelines. This means, according to FTA, in the absence of measurements or in-situ testing it is safe to assume that vibration levels beyond 200 feet from the track will not cause an impact to residential locations. Based on a Geographic Information System (GIS) analysis and field trips to the South Florida section of project, residences have been identified within 200 feet from the FEC Railway.

No Build Alternative

There are significant sources of existing ground-borne vibration along the project corridor from West Palm Beach to Miami, FL primarily from the operation of freight trains along the FEC Railway and passenger/freight trains along the SFRC. In-situ testing within the study area has been conducted to assess vibration levels caused by commuter and freight train operations. Existing vibration levels were measured and used as a baseline to predict potential future vibration levels in the corridor.

The FEC Railway is primarily used for heavy freight transport of containers, gravel and other heavy loads. These long freight trains make up the existing heavy freight operations the dominant vibration source on this line. The heavy freight operations typically include eighteen operations per day as of the latest figures provided by the FEC rail operators. In addition, the freight operator (CSX) and the South Florida Rail Transit Authority (SFRTA) share a rail corridor west of I-95. Passenger conventional commuter rail (Tri-Rail) and freight rail operates on this corridor with several heavy freight operations and fifty roundtrip passenger rail operations per day.

Figure 4 depicts the summary data of heavy freight FEC operations measured in South Florida. The FEC heavy freight operations were measured and found to produce vibration levels of approximately 95 VdB at 130 feet from the track, while **Figure 5** depicts the summary data of Tri-Rail passenger operations measured in South Florida.

Figure 4: Heavy Freight Vibration Levels along the FEC Railway Corridor

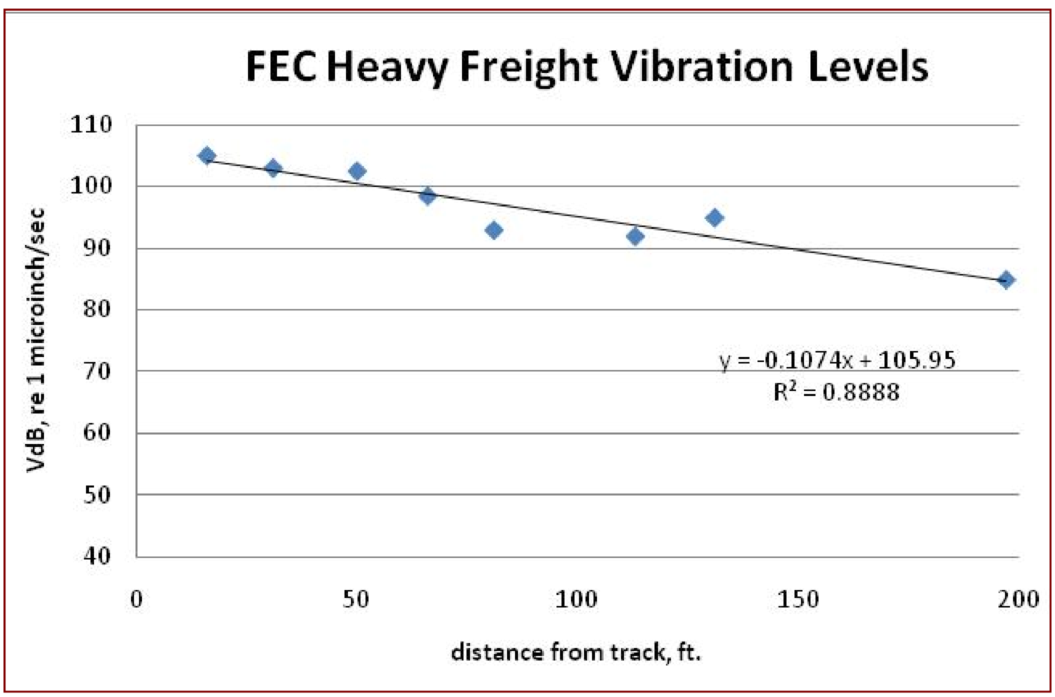
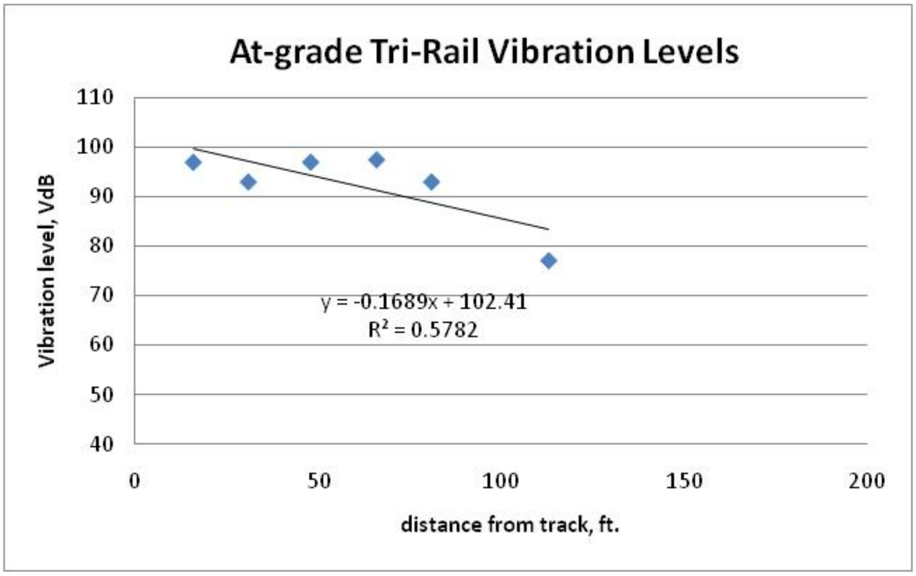


Figure 5: Tri-Rail Passenger Vibration Levels along the Tri-Rail Railway Corridor



Transportation System Management (TSM) Alternative

According to the FTA manual, measured background vibration levels and available future bus operation information are required to evaluate the TSM Alternative. An evaluation was performed to determine buffer distances that were incorporated into GIS to determine the number of parcels that could be potentially affected by the TSM alternative.

The bus fleet maximum speed was assumed to be 60 mph and would consist of 160 buses between 7:00 a.m. and 10:00 p.m., and 36 buses between 10:00 p.m. and 7:00 a.m. Based on the FTA guidance manual, the future buffer distances were calculated for Category 2 and 3 land uses and the results are shown in **Table 2**.

Table 2: Vibration Buffer Distance and Potentially Affected Parcels by Land Use Category

Type of Technology	*Buffer Distance (Feet)/Affected Parcels*	
	Category 2	*Category 3*
Regional Bus	50/0	0/0

Modally Generic Alternatives

Phase 2 of the SFECCTA study, has screened alternatives and a series of modally generic alternatives were developed and analyzed. The term “Modally Generic” means that a consistent generic transit mode, or vehicle type, was used for transit ridership transit planning modeling purposes. These alternatives were designed primarily to explore the different characteristics of transit services such as maximum speed, number of station stops, fare, park-and-ride access, and service frequency. These five premium modal technologies are:

- Regional Rail Transit (RGR)
- Light Rail Transit (LRT)
- Rail Rapid Transit (RRT)
- Bus Rapid Transit (BRT)
- Regional Bus (RGB)

According to the FTA manual, measured background vibration levels and available future operation characteristics are required to evaluate the different transit technology alternatives. Vibration measurements were conducted between December 2007 and September 2009, the purpose of these measurements were to characterize existing sources and to investigate vibration fall-off rates in the sandy and coquina soils of southern Florida. Vibration measurements were conducted for only the two technologies available in South Florida, Regional Rail (Tri-Rail) and Rail Rapid Transit (Metrorail).

Using the measured vibration levels and the FTA screening procedures, an evaluation was performed to determine buffer distances that were incorporated into GIS to determine the number of parcels that could be potentially affected within the SFECCTA project area between Miami and Jupiter, Florida. Based on the FTA screening methodology, the screening distance for each technology is outlined in **Table 3**. Incorporating these buffer distances and appropriate land use classifications in GIS, the number of potentially affected parcels for each category is shown in **Table 4**.

When evaluating the “Modally Generic” alternatives, **Table 4** shows that “Regional Rail (Push/Pull) and (DMU)” and the “Rail Rapid Transit” technologies have the highest number of potentially impacted parcels. Furthermore, **Table 4** shows that both “Bus Rapid Transit” and “Regional Bus” have significantly lower numbers of potential impacted parcels, which is attributable to low vibration levels associated with a rubber-tire source.

Table 3: Vibration Screening Distance (Feet) by Land Use Category for Modally Generic Alternatives

Type of Technology	*Category 2*	*Category 3*
Regional Rail (Push-Pull)	180	162
Regional Rail (DMU)	210	194
Light Rail	150	100
Rail Rapid Transit	209	178
Bus Rapid Transit	50	0
Regional Bus	50	0

Table 4: Number of Potentially Vibration Affected Parcels for Modally Generic Alternatives

Type of Technology	*Category 2*	*Category 3*
Regional Rail (Push-Pull)	2,015	1,231
Regional Rail (DMU)	2,688	1,375
Light Rail	1,570	664
Rail Rapid Transit	2,657	1,278
Bus Rapid Transit	376	0
Regional Bus	376	0

Modally Specific Alternatives

Based on the results of the "Modally Generic" alternatives analysis, a series of seven "Modally Specific" alternatives (including a TSM Alternative) were developed and analyzed. The term "Modally Specific" means each was based on a specific vehicle technology, but these were not fully developed in terms of all characteristics for each technology. These alternatives represent a full range or spectrum of alternatives that could reasonably be implemented along the SFECCTA project area. Detailed descriptions of these seven alternatives are available in the Draft ESR. These seven modal alternatives are:

- Conventional Commuter Rail (Push/Pull)
- Integrated Network (DMU and Push/Pull)
- Metrorail and Commuter Rail (DMU and Rail Rapid Transit)
- Urban Mobility (light rail)
- Local and Express (DMU)

TSM w/Regional Bus (Bus)

- Bus Rapid Transit and Commuter Rail (DMU and Bus Rapid Transit)

Using the measured vibration levels and the FTA screening procedures, a refined evaluation was performed to determine buffer distances that were incorporated into GIS to determine the number of parcels that could be potentially affected for both the FEC Railway and SFRC between Miami and Jupiter, Florida. Based on the FTA screening methodology, the screening distance for each alternative is outlined in **Table 5**. Most of these alternatives combine two technologies and the widest of the buffer distances was used for this analysis. Incorporating these buffer distances and appropriate land use classifications in GIS, the number of potentially affected parcels for each category is shown in **Table 6**.

Table 6 shows that "Modally Specific" alternatives that include "Regional Rail (Push/Pull) and (DMU)" and the "Rail Rapid Transit" technologies are similar in vibration effects and have approximately the same number of potentially impacted parcels. That is primarily due to the fact that vibration impact buffer distances are related to the technology type and both these technologies have potential for high vibration levels. However, the "TSM w/Regional Bus" has no potential impacted parcels, which is attributable to low vibration levels associated with a rubber-tire source.

Table 5: Vibration Screening Distance (feet) for Modally Specific Alternatives

Type of Technology	*Category 2*	*Category 3*
Conventional Commuter Rail	180	162
Urban Mobility	156	144
Local and Express	210	194
Integrated Network	210	194
Metrorail and Commuter Rail	210	194
BRT and Commuter Rail	210	194
TSM w/Regional Bus	50	0

Table 6: Number of Potentially Vibration Affected Parcels for Modally Specific Alternatives

Type of Technology	*Category 2*	*Category 3*
Conventional Commuter Rail	2,015	1,231
Urban Mobility	1,678	1,115
Local and Express	2,688	1,375
Integrated Network	2,898	1,414
Metrorail and Commuter Rail	2,688	1,375
BRT and Commuter Rail	2,688	1,375
TSM w/Regional Bus	0	0

Modally Detailed Alternatives

The previous seven "Modally Specific" alternatives were presented to the stakeholders and the general public through a series of meetings and the public workshops. These alternatives were then evaluated by a series of criteria based on: public input; the established goals and objectives of the project; and the criteria established by the FTA for New Starts Funding. Based on this input and additional analyses an overall concept was selected for further, more detailed study resulting in a set of pre-final alternatives. The overall concept entails combinations of the three highest ranking "Modally Detailed" alternatives from the above evaluation criteria.

A series of specific alternatives were developed and analyzed based on the screening of the "Modally Detailed" alternatives. This final evaluation will result in a recommendation for a LPA for presentation and adoption by the three Metropolitan Planning Organizations (MPOs) within the SFECCTA project area. It is anticipated that based on these specific alternatives, public and agency review of the documents at the public hearing or through document circulation reviews, as well as MPO inputs, the LPA will be selected and presented in the *Final ESR*.

Detailed descriptions of the "detailed alternatives" are available in the *Draft ESR*. The three detailed alternatives are:

- Regional Rail Network (DMU/Push-Pull)
- Bus Rapid Transit (Regional Bus)
- TSM w/Regional Bus

Using the measured vibration levels and the FTA screening procedures, a refined evaluation was performed to determine buffer distances that were incorporated into GIS to determine the number of parcels that could be potentially affected for both the FEC Railway and SFRC between Miami and Jupiter, Florida.

Based on the FTA screening methodology, the screening distance for each alternative is outlined in **Table 7**. The first alternative combined two technologies and the wider buffer distance was used for this analysis. Incorporating these buffer distances and appropriate land use classifications in GIS, the number of potentially affected parcels for each category is shown in **Table 8**.

The "Modally Detailed" alternatives have confirmed that the highest number of potentially impacted parcels are associated with "Regional Rail (Push/Pull) and (DMU)" as shown in **Table 8**. It is shown that "Bus Rapid Transit" has a small number of potentially impacted parcels while the "TSM w/Regional Bus" has no potentially impacted parcels, which is attributable to the low vibration levels associated with rubber-tire sources.

Conclusion

Phase 2 of the SFECCTA study has screened the proposed alternatives in an iterative and stepwise manner. Generally, when considering the "Modally Generic", "Modally Specific" and the "Modally Detailed" alternatives, the vibration screening analysis has indicated that the numbers of potentially impacted parcels for Category 3 land uses are lower than the number of potentially impacted parcels for Category 2 land uses. This is due, in part, to nighttime sensitivity associated with Category 2 land uses.

Finally, when evaluating the different modal technologies, this analysis has indicated that the majority of these modal technologies are comparable. The rail technologies are very similar to each other whereas the bus technologies have much lower vibration sources (and are also similar to each other). In addition, the highest number of potentially impacted parcels are associated with "Regional Rail (Push/Pull) and (DMU)" and the "Rail Rapid Transit". During subsequent phases of the SFECCTA study, a detailed vibration analysis would be conducted to specifically access vibration impacts and determine the appropriate mitigation for these impacts.

Table 7: Vibration Screening Distance (feet) for Modally Detailed Alternatives

Type of Technology	*Category 2*	*Category 3*
Regional Rail Network	210	194
Bus Rapid Transit	50	0
TSM w/Regional Bus	50	0

Table 8: Number of Potentially Vibration Affected Parcels for Modally Detailed Alternatives

Type of Technology	*Category 2*	*Category 3*
Regional Rail Network	4,021	1,729
Bus Rapid Transit	376	0
TSM w/Regional Bus	0	0

References

Transit Noise and Vibration Impact Assessment, FTA-VA-90-1003-06, Federal Transit Administration, U.S. Department of Transportation, 2006.