4.7 VIBRATION

4.7.1 INTRODUCTION

This chapter describes the existing vibration levels along the proposed South Coast Rail alternatives, and discusses the vibration levels and potential impacts associated with the proposed commuter rail operations along the various corridor alignment alternatives for the South Coast Rail project. Background information on the proposed project and a summary of each of the proposed Alternatives is provided in Chapter 3, Alternatives.

4.7.1.1 RESOURCE DEFINITION

Ground-borne vibration, in the context of transit, refers to movement of the ground caused by train movements and is usually the result of interactions between the steel wheels of the locomotives and rail cars and the rail surfaces. Examples of such interactions (and subsequent vibration) include train wheels over jointed rail and untrue railcar wheel with “flats.” Unlike noise, which travels in air, transit vibration typically travels along the surface of the ground. Depending on the geologic properties of the surrounding ground and the type of building structure exposed to transit vibration, the vibration propagation path between the track and the structure may be more or less efficient. Buildings with a solid foundation set in bedrock are “coupled” more efficiently to the surrounding ground and experience higher vibration levels than those buildings located in sandy soil.

Vibration induced by vehicle passbys is generally discussed in terms of displacement, velocity, or acceleration. However, human responses and responses by buildings and other objects are more readily described with velocity. Therefore, the average velocity (called the root mean square (RMS) velocity) is used to assess impacts associated with the human response to vibration. The RMS vibration velocity levels are expressed in inches per second (ips) or vibration velocity levels in decibels (VdB). Vibration levels are referenced to 1-micro inch per second (mips).

4.7.1.2 REGULATORY CONTEXT

The vibration assessment for the South Coast Rail project was prepared in accordance with the Federal Transit Administration’s (FTA) *Transit Noise and Vibration Impact Assessment*[1] guidance manual. The FTA guidance manual sets forth the basic concepts, methodology, and procedures for evaluating vibration levels from transit operations. There are no state or local regulations regarding vibration levels.

4.7.1.3 METHODOLOGY

A vibration measurement program was conducted in the study area to determine the existing vibration levels along the alignments of the various project alternatives. The vibration measurements were obtained using a CEL Model 593 meter with a PCB Model 393C accelerometer. The measured vibration levels consisted of a one-second interval time history of the train passby event reported in RMS velocity level in VdB relative to 1-micro inch per second.

Vibration measurements were obtained in 1995 as part of an initial project study that proposed utilizing the Attleboro Alternative from the Northeast Corridor to New Bedford and Fall River. Vibration

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[1] FTA-VA-90-1003-06; May 2006

measurements were obtained during freight rail operations along the existing single-track corridor from Attleboro Center to Myricks Junction where it separates into two branches. One branch goes to New Bedford and the other branch to Fall River. In addition, vibration measurements were obtained along the Northeast Corridor to determine vibration levels from MBTA Commuter Rail trains that operate along the corridor and would be similar to the commuter trains that would operate on the South Coast Rail corridor.

Additional vibration measurements were obtained in September 2008 to determine the existing vibration levels from MBTA Commuter Rail trains along the Stoughton rail line. Stoughton vibration measurements were obtained to supplement the study of the Stoughton Alternative assessment that was prepared in 2000. For that study, the vibration measurements obtained in 1995 along the Northeast Corridor from MBTA Commuter Rail operations were used to represent the existing vibration levels along the Stoughton Line since the same type of commuter rail trains operate on both lines.

Vibration was measured at nine locations. These measured vibration levels are representative of the existing vibration levels along each of the proposed South Coast Rail alternatives. Typical ground-borne vibration levels from transit and other common sources are shown in Figure 4.7-1. The vibration measurement locations and land use surrounding the measurement locations are summarized in Table 4.7-1 and these locations are shown graphically in Figure 4.7-2.

Table 4.7-1 Vibration Measurement Locations

ID	Measurement Location	City/Town	Land Use
	Southern Triangle – Common to All Rail Alternatives		
1	Beechwood Road	Freetown	Residential
2	Chace Road	Freetown	Residential
	Attleboro Alternative		
3	Foley Street Playground	Attleboro	Playground
4	292 Meadowbrook Lane	Norton	Residential
	Stoughton Alternative / Whittenton Alternative		
8	Pine Street (Waterfall Hills Apartments)	Canton	Residential
9	1508 Central Street	Stoughton	Residential

Actual vibration measurements were used to evaluate existing conditions because they provide a more accurate assessment of vibration along the South Coast Rail alternatives than would modeling based on generalized soils or geologic information. Some geologic conditions are associated with efficient propagation characteristics that result in higher than normal vibration levels. For example, shallow bedrock, less than 30 feet below the surface, is likely to have efficient propagation. Other factors that can be important are soil type and stiffness. In particular, stiff clay soils have been associated with efficient vibration propagation. Investigation of soil boring records can be used to estimate the depth to bedrock and the presence of problem soil conditions. Geological maps or subsurface borings may be used at a later stage in the project if more detailed analysis of ground propagation is needed for specific sensitive receptors.

Figure 4.7-1 Typical Ground-Borne Vibration Levels

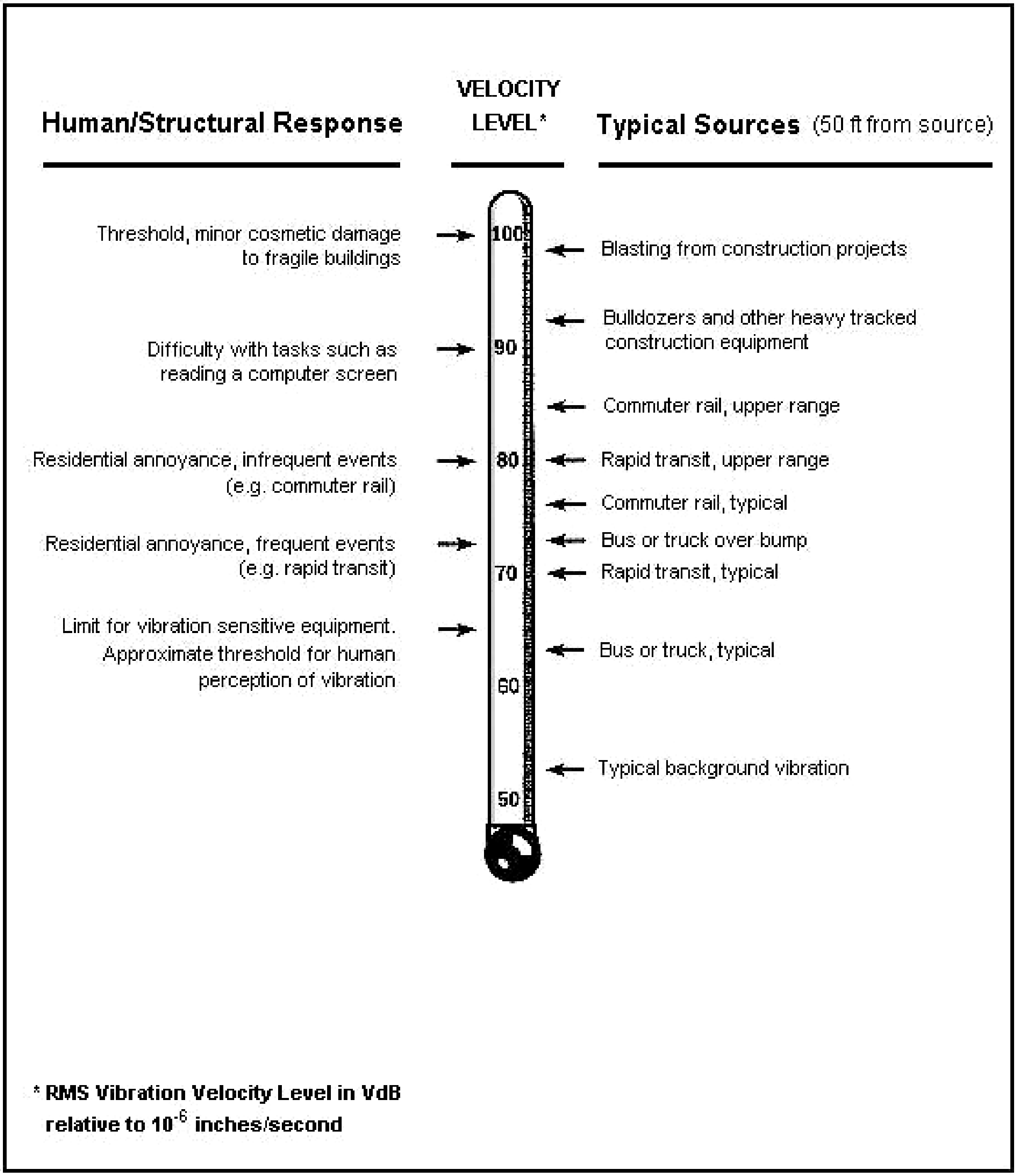

Table 4.7-2 Vibration Measurement Locations and Measurement Results (VdB)

ID	Measurement Location	City/Town	Land Use	Distance (feet)	Train Operation	Train Speed (mph)	Measured Vibration Level (VdB)
1	Beechwood Road	Freetown	Residential	75	Freight	20	88
2	Chace Road	Freetown	Residential	100	Freight	20	85
3	Foley Street Playground	Attleboro	Playground	100	Commuter	60	80
4	292 Meadowbrook Lane	Norton	Residential	50	Freight	20	91
8	Pine Street (Waterfall Hills Apartments)	Canton	Residential	80	Commuter	35	95
9	1508 Central Street	Stoughton	Residential	60	Commuter	20	86

Source: KM Chng Environmental Inc., 1995 and 2008.

4.7.2 EXISTING CONDITIONS

Vibration measurements were collected in the study area to determine the existing vibration levels along the proposed South Coast Rail alternatives. Existing land uses in the study area are exposed to a variety of vibration sources ranging from trucks and vehicle passbys along local roadways, MBTA commuter rail train passbys along the existing rail corridors (Attleboro and Stoughton commuter rail lines), and freight rail operations along the existing New Bedford and Fall River freight rail corridors.

The measured vibration levels are summarized in Table 4.7-2 and discussed in the following sections for each of the South Coast Rail alternatives. These measured vibration levels are representative of the existing vibration levels along the alignment of each of the proposed alternatives.

4.7.2.1 SOUTHERN TRIANGLE

In 1995, vibration measurements along the Southern Triangle of the freight rail corridor were obtained in Freetown (location 1 – Beechwood Road and location 2 – Chace Road). The condition of the freight rail tracks in this section of the rail corridor constrained train speeds to approximately 20 mph. The measured vibration levels from the freight rail operations ranged from 88 VdB at a distance of 75 feet at location 1, and 85 VdB at a distance of 100 feet at measurement location 2. The freight rail corridor consists of jointed track and rail cars with wheel flats, both of which contribute to higher vibration levels from freight operations. Since 1995, freight operations between New Bedford and Fall River have not changed. It was assumed therefore, that vibration along these corridors has not changed either. As a result, no new vibration measurements were obtained along these sections of the corridors during the 2008 vibration measurement data collection program.

4.7.2.2 ATTLEBORO ALTERNATIVE

Vibration measurements along the Northeast Corridor in Attleboro (location 3 – Foley Street Playground), and along the freight rail corridor in Norton (location 4 – 292 Meadowbrook Lane) were obtained in 1995. Train operations along the Northeast Corridor included MBTA Commuter Rail trains (Providence Line) traveling at speeds of approximately 60 mph. The measured vibration levels from the Commuter Rail trains operating on the Northeast Corridor were 80 VdB at a distance of 100 feet. The

Northeast Corridor consists of continuous welded rail (CWR), resilient rail fasteners, and a vehicle maintenance program that includes wheel truing (to eliminate wheel flats), all of which contribute to reduced vibration levels.

The vibration level measured at speeds of approximately 20 mph along the freight rail corridor in Norton was 91 VdB at a distance of 50 feet. As described in the section above, the freight rail corridor consists of jointed track and rail cars with wheel flats, both of which contribute to higher vibration levels from freight operations. The vibration levels measured in 1995 were assumed to be similar to current vibration levels along the same existing rail corridors because the same type of freight trains operate over the same tracks and travel at the same speed over terrain with the same ground propagation characteristics. As a result, no new vibration measurements were obtained along these sections of the corridor during the 2008 vibration measurement data collection program.

4.7.2.3 STOUGHTON / WHITTENTON ALTERNATIVE

Vibration measurements were obtained along the Commuter Rail Stoughton Line as part of the 2008 measurement program. Vibration measurements were obtained at two locations, one in Canton (location 8 – Pine Street) and one near downtown Stoughton (location 9 – 1508 Central Street). As shown in Table 4.7-2, the measured vibration levels along this section of the Stoughton Line ranged from 86 VdB to 95 VdB at distances ranging from 60 to 80 feet from the tracks.

4.7.2.4 RAPID BUS ALTERNATIVE

The Rapid Bus Alternative would consist of a new dedicated bus lane on Route 24 and Route 140. Existing vibration levels are due to highway traffic and were not obtained for this alternative as typical highway vibration levels are below the threshold for human perception of vibration. Typical rubber tired vehicles such as trucks and buses traveling at 50 mph would generate vibration levels of 65 VdB at a distance of 50 feet.

4.7.2.5 SUMMARY OF IMPACTS

As documented above, the existing measured vibration levels along the Southern Triangle range from 85 to 88 VdB at distances of 75 to 100 feet from the tracks. Depending on the train speed, the condition of the vehicle wheels, and the ground propagation characteristics, the vibration levels at residences along the New Bedford and Fall River lines are expected to range from 85 to 95 VdB at a distance of 50 feet from the track, 78 to 88 VdB at a distance of 100 feet from the track, and 72 to 82 VdB at a distance of 200 feet from the track.

Existing vibration along the Attleboro Alternative is 91 VdB at a distance of 50 feet along the Attleboro Secondary, and is 80 VdB along the Northeast Corridor at a distance of 100 feet from the tracks. There are no train operations and therefore no vibrations along the Attleboro Bypass.

Along the Stoughton and Whittenton Alternatives, the existing measured vibration levels along the active Stoughton Line ranged from 86 to 95 VdB at distances of 60 to 80 feet from the tracks. Vibration levels along the New Bedford Main Line (Weir Junction to Cotley Junction) are expected to range from 85 to 91 VdB at distances of 50 to 100 feet from the tracks. These vibration levels were not measured, but are expected to be similar to the freight rail vibration levels that were measured along the Southern

Triangle and the Attleboro Secondary. There are no train vibrations along the out-of-service segment of the corridor.

Highway vibration measurements for Rapid Bus Alternative are expected to be representative of typical highway conditions. Rubber tired vehicles such as trucks and buses traveling at 50 mph would generate vibration levels of 65 VdB at a distance of 50 feet.

4.7.3 ANALYSIS OF IMPACTS AND MITIGATION

4.7.3.1 INTRODUCTION

Ground-borne vibration, in the context of transit, refers to movement of the ground caused by train movements and is usually the result of interactions between the steel wheels of the locomotives and rail cars and the rail surfaces. Examples of such interactions (and subsequent vibrations) include train wheels over jointed rail and untrue railcar wheel with "flats." Unlike noise, which travels in air, transit vibration typically travels along the surface of the ground. Depending on the geologic properties of the surrounding ground and the type of building structure exposed to transit vibration, vibration propagation may 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 those buildings located in sandy soil.

Vibration induced by vehicle passbys can generally be discussed in terms of displacement, velocity or acceleration. However, human responses and responses by buildings and other objects are more readily described with velocity. Therefore, the average velocity (called the root mean square (RMS) velocity) is used to assess impacts associated with the human response to vibration. The RMS velocity is expressed in inches per second (ips) or decibels (VdB). Vibration levels are referenced to 1 micro inch per second (mips). Typical ground-borne vibration levels from transit and other common sources are shown in Figure 4.7-1.

The vibration assessment was prepared in accordance with the Federal Transit Administration's (FTA) *Transit Noise and Vibration Impact Assessment*[2] guidance manual. The FTA guidance manual sets forth the basic concepts, methodology and procedures for evaluating vibration levels from transit operations. There are no state or local regulations regarding vibration levels.

Section 4.7.2 described the existing conditions within the study area, relative to vibration, and this section addresses the vibration levels and potential impacts associated with the proposed commuter rail operations along the various corridor alignment alternatives. The remainder of this section describes the vibration analysis methodology, the assessment criteria, and the number and location of potential vibration impacts along each of the proposed alternative project corridors.

The Secretary's Certificate[3] requires the Draft Environmental Impact Report (Draft EIR) to discuss consistency with applicable state and federal guidelines and regulations, and that the vibration impact assessment for the project alternatives identify impacted areas along the rail and bus routes and at the station sites. The Certificate further requires the Draft EIR evaluate measures to avoid and minimize vibration impacts and include an assessment of impacts to wildlife. This section evaluates impacts to

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[2] FTA-VA-90-1003-06; May 2006

[3] The Commonwealth of Massachusetts Executive Office of Energy and Environmental Affairs, Certificate of the Secretary of Energy and Environmental Affairs on the Environmental Notification Form, South Coast Rail Project (EEA# 14346), April 3, 2009.

residential and other buildings. Section 4.14, Biodiversity, Wildlife and Vegetation, considers potential vibration impacts to wildlife.

4.7.3.2 IMPACT ASSESSMENT METHODOLOGY

The vibration assessment was prepared in accordance with the Federal Transit Administration's (FTA) Transit Noise and Vibration Impact Assessment[4] guidance manual. The FTA guidance manual sets forth the basic concepts, methodology and procedures for evaluating vibration levels from transit operations.

FTA guidelines were used to predict vibration levels from the proposed commuter rail operations for each of the proposed project alternatives. The FTA vibration model combines various algorithms with empirically developed ground surface curves to estimate transit vibration levels at various distances from the track for average soil conditions. FTA surface vibration curves (adjusted for speed) were used to predict ground-borne vibration levels from transit operations at receptor locations along each of the project alternative corridors (Figure 4.7-3). In general, vibration levels increase at higher train speeds. The FTA model was used to determine the impact distance from the rail corridor within which the project transit vibration levels would exceed the FTA impact criteria. As shown in Figure 4.7-3, vibration curves are specified for locomotives, lighter commuter rail passenger cars, and rubber tired vehicles (buses).

The FTA guidance manual indicates that the vibration levels generated by both diesel and electric locomotives use the same upper curve shown in Figure 4.7-3. As a result, the vibration impact assessment for both the diesel and electric alternatives for the South Coast Rail project is the same. The vibration curves shown in Figure 4.7-3 are for generalized ground propagation characteristics. Although it is known that geographic conditions have a significant effect on vibration levels, it is rarely possible to develop more than a generalized assessment of the ground vibration propagation characteristics without a much more detailed vibration measurement program. For example, there are conditions where ground-borne vibration propagates much more efficiently than normal. Shallow bedrock, less than 30 feet below the surface, is likely to have efficient propagation because much of the energy that would normally radiate down into the ground is reflected back towards the surface by the bedrock. The result is higher than normal ground surface vibration levels. Other factors that have an effect on vibration propagation are soil type and stiffness. In particular, stiff clay soils are also associated with efficient vibration propagation. However, the FTA recommends using the generalized ground propagation vibration curves in Figure 4.7-3 for Environmental Assessment (EA) and Environmental Impact Statement (EIS) level analysis. A more detailed vibration analysis can be performed during final design when actual ground vibration propagation measurements can be obtained in areas where potential impacts have already been identified from the general assessment.

Trains traveling over switches or other special track work with gaps in the rail generate vibration levels that are 10 VdB higher than the levels indicated by the curves shown in Figure 4.7-3. For example, a locomotive traveling at a speed of 50 mph would generate a vibration level of 80 VdB at a distance of 80 feet from the tracks. A locomotive traveling at a speed of 50 mph over a switch would generate a vibration level of 80 VdB at a radial distance of approximately 225 feet from the switch.

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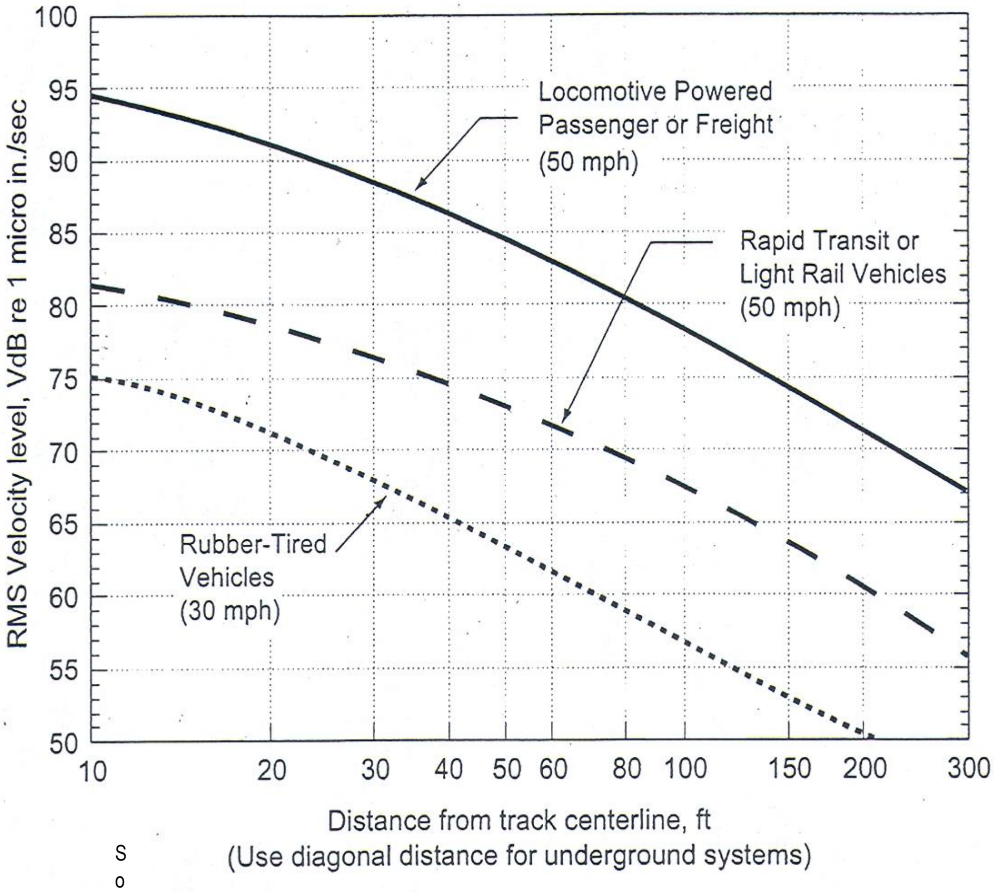
[4] FTA-VA-90-1003-06; May 2006

Figure 4.7-3 FTA Generalized Ground-Surface Vibration Curves



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ource: Transit Noise and Vibration Impact Assessment, Federal Transit Administration, Washington, D.C., May 2006.

At train stations and layover facilities, train-related vibration levels are generally significantly lower due to the slower train speeds. For example, a train traveling at a speed of 20 mph as it enters or leaves a train station would generate a vibration level of 80 VdB at a distance of 32 feet from the track. No vibration is generated while the trains are stopped at the stations. For a layover facility that has switches, a train traveling at 20 mph would generate a vibration level of 80 VdB at a radial distance of 100 feet from the switch.

For the rail alternatives, the vibration levels from switches located at each of the major junctions (Weir Junction, Myricks Junction, Cotley Junction, Whittenton Junction, Raynham Junction, the junction of the Attleboro Bypass and the Northeast Corridor, and the junction of the Attleboro Bypass and the Attleboro Secondary) were evaluated, along with the switches associated with the proposed layover facilities.

The FTA vibration curve in Figure 4.7-3 for a locomotive powered passenger train was used to determine the impact distance from the rail corridor within which vibration levels from train operations would exceed the FTA impact criterion. Using data from the detailed train simulation runs for the South Coast

Rail project (provided by SYSTRA), the locomotive vibration curve was adjusted for the speed of the trains (in 5 mph increments) to determine the impact distance from the rail corridor within which vibration impact is expected to occur. Train speeds ranged from 70 mph along sparsely populated areas of the rail corridor to 30-40 mph in more populated areas. In the vicinity of the proposed train stations along each of the project corridors, acceleration and deceleration train speed profiles were used to account for trains stopping at the stations.

The vibration analysis assumed the use of continuous welded rail for each of the rail alternatives. Continuous welded rail generates less vibration relative to other track configurations, such as jointed rail. In addition, since the heavier train locomotives generate higher vibration levels than the lighter passenger rail cars, the vibration analysis focused primarily on the vibration levels generated by the locomotives.

4.7.3.3 VIBRATION ASSESSMENT CRITERIA

The FTA criteria for evaluating ground-borne vibration impacts from train passbys at nearby sensitive receptors are shown in Table 4.7-3. These vibration criteria are related to ground borne vibration levels that are expected to result in human annoyance, and are based on RMS velocity levels expressed in VdB. The FTA's experience with community response to ground-borne vibration indicates that when there are only a few train events per day, it would take higher vibration levels to evoke the same community response that would be expected from more frequent train events. This is taken into account in the FTA criteria by distinguishing between projects with frequent, occasional and infrequent events. Frequent events are defined as more than 70 vibration events per day; occasional events are defined as between 30 and 70 vibration events per day; and infrequent events are defined as fewer than 30 vibration events per day.

The vibration criteria levels shown in Table 4.7-3 are defined in terms of human annoyance for land use categories 1 and 2, and for vibration sensitive equipment for land use category 1 buildings. Category 2 land uses are residences and buildings where people normally sleep such as hospitals, nursing homes and hotels. Category 3 receptors are institutional land uses with primarily daytime use such as schools, libraries and churches. Category 1 receptors are buildings where vibration levels could interfere with the operation of vibration sensitive equipment such as electron microscopes and magnetic resonance imaging scanners. Vibration interference levels for these types of equipment are well below the vibration levels shown in Table 4.7-3 for category 2 and 3 receptor land uses that are associated with human annoyance. In addition, vibration criteria have also been established for other specific buildings such as concert halls, recording studios, auditoriums and theaters that are also contained in Table 4.7-3.

The FTA has issued draft supplemental vibration assessment guidelines for existing active rail corridors where additional tracks are installed, or where rail operations on existing tracks are expected to increase. The supplemental vibration guidelines state that for heavily used rail corridors (more than 12 trains per day), where the increase in operations is less than a doubling of existing rail operations, and if the project related vibration levels are less than 3 VdB higher than existing vibration levels, then the additional vibration from the proposed project would not result in vibration impacts. For the South Coast Rail project, the FTA’s supplemental methodology for existing rail corridors would apply to the Northeast Corridor north of the Attleboro Bypass, and to the rail corridor north of Stoughton Station. The commuter rail trains that currently operate along these sections of the rail corridor are the same

Table 4.7-3
FTA Ground-Borne Vibration Impact Criteria

Receptor Land use		RMS Vibration Levels (VdB)		
Category	**Description**	**Frequent Events[1]**	**Occasional Events[2]**	**Infrequent Events[3]**
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 receptors	75	78	83
Specific Buildings	TV/Recording Studios/Concert Halls	65	65	65
	Auditoriums	72	80	80
	Theaters	72	80	80

Notes:
1. "Frequent Events" defined as more than 70 vibration events of the same source per day. Most rapid transit projects fall into this category.
2. “Occasional Events” 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.
Source: Federal Transit Administration, Transit Noise and Vibration Impact Assessment, FTA-VA-90-1003-06, May 2006

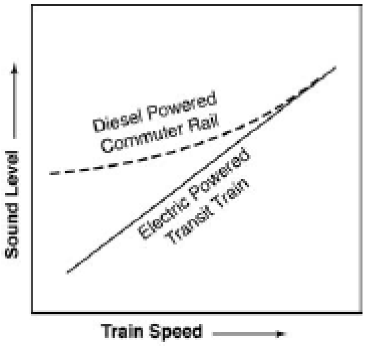
trains that would operate on the South Coast Rail project. As a result, the vibration levels generated by the existing commuter rail trains are the same as those generated by the trains for the South Coast Rail project.

Based on the FTA’s supplemental guidelines for existing rail corridors, there would be no vibration impacts along the Northeast Corridor or the active Stoughton Line, since there would be no increase in the vibration levels from the project. Adding an additional track to the existing rail corridor that would move the trains approximately 20 feet closer to the residences along the rail corridor would result in an increase in vibration levels of less than 3 VdB. For example, a train locomotive traveling at 50 mph would generate a vibration level of 78 VdB at a receptor located at a distance of 100 feet from the nearest track. If an additional track were added to the rail corridor that moved the trains 20 feet closer to the receptor, the vibration level would be 80 VdB at a distance of 80 feet from the nearest track. Since the addition of the new track would not result in an increase in vibration level of more than 3 VdB, in accordance with the FTA’s draft supplemental guidelines for an active rail corridor, there would be no vibration impact from the addition of the new track. However, a more detailed vibration analysis should be performed during final design when drawings showing the location of the proposed new tracks are available and can be used to determine the distance to the nearest receptors.

4.7.3.4 SUMMARY OF IMPACTS BY ALTERNATIVE

Train speed simulation runs were conducted for each of the rail alternatives, including operating train speeds along each segment of the rail corridor (in 5 mph increments). This data was used in the vibration impact assessment. The relationship between impact distance and train speed is depicted in Figure 4.7-4 and shown in Table 4.7-4. The impact distance was used in conjunction with the aerial photographs to determine the number and location of the impacted residential receptors with predicted vibration levels of 80 VdB or higher for each of the project alternatives. As indicated in Table 4.7-3, the FTA vibration criterion for residential receptors exposed to infrequent events (less than 30 events per day) is 80 VdB that would result in human annoyance. Most of the vibration impacts were in the range of 80 to 83 VdB. For receptors located close to the tracks, the predicted vibration levels were in the

Figure 4.7-4 Example Sound Level Dependence on Speed



Source: Federal Transit Administration, Transit Noise and Vibration Impact Assessment, FTA-VA-90-1003-06, May 2006

range of 85 to 89 VdB. These vibration levels are well below the onset of minor structural damage (such as cracks in plaster walls) threshold of 100 VdB for fragile buildings.

The vibration impact assessment of the track switches along each of the project alternatives indicates that only one location has a receptor that is located within 225 feet of a switch that would result in a vibration impact of 80 VdB. A residential receptor on Ingell Street near Weir Junction would be exposed to a vibration level of 80 VdB during a train locomotive passby over the switch at Weir Junction. This impacted receptor is included in the vibration assessment for the Southern Triangle. No vibration impacts are expected to occur near any of the other switch locations associated with the other project alternatives.

For the vibration assessment at sensitive receptors near train stations, acceleration and deceleration train speed profiles were used to determine the vibration levels from the trains entering and leaving the stations. The results of this analysis are included in the impact assessment for each of the project alternatives.

For track switches at layover facilities, a train traveling at 20 mph entering and leaving the layover facility would generate a vibration level of 80 VdB at a radial distance of 100 feet from the switch. An assessment of the receptors near the proposed layover facilities indicates that only at the Weaver’s Cove site along the Fall River Secondary are sensitive receptors (two residences) located within 100 feet of the track switches. The other proposed layover facility sites are located in industrial areas where there are no sensitive receptors located within 100 feet of the layover facility switches.

Because trains on the mainline corridor travel at higher speeds they generate higher vibration levels when they travel over the switches that lead into the layover facilities. Mainline trains traveling at 50 mph would generate a vibration level of 80 VdB at a distance of 225 feet from the switch. An assessment of the receptors near these mainline switches indicate that at the Freetown ISP Site and the New Bedford Wamsutta Street Site there are no sensitive receptors located within 225 feet of the mainline switch. At the Fall River Weaver’s Cove Site there is one residential receptor within 225 feet of the mainline switch. At the New Bedford Church Street Site there are two residential receptors within 225 feet of the mainline switch. The results of the vibration impact assessment for each of the alternatives are described below.

Table 4.7-4 Impact Distance vs. Train Speed

Train Speed	Impact Distance [1]
70 mph	115 feet
65 mph	110 feet
60 mph	100 feet
55 mph	95 feet
50 mph	80 feet
45 mph	75 feet
40 mph	70 feet
35 mph	60 feet
30 mph	50 feet
25 mph	42 feet
20 mph	32 feet

[1] Distance from the rail corridor within which a vibration level of 80 VdB is expected to occur.

Source: Federal Transit Administration, Transit Noise and Vibration Impact Assessment, FTA-VA-90-1003-06, May 2006

Southern Triangle (Common to All Rail Alternatives)

Portions of the rail lines within the southern part of the South Coast Rail Study Area are common to all rail alternatives. These rail lines form a rough triangular shape running south from Myricks Junction to Fall River (the Fall River Secondary) and from Weir Junction through Myricks Junction to New Bedford (the New Bedford Main Line), and are therefore referred to as the Southern Triangle. Although there is no commuter rail in the Southern Triangle, the existing tracks in this area are used by freight rail resulting in associated vibration levels under existing conditions, as described in Section 4.7.2.1.

The following sections describe the vibration impacts that may result from operation of these two components of the South Coast Rail project. The northern part of the South Coast Rail Study Area is encompassed by the other rail build alternatives described in subsequent sections.

Along the New Bedford Main Line from Weir Junction to Myricks Junction there are a total of 14 impacted residential receptors that are predicted to receive a vibration level of 80 VdB or higher during a train passby. Along the New Bedford Main Line from Myricks Junction to New Bedford, there are a total of eight impacted receptors that are predicted to receive a vibration level of 80 VdB or more during a locomotive passby. Along the Fall River Secondary from Myricks Junction to Fall River, there are a total of 73 impacted receptors that are predicted to receive a vibration level of 80 VdB or higher during a train passby. Of the 73 impacted receptors, three would be acquired for the rail right-of-way. The total number of impacted receptors for the Fall River Secondary after the acquisitions would thus be 70. There are a total of 95 impacted receptors along the Southern Triangle section of the project corridor. Five of these impacted receptors are multi-unit apartment buildings and the rest are single-family homes. There are no institutional receptors or buildings with vibration sensitive equipment that would be impacted along the Southern Triangle. The general location of these impacted receptors (by municipality) is described in Table 4.7-5.

The specific locations of these impacted receptors are identified in Table 4.7-3, along with their estimated vibration levels. The predicted vibration levels range from 80 to 89 VdB as shown in Table 4.7-6. Many of the impacted receptors exceed the FTA impact criteria of 80 VdB by 3 VdB or less. A change

Table 4.7-5 Summary of Potential Vibration Impacts - Southern Triangle

Segment	Municipality	Impacted Residences[1]
New Bedford Main Line - Weir Junction to Myricks Junction	Taunton	10
	Berkley	4
New Bedford Main Line - Myricks Junction to New Bedford	Berkley	0
	Lakeville	2
	Freetown	4
	New Bedford	2
Fall River Secondary	Berkley	6
	Lakeville	0
	Freetown	16
	Fall River	51
Totals		**95**

[1] Impact = vibration levels equal to or greater than 80 VdB

in vibration level of 3 VdB is just barely perceptible. There would be 21 impacted receptors that are predicted to have vibration levels of 85 VdB or higher. The highest predicted vibration level of 89 VdB is at a residential receptor located close to the tracks at the end of Simpson Lane in Freetown. The locations of these impacted receptors are shown graphically in Figures 4.7-5a through 4.7-5c along the Fall River Secondary and Figures 4.7-6a through 4.7-6e along the New Bedford Main Line. The impacted receptors are those located closest to the rail corridor.

Attleboro Alternatives

The Attleboro Alternatives (Electric and Diesel) would provide commuter rail service to South Station using the Northeast Corridor, proposed Attleboro Bypass, Attleboro Secondary, New Bedford Main Line, and Fall River Secondary.

Along the Attleboro Bypass and Attleboro Secondary, the vibration assessment indicates that there are a total of 22 impacted residential receptors with predicted vibration levels of 80 VdB or higher. There are no institutional receptors or buildings with vibration sensitive equipment that would be impacted by the Attleboro Alternatives. The general location of these impacted receptors (by municipality) is described in Table 4.7-7.

The specific locations of these impacted receptors are identified in Table 4.7-8, along with their estimated vibration levels. The predicted vibration levels shown in Table 4.7-8 range from 80 to 86 VdB, and indicate that many of the impacted receptors exceed the FTA impact criterion of 80 VdB by 3 VdB or less. Two of the impacted receptors are predicted to have vibration levels of 85 VdB or higher. The locations of the impacted receptors are shown graphically in Figures 4.7-7a through 4.7-7c. The impacted receptors are those located closest to the rail corridor.

Since the vibration curves used to assess impacts from both diesel and electric locomotives are the same (in accordance with FTA guidelines), the results of the vibration impact assessment for both the diesel and electric Attleboro Alternatives are the same. In accordance with the FTA's supplemental guidelines

Table 4.7-6 Potential Vibration Impacts by Sensitive Receptor – Southern Triangle

Segment	Municipality	Street	Impacted Residences	Estimated Vibration Level
New Bedford Main Line - Weir Junction to Myricks Junction	Taunton	Ingell Street	1	80 VdB
	Taunton	Hart Street	4	81 to 88 VdB
	Taunton	Plain Street	4	81 to 80 VdB
	Taunton	Debra Drive	1	83 VdB
	Berkley	Crabapple Drive	1	80 VdB
	Berkley	Cotley Street	1	80 VdB
	Berkley	Padelford Street	2	81 to 84 VdB
New Bedford Main Line -	Lakeville	Howland Road	2	80 to 81 VdB
Myricks Junction to New Bedford	Freetown	Braley Road	4	82 to 86 VdB
	New Bedford	Lynn Street	2	80 VdB
Fall River Secondary	Berkley	Mill Street	5	81 VdB
	Berkley	Adams Lane	1	88 VdB
	Freetown	Richmond Road	4	82 to 88 VdB
	Freetown	Forge Road	5	82 to 85 VdB
	Freetown	Elm Street	3	82 to 83 VdB
	Freetown	Green/Simpson Lane	3	81 to 89 VdB
	Freetown	Alexandria Drive	1	81 VdB
	Fall River	Leeward Road	7	81 to 82 VdB
	Fall River	Rolling Green Drive	1*	80 VdB
	Fall River	North Main Street	12**	81 to 83 VdB
	Fall River	Wayland Street	1	81 VdB
	Fall River	Pickering Street	6**	80 to 86 VdB
	Fall River	St. James Street	1	81 VdB
	Fall River	Garside Street	1	82 VdB
	Fall River	Murry Street	6	80 to 88 VdB
	Fall River	George Street	1	85 VdB
	Fall River	Burns Street	2	82 to 86 VdB
	Fall River	Cory Street	2	84 to 88 VdB
	Fall River	Almy Street	2	80 to 81 VdB
	Fall River	Railroad Avenue	5	82 to 86 VdB
	Fall River	Brownell Street	1	82 VdB
	Fall River	Thompson Street	1	81 VdB
	Fall River	Cedar Street	1	86 VdB
	Fall River	Meadow Street	1	86 VdB
Totals			**95**	

* This impacted receptor is a multi-unit apartment buildings.

Table 4.7-7 Summary of Potential Vibration Impacts - Attleboro Alternative

Segment	Municipality	Impacted Residences[1]
Attleboro Bypass	Attleboro	2
Attleboro Secondary to Weir Junction	Norton	5
	Taunton	15
Totals		**22**

[1] Impact = vibration levels equal to or greater than 80 VdB

Table 4.7-8 Potential Vibration Impacts by Sensitive Receptor - Attleboro Alternative

Segment	Municipality	Street	Impacted Residences	Estimated Vibration Levels
Attleboro Bypass	Attleboro	Richardson Avenue	1	81 VdB
	Attleboro	Plain Street	1	81 VdB
Attleboro Secondary To Weir Junction	Norton	Charles Lane	2	83 VdB
	Norton	Woodward Street	2	81 to 83 VdB
	Norton	Taunton Avenue	1	86 VdB
	Taunton	Harvey Street	2	81 to 84 VdB
	Taunton	Jeffrey Lane	1	81 VdB
	Taunton	Crane Avenue	2	80 to 85 VdB
	Taunton	Freemont Street	1	82 VdB
	Taunton	Horton Street	1	82 VdB
	Taunton	Winthrop Street	1	84 VdB
	Taunton	Cohannet Street	3	82 to 84 VdB
	Taunton	Walnut Street	1	80 VdB
	Taunton	Weir Street	3	81 to 82 VdB
Totals			**22**	

for existing rail corridors (as discussed in Section 4.7.3.2), there would be no project related vibration impacts along the Northeast Corridor north of the Attleboro Bypass.

Stoughton Alternatives

The Stoughton Alternatives (Electric and Diesel) would provide commuter rail service to South Station using the Northeast Corridor, Stoughton Line, New Bedford Main Line, and Fall River Secondary.

Along the Stoughton Alternative, the vibration assessment indicates that there are a total of 51 impacted receptors with predicted vibration levels of 80 VdB or higher. One of these impacted receptors is a multi-unit apartment building and the rest are single-family homes. The general locations of these impacted receptors (by municipality) are described in Table 4.7-9.

There are no institutional receptors or buildings with vibration sensitive equipment that would be impacted by the Stoughton Alternatives. In addition, the vibration levels at the Easton Historic Train

Table 4.7-9 Summary of Potential Vibration Impacts - Stoughton Alternative

Segment	Municipality	Impacted Residences[1]
Stoughton Station to Weir Junction	Stoughton	12
	Easton	17
	Raynham	13
	Taunton	9
Total		**51**

[1] Impact = vibration levels equal to or greater than 80 VdB

Station and other historic buildings in Easton Village would be below the 100 VdB vibration threshold for the onset of minor structural damage (such as small cracks in plaster walls) to fragile and historic buildings.

The specific locations of these impacted receptors (by street name) are identified in Table 4.7-10, along with their estimated vibration levels. The predicted vibration levels shown in Table 4.7-10 range from 80 to 87 VdB, with many of the impacted receptors exceeding the FTA impact criterion of 80 VdB by 3 VdB or less. Ten of the impacted receptors are predicted to have vibration levels of 85 VdB or higher. One of the multi-unit apartment buildings on Paul Bunker Drive, located closest to the rail corridor, is expected to have a vibration level of 81 VdB. The locations of the impacted receptors are shown in Figures 4.7-8a through 4.7-8e. The impacted receptors are those located closest to the rail corridor.

FTA guidance for ground-borne vibration for different transit modes is provided in *Transit Noise and Vibration Impact Assessment (*FTA 2006). Figure 10-1 of that guidance document presents curves for ground-borne vibration based on measurements of ground-borne vibration at representative North American transit systems. According to this FTA guidance document the same curve applies to trains that are powered by diesel or electric locomotives. Since the vibration curve used to assess impacts is the same for diesel and electric locomotives the results of the vibration impact assessment for the diesel and electric Stoughton Alternatives are identical. Based on the FTA's supplemental guidelines for existing rail corridors, there would be no project related vibration impacts north of Stoughton Station.

Whittenton Alternatives

The Whittenton Alternatives (Electric and Diesel) would provide commuter rail service to South Station through Stoughton, connecting to the existing Stoughton Line using the Whittenton Branch through the City of Taunton. Along the Whittenton Alternative from Stoughton Station to Weir Junction, the vibration assessment indicates that there are a total of 55 impacted receptors with predicted vibration levels of 80 VdB or higher. Three of these impacted receptors are multi-unit apartment buildings on Bay Street in Taunton. The rest of the impacted receptors are single-family residences. There are no institutional receptors or buildings with vibration sensitive equipment that would be impacted by the Whittenton Alternative. The general locations of these impacted receptors (by municipality) are shown in Table 4.7-11.

The specific locations of these impacted receptors (by street name) are identified in Table 4.7-12. The predicted vibration levels shown in Table 4.7-12 range from 80 to 86 VdB, with many of the impacted receptors exceeding the FTA impact criterion of 80 VdB by 3 VdB or less. Five of these impacted receptors are predicted to have vibration levels of 85 VdB or higher. The locations of the impacted receptors along the Whittenton Branch are shown graphically in Figures 4.4-9a and 4.4-9b. The locations

Table 4.7-10 Potential Vibration Impacts by Sensitive Receptor - Stoughton Alternative

Segment	Municipality	Street	Impacted Residences	Estimated Vibration Levels
Stoughton Station to Weir Junction	Stoughton	Rogers Drive	6	81 VdB
	Stoughton	Plain Street	2	82 to 85 VdB
	Stoughton	Columbus Avenue	1	81 VdB
	Stoughton	Butler Way	2	81 to 86 VdB
	Stoughton	Washington Street	1	81 VdB
	Easton	Elm Street	1	80 VdB
	Easton	Main Street	1	82 VdB
	Easton	Center Street	5	82 VdB
	Easton	Williams Street	2	82 to 83 VdB
	Easton	Avis Circle	1	80 VdB
	Easton	Baldwin Street	5	80 to 81 VdB
	Easton	Tait Avenue	1	80 VdB
	Easton	Foundry Street	1	86 VdB
	Raynham	Bridge Street	1	82 VdB
	Raynham	Elm Street West	3	81 to 83 VdB
	Raynham	Carver Street	2	80 to 86 VdB
	Raynham	Britton Street	2	86 VdB
	Raynham	Wampanoag Road	2	82 to 87 VdB
	Raynham	King Philip Street	3	80 to 87 VdB
	Taunton	Thrasher Street	3	80 to 87 VdB
	Taunton	Summer Street	2	83 to 85 VdB
	Taunton	W. Summer Street	2	83 VdB
	Taunton	Sherwood Drive	1	81 VdB
	Taunton	Paul Bunker Drive	1*	81 VdB
Totals			**51**	

*This impacted receptor is a multi-unit apartment buildings.

Table 4.7-11 Summary of Potential Vibration Impacts - Whittenton Alternative

Segment	Municipality	Impacted Residences[1]
Stoughton Line	Stoughton	12
	Easton	17
	Raynham	6
Whittenton Branch	Raynham	3
	Taunton	8
Attleboro Secondary	Taunton	9
Totals		**55**

[1] Impacts = vibration levels equal to or greater than 80 VdB

Table 4.7-12 Potential Vibration Impacts by Sensitive Receptor - Whittenton Alternative

Segment	Municipality	Street	Impacted Residences	Estimated Vibration Levels
Stoughton Line	Stoughton	Rogers Drive	6	81 VdB
	Stoughton	Plain Street	2	82 to 85 VdB
	Stoughton	Columbus Avenue	1	81 VdB
	Stoughton	Butler Way	2	81 to 86 VdB
	Stoughton	Washington Street	1	81 VdB
	Easton	Elm Street	1	80 VdB
	Easton	Main Street	1	82 VdB
	Easton	Center Street	5	82 VdB
	Easton	Williams Street	2	82 to 83 VdB
	Easton	Avis Circle	1	80 VdB
	Easton	Baldwin Street	5	80 to 81 VdB
	Easton	Tait Avenue	1	80 VdB
	Easton	Foundry Street	1	86 Vdb
	Raynham	Bridge Street	1	82 VdB
	Raynham	Elm Street West	3	81 to 83 VdB
	Raynham	Carver Street	2	80 to 86 VdB
Whittenton Branch	Raynham	King Philip Street	3	82 to 85 VdB
	Taunton	Redwood Drive	3	80 to 83 VdB
	Taunton	Bay Street	5*	81 to 82 VdB
Attleboro Secondary	Taunton	Horton Street	1	82 VdB
	Taunton	Winthrop Street	1	84 VdB
	Taunton	Cohannet Street	3	82 to 84 VdB
	Taunton	Walnut Street	1	80 VdB
	Taunton	Weir Street	3	81 to 82 VdB
Totals			**55**	

* Three of these impacted receptors are multi-unit apartment buildings.

of the impacted receptors along the Stoughton Line segment of this alternative are shown in Figures 4.7-8b through 4.7-8d. The impacted residential receptors are located closest to the rail corridor.

The specific locations of these impacted receptors (by street name) are identified in Table 4.7-12. The predicted vibration levels shown in Table 4.7-12 range from 80 to 86 VdB, with many of the impacted receptors exceeding the FTA impact criterion of 80 VdB by 3 VdB or less. Five of these impacted receptors are predicted to have vibration levels of 85 VdB or higher. The locations of the impacted receptors along the Whittenton Branch are shown graphically in Figures 4.4-9a and 4.4-9b. The locations of the impacted receptors along the Stoughton Line segment of this alternative are shown in Figures 4.7-8b through 4.7-8d. The impacted residential receptors are located closest to the rail corridor.

Since the vibration curves used to assess impacts from both diesel and electric locomotives are the same (in accordance with FTA guidelines), the vibration impact assessment for both the diesel and electric Whittenton Alternatives are identical. In accordance with the FTA's supplemental guidelines for existing rail corridors, there would be no project related vibration impacts north of Stoughton Station.

Rapid Bus Alternative

The Rapid Bus Alternative would provide commuter bus service to South Station via Route 140, Route 24, and I-93. South of the I-495 interchange in Raynham, buses would travel in the general purpose lanes with mixed traffic. North of I-495, buses would use a combination of new zipper bus lanes, new reversible bus lanes, two-lane bus roadways, existing zipper HOV lanes, and existing HOV lanes, along with a short section in mixed traffic. Using the FTA vibration curve (adjusted for speed) for rubber tired vehicles (buses) in Figure 4.7-3, the vibration assessment indicated that for buses traveling at a speed of 60 mph, the impact distance for a vibration level of 80 VdB is 15 feet. Using the FTA vibration impact criterion of 72 VdB for frequent events (greater than 70 events per day), the impact distance is 40 feet. Since there are no receptors located within these distances of the highway, no vibration impacts are expected to occur from the Rapid Bus Alternative.

4.7.3.5 TEMPORARY CONSTRUCTION IMPACTS

Typical vibration levels from construction equipment at a reference distance of 25 feet are: 104 VdB for an impact pile driver; 87 VdB for a bulldozer; 86 VdB for a loaded truck; and 79 VdB for a jackhammer. In general, if most construction activity is located more than 75 feet from the nearest sensitive receptors, the estimated vibration levels would be expected to be below the FTA annoyance criterion of 80 VdB. However, pile driving is the major impact device that generates the highest vibration levels during construction. Pile driving located within 50 feet of a building could result in vibration impacts, if pile driving is required for this project. At this distance, the vibration levels from pile driving would be below the onset of minor building damage (cracks in plaster walls) threshold of 100 VdB for fragile buildings. To get the vibration levels below the human annoyance level of 80 VdB, the pile driving activity would require approximately 175 feet from the nearest sensitive receptor.

Construction-period vibration impacts would be assessed for each alternative during the final design phase, when construction methods and the locations of specific types of construction equipment have been identified.

4.7.4 SUMMARY OF IMPACTS

The results of the vibration impact assessment for each of the South Coast Rail alternatives are summarized in Table 4.7-13. This summary includes the vibration impacts from the Southern Triangle from Weir Junction to New Bedford and Fall River that are common to all Build Alternatives. As indicated in Table 4.7-13, the Rapid Bus Alternative results in no vibration impacts from the project.

Because the rubber tired buses generate much lower vibration levels than the trains, and because the buses operate on highways where the receptors are located more than 40 feet from the roadway. The vibration impacts from the Stoughton Alternatives and the Whittenton Alternatives are essentially the same (146 impacts vs. 150 impacts), because both of these alternatives follow the same track alignment for most of the corridor, except for the section between the Whittenton Branch turnout and Weir Junction. The Attleboro Alternatives result in the fewest impacted receptors (117 impacts). The noted vibration levels reflect annoyance and would not rise to a level considered to cause structural damage.

Table 4.7-13 Summary of Potential Vibration Impacts without Mitigation by Alternative

Alternative	Impacted Residences
No Build (Enhanced Bus) Alternative	0
Attleboro Alternatives	117
Stoughton Alternatives	146
Whittenton Alternatives	150
Rapid Bus Alternative	0

4.7.5 MITIGATION

Vibration mitigation is generally provided by installing ballast mats under the tracks to absorb or reduce the vibration levels before they enter the ground and propagate to the nearby receptors. Although ballast mats can provide anywhere from 3 to 10 VdB reduction in vibration levels, their effectiveness depends on the ground propagation characteristics, the method of installation (directly onto the ground or on a hard surface like concrete), and the frequency range of the vibration levels generated by the train passbys (ballast mats are less effective for vibration frequencies below 20-30 hertz). In addition, the FTA vibration curves used in the analysis (from Figure 4.7-3) are somewhat conservative, and represent the high range of the possible vibration levels generated by a locomotive passby. Therefore, when vibration impacts are predicted to occur using the FTA vibration curves, the FTA recommends that a more detailed vibration analysis be performed during final design for the preferred alternative before the project commits to installing ballast mats.

If vibration impacts are still predicted to occur following the FTA's more detailed vibration assessment procedures, then ballast mats are generally considered to be the most effective mitigation measure. Since ballast mats can provide anywhere from 3 to 10 VdB reduction in vibration levels (depending on the method of installation), based on the predicted vibration levels from the different project alternatives presented in Section 4.7.3.4, ballast mats would be effective in reducing the vibration levels to below the FTA annoyance criterion of 80 VdB.

For the impacted receptor located within 225 feet of the switch at Weir Junction, "frogs" (sections of railroad track at a switch that guide rail car wheels from one track to the other) with spring-loaded mechanisms can be used rather than conventional frogs without spring-loaded mechanisms. The spring-loaded mechanism closes the gaps between the running rails. This substantially reduces the vibration emanating from switches and thus eliminates the impact at this receptor.

For the impacted receptors located within 100 feet of the switches inside the proposed layover facility (the Fall River Weaver's Cove Site), or 225 feet from the mainline switches that lead into the layover facilities (the Fall River Weaver's Cove Site and the New Bedford Church Street Site), either the layout of the facility could be re-designed so that the switches are not located near sensitive receptors, or "frogs' with spring-loaded mechanisms could be installed to reduce vibration levels.

During construction, if pile driving is required, vibration impacts can be reduced by pre-augering the hole so that the actual impact driving of the pile would only occur during the last few feet of installation. Another mitigation measure is sonic or vibratory pile driving (93 VdB at 25 feet), where the pile is vibrated into the ground eliminating the need for an impact hammer.