6. SUMMARY OF NOISE MITIGATION OPTIONS AND RECOMMENDATIONS

This report provides a summary of potential noise mitigation measures that can be considered in response to highway-induced noise impacts. The FHWA, through 23 CFR, Part 772, identifies situations where federal funds may be used for noise abatement. ODOT Noise Procedures (Policy 417-001(SP)) further define highway noise impact assessment procedures, noise abatement procedures, coordination requirements, and noise abatement criteria, applicable to both federally funded and 100% state-funded projects.

As per state and federal procedures, noise abatement will be considered when noise impacts are identified; noise abatement measures would effectively reduce noise impacts; and the overall noise abatement benefits outweigh any adverse effects and the associated costs of the proposed abatement. The specific noise abatement measures identified in 23 CFR, Part 772 include:

(1) Traffic management measures;
(2) Alteration of horizontal and vertical alignments;
(3) Acquisition of property rights for construction of noise barriers;
(4) Construction of noise barriers (within or outside highway right of way);
(5) Acquisition of real property to serve as a buffer to preempt development; and
(6) Noise insulation of public use nonprofit institutional structures.

In addition to the noise mitigation measures mentioned above, this report further investigated any and all potentially feasible and reasonable noise mitigation measures that may be available to the Department. Noise mitigation measures were evaluated at the noise source, in the noise path, and at the noise receiver. Additionally, planning initiatives (at both the state and local level) are also discussed for their potential to promote noise compatible land use planning, and avoid future conflicts between non-compatible land uses.

This section of the report will present a summary of the noise abatement options that have been considered. **Tables 4 through 7** provide a summary of the noise mitigation measures that have been considered at the noise source, in the noise path, at the noise receiver, and through planning initiatives. These tables identify the specific mitigation measure considered, and present a summary of potential benefits, relative cost, maintenance concerns, pros, cons, and a summary of feasible situations for which the mitigation measure could be most effective.

Table 4 provides a list of noise abatement options that are available to reduce noise levels at the noise source. These potential mitigation measures are described in detail in **Section 5.1 - Noise Source**. As shown in **Table 4**, at the noise source, engineering considerations appear to have the greatest potential to reduce noise levels associated with highway projects. Perhaps the most effective (and cost-effective) option is to modify the horizontal alignment to avoid noise-sensitive areas or the vertical alignment to increase roadway cuts and provide natural shielding to near-by noise sensitive land uses. This technique is effective for new transportation projects, but may have limited application to roadway improvement projects, where the general location of the roadway alignment is already set. Effective noise mitigation is also available by modifying the existing or proposed pavements, and replacing standard PCC pavement types with open graded and softer pavement options. Assuming PCC pavements as a standard, noise reductions of 3 to 8

dBA can be achieved by implementing alternate pavements and/or implementing roadway surface treatments/overlays. The report presents a summary of the options, benefits, and costs that can be anticipated.

Table 4: NOISE SOURCE

	Effectiveness/ Benefit	Cost	Maintenance	Pros	Cons	Feasible Situations	Within the Control of the Department
Vehicles:							
Engine-Power Train-Mechanical Noise	Fair	N/A	N/A	Only benefits individual vehicles	Cannot benefit the entire vehicle fleet	N/A	No
Exhaust Noise	Fair						
Tire Noise	Fair						
Engine Brakes	Good						
Operational Factors:							
Speed Considerations	Fair	Low	Low	Increase safety	Require enforcement	On local roads	Yes
Reductions in Vehicle Volume	Fair			Reduce congestion	Impacts regional travel		Yes
Modification to Vehicle Composition and Reduced Truck Volumes	Average				Impacts regional commerce		Yes
Other Traffic Calming and Flow Improvement Measures	Fair			Increase safety	Only apply to local roadways		Yes
Driver Behavior	Fair				Out of ODOT control		No
Engineering Considerations:							
Alteration of Vertical/ Horizontal Alignments	Good/Excellent	Low/High	Low	Can eliminate impact	Can impact other resources	New highway alignments	Yes
Reduced Grades	Good	Low/High	Low	Reduce truck noise	Engineering reproduction	New highway alignments	
Tunnels	Excellent	High	High	Can eliminate impact	High cost	Mountainous or highly developed areas	
Pavements Options and Characteristics							
Portland Concrete Cement (PCC)	Fair	Medium/High	Low	Durable	Loudest	New construction	Yes
Porous PCC	Good (4-7 dBA from PCC)	Medium/High	Low/Medium	Good noise reduction	Needs periodic cleaning	New construction	
Densely-Graded Asphalt	Average (3-4 dBA from PCC)	Medium	Medium	Smooth ride	Not durable	New construction	
Open Graded Friction Coarse Pavements (OGFC)	Good (4-7 dBA from PCC)	Medium	Medium/High		Needs periodic cleaning	New construction	
Rubberized Asphalts and Quiet Pavements	Good (7-8 dBA from PCC)	Medium	Medium/High	Good noise reduction	Requires a high temperature	New construction	
Roadway Surface Treatments and Overlays	Average/Good (3-8 dBA from PCC)	Low	Medium High		Not durable	Maintenance/Resurfacing	

While recent reports document potential benefits associated with alternate pavement types, FHWA will not allow state DOT's to consider alternate pavement as a form of noise mitigation unless the state enters into "Quiet Pavement Research" or a Quiet Pavement Pilot Program (QPPP). Each of these programs has different requirements (documented in the body of the report) that should be considered prior to considering alternate pavement as a noise mitigation measure. Additionally, ODOT should also consider the potential noise benefits against potential increased costs, durability, maintenance issues, and safety (traction) concerns, before any final decisions are made to implement this form of noise abatement.

Operational factors and modifications can also provide some benefit of reduced noise from highway sources. Perhaps the most effective technique related to operational factors is to restrict/reduce heavy truck volumes and reduce posted speeds on problem roadways. Unfortunately, these techniques can impact the regional movement of people and goods; and therefore can only be considered in specific situations.

Table 5 provides a list of noise abatement options that are available to reduce noise levels in the noise path. These potential mitigation measures are described in detail in **Section 5.2 - Noise Path**. As shown in **Table 5**, in the noise path, noise barriers and earth berms appear to have the greatest potential for implementation in response to an identified noise impact. Noise barriers and earth berms can achieve noise reductions in the range of 5 to 15 dBA. Noise barriers have a relatively high cost, in the range of 2.1 million dollars per lineal mile, however, these options still appear to be the most feasible and reasonable form of noise mitigation available for both existing and future roadway projects (both Type I and Type II projects). Earth berms are often a preferred alternative to noise barriers; however, the implementation of berms can have engineering concerns, due the large horizontal footprint typically required to achieve adequate berm height. Given these concerns, the design and construction of earth berms is often more difficult when considering improvements to existing roadways, or as a form of Type II noise mitigation. The cost of earth berms can vary significantly, depending on the availability of open space and fill material. For these reasons, earth berms are considered as an effective alternative to noise barriers on a case-by-case basis. Buildings and other man-made structures can also reduce noise levels (comparable to noise barriers or berms), but are generally located outside of ODOT right-of-way, and generally beyond the control of the department for implementation in response to noise impacts.

Vegetative screening can provide some benefits to reduce noise levels, if the vegetation has adequate width and density. Unfortunately, vegetation must be in the range of 100 to 200 feet wide to provide effective noise reductions. Additionally, unless the vegetation is coniferous, noise benefits tend to vary from season to season. Given theses requirements, existing vegetation between the roadway and the receivers can help to reduce noise levels; however, it is very difficult to plant vegetation with adequate density and thickness to provide noise abatement in response to noise impacts. FHWA and ODOT do recognize the psychological benefits of vegetation screening and do support this technique as an alternative to noise mitigation or as a means to improve the aesthetic appearance of noise mitigation features (such as barriers or berms).

Table 5: NOISE PATH

	Effectiveness/ Benefit	Cost	Maintenance	Pros	Cons	Feasible Situations	Within the Control of the Department
Barriers	Excellent (5-15 dBA)	Medium/ High	Medium	Most effective Aesthetic options Require minimal right-of-way	Impacts Viewshed	Almost always - Type 1 and Type 2	Yes
Earth Berms	Excellent (5-15 dBA)	Low/ Medium	Low	Most effective Aesthetically pleasing	Excessive Space Requirements	Wide Corridors - Often Type 1	Yes
Buildings and Other Man-Made Structures	Good (up to 10 dBA)	N/A	N/A	No cost to ODOT Can function as a noise barrier	Developer driven	Requires Local Planning	No
Vegetative Screening	Fair/Average	Medium	Low	Psychologically beneficial Aesthetic options	Seasonal Variations Require lots of space	Almost Always	Yes
Active Noise Cancellation	N/A	High	High	In theory - can eliminate noise	Non-existent in 3D application Experimental	N/A	N/A

Active Noise Cancellation is a very complex form of noise mitigation that is still in a very experimental phase when considering noise abatement in three-dimensional situations. This concept has been effectively developed for one-dimensional applications, such as noise cancelling headsets used in the aviation industry or in HVAC duct-work. Unfortunately, to date no products exist commercially (or are approved by FHWA or any state DOT) that have the potential to reduce noise levels adjacent to highway corridors. Additionally, it is assumed that any concepts of noise cancellation for highway sources would have high construction and maintenance costs, although no specific products were identified or evaluated in detail as part of this analysis. Therefore, this concept remains a significant challenge to provide feasible and reasonable noise reductions in response to existing and/or future highway-related noise impacts.

Table 6 provides a list of noise abatement options that are available to reduce noise levels at the noise receiver. These potential mitigation measures are described in detail in **Section 5.3 - Noise Receivers**. As shown in **Table 6**, there are limited options available to address noise levels at the receiver. Noise masking can help to reduce the annoyance of highway-related noise; however, this technique cannot reduce noise levels, and typically has minimal opportunity for implementation.

Sound insulation is an effective technique for reducing interior noise levels for special land uses. These uses include nonprofit institutional structures such as churches, hospitals, libraries, and schools. Sound insulation is an effective technique to reduce interior noise level impacts, but not a preferred technique, since this option cannot effectively reduce exterior noise levels. ODOT currently has a formal evaluation process in place to provide sound insulation, where warranted.

Table 7 provides a list of noise abatement options that are available to reduce noise levels through Planning Initiatives. These potential mitigation measures are described in detail in **Section 5.4,** and shown in **Table 7.** As indicated, noise compatible land use planning is a noise abatement technique that has excellent potential to reduce or eliminate future highway-induced noise impacts. The concept involves encouraging logical development trends, by developing less-sensitive land uses adjacent to transportation corridors and promoting the use of open space to provide buffer zones between highways and noise-sensitive developments. This concept relies on effective planning at the local level, and requires effective communication between state and local government to become an effective tool. This concept is voluntary in nature, and requires local government to proactively plan for and prevent incompatible land uses adjacent to highway corridors. Effective implementation also relies on State DOT's to promote and educate local municipalities and planning organizations of the tools available. The concept may also require state DOT's to perform inventories of land uses and noise levels to provide local planners with the information necessary to implement an effective program. The cost of this concept varies significantly, depending on the needs of specific communities and the goals of the program. However, regardless of these variations, noise compatible land use planning is a very effective tool that, if done effectively, can avoid future noise impacts, reduce the needs for other forms of noise mitigation, enhance transportation corridors, promote commercial and industrial development, increase local tax base, and improve the overall quality of life adjacent to transportation corridors. ODOT has initiated noise compatible land use planning and is currently working with the Miami Valley Regional Planning Commission to promote these strategies. If successful, it may be appropriate for the Department to expand this program to other areas, and ultimately state wide, to avoid future noise impacts through effective planning.

Table 6: NOISE RECEIVERS

	Effectiveness/ Benefit	Cost	Maintenance	Pros	Cons	Feasible Situations	Within the Control of the Department
Sound Insulation	Average	Medium	Low	Reduces interior levels	Does not alleviate exterior noise Typically applicable for special land uses	Case-by-case basis	Yes
Noise Masking	Fair	Low/ Medium	Low/ Medium	Provides pleasing sounds Enhances Community	Does not reduce noise levels Increases noise levels	Limited	Yes

Table 7: PLANNING INITIATIVES

	Effectiveness/ Benefit	Cost	Maintenance	Pros	Cons	Feasible Situations	Within the Control of the Department
Noise Compatible Land Use Planning	Excellent	Low/ High	Low	Eliminates problem before it occurs Seperates noise sensitive land uses from potential highways Promotes harmonious land use compatibility	Requires local government initiative Voluntary in nature	Undeveloped Areas	No/Limited
Acquisition of Land to Serve as a Buffer to Preempt Development	Excellent	High	Low	Improves roadside appearance Separates noise-sensitive land uses from potential highways Eliminates problem before it occurs	May be restricted by Ohio Revised Code Costly Render the land useless for development	Undeveloped Areas	No

While the acquisition of land to serve as a buffer is also an effective planning tool, this concept is generally adopted by highway agencies during the roadway planning and design stages. The concept involves the purchase of undeveloped lands to serve as a buffer to preempt future development directly adjacent to highway corridors. While effective at eliminating noise impacts, this is a very costly strategy that is often not supported by ODOT and FHWA for specific transportation improvement projects. Additionally, this strategy is not allowable in Ohio due to specific limitations outlined in the Ohio Revised Code §5501.32.

Table 8 provides a complete summary of the noise mitigation options that were evaluated as part of this research effort. Based on the results of this study and ongoing research in the field of highway noise mitigation, below is a summary of noise mitigation recommendations that should be further considered by ODOT to address existing and future highway-related noise impacts.

Clearly, the most effective forms of noise mitigation currently available to State DOT's are noise barriers and earth berms. While these options have relatively high costs, the potential benefits that can be provided by barriers and/or berms are unmatched by any other strategy. Additionally, noise barriers and earth berms are typically effective strategies to reduce impacts on both existing and planned roadway corridors.

Engineering considerations can also reduce future noise impacts. The most effective engineering options appear to be the modification of horizontal and vertical alignments and alternate pavement types. Often the modification of vertical and horizontal alignments is limited to new roadways on new location, where ODOT has more flexibility to modify the location of the roadway. Alternate pavement types can also provide significant noise reductions; however, unless ODOT enters into Quiet Pavement Research and/or a Quiet Pavement Pilot Program (QPPP), FHWA will not support alternate pavement as an effective noise mitigation measure.

Noise Compatible Land Use planning can effectively avoid future noise level impacts at currently undeveloped lands by promoting logical development trends and site planning. The cost of these programs can vary greatly, depending on the initiatives and goals of the program. Again, this technique requires proactive planning and effective communication and cooperation between state and local agencies to develop an effective program. While this program is voluntary and its costs may vary, the anticipated benefits can be significant. ODOT is currently promoting these concepts with the Miami Valley Regional Planning Commission, and if successful, may want to consider expanding the program to other regions/municipalities, and ultimately state-wide.

Table 8: SUMMARY OF NOISE MITIGATION OPTIONS

Mitigation Technique	General Effectiveness	Monetary Costs	Conditions Where Feasible	Within the Control of the Department
Vehicle Components	Fair	N/A	N/A	No
Operational Factors	Fair	Low	Local Roads	Yes
Engineering Considerations	Good/Excellent	Medium	New Construction	Yes
Pavements	Average/Good	Low/Medium	New Construction	Yes
Barriers	Excellent	Medium	Almost Always - Type 1 and Type 2	Yes
Earth Berms	Excellent	Low	Wide Corridors	Yes
Buildings and Other Man-made Structures	Good	N/A	Requires Local Planning	No
Vegetative Screening	Fair	Medium	Almost Always	Yes
Active Noise Cancellation	N/A	High	N/A	N/A
Sound Insulation	Average	Medium	Case by Case	Yes
Noise Masking	Fair	Low/Medium	Limited	Yes
Noise Compatible Land Use Planning	Excellent	Low/Medium	Undeveloped Areas	No/Limited
Acquisition of Land to Serve as Buffer Zone to Preempt Development	Excellent	High	Undeveloped Areas	No