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Proactive Noise Avoidance and Mitigation Measures

Study SD2005-06-F
Final Report

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16. Abstract The focus of this research project is the mitigation and avoidance of highway noise through a program of shared responsibility between the South Dakota DOT and local governments. Its objectives are to equip the South Dakota DOT and local communities with education and tools to implement noise compatible land use planning; to recommend policies and guidelines for the South Dakota DOT to use to determine appropriate designs and roadway surfaces in noise sensitive areas; and to define performance measures to assess the effectiveness of the program. The research project included summarizing existing research; interviewing state and local stakeholders, and other state DOT officials; developing model local regulations; revising the South Dakota DOT's noise policy; conducting workshops; developing a 15-minute DVD, brochure, guidebook and PowerPoint presentation; designing, developing, testing and documenting GIS noise planning tools; and providing planning level noise contours for South Dakota interstate highways.			
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South Dakota Department of Transportation
Proactive Noise Avoidance and Mitigation Measures

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RELATED MATERIALS DISTRIBUTED SEPARATELY

1. DVD – "Proactive Noise Avoidance and Mitigation Measures"
2. Trifold Brochure – "How to Prevent Adverse Effects from Highway Noise"
3. Proposed SDDOT Noise Policy, DOT- E&P – PD – 3.0
4. Training Workshop PowerPoint Presentation
5. Tools For Preventing Adverse Effects From Highway Noise (A State/Local Partnership Approach)

I. EXECUTIVE SUMMARY

A. Problem Description

The South Dakota Department of Transportation (SDDOT) seeks to work cooperatively with local governments, community leaders and developers to minimize the impacts of highway noise through an approach of shared responsibility. Although the Federal Highway Administration (FHWA) has and continues to encourage communities to adopt noise compatible land use practices (23CFR772.13), the incentives for its use are sometimes weak, and aid to local governments, community leaders and developers is limited or nonexistent. With the cost of noise barriers ranging between $1M and $4M per mile, there is financial incentive on the part of SDDOT and local communities to minimize the construction of noise barriers where it is possible, so that the limited, available federal and state matching funds can be used for other important highway uses.

Increasing highway traffic noise is an important issue in South Dakota. Highway traffic noise increases as traffic and truck volumes grow over time, causing noise impacts on the adjacent land uses. This scenario has occurred in many parts of South Dakota. Some of the problems with highway traffic noise growth have been aggravated by the use of certain pavement surface textures and rumble strips. Some of the problem has occurred because there's a perception on the part of planners, developers and residents that the SDDOT will construct noise barriers if the highway traffic noise becomes too loud or annoying. Some of the problem has occurred because the SDDOT has not provided local communities with the tools that are needed to plan and implement more noise compatible land use planning. The intent of this research project is the mitigation and avoidance of highway noise, by promoting a relationship of shared responsibility between SDDOT and local governments who are responsible for regulating development. SDDOT's responsibilities will be defined primarily through revisions to its Noise Analysis and Abatement Policy. This will enable planners and engineers to implement policy that is consistent with 23CFR772, and current with respect to pavement types and textures and rumble strips. SDDOT will also encourage local governments, community leaders, and developers through education and provision of guidelines, to take more responsibility to regulate land development in a manner that is consistent with the principles of noise compatible development.

B. Project Objectives

1. Objective 1 – Equip SDDOT and Local Communities

Objective 1 of the research project is **to equip the Department and local agencies to educate elected officials, business and community leaders, developers, local staff, and interested citizens, on the application, advantages, and public and private benefits of noise mitigation and avoidance measures.**

Objective 1 focused attention on what SDDOT can do to enable local governments to implement noise compatible land use planning practices in their communities by providing the tools needed by local governments. The outcome of this portion of the research has been a revised SDDOT noise policy, and a battery of tools that the SDDOT and local officials can use to implement noise compatible land use planning in their communities.

2. Objective 2 – Recommend Policies and Guidelines for SDDOT

Objective 2 of the research project is to **recommend policies and guidelines for the SDDOT to use to determine appropriate designs and roadway surfaces in noise sensitive areas.**

Objective 2 focused attention on what SDDOT can do to improve its pavement policies and designs. The outcome of this portion of the research has been a series of recommendations for pavement surface textures and rumble strips for SDDOT to follow. Use of quieter pavements and more judicious use of rumble strips helps address the highway noise problem by minimizing annoyance from pavement and rumble strips while maintaining safe pavement conditions.

3. Objective 3 – Define Performance Measures

Objective 3 of the research project is to **define performance measures, identify sources of supporting data, and validate their ability to assess the effectiveness of noise avoidance and mitigation measures applied in South Dakota.**

Performance measures are necessary to evaluate the effectiveness of the program, to financially justify its continuation, and to identify improvements that may be needed to increase its effectiveness. Raw data used directly or indirectly as performance measures is useful in identifying not only successes but shortcomings, so the program can be improved. The implementation plan includes recommended performance measures.

C. Study Tasks

The objectives were addressed through a number of tasks. The tasks specified in the original request for proposals, and one additional task (Task 18) are listed below along with a summary of the steps used to complete them.

Task 1: Meet with the project's technical panel to review the project's scope and work plan.

The Principal Investigator attended a meeting with the Technical Panel on June 14, 2005 to review the project's scope and approved research work plan.

Task 2: Review and summarize existing research concerning design and construction of roadways that mitigate or avoid noise, as well as the highway noise analysis and abatement policies and guidelines of state and local agencies in South Dakota.

This task focused on summarizing current research pertaining to quiet pavement design and rumble strip noise vs. rumble strip effectiveness; and reviewing the noise policies of South Dakota state and local agencies.

Task 3: Through interviews with state and local planning professionals and other stakeholders, develop background and identify key issues related to noise pollution in South Dakota.

During June and July 2005, the consultant team contacted the Technical Panel and a SDDOT furnished list of local stakeholders, and a summary of findings was created. The interviews identify perceptions of community noise impacts and current or potential regulatory tools to reduce noise impacts. The findings from this task were used to develop the most useful guidance information for local planning officials, and SDDOT.

Task 4: Through review of current and recent literature, and through contact with other states that are geographically and demographically similar to South Dakota, identify concepts and techniques for avoiding, abating, and controlling roadway noise.

Eight key noise specialists in the planning and environmental sections of other state DOT's that are geographically and demographically similar to South Dakota were contacted in July 2005. They completed a questionnaire and were subsequently interviewed to find out what actions state DOT's had either implemented or were considering implementing to avoid, abate or control highway noise, and to find out what types of assistance other state DOT's were providing to local communities, and what types of assistance local governments were requesting.

Task 5: Prepare a technical memorandum based on prior tasks to support scoping and design considerations related to noise avoidance, as well as noise compatible planning measures such as land use planning, ordinances, zoning, subdivision regulations, and building codes. Discuss the costs, benefits, advantages, disadvantages, and feasibility of such measures.

The results of Tasks 1 – 4 were summarized in Technical Memorandum #1, issued July 28, 2005. Technical Memorandum #1 summarized the team's research on pavements and rumble strips, South Dakota state and local noise policies, review of SDDOT's noise policy, interviews with the Technical Panel and local stakeholders, interviews with representatives of other State Highway Agencies (SHAs), and background research and approaches to support local noise compatible land use planning in South Dakota. Technical Memorandum #1 Update was issued October 24, 2005 and incorporated input received at the August 16, 2005 review meeting and subsequent follow-up.

Task 6: Identify effective noise avoidance, mitigation and abatement measures designed to protect and preserve land uses in existence prior to initiation of Type I (new location or alignment) and Type II (noise abatement on an existing highway) highway projects.

The research team interviewed two planners and a legal counsel to the SDDOT regarding the local planning and zoning tools available in South Dakota, summarized South Dakota's existing regulations, and provided additional alternative approaches to noise compatible land use planning.

Task 7: Meet with the project's technical panel to summarize the findings of prior tasks and to propose, for the panel's approval, concepts that will form the technical basis for the remaining tasks.

The Principal and Co-Principal Investigators attended a meeting on August 16, 2005, to summarize the findings of the previous tasks, and received comments on Technical Memorandum #1.

Task 8: If approved by the panel after Task 7, draft an improved noise analysis and abatement policy for the Department, identifying additional guidelines and implementation procedures for the SDDOT to facilitate consistent and effective noise management. This task should include scoping, environmental, and design guidelines that are consistent with the 1995 FHWA "Highway Traffic Noise Analysis and Abatement Policy and Guidance." The task should also provide recommendations on the use of rumble strips, surfacing types and textures for roadways in noise sensitive areas.

The current SDDOT noise policy and design practices for pavements and rumble strips were reviewed and recommendations for improvements were developed and included as part of the implementation recommendations.

Task 9: Draft model ordinances or ordinance sections to support noise compatible measures such as land use planning, ordinances, zoning, subdivision regulations, and building codes, that can be used for noise compatible design, construction, and placement of buildings, improvements and structures.

This task included analysis of alternative approaches to providing noise compatible land use planning in South Dakota, and proposed an approach with three alternative levels of assistance to local communities.

Task 10: Prepare a technical memorandum and meet with the project's technical panel to review the draft noise policy, recommended design guidelines, model ordinances, and effectiveness measures.

Technical Memorandum #2 compiled the results of Tasks 8 and 9.

Task 11: Conduct workshops in Sioux Falls and Rapid City, with elected officials, business leaders, developers, and other professionals as identified by the technical panel, to validate the draft noise policy, design guidelines, model ordinances, and effectiveness measures.

The Principal and Co-Principal Investigators conducted workshops in Rapid City on April 11, 2006 and Sioux Falls on April 12, 2006 with local planners, government officials and developers.

Task 12: Revise the draft noise policy, design guidelines, model ordinances, and effectiveness measures, based on the comments and direction of the technical panel as well as feedback obtained from the two workshops.

This task incorporated the input from the Technical Panel and from feedback received at the workshops, for use in subsequent tasks. The product was a revision to the draft noise policy, design guidelines, model ordinances, and effectiveness measures.

Task 13: Prepare materials, including a 10 to 15 minute South Dakota based noise avoidance and abatement video that state and local agencies can use to educate

elected officials, business and community leaders, developers, interested citizens, and local staff on the application and benefits of the noise policy, ordinances, and effectiveness measures.

This task included development of a 15 minute DVD, a tri-fold brochure, and a guidebook with planning tools for preventing adverse effects from highway noise.

Task 14: Prepare an implementation plan that identifies resources and strategies that state and local officials can use to market the noise policy, design guidelines, model ordinances, and effectiveness measures, including organizational procedures for implementing the policy by the Department.

An implementation plan, based on the workshop and technical panel input, was developed to assist SDDOT in rolling out the recommendations of the research.

Task 15: Complete an analysis of the research benefits that identifies and quantifies the benefits that can be expected as a result of this research.

The research benefits were developed in detail as a part of the research conducted for the final report.

Task 16: Prepare a final report summarizing the research methodology, findings, conclusions, and recommendations.

This Final Report summarizes the work of previous tasks and of all the research work that was not included in prior technical memorandums. The outline of the final report was presented for discussion and approval at the Task 10 review meeting.

Task 17: Make an executive presentation to the SDDOT's Research Review Board at the conclusion of the project.

The Principal Investigator made an executive presentation to SDDOT's Research Review Board on June 14, 2006. This included a Power Point presentation summarizing the highlights of the project, and a review of the materials prepared as a part of the project.

Task 18: Design, develop, test and document GIS Noise Planning tools and prepare noise contours in GIS for 150 interstate highway segments in South Dakota.

This additional task involved designing, developing, testing and documenting two GIS Noise Planning Tools (a Distance Calculation Tool and a Contour Calculation Tool); and preparing noise contours in GIS for 150 interstate highway segments in South Dakota. The GIS Noise Contour Tools, written as ArcGIS 9.1 extensions, consisted of: a Distance Calculation Tool that used the road median and traffic information to calculate distances to user specified noise levels; and a Contour Calculation Tool that calculates and plots the noise contours based on the distances from the road median.

D. Products

In addition to the findings, conclusions and recommendations, several products have been prepared as a part of the research project. They include:

1. Proposed noise policy that: clarifies confusing elements of the existing Type I noise policy; updates the policy to be consistent with current FHWA policy and guidelines; places greater emphasis on SDDOT's responsibility to provide tools to local governments that will better enable local communities to implement noise compatible land use planning; and integrates the planning of Type I noise projects into the Department's scoping and design process.

2. 15 minute DVD that illustrates highway traffic noise growth, describes its many adverse effects, defines a cooperative means to solve the problem, and provides examples and a proposed plan of action.

3. 40 page guidebook for local planners entitled "Tools For Preventing Adverse Effects From Highway Noise", containing: Federal Highway Administration requirements related to highway noise; areas affected by highway noise; key elements to include in a local comprehensive plan; sample ordinance sections to support noise compatible measures in local subdivision regulations; a sample section of a local zoning ordinance on highway noise prevention and mitigation; sample language to support noise compatible measures in local building codes; guidance on relevant provisions for local official maps; guidance on relevant provisions for local capital improvement programs; guidance on a proposed site plan review coordination mechanism between the local government and SDDOT; and guidance on noise analyses for proposed noise sensitive developments.

4. Tri-fold brochure summarizing key elements from the guidebook.

5. 3-hour, 202 slide PowerPoint presentation for use at training programs for local planners.

6. GIS based noise contour calculating tool, based on the TNM Lookup Tables. SDDOT planning officials will use the tool to provide the future condition 61, 66, and 71 dBA noise contours to local planning officials.

7. Future conditions 61, 66, and 71 dBA noise contours for all interstate highway segments in South Dakota, calculated using the GIS based noise contour plotting tool.

E. Recommendations

The findings and conclusions of the research led the research team to the following recommendations, organized into groupings pertaining to noise policy, design and public outreach to support noise compatible land use planning, to achieve the project objectives:

1. Noise Policy

Recommendation #1: SDDOT should revise their noise policy to define "substantial increase" as some value between 10 and 15 dBA.

State DOTs surveyed in the research define "substantial increase" as anywhere from 6 to 15 dBA. In general the more rural states define "substantial increase" as a value between 10 and 15 dBA. South Dakota uses 66 dBA as its NAC B criteria. Therefore, where the existing loudest hour noise levels are less than 51 dBA, it takes a 15 dBA increase or greater to cause a noise impact. 51 dBA is considered a quiet urban daytime noise level. In terms of loudness, a 10 dBA increase in sound pressure level is twice the loudness, so a 15 dBA increase is perceived as more than twice as loud.

Recommendation #2: SDDOT should establish a rating form for determination of reasonableness.

A significant portion of the FHWA policy guidance to State DOTs is devoted to the factors that should be included in the determination of reasonableness. The list of considerations can be used to develop a rating form. The weight, given to each item is determined by the SHA. In South Dakota, where the Department is seeking to encourage noise compatible land use planning, a relatively greater weight can be given to the age of development along the highway. In locations where a high percentage of residential development occurred adjacent to the highway, before the original highway construction, greater consideration should be given to providing noise abatement for a lane addition project. Such information can be determined using: the original project drawings; historic aerial photography, and if necessary, review of building permit filings. Similarly, if the adjacent community has developed and implemented noise compatible land use planning, since the residential development was constructed adjacent to the highway, some consideration of this should be a part of the decision making process. Lastly, if adjacent land use is changing from less to more noise compatible, less consideration should be given to providing noise abatement.

Recommendation #3: SDDOT should establish a guideline for evaluating whether a proposed SDDOT project is a Type I project, requiring a noise study.

Under FHWA 23CFR772, new highways on new alignment, significant modifications of existing highways, and the addition of through travel lanes to existing highways, qualify as Type I projects. FHWA does not provide specific guidelines on the "significance" of horizontal and vertical alignment changes, or the type and length of additional through travel lanes that qualify a project as Type I. Such guidance will assist SDDOT planners during scoping and preliminary design to better define and prepare for Type I projects.

Recommendation #4: SDDOT should increase the allowable cost per benefited receiver to the FHWA minimum of $25,000.

Although only one of several criteria, cost per benefited receiver is an important criteria used to determine reasonableness. The maximum cost per benefited receiver should reflect real estate acquisition prices and the cost of the noise abatement, and

should also address price escalation. The SDDOT policy, in effect since 1996, uses a value of $15,000 as the maximum cost per benefited receiver. Escalating that value to 2005 dollars yields a value of $20,213. The soon to be released updated FHWA policy and guidance document establishes a minimum value of $25,000. To comply with the FHWA policy, the cost per benefited receiver should be raised to $25,000.

Recommendation #5: SDDOT should adopt the proposed SDDOT noise policy, forward it to FHWA and distribute it to SDDOT main office, district office and consultants.

The proposed updated SDDOT noise policy (DOT-E&P-PD-3.0) has been reviewed by the Technical Panel and by FHWA, but must still be officially adopted by SDDOT's Executive Team. Following its adoption, the policy should be distributed as a new policy to SDDOT main office, district offices, and consultants. The policy itself should be reviewed and updated biennially.

2. Design

Recommendation #6: SDDOT should modify their PCC longitudinal tining specifications to require termination of longitudinal grooves at a minimum distance of 100 mm and a maximum distance of 380 mm from the transverse joints.

SDDOT presently provides longitudinal tining of PCC pavements, but does not have a requirement in their specifications for terminating longitudinal tining a safe distance from roadway joint systems to prevent spalling at the joints. The research identified that other states, with similar problems, have incorporated measures into their specifications to terminate the grooves in the vicinity of the joints.

Recommendation #7: SDDOT should change the bridge transverse tining specification to require a spacing pattern of: (1) 3mm wide (+/- 0.5mm) and 3 mm deep maximum; and (2) random spacing of either 13 mm or 26 mm average tine spacing. The 13 mm random tine spacing should have the following tine pattern (in millimeters): 10/14/16/11/10/13/15/16/11/10/21/13/10. The 26mm random tine spacing should have the following tine pattern (in millimeters): 24/27/23/31/21/34.

SDDOT uses a random transverse tined surfacing on bridge decks based on safety considerations. Transverse tining is noticeably louder than longitudinal tining, and some transverse tining patterns have proven to be particularly annoying. The research identified the FHWA Technical Advisory T5040.36, "Surface Texture for Asphalt and Concrete Pavements", that recommends a pattern to minimize tire-pavement noise on transverse tined PCC surfaces.

Recommendation #8: SDDOT should continue the practice of using the dense type hot mix asphalt (HMA) surface textures.

The SDDOT standard specifications and standard special provisions call for asphalt surfaces with top course aggregates that are consistent with "normal" dense type hot mix asphalt (HMA) surface textures (i.e. stone matrix asphalt, superpave asphalt, etc.). The research showed that neither rubberized nor open graded friction course

(OGFC) asphalts have been proven to be durable, or provided consistent and long term noise reductions in climates similar to South Dakota's. Rubberized asphalt has not been proven to ensure safe riding conditions for extreme winters, and temperature variations that result from numerous freeze-thaw cycles.

Recommendation #9: SDDOT should include two alternative options for resurfacing PCC pavement where a quieter pavement is desired: resurface with Dense Graded Friction Course (DGFC) pavement or diamond grinding of the PCC pavement.

In locations where SDDOT is considering rehabilitation of an existing pavement, and a quieter pavement is desired due to the proximity of noise sensitive land uses, the research findings indicated that providing a Dense Graded Friction Course (DGFC) pavement overlay or diamond grinding the PCC pavement can provide a quieter pavement surface.

Recommendation #10: For chip seal applications on road projects where quieter pavement is desired, SDDOT should use Type 1B aggregate for the upper course and Type 2A aggregate for the lower course.

The SDDOT has not received noise complaints subsequent to applying chip seal treatments, however due to its rougher texture it may be noticeably noisier than HMA surface textures. The research found that the increase in noise levels with chip seal treatments can be partially mitigated by using a two-course surface treatment where a small size aggregate is used for the top layer. The smaller aggregate size results in reduced vehicle tire/surface noise. The SDDOT Type 1B (upper course), and Type 2A (lower course) aggregates should be used because of their smaller sieve requirements as per the SDDOT standard specifications.

Recommendation #11: SDDOT should continue to follow the progress of FHWA and state highway agency quiet pavement noise research programs and make adjustments to pavement surface finishes.

SDDOT should continue to follow the progress of quiet pavement noise research programs and make adjustments to their pavement surface finishes, consistent with other performance goals (ex. safety). SDDOT should not participate in pavement research involving its standard pavements, as their performance has been well documented by SDDOT. If SDDOT wanted to use a pavement surface finish that had limited acoustical, skid and durability test information, then the research team recommends SDDOT participates in that specific research.

3. Shoulder Rumble Strips

Recommendation #12: SDDOT should provide public information and education about shoulder rumble strip policy.

The benefits of shoulder rumble strips are proven, and SDDOT policy has adopted their use on multiple highway types (i.e. 2-lane, 4-lane divided, interstate, etc.). Rumble strips are also annoying. Therefore, the SDDOT should provide public information and education regarding rumble strip policy and the highway safety benefit they provide.

Recommendation #13: SDDOT should continue to use rumble strips in rural areas, avoid rumble strips in urban areas and provide guidance for transition areas between rural and urban areas.

Based on the lack of current references regarding adverse effects of shoulder rumble strips related to noise, it is recommended that the SDDOT continue to use them in rural areas, avoid using them in urban areas (or remove them in urban areas where highway improvements are being planned and designed) and develop guidance on their use in transition areas (rural to urban).

4. Assistance Services for Local Governments

Recommendation #14: SDDOT should incorporate all elements of Level One technical assistance services for local governments

A major aspect of the research involved the interviewing of the 12 Technical Panel members; 13 South Dakota local stakeholders; and 11 key individuals at the Planning/Environmental sections of other State DOT's to determine the level of technical assistance, and the specific tools needed by local units of government to implement proactive noise avoidance and mitigation measures in their communities. Interviewees completed an extensive questionnaire that was used to formulate the specific elements of a desired technical assistance program. The majority of the Technical Panel was comprised of SDDOT employees, and also included representatives from the Cities of Pierre, Rapid City, Sioux Falls, and FHWA. The majority of the local stakeholders were municipal planners, municipal engineers or city council people from the Cities of Pierre, Rapid City and Sioux Falls, Rapid City, and Spearfish, and Minnehaha County, one representative from the private sector, and a landscape architect. Eleven key individuals at the Planning/Environmental sections of other state DOT's were contacted. Eight of the eleven completed the questionnaire, and were subsequently interviewed. They included: Arizona, Colorado, Iowa, Nebraska, North Dakota, Michigan, Montana, and Wisconsin.

Three local experts (including SDDOT's legal counsel) were interviewed to determine the legal constraints of implementing noise compatible land use planning at the local level. It was found that South Dakota communities have available to them all the traditional local planning and zoning tools and a few more contemporary ones. However, the statutes authorizing these tools are not closely based on the model state planning and zoning enabling acts like most other states in the country. Instead, they are more an outline version of them with very brief statements of purpose, power, procedure and standards. South Dakota is a state with a limited view of the role of state government vis a vis that of local government, and hence limited authority has been delegated to state agencies, beyond the obvious main function of an agency (such as building and maintaining roads, as in the case of SDDOT). There are only about a dozen home rule cities and counties, and an independently prepared charter (as opposed to a model charter) is the basis for governance in such communities. Home rule communities can take any action not expressly prohibited by state law. South Dakota is a Dillon's Rule state as relates to non-home rule communities. However, few home rule communities appear to have exercised much of the independent authority in the planning and zoning arena that usually rests in

home rule communities. Thus, nearly all jurisdictions are effectively Dillon's Rule communities as far as local planning and zoning go.

Based on the input from interviewees and local experts, 7 alternative approaches were evaluated for noise compatible land use planning and development regulation in South Dakota. The following observations were significant in reaching a decision on the appropriate approach to avoid future noise mitigation along interstate and SD State highways:

- If there are no noise sensitive land uses next to the highway there are no highway noise impacts to mitigate (now or in the future);
- If there are no highway noise impacts that SDDOT is required to mitigate, there are no expenses for noise barriers and the money that would have been spent for that purpose (often between $1M and $4M/mile on each side the road) can be used for other highway purposes;
- Road authorities have no authority over the land use decisions which allow noise sensitive land uses next to highways, but road authorities have responsibilities after the fact for noise impacts if the traffic which causes the problem results in a Type I capacity improvement project and noise barriers are found to be reasonable and feasible;
- Local governments have exclusive local land use planning, zoning, subdivision regulation and building code authority which if properly used can prevent future highway noise impacts by only permitting noise compatible land uses next to highways, or by requiring future development of noise sensitive land uses to mitigate highway noise at the time of construction;
- Therefore, the costs of providing education, technical assistance and a wide variety of guidance materials to local governments and developers, including providing one full time equivalent (FTE) noise specialist, is a fraction of the cost of just one noise barrier. Such expenses would be more easily justified if they resulted in prevention of future highway noise impacts. If these education and technical assistance efforts resulted in local planning, zoning and development approval of noise compatible land development next to highways or, if noise sensitive land uses were permitted by local governments next to highways, but only with noise barriers or super-insulation in place so that there were no adverse highway noise impacts to address as noise levels rose, the costs would be even more easily justified.

These simple observations presented a compelling case for a SDDOT initiated technical assistance program on highway noise prevention targeted to local governments.

It was also reasoned that local governments will do nothing significant to prevent adverse effects from highway noise without some technical assistance, because:

- Local governments do not know about the potential problems or their role in preventing them;
- Local governments do not know what options are available to prevent adverse highway noise impacts;

- Local governments are unlikely to adopt any noise barrier regulations if they do not receive technical assistance on the design, construction and maintenance of noise barriers from SDDOT;
- If local governments do nothing, then the future costs of road expansion projects will be much greater on the SDDOT than on the local governments, as noise impacts on abutting homes and other noise sensitive land uses must be addressed as part of Type I capacity improvement projects.

The recommendation consists of Level One technical assistance services shown in Table E-1, to prevent adverse highway noise impacts.

Table E-1
Level One Technical Assistance Services For Local Governments

Technical Assistance Level	Elements of Technical Assistance
Level One	1. Preparation and distribution of educational materials, including a 15-minute DVD, and tri-fold brochure to local units of governments and developers. 2. Preparation and delivery of annual training programs using the 3-hour PowerPoint slide presentation, and guidebook. 3. Development and distribution of the guidebook "Tools for Preventing Adverse Effects From Highway Noise" that includes model local planning, zoning, subdivision regulation and building code elements to enable noise compatible land use planning and mitigate highway noise impacts associated with noise sensitive development. 4. Provision of future condition noise contours defining an area adjacent to highways that is impacted by highway noise. 5. Ongoing response to technical assistance requests from local governments and developers. 6. Development of SDDOT technical standards for an approved local highway noise prevention land use planning and development regulation program.

Recommendation #15: SDDOT should determine which, if any, Level Two and Level Three services will be provided, and develop an implementation plan for the additional services.

This work element involves evaluation of the additional Level Two and Level Three assistance services listed in Table E-2 below. We recommend that SDDOT perform this evaluation over the first three quarters of 2007 while the general technical

assistance program is implemented. After a decision is made on which elements of Level Two and Level Three assistance are to be provided, an implementation plan for each should subsequently be developed.

Table E-2
Additional Assistance Services For Local Governments

Technical Assistance Level	Additional Elements of Assistance
Level Two	1. Provision of SDDOT ROW acquisition services for construction of noise barriers by developers or local governments. 2. Development of SDDOT standards for noise barriers. 3. Review and comment on proposed noise barrier specifications in particular locations by communities participating in the program. 4. Inspection of noise barriers during construction to assure conformance with SDDOT standards. 5. Inspection of noise barriers upon completion of construction to assure conformance with SDDOT standards.
Level Three	1. Acceptance of responsibility for long term maintenance of noise barriers constructed by others within the SDDOT ROW. 2. Cost sharing with local governments participating in the program on construction of certain Type II noise barriers.

Recommendation #16: SDDOT should encourage local units of government to adopt the "quality of life" standards that define the highway noise overlay district for three types of noise sensitive land uses.

Noise standards are needed to define the area adjacent to highways that is impacted by highway noise and the limits of the highway noise overlay zoning district. Such standards should equal or exceed the FHWA standards, which only define a noise impact rather than a desired condition, and should be consistent with the L_{dn} standards used by other federal agencies. Local governments should use:

- The loudest hour L_{eq} of 61dBA as the recommended outdoor noise criterion. This preserves the yard area for conversational speech for NAC B (noise sensitive) land uses. The distance is measured from the centerline, or median, of the roadway to the nearest edge of the active use area.
- The loudest hour L_{eq} of 41dBA (corresponding to an outdoor loudest hour L_{eq} of 61dBA) as the noise criterion for buildings where people regularly sleep, and where there is infrequent or only transient outdoor use. The distance is measured from the centerline, or median, of the roadway to the nearest point of the principal building.
- The loudest hour L_{eq} of 51dBA (corresponding to an outdoor loudest hour L_{eq} of 71dBA) as the recommended indoor noise criterion for buildings where

people do not regularly sleep, and where there is infrequent or only transient outdoor use. The distance is measured from the centerline, or median, of the roadway to the nearest point of the principal building.

The traffic volumes used to develop the distances to the 61 and 71 dBA noise contours are based on one of two methods. In locations where the existing highway capacity is significantly greater than the present conditions traffic volumes, the 20-year traffic projection, determined by the SDDOT, is used as the traffic volume. The operating speed used in the calculation is the posted speed limit. In locations where the existing traffic volumes are approaching the highway capacity for interstate and South Dakota state highway segments, the operational capacity of the highway and the operating speed associated with the operational capacity are used in the calculation.

The planning level calculation methodology provided in the TNM Look-up Tables assumes acoustically soft ground, auto speed, auto volume, heavy truck speed, and heavy truck volume are the only input variables needed. Variation in terrain, obstructions, grades, and natural barriers are ignored in the calculations.

5. SDDOT Program

Recommendation #17: SDDOT should hire a full-time equivalent (FTE) Noise Specialist.

Implementing the recommendations of the research will require the hiring of 1.0 full-time equivalent (FTE) Noise Specialist. The Noise Specialist would be responsible for SDDOT's Type I noise policy and program, and would be the important resource person for local governments seeking to implement noise compatible land use planning in their communities. The SDDOT should develop a detailed job description, obtain hiring authorization, advertise for the position, evaluate candidates, and complete the hiring process in time so the noise specialist begins employment at the beginning of FY 2008. Once hired, the Noise Specialist should receive training in the FHWA TNM model, land use planning and zoning, and should participate in the Transportation Research Board's ADC40 Committee activities regularly.

Recommendation #18: SDDOT should incorporate GIS Noise Planning Tools into the SDDOT GIS platform, make the interstate highway noise contours available to local governments and use the GIS Distance Calculation Tool and Contour Calculation Tool to develop noise contours for other major South Dakota state highways.

This work element involves incorporating the GIS Noise Planning Tools, developed as part of the research project, into SDDOT's GIS platform; making the Interstate highway noise contours, developed as part of the research project, available to local units of government; and utilizing the GIS Distance Calculation Tool and Contour Calculation Tool, with traffic data provided by SDDOT's Office of Transportation Inventory Management, to develop noise contours for other major South Dakota state highways. Noise contours should be made available only via SDDOT's web site so that changes to the noise contours that could occur based on changes in traffic projections, speeds or commercial truck volumes can be updated and communicated

broadly and quickly. Procedures and protocols for making the Interstate highway noise contours and other SD highway noise contours available to local units of government should be developed. Traffic data used to develop the noise contours should be reviewed annually to verify that no significant changes have occurred to the traffic data. Also, changes to noise contours and roadways as a result of SDDOT Type I projects should be incorporated annually.

Recommendation #19: SDDOT should send the final report to participants of the April 2006 workshops.

Those local units of government who sent representatives to the April 2006 workshops should receive copies of the final report and electronic versions of the products of the research that will be made available by SDDOT, since materials distributed at the workshops have since been updated.

Recommendation #20: SDDOT should hire the research team to conduct the 3-hour workshop for interested units of local government every year for the next 3 years.

For interested units of local government who have not participated in a workshop, the SDDOT should hire the research team to conduct the 3-hour workshop annually for the next 3 years. As a part of this, the research team will update the Power Point slide presentation. Materials developed from the research, including the final report, DVD, brochure, and "Tools for Preventing Adverse Impacts from Highway Noise" should be distributed at the workshops. The workshops could be offered as part of another venue, such as the annual Statewide Planning Conference (usually held in October), or as a stand-alone workshops. In subsequent years, the training should be provided by the Noise Specialist.

Recommendation #21: SDDOT should develop procedures and provide assistance to achieve a coordinated review process for development projects along interstate and state highways.

Local units of government who adopt the highway noise overlay district provisions will require assistance and participation from SDDOT under the coordinated review and approval process for Interstate and State highways. SDDOT will need to develop the procedures for the coordination process and the Noise Specialist should participate in the ongoing coordinated site plan reviews.

Recommendation #22: SDDOT should provide ongoing technical assistance for the implementation of proactive noise avoidance and mitigation measures.

Under the Level One technical assistance program, planning department officials from local units of government will require ongoing technical assistance from the SDDOT. This assistance should be provided by the Noise Specialist and may be expanded in the future to include some or all of the portions of Level Two and Three technical assistance.

F. Benefits of the Research

The benefits of proactive noise mitigation and avoidance measures will stem from the partnership between SDDOT and local units of government that will guide future development adjacent to South Dakota highways so that it is compatible with highway noise. In this partnership, the Department proposes policies and provides resources to local governments, who in turn use those resources and the powers already granted to them to guide development in two ways: by encouraging noise compatible development adjacent to highways; and by guiding noise sensitive development to achieve development that is noise compatible.

The benefits of noise compatible land use planning will accrue to:

- People who live, work or visit lands adjacent to highways;
- Local communities
- The South Dakota DOT
- The traveling public

II. PROBLEM DESCRIPTION

The South Dakota Department of Transportation (SDDOT) seeks to work cooperatively with local governments, community leaders and developers to minimize the impacts of highway noise through an approach of shared responsibility. To date, however, the focus of highway noise abatement in the United States has been narrow, involving the construction of Type I or Type II noise barriers by state highway departments along highways constructed using federal funds. The use of federal funds requires the evaluation of noise impacts, and provision of noise barriers where they are found to be reasonable and feasible in accordance with 23CFR772 (FHWA, 1982). Although the Federal Highway Administration (FHWA) has and continues to encourage communities to adopt noise compatible land use practices (23CFR772.13), the incentives for its use are sometimes weak, and aid to local governments, community leaders and developers is limited or nonexistent. With the cost of noise barriers ranging between $1M and $4M per mile, there is financial incentive on the part of SDDOT and local communities to minimize the construction of noise barriers where it is possible, so that the limited, available federal and state matching funds can be used for other important highway uses.

Increasing highway traffic noise is an important issue in South Dakota. It causes adverse effects on people and property, local governments, and state government. Many people are adversely affected by highway noise. Property owners and renters, people who attend places of worship, students attending schools, travelers sleeping in hotels, to name a few. Most single family residents use a portion of their rear property for rest and relaxation. When highway noise intrudes into this area, people lose their outdoor space as a place of enjoyment. Studies have also shown that the sales prices of homes located adjacent to Interstate highways are lower than for similar homes located further from the highway. This results in a lower tax base and increased difficulty in selling the properties.

Highway traffic noise increases as traffic and truck volumes grow over time, causing noise impacts on the adjacent land uses. We examined highway traffic noise growth along a portion of I-29 in Sioux Falls, just north of 57th Street. Using the 66 dBA noise contour to define an area adjacent to the highway that is adversely affected by highway noise, we noted how traffic noise increased over time. In the early 1960's land on both sides of I-29 was undeveloped. In 1980 the 66 dBA contour was located only 135 feet from the median of I-29, which was within the right-of-way owned by the state. By 1991 it had moved out another 110 feet, and by 2005 another 60 feet. Because of increasing traffic, the highway will reach its operational capacity by the year 2025, and the 66 dBA contour will be 435 feet from the median. Since 1980, not only has I-29 traffic in the Sioux Falls area grown by a factor of 350% but the percentage of heavy commercial vehicles in the traffic mix has increased from 10 to 15%. Since each heavy commercial vehicle generates about the same noise as 28 autos, greater truck volumes cause the traffic stream to be noisier for the same operating speed. This scenario has occurred in many parts of South Dakota.

If the South Dakota DOT is required to construct noise barriers to abate noise from its projects, federal funding provided for highway and bridge improvements that normally benefits many people will be diverted to build expensive noise barriers that only benefit a few. Using a year 2006 average noise barrier cost of $30 per square foot, it costs $2.4M to construct one mile of 15 foot high ground mounted noise barrier on just one side of a highway. Such a noise barrier may benefit up to 500 residences. By comparison, for $2.4M, the Department could benefit many by: resurfacing just over 20 miles of two-lane roadway; replacing six 100-foot long, 2-lane bridges; or fully regrading and providing new pavement for over 2 miles of two lane highway. The Department wants to provide the improvements South Dakotan's want most which are safe and smooth highways.

Some of the problems with highway traffic noise growth have been aggravated by the use of certain pavement surface textures and rumble strips. Some of the problem has occurred because there's a perception on the part of planners, developers and residents that the SDDOT will construct noise barriers if the highway traffic noise becomes too loud or annoying. Some of the problem has occurred because the SDDOT has not provided local communities the tools that are needed to plan and implement more noise compatible land use planning.

The intent of the research project is the mitigation and avoidance of highway noise, by promoting a relationship of shared responsibility between SDDOT and local governments who are responsible for regulating development. SDDOT's responsibilities will be defined primarily through revisions to its Noise Analysis and Abatement Policy. This will enable planners and engineers to implement policy that is consistent with 23CFR772, and current with respect to pavement types and textures and rumble strips. SDDOT will also encourage local governments, community leaders, and developers through education and provision of guidelines, to take more responsibility to regulate land development in a manner that is consistent with the principles of noise compatible development.

III. OBJECTIVES

The stated objectives of the research are listed below in italics, followed by a discussion explaining how and to what extent each objective was accomplished, and the relationship of each objective to the problem description.

A. Objective 1 – Equip SDDOT and Local Communities

Objective 1 *of the research project is to equip the Department and local agencies to educate elected officials, business and community leaders, developers, local staff, and interested citizens, on the application, advantages, and public and private benefits of noise mitigation and avoidance measures.*

This objective focused attention on what SDDOT can do to enable local governments to implement noise compatible land use planning practices in their communities by providing the tools needed by local governments.

This objective was accomplished through:

1. Interviewing local planning officials in South Dakota to determine how the SDDOT could best assist them in implementing noise compatible land use planning practices. Specifically, what guidance, tools, resources, training and follow-up would be of the greatest benefit.

2. Interviewing SDDOT officials knowledgeable about emerging local planning and development problems and pressures in South Dakota.

3. Interviewing officials from other State Highway Agencies (SHA's) to obtain their experiences with encouraging noise compatible land use planning in their states, and to determine failures and successes.

4. Reviewing the present SDDOT noise policy to identify ways in which the Department could be more proactive by providing tools to promote and enable noise compatible land use planning by local communities, and find ways to better protect the Department from having to construct noise barriers in the future by clarifying its policies.

5. Issuing a new SDDOT policy that will better guide SDDOT officials to equip and educate local government officials with the tools they need to implement noise compatible land use planning.

6. A review of land use planning and land development regulation in South Dakota.

7. Developing, evaluating alternative approaches, and recommending the most appropriate approach to apply in South Dakota to encourage noise compatible land use planning.

8. Developing and providing tools for local planning officials, specifically:

    a. A 15 minute DVD that illustrates highway traffic noise growth, describes its many adverse effects, defines a cooperative means to solve the problem, and provides examples and a proposed plan of action (Distributed separately).

b. A 40 page guidebook for local planners entitled "Tools For Preventing Adverse Effects From Highway Noise," containing: Federal Highway Administration requirements related to highway noise; areas affected by highway noise; key elements to include in a local comprehensive plan; sample ordinance sections to support noise compatible measures in local subdivision regulations; a sample section of a local zoning ordinance on highway noise prevention and mitigation; sample language to support noise compatible measures in local building codes; guidance on relevant provisions for local official maps; guidance on relevant provisions for local capital improvement programs; guidance on a proposed site plan review coordination mechanism between the local government and SDDOT; and guidance on noise analyses for proposed noise sensitive developments.

c. A tri-fold brochure summarizing key elements from the guidebook (Distributed separately).

d. A 3-hour, 202 slide PowerPoint presentation for use at training programs for local planners.

e. A GIS based noise contour calculating tool, based on the TNM Lookup Tables. SDDOT planning officials will use the tool to provide the future condition 61, 66, and 71 dBA noise contours to local planning officials.

f. Future conditions 61, 66, and 71 dBA noise contours for all interstate highway segments in South Dakota, calculated using the GIS based noise contour plotting tool.

9. Conducting two training workshops (one in Sioux Falls, one in Rapid City) using draft versions of the planning tools.

10. Revising the tools with the input received from the workshops.

The outcome of this portion of the research has been a new SDDOT noise policy, and a battery of tools that the SDDOT and local officials can use to implement noise compatible land use planning in their communities. Meeting this objective of the research will result in many fewer highway noise impacts in the future.

B. Objective 2 – Recommend Policies and Guidelines for SDDOT

Objective 2 of the research project is to *recommend policies and guidelines for the SDDOT to use to determine appropriate designs and roadway surfaces in noise sensitive areas.*

This objective focused attention on what SDDOT can do to improve its pavement policies and designs. This objective was accomplished through:

1. Reviewing SDDOT's present policies, specifications and details for pavement surface treatments and rumble strips.

2. Interviewing SDDOT personnel involved with pavement design and research.

3. Reviewing and synthesizing current research on tire/pavement noise for Portland Cement Concrete (PCC) and asphalt pavements. This included reviewing published research papers, and interviewing individuals conducting pavement noise research.

4. Reviewing and synthesizing published research on rumble strip noise.

5. Interviewing officials from other SHA's to solicit their experiences with various pavement and rumble strip types, and to determine their present practices.

6. Reviewing policies and specifications of other SHA's to determine what pavement types and surface texture treatments are preferred for reducing pavement noise.

The outcome of this portion of the research has been a series of recommendations for pavement surface textures and rumble strips for SDDOT to follow. Use of quieter pavements and more judicious use of rumble strips helps address the highway noise problem by minimizing annoyance from pavement and rumble strips while maintaining safe pavement conditions.

C. Objective 3 – Define Performance Measures

Objective 3 of the research project is to *define performance measures, identify sources of supporting data, and validate their ability to assess the effectiveness of noise avoidance and mitigation measures applied in South Dakota*.

Performance measures are necessary to evaluate the effectiveness of the program, to financially justify its continuation, and to identify improvements that may be needed to increase its effectiveness. Raw data used directly or indirectly as performance measures is useful in identifying not only successes but shortcomings, so the program can be improved upon.

Section VI provides an implementation plan that includes specific work elements formulated from the research recommendations, and recommended performance measures. The work elements are grouped into two categories: SDDOT policy and program; and resources for local units of government.

IV. TASK DESCRIPTIONS

Task 1: Meet with the project's technical panel to review the project's scope and work plan.

The Principal Investigator attended a meeting with the Technical Panel on June 14, 2005 to review the project's scope and approved research work plan.

Task 2: Review and summarize existing research concerning design and construction of roadways that mitigate or avoid noise, as well as the highway noise analysis and abatement policies and guidelines of state and local agencies in South Dakota.

This task focused on three items:

1. Summarizing current research pertaining to quiet pavement design;
2. Summarizing current research pertaining to rumble strip noise vs. rumble strip effectiveness; and
3. Reviewing the noise policies of South Dakota state and local agencies.

Task 3: Through interviews with state and local planning professionals and other stakeholders, develop background and identify key issues related to noise pollution in South Dakota.

During June and July 2005, the consultant team contacted the Technical Panel and a SDDOT furnished list of local stakeholders from Sioux Falls, Pierre, Rapid City and Spearfish to discuss their perspectives on community noise impacts, as well as the current and potential regulatory tools that might be used to reduce noise impacts in their communities.

A summary of findings was created for two groups, the Technical Panel for the research project and local stakeholders. The interviews, summarized in Section V.D., identify perceptions of community noise impacts and current or potential regulatory tools to reduce noise impacts.

The findings from this task were used in subsequent tasks to develop the most useful guidance information for public officials that are faced with land use decisions adjacent to highway corridors, and to provide SDDOT with information on actions that they can implement to help avoid, abate or control highway noise.

Task 4: Through review of current and recent literature, and through contact with other states that are geographically and demographically similar to South Dakota, identify concepts and techniques for avoiding, abating, and controlling roadway noise.

Eleven key individuals in the planning and environmental sections of other state DOT's that are geographically and demographically similar to South Dakota were contacted in July 2005. Eight noise specialists from Arizona, Colorado, Iowa, Nebraska, North Dakota, Michigan, Montana, and Wisconsin DOT's completed a questionnaire and were subsequently interviewed.

The noise specialists were asked two questions. Each question included a list of possible actions or assistance. The intent of the first question was to find out what actions state DOT's had either implemented or were considering implementing to avoid, abate or control highway noise. These questions focused on actions other than those typically used on Type I noise mitigation projects.

The intent of the second question was to find out what types of assistance other state DOT's were providing to local communities, and what types of assistance local governments were requesting

so as to improve noise compatible land use planning. See Appendix C for a copy of the questionnaire. The two questions were:

1. Has the Department implemented or is the Department considering implementing any of the following actions specifically to avoid, abate or control highway noise?

2. Has the Department provided, or has the Department received requests from local governments for any of the following types of assistance to improve noise compatible land use planning in their communities?

Task 5: Prepare a technical memorandum based on prior tasks to support scoping and design considerations related to noise avoidance, as well as noise compatible planning measures such as land use planning, ordinances, zoning, subdivision regulations, and building codes. Discuss the costs, benefits, advantages, disadvantages, and feasibility of such measures.

The results of Tasks 1 – 4 were summarized in Technical Memorandum #1, issued July 28, 2005. Technical Memorandum #1 summarized the team's research on pavements and rumble strips, South Dakota state and local noise policies, review of SDDOT's noise policy, interviews with the Technical Panel and local stakeholders, interviews with representatives of other SHA's, and background research and approaches to support local noise compatible land use planning in South Dakota. Technical Memorandum #1 Update was issued October 24, 2005 and incorporated input received at the August 16, 2005 review meeting and subsequent follow-up.

Task 6: Identify effective noise avoidance, mitigation and abatement measures designed to protect and preserve land uses in existence prior to initiation of Type I (new location or alignment) and Type II (noise abatement on an existing highway) highway projects.

The research team interviewed two planners and a legal counsel to the SDDOT regarding the local planning and zoning tools available in South Dakota. South Dakota's existing regulations and additional alternative approaches to noise compatible land use planning are described in Section V.E. of this report.

Task 7: Meet with the project's technical panel to summarize the findings of prior tasks and to propose, for the panel's approval, concepts that will form the technical basis for the remaining tasks.

The Principal and Co-Principal Investigators attended this meeting on August 16, 2005. In addition to summarizing the findings of the previous tasks, the research team received comments on Technical Memorandum #1 (Task 5).

Task 8: If approved by the panel after Task 7, draft an improved noise analysis and abatement policy for the Department, identifying additional guidelines and implementation procedures for the SDDOT to facilitate consistent and effective noise management. This task should include scoping, environmental, and design guidelines that are consistent with the 1995 FHWA "Highway Traffic Noise Analysis and Abatement Policy and Guidance." The task should also provide recommendations on the use of rumble strips, surfacing types and textures for roadways in noise sensitive areas.

The current SDDOT noise policy (SDDOT, 2004) was reviewed and recommendations were made as part of Technical Memorandum #2. The Technical Panel reviewed and accepted many of the recommendations. The proposed SDDOT noise policy was distributed separately from this document.

Task 9: Draft model ordinances or ordinance sections to support noise compatible measures such as land use planning, ordinances, zoning, subdivision regulations, and building codes, that can be used for noise compatible design, construction, and placement of buildings, improvements and structures.

This task included analysis of alternative approaches to providing noise compatible land use planning in South Dakota, and proposed an approach with three alternative levels of assistance to local communities. The analysis and recommendations were included in Technical Memorandum #2. The Technical Panel approved a recommended approach and level of assistance. The recommended approach and level of assistance selected resulted in development of tools for preventing adverse effects from highway noise; GIS planning tools; interstate highway noise contour calculations; noise policy revisions; the DVD and noise brochure. The GIS planning tools are included as Appendix E. The interstate highway noise contour calculations are included in Appendix F. The other materials mentioned were distributed separately from this document.

Task 10: Prepare a technical memorandum and meet with the project's technical panel to review the draft noise policy, recommended design guidelines, model ordinances, and effectiveness measures.

Technical Memorandum #2 compiled the results of Task 8 (draft revised noise policy) and Task 9 (draft model noise ordinances, guidelines, etc. to support noise compatible land use development). Copies of this technical memorandum were distributed to panel members electronically in pdf format.

Task 11: Conduct workshops in Sioux Falls and Rapid City, with elected officials, business leaders, developers, and other professionals as identified by the technical panel, to validate the draft noise policy, design guidelines, model ordinances, and effectiveness measures.

The Principal and Co-Principal Investigators conducted workshops in Rapid City on April 11, 2006 and Sioux Falls on April 12, 2006 with local planners, government officials and developers to validate the planning tools developed in the previous tasks. A Power Point presentation was developed for the workshops, and a handout packet entitled "Tools for Preventing Adverse Effects from Highway Noise" was distributed to participants.

Task 12: Revise the draft noise policy, design guidelines, model ordinances, and effectiveness measures, based on the comments and direction of the technical panel as well as feedback obtained from the two workshops.

This task incorporated the input from the Technical Panel and from feedback received at the workshops, for use in subsequent tasks. The product is a revision to the draft noise policy, design guidelines, model ordinances, and effectiveness measures.

Task 13: Prepare materials, including a 10 to 15 minute South Dakota based noise avoidance and abatement video that state and local agencies can use to educate elected officials, business and community leaders, developers, interested citizens, and local staff on the application and benefits of the noise policy, ordinances, and effectiveness measures.

The requirements for Task 13 were to prepare materials including a 10 to 15 minute South Dakota based noise avoidance and abatement video that state and local agencies can use to educate elected officials, business and community leaders, developers, interested citizens, and local staff on the application and benefits of the noise policy, ordinances, and effectiveness measures.

This task included development of materials that came out of the work of the previous tasks. The materials developed as a part of previous tasks were also made into a guidebook format. Both the video and the guidebook were used to prepare an introductory trifold brochure for local officials, developers and interested citizens. The video prepared as a DVD and the trifold brochure will be distributed separately from the Final Report.

Task 14: Prepare an implementation plan that identifies resources and strategies that state and local officials can use to market the noise policy, design guidelines, model ordinances, and effectiveness measures, including organizational procedures for implementing the policy by the Department.

An implementation plan, based on the workshop and technical panel input, was developed to roll out the plan for use by local governments. The product of this effort, included as Section VI (Implementation Recommendations) of this report, is a written plan and timeline that SDDOT can use as a working document to provide the necessary direction to the program. The plan includes recommendations for staff and department responsibilities and staffing and other resources required.

Task 15: Complete an analysis of the research benefits that identifies and quantifies the benefits that can be expected as a result of this research.

The research benefits were developed in detail as a part of the research for the final report. See Section VII (Benefits of Research) for more details.

Task 16: Prepare a final report summarizing the research methodology, findings, conclusions, and recommendations.

This Final Report summarizes the work of previous tasks and of all the research work that was not included in prior technical memorandums. The outline of the final report was presented for discussion and approval at the Task 10 review meeting.

Task 17: Make an executive presentation to the SDDOT's Research Review Board at the conclusion of the project.

The Principal Investigator made an executive presentation to SDDOT's Research Review Board on June 14, 2006. This included a Power Point presentation summarizing the highlights of the project, and a review of the materials prepared as a part of the project.

Task 18: Design, develop, test and document GIS Noise Planning tools and prepare noise contours in GIS for 150 interstate highway segments in South Dakota.

This task involved designing, developing, testing and documenting two GIS Noise Planning Tools (a Distance Calculation Tool and a Contour Calculation Tool); and preparing noise contours in GIS for 150 interstate highway segments in South Dakota. The interstate highway segments included: I-90 (84 segments); I-29 (55 segments); I-229 (10 segments) and I-190 (2 segments). The GIS Noise Contour Tools, written as ArcGIS 9.1 extensions, consisted of: a Distance Calculation Tool that used the road median and traffic information to calculate distances to user specified noise levels; and a Contour Calculation Tool that calculates and plots the noise contours based on the distances from the road median. Appendices E and F include the primary products of this effort.

V. FINDINGS AND CONCLUSIONS

A. Pavement Surface Treatments

i. SDDOT Pavement Surface Treatment Standards

SDDOT in the past has utilized a variety of pavement surface textures on its asphalt and PCC pavements. SDDOT also continues to follow the progress of all pavement research including quiet pavement design, surface texture skid resistance, durability, constructability and structural integrity. The following describes the present pavement surfaces used by SDDOT in new and reconstructed pavements.

1. Asphalt Pavements

The SDDOT standard specifications and standard special provisions call for asphalt surfaces with top course aggregates that are consistent with "normal" dense type hot mix asphalt (HMA) surface textures (i.e. stone matrix asphalt, superpave asphalt, etc.). The SDDOT will not use rubberized asphalt or open graded friction course (OGFC) asphalt because of the uncertainty of its durability in South Dakota's climate and the variability in noise reduction that has been measured on these pavement types. According to the Colorado Department of Transportation (CDOT), rubberized asphalt has not been proven to ensure safe riding conditions for extreme winters, and temperature variations that result from numerous freeze-thaw cycles. Also, CDOT has gathered noise monitoring information on OGFC, and found a 4 dBA discrepancy between two separate test locations and has thus decided that more research is clearly needed regarding these pavement types (CDOT, 2004).

SDDOT currently uses a chip seal treatment over old asphalt on state roadways including high speed and high volume interstate highways. The chip seal treatment includes a fog seal (or emulsified asphalt) to retain a spread of cover aggregate.

2. Concrete Pavements

The SDDOT requires that PCC pavements include surface texturing to increase skid resistance (SDDOT, 2005). The allowable surface textures include: a longitudinal carpet (or other specified material) dragging procedure; random transverse or uniform longitudinal tining preceded by a longitudinal carpet drag (SDDOT, 2005); and uniform longitudinal grinding utilizing diamond blades (SDDOT, 2001).

The SDDOT currently specifies a uniform longitudinal tine for high volume, high speed roads. The surface of concrete bridge decks and approach slab is specified as a transverse metal-tine finish (SDDOT, 2003). Low speed roads also utilize transverse tining. Both longitudinal and random transverse tines are preceded by brooming or carpet dragging to provide micro texture on roadway surfaces. Also, diamond grinding is used as the remedial measure for transverse tining that results in noise complaints.

ii. Summary of Pavement Noise Research

Highway traffic noise produces unwanted sounds that affect the quality a life for persons near roadways (CDOT, April 2004). To address such noise concerns, quiet pavement noise research continues to evaluate pavement surfaces as new technologies continue to emerge in the highway transportation field.

Early pavement noise studies show that asphalt concrete highway surfaces generally produce lower tire emission noise levels than PCC pavement surfaces, and that a transversely tined PCC pavement surface produces the highest noise levels (NCHRP, 1998). Subsequent noise studies on asphalt concrete have further confirmed that a more porous surface such as OGFC can produce slightly lower noise reductions because high air void content provides pockets that "trap" noise (CDOT, April 2004). However, this pavement type has limitations because the voids can fill in over time, thus increasing noise levels, and it is susceptible to adverse effects due to freeze/thaw cycles.

Many studies have been performed to review tire noise generated from PCC pavement surfaces, and results generally indicate the following (in order from lowest noise to highest noise) – diamond grinding, uniform longitudinal tining, uniform transverse tining, and random transverse tining (Rochat, 2005). A test on portions of State Route 202 in Arizona regarding the level of noise generated from various PCC pavement surfaces produced the same results as those cited by Rochat, see Table II.1 (IGGA, 2003).

Table V.1: Typical Noise Levels of Arizona PCC Pavement

Surface Texture Type	CPX[(1)] Noise Level Measured at Tire (dBA)	Change in Value from Diamond Grind (dBA)
Diamond Grind	95.5	0.0
ADOT Uniform Longitudinal Tined (3/4")	99.1	+3.6
ADOT Uniform Transverse Tined (3/4")	102.5	+7.0
Random Transverse (Wisconsin Spec)	104.9	+9.4

(1) CPX = Close Proximity Trailer Test Method

Colorado has reported similar results for the PCC surface textures as those identified above. This report also included evaluation of a carpet dragged texture surface. The report results are provided in Table II.2 (CDOT, April 2004).

Table V.2: Summary of PCC Pavement in Colorado

Surface Texture Type	CPX Noise Level Measured at Tire (dBA)	Change in Value from Carpet Drag (dBA)
Carpet Drag	97.9	0.0
Longitudinal Tined	98.6	+0.8
Transverse Tined	102.6	+4.7

The SDDOT has obtained satisfactory results in noise reduction and skid resistance on their Interstates where random spaced longitudinal tines were applied (Hedman, 2005).

A comprehensive summary list of the general pavement surfaces used in highway construction and a ranking of the tire/pavement noise (from quietest to noisiest) generated from each surface is presented in Table II.3 (CDOT, April 2004; IGGA, 2003; ACPA, 2003; Thornton, 2004).

Table V.3: Summary of Noise Levels for Pavement Surfaces

Surface Texture Type	Rank	Range of CPX Noise Level Measured at Tire (dBA)
Open Graded Asphalt (OGFC)	1	93.1 to 96.9
Dense Graded Asphalt (DGFC)	2	95.1 to 98.0
PCC with longitudinal diamond grinding	3	95.5 to 99.6
PCC with dragged surface (carpet, burlap, broomed, etc.)	4	97.9 to 101.8
PCC longitudinal tining	5	98.6 to 102.0
PCC transverse tining (uniform spacing)	6	102.5 to 107.1
PCC transverse tining (random spacing)	7	104.9 to 109.2

The SDDOT has not received noise complaints subsequent to applying chip seal treatments, however due to its rougher texture it may be noticeably noisier than HMA surface textures. The increase in noise levels with chip seal treatments can be partially mitigated by using a two-course surface treatment where a small size aggregate is used for the top layer (Texas DOT, 2004).

For PCC pavements, skid resistance with longitudinal tining is less than that of a roadway transverse tining. The time for surface drainage to occur with longitudinal tining exceeds the time for surface drainage to occur with transverse tining. This inability to remove water becomes a bigger problem in areas of high freezing activity or heavy rain storms (Utah DOT, 2000).

The SDDOT's random transverse tining surface treatment specification for bridge decks agrees with current FHWA guidance for selecting roadway construction techniques when considering wet pavement friction and low-tire/surface noise characteristics. The FHWA recommends an individual transverse tine width of 3mm and a depth of 3mm. Research has shown that narrower, deeper grooves are better than wider, shallower grooves for minimizing noise (FHWA, 2005). The random transverse tining surface treatment specification for bridge decks by the SDDOT is within the FHWA recommended values for individual transverse tine width and depth.

Additional research has also shown that the uniform transverse spacing is not necessarily louder than a random pattern, however the random pattern will eliminate the "whine" sound that is more annoying and that often results in more noise complaints (MDT, 2004).

Longitudinally tined pavements may result in joint spalls when the tines are allowed to intersect with transverse roadway joint systems. To prevent joint spalls at the joint systems, NYSDOT provides a specification to terminate longitudinal grooves within the following limits for joint systems:

Closest Allowable Distance = 100mm (4 in)
Farthest Allowable Distance = 380mm (15 in)

where, "distances" are measured perpendicular to the centerline of the joint system (NYSDOT, 2005).

iii. Additional Information

The development and specification for highway pavement surfaces will only be improved through continued research related to highway noise from various pavement surfaces. The Minnesota DOT participated in a pooled-fund noise study during Fall 2004 that monitored 41 test sections in Minnesota. Information from a final report will be made available at:

www.mnltap.umn.edu/publications/exchange/2005-2 .

The web site that includes the Iowa Department of Transportation's recently posted solicitation for organizations to participate in Part 3 of a pool funded study involving PCC Surface Characteristics is a pdf file and may be found at the following address:

http://www.pooledfund.org/documents/solicitations/956.pdf

Other useful information may be found at the following web addresses:

http://www.fhwa.dot.gov/pavement/hq/contact.cfm

http://www.pavement.com/PavTech/Tech/Dwnlds/main.html

http://www.tcpsc.com/RelatedLinks.aspx

B. Shoulder Rumble Strips

i. SDDOT Shoulder Rumble Strip Policy

The SDDOT policy regarding highway width and surface type standards (SDDOT, 1998), requires that rumble strips be applied on the following:

- 2 lane rural and urban highways with PCC pavement roadways when the ADT is greater than 550
- 2 lane rural and urban highways with asphalt concrete roadways having paved shoulders (ADT is 2500+)
- 4 lane divided arterials, and Interstate highways for both PCC and asphalt concrete roadways

ii. SDDOT Shoulder Rumble Strip Standards

1. Asphalt Pavements

The SDDOT special details require that a standard 7 inch wide by 16 inch long (minimum) milled rumble strip be used for typical shoulder installations. The rumble strips are offset 6 inches to 12 inches from the edge of pavement. They are constructed as continuous strips that terminate at ramp locations, median crossovers, intersecting roads or entrances, or any other similar interruptions.

2. Concrete Pavements

The SDDOT special details require rumble strips to be formed as 3 inch humps, 6 inches center to center that are grouped in 16 inch by 51 inch rectangular sections, with spacing of sections at 40 feet center to center. The rumble strips are offset 6 inches from the outside edge of the driving lane. These rumble strip sections terminate at ramp locations, median crossovers, intersecting roads or entrances, or any other similar interruptions.

iii. Summary of Shoulder Rumble Strip Research

Rumble strips (milled or rolled) are designed to create noise levels that can be heard inside of a commercial motor vehicle cab, and to create strong vibrations. The milled type rumble strips have been proven to be more effective than a rolled design because of the increased noise and vibration created to alert a driver that is leaving the travel lane (FHWA, 1998). This milled design is consistent with the standard SDDOT details for asphalt concrete rumble strips.

Complaints from residents living in close proximity to roadways equipped with continuous rumble strips do occur even though a vehicle leaving the travel lane is an infrequent event. One suggestion was to move the rumble strip further from the travel lane, however this results in a shorter time for a driver to react and correct their vehicle's path. A larger offset may not always be an effective method of alleviating noise problems. For example there were still noise complaints in Wisconsin after the rumble strips were removed from the edge of the travel lane to a distance of 2.5 feet from the edge of the travel lane (FHWA, 1998).

iv. Additional Information

Additional information regarding rumble strips may be found at:

http://safety.fhwa.dot.gov/roadway_dept/rumble/index.htm

C. State and Local Noise Policies in South Dakota

i. Existing Noise Policies in South Dakota

South Dakota State agencies were contacted to determine if any State agencies had policies pertaining to noise, however, none were found to have policies pertaining to noise.

During the course of interviewing local stakeholders, local planners from the various units of local government were asked if they had any policies pertaining to noise and

if so to describe them. Numerous municipalities have adopted general nuisance ordinances, which regulate noise in a general sense. There are no South Dakota municipalities with regulations or policies specific to highway noise.

South Dakota's largest city, Sioux Falls, has a noise ordinance (MCC, 2001). It is contained in Chapter 25 ½, Noise Control of the City of Sioux Falls Municipal Code. Subsections of the noise ordinance cover definitions, noises prohibited, use district noise levels, sound level measurement, exemptions, permits, motor vehicle noise, enforcement responsibility, and additional remedies. The ordinance makes it "unlawful for any person to make, continue, or cause to be made or continued any noise disturbance within the limits of the city". Noise disturbance is defined as any sound which annoys or disturbs reasonable persons with normal sensitivities, or which injures or endangers the comfort, repose, health, hearing, peace and safety of other persons." The ordinance establishes maximum permissible normal and impulsive sound levels for residential, noise sensitive (hospitals, schools, court, etc.), commercial, industrial and agricultural land uses. The section on motor vehicle noise applies only to individual motor vehicles. This is a general nuisance ordinance that does not address noise compatible land use planning.

Another section of the Sioux Falls Municipal Code establishes a Design Review District for the I-229 corridor, and standards for building orientation, parking, landscaping, signs, lighting, building construction, storage and screening in an effort to preserve the unique visual image and character of this portion of the City (SFMC). The ordinance applies to lands located within 650 feet of the centerline of right-of-way. Although this ordinance does not address noise compatible land use planning, it establishes design standards and identifies the planning commission as having review responsibility.

Pennington County has a special overlay district entitled "Ellsworth Air Force Installation Compatible Use Area."[1] This district permits noise compatible land uses without special review and approval in the land area affected by noise from the Ellsworth Air Force base and prohibits most noise sensitive land uses in the areas subject to the highest noise levels. It also permits some noise sensitive land uses (including single family and multiple family residences) within some noise zones if special restrictions that include the incorporation of noise attenuation measures are built into the design and construction of structures. The amount of required noise level reduction is not specified, nor are the specific measures to be employed specified. However, residential uses are "discouraged" in noise zones DNL 66-70 dB and "strongly discouraged" in DNL 71-75 dB. DNL, the day-night noise level, is the equivalent A-weighted sound level for a 24-hour period, with an additional 10 dB weighting imposed on levels between 10 p.m. and 7 a.m.

ii. Review of Existing SDDOT Noise Policy

This review included discussions with SDDOT planning, programming, environmental and engineering personnel at all levels in the organization, concerning the policy and possible improvements, and our subsequent review of the current SDDOT Noise Policy, PD-2004-02 (SDDOT, 2004).

[1] www.co.pennington.sd.us/planning/PDF%20Forms/Zoning%20Ordinances.pdf

There was uniform agreement on the part of SDDOT personnel familiar with the noise policy and the programming/processing of projects that:

1. SDDOT should continue to refrain from instituting a Type II noise barrier program. Type II noise barriers are noise barriers constructed along existing highways. The Federal regulation (23 CFR 772) does not require State highway agencies to implement Type II programs, but rather identifies them as voluntary.

2. SDDOT should apply the same noise policies and standards used for Federal-aid projects as 100% State funded highway projects.

3. SDDOT should better integrate their noise policy into the project level and corridor planning scoping processes, and thus become more pro-active in identifying Type I noise projects early on. Neither of the scoping process documents used by the SDDOT includes any reference to noise and to whether the project is a Type I.

4. Local planning professionals have an interest in noise compatible land use planning within their communities and SDDOT will provide assistance to local communities so that they can institute effective noise compatible land use planning in their communities.

5. For Interstates, other access controlled highways, major arterials and state highways (which are in the Needs Manual), SDDOT will provide future conditions 61, 66 and 71 dBA loudest hour noise contours. Although some of this information may be available from the original noise studies performed for the project, and may have been provided as required in 23CFR 772, the information could be outdated due to differences between projected and actual traffic volumes and vehicle mixes.

It is recommended that all of the five items listed above be included in an improved noise analysis and abatement policy.

The research team identified the following additional technical details that should be improved upon:

1. To eliminate confusion, remove language with inferences to the Type II program, and strengthen the language that indicates SDDOT's non-involvement in the Type II noise barrier program. Also, clarify that the SDDOT policy pertains to Type I projects.

2. The present policy identifies the analysis location as the edge of the right-of-way, however, the intent of the federal policy is to protect against speech interference. Thus several states use an approach that identifies active use areas, and calculates existing and future with the project noise levels at those locations. Active use areas would be locations where there is frequent human use, such as patios, decks, swimming pools, swingsets, and other features

3. Clarify, for Type I projects, what adjacent, future noise sensitive development will be considered as existing development for the purposes of evaluating a noise impact. It is typical to consider that receipt of land division or plat approval for a new subdivision or condominium development, or approval of a zoning permit or conditional use permit, or issuance of a building permit constitutes "planned,

designed and programmed". That means that even though homes were not yet built, the highway project would have to proceed assuming they were. The problem is that if all it takes to be considered developed is a plat, then if local zoning allows a residential plat on property next to a proposed highway, some developers may take advantage of the situation and plat even though they have no intention of actually developing the property for some time. Conversely, the date which the public is officially notified of the adoption of a Federal-aid highway project is typically the date of FHWA approval of the final environmental document. From that point forward, all development that was "planned, designed and programmed" would not have to be considered for noise mitigation by SDDOT as part of the Type I project.

4. Clarify that SDDOT, because it does not have a Type II program, will not construct noise barriers along existing highways. Furthermore, clarify that the Federal government will not participate in Type II noise barriers on projects approved after November 28, 1995.

5. Clarify <u>that</u> "approach", when identifying traffic noise impacts, means within 1 dBA of equal to or greater than.

6. Increase the cost per protected residence index from $15,000/residence to the FHWA minimum of $25,000/residence.

7. Clarify what SDDOT will typically do on Type I projects to consider the views of impacted residents when deciding whether to construct noise mitigation measures. It is often best not to hold such discussions as part of a public hearing as the policy indicates, but rather provide a different forum where the analysis, results, and recommendations can be presented and the views of the affected residents solicited. Public Hearings are a legal requirement of a project that has significant right-of-way takings. Typically meetings with affected residents take place after the lands for construction of the highway have been taken.

8. The section on coordination with public officials should be revised in accordance with the decisions made as a result of the research project. This covers what information the SDDOT will provide to local communities, whether noise separation distances, or noise contours for some future or capacity condition.

These findings and conclusions led to the development of a proposed, revised SDDOT Traffic Noise Analysis and Abatement Policy, DOT-E&P-PD-3.0 (SDOT, 2006).

D. Perspectives on Local Noise Impacts and Potential Regulatory Tools

i. Technical Panel

Twelve members of the Technical Panel completed a questionnaire. The majority of the Technical Panel was comprised of SDDOT employees, from the Office of Research, the Division of Planning and Engineering, Division of Operations and the Sioux Falls and Rapid City Regional Offices. The Technical Panel also included a representative from the City of Pierre, City of Sioux Falls, City of Rapid City, and FHWA.

The majority of respondents from the Technical Panel spent less than 5% of their time working on noise concerns.

The questionnaire was organized around two subject areas, (1) community noise impacts and (2) potential regulatory tools to reduce noise impacts. A copy of the questionnaire is included as Appendix C. Survey results from the Technical Panel are summarized in Tables V.4 through V.16.

1. Community Noise Impacts

In terms of noise sources, vehicular traffic and noise from trucks are the top sources of noise for the Technical Panel (Table V.4). Almost two thirds of Technical Panel respondents cited that traffic noise was a problem in their jurisdiction, with 4 out of 8 naming site specific locations where traffic noise occurs in their jurisdiction (Table V.5).

Half of the Technical Panel (6 out of 12) has heard complaints from South Dakota residents about traffic noise, while others mentioned the increased number of new homes close to arterial roads in their jurisdictions bringing people closer to the noise source (Table V.6). Two thirds of the Technical Panel noted that noise is a problem outside of homes (Table V.7). Half believe it is a problem inside homes. A minority of the Technical Panel felt noise was a problem inside or outside of businesses.

Finally, the Technical Panel ranked a list of possible highway noise sources, with 1 being a primary concern, 2 being a secondary concern and 3 being a tertiary concern (Table V.8). The three highest ranked noise sources were:

- Future traffic noise resulting from construction of new Federal or State highways, or capacity expansions of existing highways (with 9 respondents ranking this a primary concern),
- Future traffic growth along existing highways (with 9 respondents ranking this a primary concern)
- Large trucks and engine brake noise (with 8 respondents ranking this a primary concern).

Another noise source worth mentioning is annoyance from pavement surface textures, which 7 respondents ranked as a primary concern.

Table V.4: What is the biggest source of noise pollution in your jurisdiction?

# Responses	Source
9	Vehicular traffic
4	Trucks and engine brake
2	Railroad
2	Vehicular traffic, noise from concrete highway & joints
2	Construction
1	Air traffic
1	Motorcycles

Table V.5: In relation to all noise pollution issues, is traffic noise a problem in your jurisdiction?

# Responses	Response
4	Yes, it is a problem currently
4	Yes, in site specific and/or urban locations i.e. I-229 from 10th-26th St. (Sioux Falls), I-29 at 41st St. (Sioux Falls), Hwy 18 (Hot Springs), I-90 & SD79 (Rapid City)
1	It is a major source of noise, it is not a problem.
2	No, it is not a problem yet

Table V.6: What experiences have prompted your concerns?

# Responses	Response
6	Complaints from the public. • A citizen wrote a letter to the Governor expressing concern about noise adjacent to I-29 between I-229 and 41st Street in Sioux Falls. This is a Type II situation which may become a Type I since we will be widening this road to 3 lanes in the near future. SDDOT is currently conducting noise study of the area. • Prior to construction projects we have received several complaints regarding future noise potential from homeowners along new highway alignments, meaning both a new highway where none existed before and a changed alignment that gets closer to a dwelling. • We have received complaints from homeowners after construction where a new surface on essentially the same alignment caused more or different noise.
1	South Dakota is becoming urban in many locations. Housing is moving closer to our arterials, which are being expanded. This may lead to noise issues in the future.
1	Noise levels in the vehicle when I travel the roadways. Sound of jake brakes at night near my home in Pierre.
1	New residential developments occurring along State Highways

Table V.7: If it is a problem, is the impact experienced inside or outside either homes or businesses?

# Responses	Response
9	Outside homes
6	Inside homes
4	Outside businesses
3	Inside businesses (from airport)

Table V.8: Summary of possible highway noise sources, ranked by level of concern

Primary Concern	Secondary Concern	Tertiary Concern	Possible Highway Noise Sources
0	3	9	a) Annoyance from rumble strip noise
7	3	2	b) Annoyance from pavement surface textures
1	7	4	c) Construction noise
9	3	0	d) Future traffic noise resulting from construction of new Federal or State highways, or capacity expansions of existing highways
9	3	0	e) Future traffic growth along existing highways
8	3	1	f) Large trucks and engine brake noise
1	5	6	g) Motorcycles
1	1	0	h) Other: Trains
0	1	0	h) Other: Hot rod & exhibition driving

2. Current and Potential Regulatory Tasks to Reduce Noise Impacts

The majority of Technical Panel respondents believe the research team should focus only on freeways, major arterials and state highways, and not County or City arterials and collectors. The majority also believe that we should focus on all land uses, as opposed to only noise sensitive land uses (Table V.9 and Table V.10).

As noted in Table V.11, the Technical Panel noted that the most useful noise mitigation tools are:

- Model local land use controls that could be used and amended as required by individual communities (11 ranked this as a primary tool)
- Noise mitigation measures other than noise barriers (11 ranked this as a primary tool)
- Guidelines on recommended separation distances from highways to various noise level contours from recommended land uses (10 ranked this as a primary tool)
- Information about existing and/or future noise levels adjacent to highways (8 ranked this as a primary tool)

The majority of the Technical Panel believes that the role of local units of government in promoting noise compatible land use planning and development is the establishment and enforcement of zoning ordinance and offset controls, like separation distances and mitigation measures (Table V.12). Many respondents also cited education of the public and developers as an important role.

Only two out of twelve Technical Panel members noted that local governments should have the primary role in promoting noise compatible land use planning and development. Upon further discussion of these responses, the Technical Panel agreed that this question was interpreted to mean that local governments should have the primary role in promoting noise compatible land uses, after being provided the tools and support to do so.

Regarding noise regulations currently in place, half of the respondents cited the SDDOT noise policy (Table V.12). Another mentioned the City of Pierre and Hughes County have noise ordinances.

When asked about examples of noise compatible development in their jurisdiction, the majority of respondents said they were not aware of any examples (Table V.14). Several respondents mentioned specific locations, such as the area along I-29, I-299 and I-90, because it has both commercial and industrial uses sited next to the highway.

Respondents are very interested in learning more about the following tools, assistance, information or incentives to promote more noise compatible development (Table V.15):

- Develop regulations to require site plan review for noise-incompatible uses (11 were very interested in this tool)
- Permit noise sensitive land uses with adequate separation distances between highways and noise sensitive land uses (9 were very interested in this tool)
- Strongly encourage only noise compatible land use adjacent to highways (9 were very interested in this tool)
- Provide training/information (video/DVD, brochure, web site, public meetings) (9 were very interested in this tool)

Respondents were least interested in two of the tools in #10 of the questionnaire (Table V.16) in developing a General Nuisance Noise Ordinance. Since most respondents were SDDOT employees, they saw this issue as taking place outside of SDDOT jurisdiction. Respondents also dislike the idea of building locally-funded noise barriers or berms to protect new development from noise impacts, because of the cost of building them and maintaining them.

Table V.9: Which of the following types of roads should the research team focus on for proactive noise mitigation measures?

Yes	No	Road Type
11	0	Freeways (limited access)
11	1	Major arterials/state highways
3	8	County or City Arterials and collectors

Table V.10: Should the research team focus on only land sensitive land uses or all land uses?

# Responses	Land Use
1	Noise sensitive land uses only
11	Both noise sensitive and noise compatible land uses

Table V.11: Summary of noise mitigation tools, ranked by level of usefulness

Primary Tool	Secondary Tool	Tertiary Tool	Possible Noise Mitigation Tools
8	4	0	a) Information about existing and/or future noise levels adjacent to highways
10	1	1	b) Guidelines on recommended separation distances from highways to various noise level contours from recommended land uses
11	0	1	c) Model local land use controls that could be used and amended as required by individual communities
7	5	0	d) Means to prevent the need to erect future noise barriers
11	1	0	e) Noise mitigation measures other than noise barriers
2	3	7	f) Noise barriers constructed along existing highways

Table V.12: What responsibilities should local units of government have in promoting noise compatible land use planning and development?

# Responses	Response
13	Establishment and enforcement of zoning ordinance and offset controls, like separation distances and mitigation measures. Education of the public and developers too.
2	Local units of government should have the primary responsibility for promoting noise compatible land use planning. The state should be advisory and provide technical assistance.
1	Shared responsibility with other levels of government

Table V.13: Does your jurisdiction have any local noise regulations in place currently?

# Responses	Response
6	Yes, the SDDOT has a Noise Policy, but no regulations
2	No
2	N/A. We have no jurisdiction with the cities we work with.
1	I think so.
1	The City of Pierre and Hughes County have noise ordinances. They do not address highway noise.

Table V.14: Are you aware of any examples of noise compatible development in your jurisdiction?

# Responses	Response
5	No
3	Yes, the greenways and bike paths near I-229 in Sioux Falls. The majority of development along I-29, I-229 and I-90 is commercial or industrial.
1	We do not have noise compatible development.
1	N/A
1	I am not aware of any planned locations.
1	Yes, north end of the US14 bypass/Garfield Avenue in Pierre. The projected land use in the Comprehensive Plan shows this area as commercial and light industrial uses compatible with the high traffic volume and noise.
1	Only the unplanned benefit of locating businesses adjacent to highways for visibility purposes.

Table V.15: Summary of tools, assistance information or incentives to promote more noise compatible development, ranked by level of interest

Primary Interest	Secondary Interest	Tertiary Interest	Tools, Assistance, Information and Incentives
3	8	1	a) Allow residential developers to build close to highways only if he/she pays the cost for a noise barrier or berm
4	2	6	b) Develop General Nuisance Noise Ordinance
11	1	0	c) Develop regulations to require site plan review for noise-incompatible uses
3	7	2	d) Develop design guidelines to include window/door upgrade, superinsulation, central heating, ventilation and air conditioning (HVAC), and no windows facing the road in noise sensitive areas
5	6	1	e) Allow noise sensitive development closer to the highway if approved noise mitigation measures are provided
2	4	6	f) Build locally-funded noise barriers or berms to protect new development from noise impacts
10	2	0	g) Permit noise sensitive land uses with adequate separation distances between highways and noise sensitive land uses
9	2	1	h) Strongly encourage only noise compatible land use adjacent to highways
7	5	0	i) Provide open space as a noise buffer
9	3	0	j) Provide training/Information (video/DVD, brochure, web site, public meetings)
4	7	1	k) Allow transfer of development rights (TDR) for developers to transfer density or to transfer use between two parcels he/she owns to keep land adjacent to the highway vacant

Table V.16: Which tools, assistance, information or incentives listed above should not be pursued and why?

# Responses	Response
3	e and f) Don't use noise barriers because of the expense of building and maintaining them.
2	b) General Nuisance Noise Ordinance is a regulatory issue and would be difficult to enforce. This is not SDDOT's jurisdiction to pursue.
1	k) TDR is an unknown term in SD. We need to be politically sensitive to the developer's costs and the cost that imposes on housing. Before the purchase we need to think about disclosure to the potential owner of the lot, housing or other use about the expected noise levels as a part of the transfer of property.
1	N/A
1	h) Strongly encouraging only noise compatible land use adjacent to highways. Developers are primarily focused on making money and most would not be motivated to take noise issues into serious consideration.
1	d) Don't get specific into design guidelines.

ii. Local Stakeholders

The research team interviewed 13 local stakeholders. The majority of the local stakeholders were municipal planners, municipal engineers or city council people, from the City of Sioux Falls, Rapid City, Spearfish, and Minnehaha County. Stakeholders also included one representative from the private sector, a landscape architect. All of the respondents spent less than 10% of their time working on noise concerns.

The questionnaire is included as Appendix C. The survey results from the stakeholders are summarized in Tables V.17 through V.29.

1. Community Noise Impacts

In terms of noise sources, respondents said that the biggest source of noise pollution in their jurisdiction is vehicular traffic and noise from industry/tourist events (Table V.17). More than half of the local stakeholder respondents cited that traffic noise was a problem in their jurisdiction, with four stating that while it wasn't a problem currently, it was becoming a bigger problem (Table V.18).

More than two thirds of the stakeholder respondents (7 out of 13) have heard complaints from South Dakota residents about traffic noise, while others mentioned the increased number of new homes close to arterial roads in their jurisdictions bringing people closer to the noise source (Table V.19). All respondents noted that noise is a problem outside of homes (Table V.20). Half believe it is a problem inside homes. A minority of the stakeholders felt noise was a problem inside or outside of businesses.

Finally, the stakeholders ranked a list of possible highway noise sources, with 1 being a primary concern, 2 being a secondary concern and 3 being a tertiary concern (Table V.21). The two highest ranked noise sources were:

- Future traffic growth along existing highways (with 10 respondents ranking this a primary concern)
- Future traffic noise resulting from construction of new Federal or State highways, or capacity expansions of existing highways (with 8 respondents ranking this a primary concern)

Another noise source worth mentioning is annoyance from pavement surface textures, which 6 respondents ranked as a primary concern.

Table V.17: What is the biggest source of noise pollution in your jurisdiction?

# Responses	Source
6	Vehicular Traffic
6	Industry/Tourist Event (Motorcycle Week, Auto Race Track)
5	Interstate Noise
4	Airport
1	Motorcycles
1	Parties

Table V.18: In relation to all noise pollution issues, is traffic noise a problem in your jurisdiction?

# Responses	Response
7	Yes, it is a problem currently
4	It is not a big problem, but it is becoming a problem
2	No, it is not a problem

Table V.19: What experiences have prompted your concerns?

# Responses	Response
3	Increased awareness of noise by the public.
3	Complaints about increasing interstate traffic
3	Complaints about traffic
2	Complaints about trucks and engine brake noise
2	Interstate traffic impacting new homes built close to the interstate
1	Complaints about motorcycles
1	Complaints about construction

Table V.20: If it is a problem, is the impact experienced inside or outside either homes or businesses?

# Responses	Response
13	Outside homes
6	Inside homes
2	Outside businesses
1	Inside businesses (from airport)

Table V.21: Summary of possible highway noise sources, ranked by level of concern

Primary Concern	Secondary Concern	Tertiary Concern	Possible Highway Noise Sources
0	5	8	Annoyance from rumble strip noise
6	7	0	Annoyance from pavement surface textures
3	6	4	Construction noise
8	3	2	Future traffic noise resulting from construction of new Federal or State highways, or capacity expansions of existing highways
10	2	1	Future traffic growth along existing highways
8	3	2	Large trucks and engine brake noise
3	5	5	Motorcycles
1	0	0	Other: Vehicle noise – different than annoyance from pavement and noise from tires and the engines themselves. When we were looking at I-90 by Haines Avenue, the vehicles themselves made noise
0	1	0	Agriculture
0	0	1	Airport

2. Current and Potential Regulatory Tasks to Reduce Noise Impacts

The majority of stakeholder respondents believe the research team should focus only on freeways, major arterials and state highways, and not County or City

arterials and collectors. The majority also believe we should focus on all land uses, as opposed to only noise sensitive land uses (Table V.22 and Table V.23).

As noted in Table V.24, the stakeholders noted that the most useful noise mitigation tools are:

- Guidelines on recommended separation distances from highways to various noise level contours for recommended land uses (12 ranked this as a primary tool)
- Model local land use controls that could be used and amended as required by individual communities (10 ranked this as a primary tool)
- Information about existing and/or future noise levels adjacent to highways (9 ranked this as a primary tool)
- Means to prevent the need to erect future noise barriers (9 ranked this as a primary tool)

The majority of the stakeholders believe that local units of government, as first line of regulation, should have the major role in controlling land use and setbacks (Table V.25). Roughly a third of stakeholders (4 out of 13) believed local governments should share responsibility with other levels of government and developers, to minimize the impacts of shared space and communicate standards and requirements.

Regarding noise regulations currently in place, 8 of the respondents had general nuisance noise ordinances in place in their municipalities, but no regulations focused on traffic noise (Table V.26).

When asked about examples of noise compatible development in their jurisdiction, 5 respondents could not think of any examples. Several respondents cited the use of the existing municipal zoning ordinances and setback requirements, because these regulatory measures direct residential uses away from main corridors (Table V.27). Several respondents mentioned specific locations, such as Southeastern Avenue, Kiwanias Avenue, 69th Street Corridor, and Minnesota Avenue south of 67th Street, and S. Louise Avenue in Sioux Falls.

Respondents are very interested in learning more about the following tools, assistance, information or incentives to promote more noise compatible development (Table V.28):

- Develop regulations to require site plan review for noise-incompatible uses (10 were very interested in this tool)
- Provide open space as a noise buffer (8 were very interested in this tool)
- Permit noise sensitive land uses with adequate separation distances between highways and noise sensitive land uses (7 were very interested in this tool)

Respondents were least interested developing design guidelines to include window/door upgrade, super-insulation, central heating, ventilation and air conditioning (HVAC), and no windows facing the road in noise sensitive areas (Table V.29). Many felt that it would be difficult to enforce design guidelines, because many communities don't have building codes adopted or staff to monitor building practices. Other respondents suggested that homeowners would become frustrated by the increased cost of the measures.

Table V.22: Which of the following types of roads should the research team focus on for proactive noise mitigation measures?

Yes	No	Road Type
12	1	Freeways (limited access)
11	2	Major arterials/state highways
3	10	County or City Arterials and collectors

Table V.23: Should the research team focus on only land sensitive land uses or all land uses?

# Responses	Land Use
5	Noise sensitive land uses only
8	Both noise sensitive and noise compatible land uses

Table V.24: Summary of noise mitigation tools, ranked by level of usefulness

Primary Tool	Secondary Tool	Tertiary Tool	Possible Noise Mitigation Tools
9	4	0	a) Information about existing and/or future noise levels adjacent to highways
12	0	1	b) Guidelines on recommended separation distances from highways to various noise level contours from recommended land uses
10	3	0	c) Model local land use controls that could be used and amended as required by individual communities
9	4	0	d) Means to prevent the need to erect future noise barriers
7	5	1	e) Noise mitigation measures other than noise barriers
4	5	4	f) Noise barriers constructed along existing highways

Table V.25: What responsibilities should local units of government have in promoting noise compatible land use planning and development?

# Responses	Response
8	As first line of regulation, municipalities should have major role in controlling land use and setbacks
4	Shared responsibility with other levels of government (SDDOT) and developers, to minimize the impacts of shared space and communicate standards & requirements.
2	A big role, however legal problems emerge when government attempt to 'protect the public' from a problem that doesn't exist
1	A major role because local governments know their constituents and their land better than anyone else.
1	A big role, however, some municipalities don't have resources or knowledge to implement controls
1	SDDOT should take the lead. The City should focus on the airport because it's a municipal airport.

Table V.26: Does your jurisdiction have any local noise regulations in place currently?

# Responses	Response
8	Yes, a general nuisance noise ordinance
2	No
1	We are in the process of creating one now
1	Yes
1	No, but we are able to mitigate noise with our zoning ordinance and comprehensive plan.
1	We have a regulation that construction contractors must get a permit for work

Table V.27: Are you aware of any examples of noise compatible development in your jurisdiction?

# Responses	Response
5	No
4	In a sense, all developments take this idea into account with setbacks. And zoning ordinances, in general, direct residential uses away from main corridors. However, it could be argued that local zoning is more conducive to locating commercial along state highways for business reasons.
4	Landscaped berming and coniferous trees to create a buffer. Examples of locations are Southeastern Avenue, Kiwanias Avenue, 69th Street Corridor, and Minnesota Avenue south of 67th Street, and S. Louise Avenue in Sioux Falls.
1	Yes, ACDC Ties uses office/commercial as a buffer.
1	Rapid City purchased land around the airport as a buffer. Their intent is to keep it open or develop industrial use.
1	We direct commercial toward major intersections and build buffer around that to protect residential. Examples are 26th and Sycamore in Sioux Falls, Minnesota and 26th in Sioux Falls.

Table V.28: Summary of tools, assistance, information or incentives to promote more noise compatible development, ranked by level of interest

Primary Interest	Secondary Interest	Tertiary Interest	Tools, Assistance, Information and Incentives
4	5	4	a) Allow residential developers to build close to highways only if he/she pays the cost for a noise barrier or berm
5	4	4	b) Develop General Nuisance Noise Ordinance
10	3	0	c) Develop regulations to require site plan review for noise-incompatible uses
3	6	4	d) Develop design guidelines to include window/door upgrade, superinsulation, central heating, ventilation and air conditioning (HVAC), and no windows facing the road in noise sensitive areas
7	3	3	e) Allow noise sensitive development closer to the highway if approved noise mitigation measures are provided
3	4	6	f) Build locally-funded noise barriers or berms to protect new development from noise impacts
7	6	0	g) Permit noise sensitive land uses with adequate separation distances between highways and noise sensitive land uses
5	7	1	h) Strongly encourage only noise compatible land use adjacent to highways
8	2	3	i) Provide open space as a noise buffer
5	6	2	j) Provide training/Information (video/DVD, brochure, web site, public meetings)
6	3	4	k) Allow transfer of development rights (TDR) for developers to transfer density or to transfer use between two parcels he/she owns to keep land adjacent to the highway vacant
1	0	0	Other: Tools/instruments to measure noise
1	0	0	Other: Similar to (E) Develop responsibility to provide mitigation measures

Table V.29: Which tools, assistance, information or incentives listed above should not be pursued and why?

# Responses	Response
5	d) Mechanism to enforce design guidelines would be difficult. Many communities don't have building codes adopted. They also don't have staff to monitor. Home owners would become frustrated by the increased cost of the measures. Also, only addresses indoor noise mitigation, not outdoor. This is not just a housing issue.
3	f) I would rather do berms and spacing than build locally-funded noise barriers.
3	k) The appropriateness of TDR is connected to topographic terrain. We are lenient with what we see as appropriate. Difficult to implement
2	a) Developers would not want to pay for mitigation measures. They would want variances or slight changes which would deplete the benefit. From a state perspective, we'd be restricting land without damages and would not compensate developers for it.
2	j) I don't know that people would use this type of resources. Public attendance is never good at these types of meetings.
2	i) We don't have money to purchase open land. Land prices are higher than the City can afford.
1	h) Noise compatible land uses adjacent to highways is not viable on terrain. As long as it's disclosed up front. They see traffic that they are driving too.
1	b) Difficult to implement, monitor and enforce a general nuisance noise ordinance. Another response was that the municipality already had one.

It is clear that traffic noise is perceived as a growing problem in South Dakota (Tables V.5 and V.16). Technical Panel members and local stakeholders cited the increasing number of homes being constructed near interstate highways. Both groups also are concerned with future traffic growth along existing highways and future noise from new highways or capacity expansions of existing highways.

Both groups clearly believe the research team should focus on limited access freeways, major arterials and state highways, and not county/city arterials or collectors (Tables V.9 and V.22). Both groups also believe the research group should focus on both noise sensitive and noise compatible land uses, as opposed to noise sensitive land uses only (Tables V.10 and V.23). However, the Technical Panel was less divided on this issue than the local stakeholders.

The Technical Panel and local stakeholders were almost identical in the survey of noise mitigation tools (Tables V.11 and V.24). The most useful tool would be guidance on recommended separation distances from highways to various noise level contours from recommended land uses. Secondly, both groups are interested in model local land use controls that could be used and amended by individual communities. The other highest ranked tools were information about existing and/or future noise levels adjacent to highways and noise mitigation measures other than noise barriers.

Only two out of twelve Technical Panel members noted that local governments should have the primary role in promoting noise compatible land use planning and development (Table V.12). Upon further discussion of these responses, the Technical Panel agreed that this question was interpreted to mean that local governments should have the primary role in promoting noise compatible land uses, after being provided the tools and support to do so.

Members of the Technical Panel and stakeholders from local municipalities also had similar notions of how to mitigate and reduce noise impacts. Tables VI.30 compares the tools that the Technical Panel and stakeholders are most interested in promoting, from Tables V.15 and V.28, respectively.

Both believe the regulations to require site plan review for noise-incompatible uses is important, as well as permitting noise sensitive land uses with adequate separation distances between highways and noise sensitive land uses. Few respondents from either group thought locally-funded noise barriers should be considered a primary tool.

More local stakeholders than Technical Panel members were interested in allowing noise sensitive development closer to the highway if approved noise mitigation measures were provided. Local stakeholders ranked “encouraging only noise compatible land use adjacent to highway” lower than the Technical Panel for building super-insulation.

When comparing the tools that both groups thought should not be pursued, the groups again diverged (Tables V.16 and V.29). The Technical Panel discouraged noise barriers, while the local stakeholders strongly disliked the concept of design guidelines.

In conclusion, all respondents recognize the need to mitigate noise impacts. Local stakeholders are interested in taking a primary role in setting the regulatory

procedures to do so. With few exceptions, most of the tools, assistance, information, incentives and guidance suggested in the questionnaire were considered helpful by the respondents.

Table V.30: Tools, assistance, information and incentives the Technical Panel and Stakeholders ranked as "Primary Interest"

Technical Panel	Stakeholders	Tools, Assistance, Information and Incentives
3	4	a) Allow residential developers to build close to highways only if he/she pays the cost for a noise barrier or berm
4	5	b) Develop General Nuisance Noise Ordinance
11	10	c) Develop regulations to require site plan review for noise-incompatible uses
3	3	d) Develop design guidelines to include window/door upgrade, superinsulation, central heating, ventilation and air conditioning (HVAC), and no windows facing the road in noise sensitive areas
5	7	e) Allow noise sensitive development closer to the highway if approved noise mitigation measures are provided
2	3	f) Build locally-funded noise barriers or berms to protect new development from noise impacts
10	7	g) Permit noise sensitive land uses with adequate separation distances between highways and noise sensitive land uses
9	5	h) Strongly encourage only noise compatible land use adjacent to highways
7	8	i) Provide open space as a noise buffer
9	5	j) Provide training/Information (video/DVD, brochure, web site, public meetings)
4	6	k) Allow transfer of development rights (TDR) for developers to transfer density or to transfer use between two parcels he/she owns to keep land adjacent to the highway vacant

iii. Other State Transportation Officials

Eleven key individuals at the Planning/Environmental sections of other state DOT's, including some that are geographically and demographically similar to South Dakota, were contacted. Eight of the eleven completed the questionnaire, and were subsequently interviewed. They included: Arizona, Colorado, Iowa, Nebraska, North Dakota, Michigan, Montana, and Wisconsin.

The key individuals were asked two questions. Each question included a list of possible actions or assistance. The intent of the first question was to find out what actions state DOT's had either implemented or were considering implementing to avoid, abate or control highway noise. These questions focused on actions other than those typically used on Type I noise mitigation projects. The intent of the second question was to find out what types of assistance other state DOT's were providing to local communities, and what types of assistance local governments were requesting so as to improve noise compatible land use planning. See Appendix D for a copy of the questionnaire. The two questions were:

- Has the Department implemented or is the Department considering implementing any of the following actions specifically to avoid, abate or control highway noise?

- Has the Department provided, or has the Department received requests from local governments for any of the following types of assistance to improve noise compatible land use planning in their communities?

1. Summary of Results

We received responses from eight of the eleven state representatives. The results are summarized in Tables V.1 through V.4.

Table V.31: Summary of Measures Implemented by State DOT's

No. Responses	Avoidance, Abatement or Control Measure
3 of 8	Repaving highway segments in populated areas using quieter pavement.
4 of 8	Conducting or sponsoring research on quiet pavements
4 of 8	Type II noise barrier program using Federal aid matching funds for constructing earth berms or noise barriers
1 of 8	Noise insulation of buildings
2 of 8	Restricting use of shoulder rumble strips in populated areas
0 of 8	Restricting use of rumble strips across travel lanes
1 of 8	Restricting use of engine brakes
1 of 8	Reducing the posted speed limit by 10 mph or more
0 of 8	Restricting commercial traffic from noise sensitive areas
4 of 8	Making changes to the State Highway Noise Policies to address these or other actions
0 of 8	Purchase of easements for future noise mitigation
0 of 8	Other

Table V.32: Summary of Measures Considered by State DOT's

No. Responses	Avoidance, Abatement or Control Measure
3 of 8	Repaving highway segments in populated areas using quieter pavement.
1 of 8	Conducting or sponsoring research on quiet pavements
1 of 8	Type II noise barrier program using Federal aid matching funds for constructing earth berms or noise barriers
0 of 8	Noise insulation of buildings
1 of 8	Restricting use of shoulder rumble strips in populated areas
0 of 8	Restricting use of rumble strips across travel lanes
1 of 8	Restricting use of engine brakes
1 of 8	Reducing the posted speed limit by 10 mph or more
0 of 8	Restricting commercial traffic from noise sensitive areas
1 of 8	Making changes to the State Highway Noise Policies to address these or other actions
1 of 8	Purchase of easements for future noise mitigation
1 of 8	Other

Table V.33: Summary of Assistance Provided by State DOT's

No. Responses	Assistance to Local Governments
5 of 8	Noise contours or recommended separation distances from busy highways (for existing or future conditions)
6 of 8	Information (brochures, web pages, videos) on traffic noise fundamentals, noise abatement and Department policies Information (brochures, web pages, videos) on noise compatible land use planning
1 of 8	Model local land use controls (Municipal Zoning Ordinance, Municipal Subdivision and/or PUD Regulations) that could be used and amended as required by individual communities
0 of 8	Model highway noise ordinance
3 of 8	Standards for design and construction of walls and earth berm noise barriers
0 of 8	Design standards for window/door upgrades, super-insulation, central heating, ventilation and air conditioning (HVAC), and other actions to improve building sound insulation
2 of 8	Training in noise compatible land use planning and the use of local land use controls

Table V.34: Summary of Assistance Requested by Local Governments

No. Responses	Assistance to Local Governments
0 of 8	Noise contours or recommended separation distances from busy highways (for existing or future conditions)
1 of 8	Information (brochures, web pages, videos) on traffic noise fundamentals, noise abatement and Department policies Information (brochures, web pages, videos) on noise compatible land use planning
0 of 8	Model local land use controls (Municipal Zoning Ordinance, Municipal Subdivision and/or PUD Regulations) that could be used and amended as required by individual communities
0 of 8	Model highway noise ordinance
1 of 8	Standards for design and construction of walls and earth berm noise barriers
0 of 8	Design standards for window/door upgrades, super-insulation, central heating, ventilation and air conditioning (HVAC), and other actions to improve building sound insulation
1 of 8	Training in noise compatible land use planning and the use of local land use controls

Each of the eight states interviewed were engaged in activities that are of interest to SDDOT and it's goal of implementing pro-active noise avoidance and mitigation measures.

Arizona Department of Transportation (AZDOT) is enrolled in the FHWA Quiet Pavement Pilot Program (QPPP) (Dennis, July 2005). AZDOT's QPPP involves testing the performance of 115 miles of asphalt-rubber asphalt concrete friction courses (ARFC's), and is focused on answering two questions: Does the ARFC provide a minimum 4 dBA reduction? ; and Does the ARFC provide the same durability (10 to 12 years) as other overlays? The results to date have been promising in both aspects. Longitudinally tined PCC is still AZDOT's standard concrete pavement. AZDOT officials acknowledge that ARFC's may not perform well in colder climates exposed to snow, ice and freeze/thaw cycles (Dennis, July 2005). Details of the program may be found at www.Quietroads.com. AZDOT does not sponsor an FHWA Type II noise barrier program, yet is working closely with local officials to promote noise compatible land use planning. They have held meetings with MPO's, held a noise compatible land use planning seminar, and encouraged communities to develop highway noise ordinances. The Town of Gilbert has the most comprehensive highway noise ordinance in Arizona (TOG, 2003). Developers performing noise studies and constructing noise barriers must follow AZDOT standards, policies and design requirements, but developers cannot construct noise

barriers in the AZDOT right-of-way. AZDOT has developed the document "Freeway Coordination Issues and Strategies for Transportation Planning" to inform local communities about the many coordination issues involved with AZDOT project and to encourage noise compatible land use practices adjacent to highways (AZDOT, 2003).

Commencing in 2006, Colorado will be participating in a six year quiet pavement research project that meets the technical requirements of the FHWA program. They will be evaluating all pavements at their disposal. Although CDOT is considering repaving highway segments in populated areas using quieter pavements, the primary factors in pavement selection are safety and durability. CDOT had a Type II noise barrier program, but the Colorado Transportation Commission cut the funding in 1999. CDOT updated their noise guidelines in 2002. For their Type I projects, CDOT provides local communities the design year 66 dBA noise contours. They have published brochures on noise fundamentals and policy, and another on pavement for the general public that are available on their web site. There is a policy in place (and posted on the web page) that allows private concerns to construct noise barriers in CDOT's right-of-way. Noise barriers must meet CDOT standards, have a local government sponsor, and must be maintained by the developer (Mero, July 2005).

Iowa DOT has replaced transverse tining of PCC pavements with longitudinal, uniform tining, and is considering asphalt overlays of transverse tined PCC pavement with their standard asphalt mix. They don't use rubberized or open graded asphalt mixes. The DOT has an inactive Type II noise barrier program that is not expected to grow in the future. Communities in Iowa are not petitioning the DOT for guidance on noise compatible land use planning, and the DOT prefers to allow the free market to dictate development adjacent to highways (Ridnour, July 2005).

Michigan was one of the first states to initiate a Type II noise barrier program. Approximately eight noise barriers were constructed under the original Type II program. To qualify, residential development must have pre-dated construction of the original highway, and pre-dated May 14, 1976, as stated in the original regulations. Although noise compatible development was a part of the original program, local communities were not required, as a prerequisite for construction of Type II barriers, to have noise compatible land use regulations in effect (Peek, August 6, 2003). Following the expiration of a six year moratorium on the construction of noise barriers in Michigan, MDOT issued its Draft Commission Policy 10136, effective July 19, 2002, that provided new policy on Type I and Type II noise abatement (Michigan DOT, July 2002). The policy was circulated for review by FHWA and others and adopted with revisions on July 31, 2003 (Michigan DOT, July 2003). The present policy supports four approaches to mitigate traffic noise impacts, one of which is noise compatible land use on undeveloped lands adjacent to highways. Communities desiring to participate in MDOT's Type II program to mitigate noise along existing highways must have noise compatible land use regulations in place that preclude future noise abatement needs. MDOT is presently developing a Guidebook for Local Communities that provides detailed information for implementing noise compatible land use planning adjacent to MDOT trunkline highways, and a revised MDOT Commission Noise Policy that includes situations that are different than Type I and II projects. It remains to be seen whether or what additional types of projects are addressed in a revised MDOT highway noise policy.

Montana DOT is presently a non-noise barrier state, but is exploring many other pro-active options to mitigate traffic noise. Many of these efforts are discussed in a recent research report "Traffic Noise in Montana: Community Awareness and Recommendations for a Rural State" (MDT, 2004). That study focused on policies, practices and procedures for non-traditional noise abatement solutions as alternatives to noise barriers. It also evaluated the present land use planning and development processes and procedures; interviewed citizens; and interviewed local planners. Montana DOT is considering repaving highway segments in populated areas and sponsoring research on quiet pavements. They use chip seal treatments over asphalt, and noted that there is little available research on chip seal treatments. Although Montana DOT does not presently have a Type II program, they are considering establishing a program. Although engine brakes are a major concern of residents, State and local officials have not restricted their use. Montana DOT sees a big need for informational materials on noise compatible land use planning, and for training in noise compatible land use practices (Helm, July 2005)

The Nebraska DOT does not have a Type II noise barrier program, but has installed quiet pavement in some areas of the state, and is monitoring performance. Nebraska is very interested and is making significant efforts to inform local planning officials and developers about the need for noise compatible land use planning adjacent to highways. For Type I projects, the DOT provides information to the local planning commissions on recommended setback distances to use for residential development (Otteman, July 2005).

North Dakota DOT is participating in a pool funded quiet pavement study, but has not implemented repaving of highway segments with quieter pavement. Shoulder rumble strips are terminated in developed areas, and the DOT has adjusted speeds in some areas of Bismark to reduce the need for applying engine brakes. The DOT has few requests for noise compatible land use planning materials and training (Gaydos, July 2005).

Wisconsin DOT was one of the first states to conduct quiet pavement research (Wisconsin DOT, January 1977). As a result of that research, the Department changed their PCC tining from transverse to uniform longitudinal. No changes were made to the Department's standard dense graded asphalt pavement, as course and fine SMA mixes, and SuperPave were found to have only limited noise reduction benefits, over the standard dense graded asphalt. Wisconsin DOT has a Type II noise barrier program that's funded with 100% State money at $1M per year. There are 207 sites (involving $108M in potential noise barrier construction) located along freeways and expressways that have been identified and prioritized in the Type II program. To qualify, local communities must pass a resolution of support for the noise barrier, and implement noise policies at the local level that restricts development adjacent to highways. Madison, WI has the most detailed zoning regulation covering noise compatible land use. More communities are becoming interested in noise compatible land use planning. On Type I projects, the DOT issues a letter to adjacent local governments, providing information, a graph showing noise levels at various distances, and requesting that the community initiate noise compatible land use planning. Wisconsin DOT does not allow noise barriers to be constructed by others within their right-of-way (Waldschmidt, July 2005).

E. Approaches to Support Noise Compatible Land Use Planning

i. Land Planning and Land Development Regulation in South Dakota

Following observations were drawn from interviews by Mark Wyckoff of the Planning & Zoning Center, Inc. with three local experts recommended by Hal Rumpca of SDDOT. These local government experts were: Sam Trebilcock, Transportation Planner with Sioux Falls; Marcia Elkins, Director of Planning and Zoning in Rapid City; and Karla Engle, SDDOT Legal Counsel.

1. General Observations

South Dakota communities have available to them all the traditional local planning and zoning tools and a few more contemporary ones. However, the statutes authorizing these tools are not closely based on the model state planning and zoning enabling acts like most other states in the country. Instead, they are more an outline version of them with very brief statements of purpose, power, procedure and standards. This leaves a lot of ambiguity and room for interpretation. That can be very good for creative communities willing to take some legal risks and bad for communities that function largely by the "seat of their pants" or without carefully researching the proper use of these tools in parts of the country where both the statutes and subsequent case law have more clearly defined these powers and procedures.

Implicit in this statement is the importance of the role of courts in the interpretation of grants of local power and authority, as well as the basic structure and power of local governments in a state. The following Specific Observations attempt to describe the current institutional structure for land use decision making in South Dakota, and offers insights into strengths and weaknesses for making local land use decisions.

2. Specific Observations

a. South Dakota is a state with a limited view of the role of state government vis-à-vis that of local government, and hence limited authority has been delegated to state agencies, beyond the obvious main function of an agency (such as building and maintaining roads, as in the case of SDDOT). There has not been, for example, a state planning agency since the 1970's and little technical assistance is provided to local governments by state agencies on any land use or infrastructure issue. There are regional planning agencies and some counties have a planning function. There are only about a dozen home rule cities and counties, and an independently prepared charter (as opposed to a model charter) is the basis for governance in such communities. Home rule communities can take any action not expressly prohibited by state law (prohibitions can be found at SDL 6-12-5, 6 and 14). The State Legislature only meets for two months a year, which does not make it amenable to extensive dialogue on complex issues and leads to legislation authorizing brief grants of power with few qualifiers. It is also comparatively easy to repeal a power/law.

b. South Dakota is a Dillon's Rule state as relates to non-home rule communities. Dillon's Rule is the doctrine that a unit of local government may exercise only those powers that the state expressly grants to it, the

powers necessarily and fairly implied from that grant, and the powers that are indispensable to the existence of the unit of local government. However, few home rule communities appear to have exercised much of the independent authority in the planning and zoning arena that usually rests in home rule communities. Thus, nearly all jurisdictions are effectively Dillon's Rule communities as far as local planning and zoning go. [2]

South Dakota law expressly permits local governments to be more restrictive than state law in some areas (see for example SDL 6-12-5 and 11-4-6). See also Art. IX Section 2 of the State Constitution.

- Home rule cities have extraterritorial planning, zoning, platting and right-of-way reservation (also known as official mapping) power. This means they have the power to act beyond the existing borders of the city. This is very important as it relates to future development and road construction. Counties do not have extra territorial authority, although they can enter into joint planning authorities with cities.

- The planning, zoning and subdivision statutes provide basic, minimalist, and vague, but largely sufficient grants of power to local governments with few qualifiers, procedures or standards to guide the use of those powers. Planning is required before zoning and has been so upheld by the State Supreme Court (see *Heine v Yankton County*, 2002 SD 88; 649 NW2nd 597).

- South Dakota courts appear to have little understanding of local planning and zoning (which is not unusual in states with few zoning cases) and often narrowly construe statutory procedures (even after a long time of local reliance on an adopted plan or zoning ordinance). There is a definite risk a court may invalidate the application of a power granted by statute on non-substantive grounds (such as a narrow reading of a procedural requirement) where the court has had little prior exposure to the application of the technique. Judges are appointed, but may have to stand for a vote if they have an opponent. Cases go from circuit court to the Supreme Court, but the process is perceived as a slow one.

- It appears local elected officials tend not to be well versed in planning and zoning law and are often not very supportive or consistent in the application of policies in adopted plans and zoning ordinances. Local developers in some jurisdictions however, are more often than other stakeholders to act quickly if they are opposed to a policy and to maintain political pressure until a particular measure they oppose is repealed or watered down.

- There is a strong sense of and belief in the concept of "local control" and considerable opposition to any action by the legislature to reduce local control, especially if the alternative is increased state control. However, local governments do not appear to be fully using the existing authority under the local planning and zoning enabling acts, thus it is hard to argue that the principal of local control really has its full meaning, for if it did,

[2] Dillon's Rule, Black's Law Dictionary, 7th ed., West Group, 1999, p. 469.

urban growth boundaries, transfer of development rights, impact fees and greater use of official maps would be common.

- The point above may be explained by a citizenry that generally wants minimalist government and does not want a lot of land use regulations.

- Citizens have expansive initiative and referendum power in South Dakota, but local legislative bodies can repeal citizen initiatives a year after enactment without another public vote. Thus the effect can be inconsistent and unpredictable. Citizens have the right to sue to prevent pollution, impairment or destruction of the environment, but there appears to have been little exercise of this authority.

- Recording important conditions on deeds so that subsequent purchasers would have legal notice of the restriction appears uncommon and is not expressly permitted in law. While communities could not record such conditions, some South Dakota communities have required developers to record certain deed restrictions if the developer wants certain permits. The sample highway noise overlay district language establishes when communities should require developers to do this, and what should be required.

- The right-of-way reservation power (official mapping power) does not appear to be widely used at the local level and does not appear to have been tested in court. There is no express impact fee authority (nor is it expressly prohibited).

- SDDOT frequently buys access rights when acquiring road right-of-way, but does not routinely acquire development rights on abutting lands and it is unclear if they have any authority to do so. Federal regulations allow acquisition of real property or interests therein (predominantly unimproved property) to serve as a buffer zone to preempt development which would be adversely impacted by traffic noise. This measure may be included in Type I projects only (FHWA, 1982).

- Development rights appear to vest on approval, rather than upon construction, but may expire by ordinance if the developer does not use them by a certain date (often as long as 2 years after approval).

- There are a fairly extensive set of nuisance laws in the state and noise can be considered a nuisance. Highway noise however, cannot be considered a nuisance because it is the result of public highways which were created as a result of a statute, which exempts them from being declared a nuisance.

- There appears to be little institutional or cultural support for local planning and zoning. Consider for example, there are:

    - Few if any “how to” manuals that attempt to broadly describe and shape local planning and zoning action;

- No consolidated and regularly updated court case summaries of all local planning and zoning cases available to local governments;

- No frequent broad based basic and advanced training on planning and zoning for local elected and appointed officials;

- No comprehensive guidelines are provided by state agencies to local officials on planning and zoning. However, there is a state planning organization that does provide some training for local officials.

- There is no history of use of road dollars as incentives by SDDOT to shape local government land use behavior, or a long tradition of technical assistance to local officials on issues related to the land use/transportation interface.

3. Local Land Use Planning

The local comprehensive or master plan sets forth the community goals, objectives and policies for future growth and development and the provision of public infrastructure and services. A future land use map lays out the desired pattern of land uses about 20-30 years into the future. A variety of inventory information related to demographics, economics, physical features, infrastructure and land use often accompany the policy parts of the plan. The plan is required to provide a legal basis for the zoning ordinance and subsequent ordinance or zoning map changes. The plan should be reviewed and amended at least once each five years.

In order for the plan to provide a basis for future zoning designed to minimize or mitigate highway noise impacts, it needs to include the following:

- Problem description
- Relevant goals, objectives and policies
- Explanation of the particular strategy to be used to achieve the goals and objectives (including relevant provisions in the zoning ordinance, subdivision regulations, CIP, etc.)

4. Local Zoning

Zoning is the old warhorse used by most communities to implement the goals and objectives of the comprehensive plan. It is comprised of text and a zoning map. The text includes a list of all the zoning districts and uses permitted in each district. The specific lot sizes, setbacks, height, bulk and similar requirements are typically laid out in the schedule of regulations for each district. The ordinance may have a variety of special districts or overlays to address particular problems such as development in floodplains or along highways.

The zoning ordinance may have a highway noise element, or such regulations may be adopted as a separate police power ordinance. In any event, the highway noise regulations will include special provisions related to development adjacent to or near highways. The emphasis is usually on providing for noise compatible land uses—usually by right, and noise sensitive land uses by some special approval process (such as by conditional use permit or variance). Specific

standards must be included to prevent or mitigate highway noise impacts. These are usually implemented through the local site plan review process.

5. Subdivision Regulations

Sometimes long before zoning provisions come into play, land is divided into various sizes and shapes and sold for development. If the lots that are created are adjacent to a highway and each has a narrow width and shallow depth, the opportunities for mitigating future highway noise will be greatly reduced. As a result it is essential that each new lot be reviewed to ensure that its size, shape and relationship to roads and other existing lands nearby does not unintentionally create a future serious noise problem for anyone. This is accomplished through land division, subdivision and/or plat regulations (term varies between jurisdictions) that are coordinated with zoning regulations. The creation of plats or platted subdivisions with many lots creates the most opportunity (and potential threat) for future problems and each should be reviewed very carefully before approval to ensure consistency with the local comprehensive plan (and any noise element), and the local zoning ordinance.

6. Building Code

The building code is an important tool in mitigating highway noise on those properties that will have homes or apartments close to a highway. New noise sensitive development or redevelopment must be carefully designed and built to minimize noise impacts. This typically requires inclusion of super-insulation standards in the building code such as no opening doors or windows on the highway side, central heating and air conditioning and no useable balconies. Even then, no outdoor active use areas could exist around the buildings housing the noise sensitive land uses.

7. Official Maps

Official maps are maps that show the future location of roads, schools, fire stations, drains, sewer lines and other public facilities. Once mapped, new private development cannot proceed until the public agency responsible for the public facility is given the opportunity to acquire the land. Official maps could be a very effective tool for preventing future highway noise problems if road authorities routinely acquired not only the right-of-way for the road, but also the fee simple or development right interest in the abutting land that would be impacted by the road. While this is expensive, and would dramatically increase road acquisition costs, it would also preclude large future costs for highway noise mitigation.

8. Capital Improvement Programs

A capital improvement program or CIP is a schedule of future public facility improvements for usually the next 5-6 years that identifies the facility, where it is to be constructed, its cost, when it will be constructed, what the means of financing is and similar information. It is an effective way of budgeting for large public facilities and for prioritizing among competing needs. Communities that must pay for all or part of noise barriers should include them in the local CIP as soon as the need is identified, because they are often very expensive and will compete for funds with other local facility needs.

ii. Alternative Approaches for Noise Compatible Land Use Planning in South Dakota

The following general alternatives were evaluated for noise compatible land use planning and development regulation in South Dakota. The "do nothing" alternative is not discussed below, but is included in Table V.35.

1. Alternative A

Only provide for farms, rangelands and forests adjacent to highways by buying the land or development rights in land within the area affected by highway noise. By far the best alternative from the standpoint of minimizing adverse noise impacts on people is to not permit any noise sensitive land uses close to highways. However, it is very expensive. This would be achieved by acquiring the fee simple or development rights of land (via the purchase of a conservation easement) on land adjacent to a highway to a specified distance. Depending on the permitted highway speed, vehicle mix, traffic volume and topography, on flat land along a highway with a speed of 55 mph or higher, this could be 700-1200 feet. This would provide a greenbelt along a highway, prevent access to the road except at limited intersections, preserve the public investment in the road, and give the maximum ability to the public to control future land use, should any be permitted. It would also permit the easiest future road expansion if necessary. This alternative is most likely to work best in rural areas—but even there is expensive.

2. Alternative B

Only permit noise compatible land uses via zoning adjacent to highways. While farms, rangelands and forests are noise compatible land uses, so are commercial and industrial uses. In suburban and urban locations, and perhaps some small towns, allowing the whole host of noise compatible land uses adjacent to highways may be both good land use and economic development policy. However, in most suburban and urban communities, there is far more highway frontage than there is a market for exclusively noise compatible land uses, especially when considering only commercial and industrial development. Consequently this alternative is unlikely to work in many locales, unless large amounts of farm, rangelands or forest land are also included as zones along the highway. A staged expansion of commercial and industrial uses at intersections may be a viable strategy in some communities. The other problem with this approach is that it promotes strip commercial and strip industrial development along highways that many communities legitimately try to prevent. It also means that strong access management controls (or purchase of access rights), needs to be in place ahead of or concurrent with the planning and zoning of noise compatible intensive land uses (like commercial and industrial development) next to highways.

3. Alternative C

Require noise sensitive development with outdoor use to be no closer to the highway than a future condition noise contour that establishes an area impacted by highway noise, or permit noise sensitive land uses adjacent to highways conditioned on noise barriers and/or super-insulation.

This alternative should only be considered in urban and suburban locations. Where there isn't enough noise compatible development to locate next to the highway, then market demand or available land may "push" noise sensitive land uses close to highways or urban redevelopment may only be feasible with noise sensitive land uses next to highways. But, if development were not permitted to locate closer than the area impacted by highway noise, then on flat terrain, that could be 700 or more feet away from a 55 mph (or greater speed) highway. Requiring a developer to be separated that far from the highway with no other lawful use of the land in-between, is likely to pose legal "takings" questions that would be hard (if not impossible) to overcome. Thus, the community either has to prohibit noise sensitive land uses from locating next to a highway (politically difficult) or it has to have a way for noise sensitive development to locate next to a noisy highway.

Noise barriers are one option that addresses outdoor use and super-insulation is an option that addresses indoor use. Properly designed and constructed noise barriers will permit single family homes to locate close to a highway by protecting outdoor conversation in active use areas. Super-insulation will protect indoor activities including sleep, but not outdoor conversation. Properly structured, the zoning ordinance would permit noise sensitive land uses only if the design included noise barriers for low rise uses such as single family homes, and super-insulation for high rise uses like apartment buildings and condominiums. Such uses would be approved under the zoning ordinance, but conditioned on the inclusion of design elements that met prescribed ordinance standards for noise berms, noise walls, or noise berm/wall combinations; or for buildings with non-opening windows, no accessible balconies, super-insulation and central heating and air conditioning. Some communities may find this approach easiest to implement as part of planned unit development (PUD) standards. If so, all the land within the area impacted by highway noise would be zoned PUD requiring developers to conform with either the noise barrier or super-insulation standards (or in some cases both). A future condition noise contour would be used to define the extent of a highway noise overlay zone subject to these special regulations.

4. Alternative D

Site design that mitigates highway noise. Some sites and some projects lend themselves to site plans that strategically use topography, and building locations and elements to redirect or buffer highway noise. A simple example is placing a garage or parking structure between a dwelling and the highway. Under some circumstances, such designs can reduce noise to acceptable levels. Unfortunately, not all sites, nor all uses, nor all site plans offer much, if any opportunities of this sort, so it is not an alternative with the same stature as the three options above.

5. Alternative E

Legal notice of highway noise condition. This option requires prospective buyers of homes or renters of apartments or other owners of noise sensitive land uses proposed for location within the area impacted by highway noise to be legally notified of the possible highway noise condition prior to purchase or lease of the affected property. This would be done by a notice in the deed or lease agreement (or even better in the listing papers along with other known property limitations) about a possible/probable highway noise problem. It is a very limited option in

that it does not require any noise mitigation. So the development could occur when noise levels on a highway are low and buyers may not be concerned about the noise, but once full capacity on the highway was approached (LOS D & E), noise levels would be much higher and over time abutting property could become blighted with declining land values. At that point, the quality of life of the people next to the highway will be substantially diminished, and the fact that they (or their predecessors in title) had legal notice of a possible future condition, is of little solace. It is also of little utility even if the option is offered before the noise level rises, because once it does, the noise level cannot be effectively reduced and the decision cannot be remade, without a likely loss in the investment. Some may have much tolerance for this approach (and may even prefer it over the other options) as it places the responsibility first on the developer and second on the buyer. However, it is "caveat emptor," or "buyer beware" approach. Unfortunately, the developer will almost always be long gone by the time the noise problem develops and then the local government which approved the project in the first place is left trying to answer noise impacted landowner's concerns, with nothing but "after the fact" remedies (like a possible noise barrier) which are often hard to site and hard to make very effective—after the fact. In a perfect world where everyone had equal access to information and a common equal understanding of the significance of all information, this option works because only those with impaired hearing or no desire to engage in outdoor conversation would choose to live next to a noisy highway. Unfortunately, it is not a perfect world and even if everyone received constructive legal notice of potential highway noise, not everyone would understand it equally. Thus, some people would make bad decisions that result in living next to a noisy highway and have few options after the fact to mitigate the impacts of that decision. This is one reason why most communities try to prevent the location of noise sensitive land uses next to highways in the first place, unless the developer pays to mitigate the highway noise with a noise barrier or super-insulation.

6. Alternative F

This alternative combines aspects of Alternatives A through E, resulting in slightly higher costs than any one specific alternative, but provides greater benefits than any singular alternative. It spreads the chances of success and risks of failure across the approaches, thus increasing the chances of success. It's primary disadvantage is that it would be more complicated to implement. There will be technical, functional, and political challenges to implementing this alternative.

7. Alternative G

This alternative combines all of the aspects of Alternatives A through E, enhanced with appropriate use of subdivision regulations, building codes and capital improvement programs to supplement the core planning and zoning strategy. It results in very low new direct public or developer costs, and has the benefit of exceeding the best of each of the selected options. It spreads the chances of success and risks of failure across many approaches, thus increasing the chances of success. Its primary disadvantage is that it requires two complex sets of regulations and a regularly updated CIP. This alternative could also present political challenges from homeowners and realtors.

The key to sorting through all the complicating features of highway noise impacts and selecting a recommended approach is recognizing the following:

- If there are no noise sensitive land uses next to the highway there are no highway noise impacts to mitigate (now or in the future);
- If there are no highway noise impacts to mitigate, there are no expenses for noise barriers and the money that would have been spent for that purpose (often between $1M and $4M/mile on each side the road) can be used for other highway purposes;
- Road authorities have no authority over the land use decisions which allow noise sensitive land uses next to highways, but road authorities have responsibilities after the fact for noise impacts if the traffic which causes the problem results in a Type I capacity improvement project and noise barriers are found to be reasonable and feasible;
- Local governments have exclusive local land use planning, zoning, subdivision regulation and building code authority which if properly used can prevent future highway noise impacts by only permitting noise compatible land uses next to highways, or by requiring future development of noise sensitive land uses to mitigate highway noise at the time of construction;
- Therefore, the costs of providing education, technical assistance and a wide variety of guidance materials to local governments and developers, (even if they were equal to the costs of one FTE Noise Specialist), is a fraction of the cost of just one noise barrier. Such expenses would be justified if they resulted in prevention of future highway noise impacts. If these education and technical assistance efforts resulted in local planning, zoning and development approval of noise compatible land development next to highways, or if noise sensitive land uses were permitted by local governments next to highways, but only with noise barriers or super-insulation in place so that there were no adverse highway noise impacts to address as noise levels rose, the costs would be even more easily justified.

These simple observations present a compelling case for a SDDOT initiated technical assistance program on highway noise prevention that is targeted to local governments and developers. It is safe to assume that local governments will do nothing significant to prevent adverse effects from highway noise without some technical assistance. This is likely because:

- Local governments do not know about the potential problem or their role in preventing them.
- Local governments do not know what options are available to prevent adverse highway noise impacts.
- Local governments are unlikely to adopt any noise barrier regulations (even if they are structured to apply only at the choice of the developer) if they do not receive technical assistance on the design, construction and maintenance of noise barriers from SDDOT.
- If local governments do nothing, then the future costs of road expansion projects will be much greater on the SDDOT than on the local governments, as noise impacts on abutting homes and other noise sensitive land uses are addressed as part of Type I capacity improvement projects.

Following are three levels of recommended SDDOT technical assistance services to local governments to prevent adverse highway noise impacts. Each level requires more expertise and hence would likely be more expensive to provide than the prior level. Services could be provided by in-house staff or outside consultants.

1. **Level One Technical Assistance Services**

- Preparation of educational and "how to" materials targeted to local units of government and developers that explains the problems and consequences of building noise sensitive development near highways and options to avoid negative impacts from highway noise.
- Preparation and delivery of training programs to deliver the above.
- Development of model local planning, zoning, subdivision regulation and building code elements to enable noise compatible land use planning and mitigate highway noise impacts associated with noise sensitive development.
- Provision of future condition noise contours defining an area adjacent to highways that is impacted by highway noise.
- Respond to technical assistance requests from local governments with regard to any of the above materials.
- Respond to technical assistance requests from developers on any of the above materials.
- Development of SDDOT standards for an approved local highway noise prevention land use planning and development regulation program.

Several of the elements require changes to the current SDDOT highway noise policy, which are included in the proposed policy revisions (distributed separately from this document).

2. **Level Two Technical Assistance Services**

- All of the Level One services, plus:
- Possible provision of ROW acquisition services for noise barriers
- Adoption of SDDOT standards for noise barriers
- Review and comment on proposed site plans for development along highway segments where highway noise is an issue
- Review and comment on proposed noise barrier specifications in particular locations if a local government has a highway noise prevention land use planning and development regulation program in place that meets SDDOT standards
- Inspection of noise barriers during construction for conformance with SDDOT standards
- Inspection of noise barriers upon completion of construction for conformance with SDDOT standards

3. **Level Three Technical Assistance Services**

- All of the Level Two services plus:
- Acceptance of responsibility for long term maintenance of any noise barriers built in SDDOT ROW.
- Cost sharing with local governments on construction of certain Type II (should SDDOT choose to implement a Type II program) noise barriers if they have an approved highway noise prevention land use planning and development regulation program in place that meets SDDOT standards.

These elements are presented in three levels to permit a staging of increasing SDDOT services and to thus spread the cost of those services. Several of the

elements require changes to the current SDDOT highway noise policy, which are included in the proposed policy revisions.

The research team recommended Alternative G with Level Two technical assistance and the Technical Panel concurred.

Table V.35: Summary of Alternative Approaches

Alternative	Cost	Benefit	Advantages	Disadvantages	Feasibility
Do nothing	Nothing at first, but eventually, large remedial (after the fact) expenses for noise barriers borne by the public at large, highway agencies or benefiting property owners (depending on politics) once highway noise levels rise to unpleasant levels, and doing nothing is no longer politically feasible.	Save a lot of SDDOT, local government and developer time, and cost associated with that time in the near term, [but eventually will probably cost more time (and certainly more money) than not acting now]	Keeps government out of an arena that many feel people ought to be able to decide for themselves. "If people don't like the noise, they can always move." That is always assumed, but for the poor, that may not be feasible and the poor are the ones likely to be stuck in noise impacted housing, because it is cheap (in part from highway noise impacts).	Initially not much, but eventually, the demand for noise remediation will result in the creation of many noise walls that are very expensive (usually $2.4 M per mile on each side of the road) and which many may believe are not aesthetically pleasing. Many of these noise barriers would not have been needed if the other alternatives were selected.	Doing nothing is very easy at first, but often difficult to build the political support for after the problem is recognized, unless waiting until a serious crisis develops.
Alternative A: Purchase rights on land next to highway within the area impacted by highway noise	Huge public costs if done along every highway segment (or even targeted urban segments) of high speed highways.	From a noise impact perspective, the entire community would benefit today and tomorrow with no exceptions.	Incredible—no negative future highway noise impacts Would also create a permanent greenbelt along the highway/city which many citizens would value.	Would likely cost more than most citizens in nearly any community would likely be willing to pay.	Would probably need new enabling legislation as it would likely be beyond the scope of current authority to buy ROW or access rights, but is within authority granted by FHWA on Type I projects. Would require huge education campaign and a citizenry that was sold on the notion of sustainable development.

Alternative	Cost	Benefit	Advantages	Disadvantages	Feasibility
Alternative B: Only noise compatible development is allowed next to highways	Very low new direct public or developer costs, but significant secondary costs on secondary roads associated with remedies for traffic congestion, aesthetic improvements.	From a noise impact perspective allows development next to highway with few negative highway noise impacts on noise sensitive land uses.	A good option where the area impacted is not too large to accommodate an equivalent amount of noise compatible development.	Results in promoting strip commercial and strip industrial development which is widely chastised for traffic, aesthetic and community character impacts. Not enough noise compatible development within urban areas to be feasible.	Technically, politically and functionally easy to prepare and implement the plans and zoning to permit the noise sensitive development. Much harder to gain political support to deal with the secondary impacts—but these come much later.
Alternative C: Noise sensitive development set back beyond highway noise impact area or allowed next to highway with noise barrier and/or super-insulation	Very low new direct public costs, but significant developer costs. However, noise barrier or super-insulation costs are ultimately borne by the new occupants of the noise sensitive development.	From a noise impact perspective allows development next to highway with few negative highway noise impacts on noise sensitive land uses.	Noise barrier or super-insulation serve to preserve the investment in the new tax base as highway noise levels rise which would not occur without noise mitigation.	Noise walls are rarely considered aesthetically pleasing. Super-insulation reduces design options and may limit marketability of some (particularly apartment) buildings.	Technically and functionally easy to prepare and implement the plans and zoning to permit the noise sensitive development using noise mitigation, but may be politically difficult as development community is likely to resist and citizens may be indifferent until impacted.

Alternative	Cost	Benefit	Advantages	Disadvantages	Feasibility
Alternative D: Creative site design used to buffer highway noise	Very low new direct public costs, but variable developer costs (depending on the site and land uses).	From a noise impact perspective allows development next to highway with reduced negative highway noise impacts on noise sensitive land uses than if creative site design was not used. However, probably will not result in as much noise mitigation as a noise barrier or super-insulation, so one and/or the other may still be necessary.	Creative site design serves to help preserve the investment in the new tax base as highway noise levels rise which would not occur without the creative design, but additional noise mitigation measures are likely necessary.	Not every site is amenable to creative design and developers may push designs that are low cost but also low functionality and also try to avoid other noise mitigation measures leaving this technique open to easier political manipulation under the guise of protection.	Technically and functionally challenging to prepare and implement the plans and zoning to permit the noise sensitive development using fair and objective creative design standards. May be hard to gain political support for as developers may be split as to opinion on the approach.
Alternative E: Legal notice of highway noise condition	Very low new direct public or developer costs	From a noise impact perspective if the notices were effective, the result would be few successful noise sensitive projects along noisy highways as few people would choose to live in or use those projects so few people would be impacted.	Cheap and relatively easy to implement if courts would permit notice to run with deed or lease.	Does little to guarantee that people make an informed choice and if they don't, then over time the result is the same negative blight-like impacts that would occur if nothing were done.	Likely to have broad political support but may require new enabling legislation which could be hard to get as the real estate industry would likely work hard to oppose.
Alternative F: (parts of all of the above—except from the do nothing alternative)	Depends on the elements selected, but probably the same costs as applicable to that element from above (only cumulative).	From a noise impact perspective will equal or exceed the best of each of the options selected.	Spreads the chances of success and risks of failure across many approaches, increasing the odds of succeeding.	Will be more complicated to plan for, design and regulate.	Technically and functionally challenging to prepare and implement the plans and zoning to permit the noise sensitive development using noise mitigation, but may also be politically difficult as development community is likely to resist and citizens may be indifferent until impacted.

Alternative	Cost	Benefit	Advantages	Disadvantages	Feasibility
Alternative G: All the above (except do nothing) enhanced with appropriate use of subdivision regulations, building codes and capital improvement programs	Very low new direct public or developer costs	From a noise impact perspective will exceed the best of each of the options selected.	Spreads the chances of success and risks of failure across many approaches, increasing the odds of succeeding.	Two more complicated sets of regulations and the local CIP to stay on top of.	Feasibility depends on extensive education and technical assistance by SDDOT to local governments, homebuilders, developers and realtors.

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iii. Noise Standards and Calculation Methodology

1. Standards for Noise Sensitive Development

Noise standards are needed to define the area adjacent to highways that is impacted by highway noise and the limits of the highway noise overlay zoning district. The FHWA Noise Abatement Criteria (NAC), contained in 23CFR772 (FHWA, 1982), provide a starting point, however, the NAC represent impact criteria. Lower noise thresholds, corresponding with an improved quality of life that preserve conversational speech, reduce annoyance, and reduce sleep interference are recommended in Table V.36 (Avery and Spica, 2004). These standards equal or exceed the FHWA standards, which only define a noise impact rather than a desired condition, and are consistent with the L_{dn} standards used by other federal agencies.

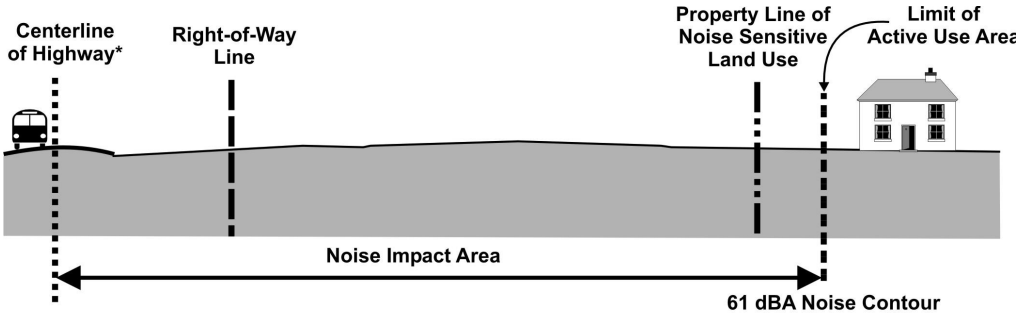
Table V.36
Relationship Between Location of Human Activity,
Noise Sensitive Land Uses, Building Construction and Noise Levels

Location of Human Activity	FHWA Noise Abatement Criteria Applicable to Noise Sensitive Land Uses	Building Construction	Noise Level Used to Establish Area Affected by Highway Noise (loudest hour L_{eq})
Indoor & Outdoor **Or** **Outdoor Only**	B	Opening windows with or without central HVAC	61 dBA exterior at edge of active use area (see Figure V.1)
Indoor Only (structures where people normally sleep)	E	Central HVAC and non-opening, double pane windows	61 dBA exterior at edge of principal building (see Figure V.2)
Indoor Only (structures where people do not normally sleep)	E	Central HVAC and non-opening, double pane windows	71 dBA exterior at edge of principal building (see Figure V.3)

Local governments are encouraged to use the loudest hour L_{eq} of 61dBA as the recommended outdoor noise criterion. This preserves the yard area for conversational speech for NAC B (noise sensitive) land uses (see Figure V.1). The distance is measured from the centerline, or median, of the roadway to the nearest edge of the active use area. The recommended indoor noise criterion for buildings where people regularly sleep, and where there is infrequent or only transient outdoor use is the loudest hour L_{eq} of 41dBA (corresponding to an outdoor loudest hour L_{eq} of 61dBA, see Figure V.2). The distance is measured from the centerline, or median, of the roadway to the nearest point of the principal building. Local governments are encouraged to use the loudest hour L_{eq} of 51dBA (corresponding to an outdoor loudest hour L_{eq} of 71dBA) as the recommended indoor noise criterion for buildings where people do not regularly sleep, and where there is infrequent or only transient outdoor use (see Figure V.3). The

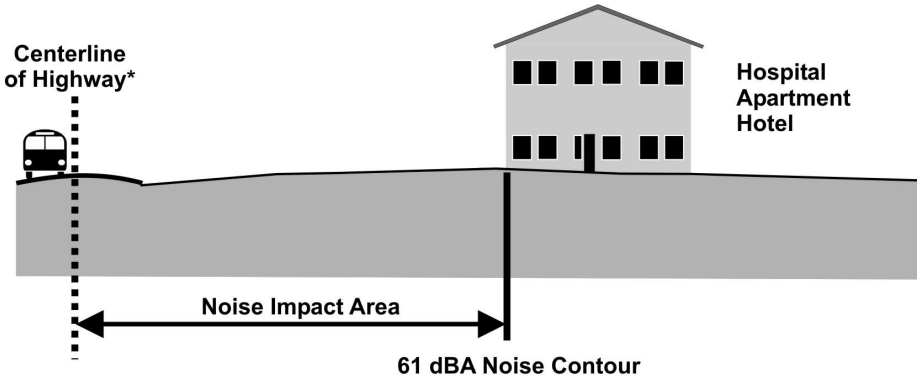
distance is measured from the centerline, or median, of the roadway to the nearest point of the principal building.

Figure V.1
Highway Noise Impact Area for Noise Sensitive Land Uses With Indoor and Outdoor or Only Outdoor Activities



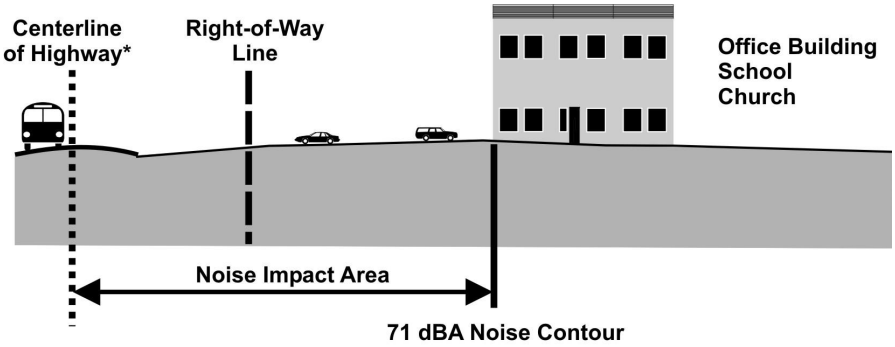
* Measurement is from the centerline of a divided highway or boulevard.

Figure V.2
Highway Noise Impact Area for Noise Sensitive Land Uses with Only Indoor Frequent Use, Including Sleep



*Measurement is from the center of a divided highway or boulevard.

Figure V.3
Highway Noise Impact Area for Noise Sensitive Land Uses with Only Indoor Frequent Use Excluding Sleep



*Measurement is from the center of a divided highway or boulevard.

2. Accounting for Traffic Growth and Highway Capacity

The traffic volumes used to develop the distances to the 61 and 71 dBA noise contours are based on one of two methods. In locations where the existing highway capacity is significantly greater than the present conditions traffic volumes, the 20-year traffic projection, determined by the SDDOT, is used as the traffic volume. This method is generally used for most rural interstate and state highway segments where the present level of service (LOS) is A, B or C, and the projected traffic growth is not expected to reach the operational capacity within the next 20 years. The operating speed used in the calculation is the posted speed limit. In locations where the existing traffic volumes are approaching the highway capacity for interstate and South Dakota state highway segments, the operational capacity of the highway and the operating speed associated with the operational capacity are used in the calculation. Operational capacity is determined using the Highway Capacity Manual 2000 (NRC, 2000).

3. Calculation Methodology

A planning level calculation methodology that accounts for the most important variables affecting highway noise is needed to provide the distances to the 61 and 71 dBA noise contours. The 66 dBA noise contour, corresponding to the FHWA NAC B, is also provided. The TNM Look-up Tables, were developed by FHWA as a planning level tool for calculating noise levels at a known distance from a highway (FHWA, July 1998). The TNM Look-up Tables, are distributed as computer software, and can be reformulated to determine the distances from the highway for a given loudest hour L_{eq} noise level. The TNM Look-up Tables use as input: speed, traffic volumes, vehicle classifications, and either acoustically soft or hard terrain. Variation in terrain, obstructions, grades, and natural barriers are ignored in the calculations. Since autos and heavy commercial trucks are the most significant noise sources in the traffic stream, if the speed and volume of both can be estimated, then distance to the 61, 66 and 71 dBA loudest hour L_{eq} noise contours can be calculated. Acoustically soft ground is assumed in the calculations.

4. GIS Noise Planning Tools

To provide the 61, 66 and 71 loudest hour L_{eq} noise contours in a format more useable to the SDDOT and to local planning officials, the TNM Look-up Tables algorithm was incorporated into an ArcMap 9.1 extension to calculate distances to a given loudest hour L_{eq} noise level in dBA for an entire road centerline feature class. This tool requires that each feature, road segment, within this feature class have four attributes defined for it.

- Auto peak hourly volume,
- Heavy commercial truck hourly volume,
- Auto operating speed (mph),
- Heavy commercial truck operating speed (mph)

For the South Dakota interstate road data the data had to be preprocessed to get into a state that could be used by the tool. Distance to noise levels can only be calculated by using the centerline of the road. The South Dakota interstate data contained the centerline of the eastbound and westbound (or northbound and southbound) lanes. This data had to be combined to create one centerline file with the appropriate traffic data attached to each road segment. For details on this procedure see Appendix E. The procedure was run for South Dakota's interstate highway segments, and is presented in Appendix E.

Once the data was in the appropriate format with the four attributes specified above, defined for each road segment, the noise distance tool was run to calculate distances to the 61, 66, and 71 dBA loudest hour L_{eq} noise levels.

Once the distances for each feature were calculated this information was used to create geographic noise contours. One noise contour shapefile was created for each noise level. For details on these tools and a picture of an example of the resulting contours, see Appendix E.

VI. IMPLEMENTATION RECOMMENDATIONS

A. Introduction

This section provides the research recommendations and an implementation plan that includes specific work elements formulated from the research recommendations, a schedule, and recommended performance measures. The research recommendations are grouped into the following categories: noise policy; pavement design; shoulder rumble strips; assistance services for local governments; SDDOT program; and resources for local units of government. The recommendations are summarized in Table VI-1. The work elements are grouped into two categories: SDDOT policy and program; and resources for local units of government.

The work elements of the implementation plan and the implementation schedule are presented in Table VI.4. The implementation plan work elements are grouped into the following categories; new SDDOT noise policy; hire 1.0 FTE noise specialist; integrate GIS planning tools; incorporate pavement recommendations; incorporate rumble strip recommendations; additional services to local governments; resources for local governments; and develop performance measures/assess program effectiveness.

Table VI.1
Implementation Recommendations

Recommendation #1: SDDOT should revise their noise policy to define "substantial increase" as some value between 10 and 15 dBA.
Recommendation #2: SDDOT should establish a rating form for determination of reasonableness.
Recommendation #3: SDDOT should establish a guideline for evaluating whether a proposed SDDOT project is a Type I project, requiring a noise study.
Recommendation #4: SDDOT should increase the allowable cost per benefited receiver to the FHWA minimum of $25,000.
Recommendation #5: SDDOT should adopt the proposed SDDOT noise policy, forward it to FHWA and distribute it to SDDOT main office, district office and consultants.
Recommendation #6: SDDOT should modify their PCC longitudinal tining specifications to require termination of longitudinal grooves at a minimum distance of 100 mm and a maximum distance of 380 mm from the transverse joints.
Recommendation #7: SDDOT should change the bridge transverse tining specification to require a spacing pattern of: (1) 3mm wide (+/- 0.5mm) and 3 mm deep maximum; and (2) random spacing of either 13 mm or 26 mm average tine spacing. The 13 mm random tine spacing should have the following tine pattern (in millimeters): 10/14/16/11/10/13/15/16/11/10/21/13/10. The 26mm random tine spacing should have the following tine pattern (in millimeters): 24/27/23/31/21/34.
Recommendation #8: SDDOT should continue the practice of using the dense type hot mix asphalt (HMA) surface textures.

Recommendation #9: SDDOT should include two alternative options for resurfacing PCC pavement where a quieter pavement is desired: resurface with Dense Graded Friction Course (DGFC) pavement or diamond grinding of the PCC pavement.

Recommendation #10: For chip seal applications on road projects where quieter pavement is desired, SDDOT should use Type 1B aggregate for the upper course and Type 2A aggregate for the lower course.

Recommendation #11: SDDOT should continue to follow the progress of FHWA and state highway agency quiet pavement noise research programs and make adjustments to pavement surface finishes.

Recommendation #12: SDDOT should provide public information and education about shoulder rumble strip policy.

Recommendation #13: SDDOT should continue to use rumble strips in rural areas, avoid rumble strips in urban areas and provide guidance for transition areas between rural and urban areas.

Recommendation #14: SDDOT should incorporate all elements of Level One and Level Two technical assistance services.

Recommendation #15: SDDOT should determine which, if any, Level Two and Level Three services will be provided, and develop an implementation plan for the additional services.

Recommendation #16: SDDOT should encourage local units of government to adopt the "quality of life" standards that define the highway noise overlay district for three types of noise sensitive land uses.

Recommendation #17: SDDOT should hire a full-time equivalent (FTE) Noise Specialist.

Recommendation #18: SDDOT should incorporate GIS Noise Planning Tools into the SDDOT GIS platform, make the interstate highway noise contours available to local governments and use the GIS Distance Calculation Tool and Contour Calculation Tool to develop noise contours for other major South Dakota state highways.

Recommendation #19: SDDOT should send the final report to participants of the April 2006 workshops.

Recommendation #20: SDDOT should hire the research team to conduct the 3-hour workshop for interested units of local government every year for the next 3 years.

Recommendation #21: SDDOT should develop procedures and provide assistance to achieve a coordinated review process for development projects along interstate and state highways.

Recommendation #22: SDDOT should provide ongoing technical assistance for the implementation of proactive noise avoidance and mitigation measures.

B. Summary of Research Recommendations

i. Noise Policy

The FHWA issued a memorandum and a copy of *Highway Traffic Noise Analysis and Abatement Policy and Guidance* on June 12, 1995 (FHWA, 1995). The memorandum required all SHA's to adopt written statewide noise policies within one year that have been approved by FHWA. The existing SDDOT policy letter, PD-2004-02, was issued as effective on May 14, 1996, and was last reviewed on October 1, 2004 (SDDOT, 2004). A revised, proposed noise policy was developed as part of the research (SDDOT, 2006). The proposed noise policy is distributed separately from this document. These proposed policy revisions are believed to be consistent with the FHWA guidance and have been reviewed by the FHWA Office of Planning, Environment and Realty. Once the proposed changes have been agreed upon by SDDOT, the regional office of the FHWA, and the FHWA Office of Planning, Environment and Realty, the policy should be issued. FHWA review is particularly important now since the FHWA *Highway Traffic Noise Analysis and Abatement Policy and Guidance* (FHWA, 1995), is presently undergoing revisions, and some changes in the federal policy may dictate changes in the SDDOT policy.

Several aspects of the policy revisions required background research as described in the following sections. These policy revisions pertain to SDDOT conformance with 23CFR 772 and to Type I projects.

Recommendation #1: SDDOT should revise their noise policy to define "substantial increase" as some value between 10 and 15 dBA.

Different states define "substantial increase" differently. A survey of a few states turned up the following:

- South Dakota – 15 dBA
- New York – 6 dBA
- Wisconsin – 15 dBA
- Ohio – 10 dBA
- Nebraska – 15 dBA
- Montana – 13 dBA

In general the more rural states define "substantial increase" as a value between 10 and 15 dBA. South Dakota uses 66 dBA as its NAC B criteria. Therefore, where the existing loudest hour noise levels are less than 51 dBA, it takes a 15 dBA increase or greater to cause a noise impact. 51 dBA is considered a quiet urban daytime noise level. In terms of loudness, a 10 dBA increase in sound pressure level is twice the loudness, so a 15 dBA increase is perceived as more than twice as loud. We recommend that SDDOT define "substantial increase" as some value between 10 and 15 dBA.

Recommendation #2: SDDOT should establish a rating form for determination of reasonableness.

A significant portion of the FHWA *Highway Traffic Noise Analysis and Abatement Policy and Guidance* (FHWA, 1995) is devoted to the factors that should be included in the determination of reasonableness. The list of considerations is provided in Table VI.2.

The criteria in Table VI.2 can be used to develop a rating form. The weight, given to each item is determined by the SHA. In South Dakota, where the SDDOT is seeking to encourage noise compatible land use planning, a relatively greater weight can be given to item 6 in Table VI.2, which deals with development along the highway. This situation occurs primarily for lane addition projects. In locations where a high percentage of residential development occurred adjacent to the highway, before the original highway construction, greater consideration should be given to providing noise abatement for a lane addition project. Such information can be determined using: the original project drawings; historic aerial photography, and if necessary, review of building permit filings. Similarly, if the adjacent community has developed and implemented noise compatible land use planning, since the residential development was constructed adjacent to the highway, some consideration of this should be a part of the decision making process. Lastly, if adjacent land use is changing from less to more noise compatible, less consideration should be given to providing noise abatement.

Recommendation #3: SDDOT should establish a guideline for evaluating whether a proposed SDDOT project is a Type I project, requiring a noise study.

Under FHWA 23CFR772, new highways on new alignment, significant modifications of existing highways, and the addition of through travel lanes to existing highways, qualify as Type I projects. FHWA does not provide specific guidelines on the "significance" of horizontal and vertical alignment changes, or the type and length of additional through travel lanes that qualify a project as Type I. Such guidance will assist SDDOT planners during scoping and preliminary design to better define and prepare for Type I projects.

Recommendation #4: SDDOT should increase the allowable cost per benefited receiver to the FHWA minimum of $25,000.

Cost per benefited receiver is only one of the seven criteria listed in Table VI.2, but is typically the prominent, and sometimes the sole criteria used to determine reasonableness. The maximum cost per benefited receiver should reflect real estate acquisition prices and the cost of the noise abatement, and should also address price escalation. Different states use different cost per benefited receiver criteria. A survey of a few states turned up the following:

- South Dakota - $15,000 / benefited receiver (from 1996 policy letter). A benefited receiver is one receiving a 5 dBA or greater reduction in noise levels with the mitigation (SDDOT, 2004).
- New York - $50,000 maximum / benefited receiver, using a maximum noise barrier cost of $200/sm ($18.59/sf) (NYSDOT, 1998).
- Wisconsin - $30,000 / abutting residence (1988 dollars, adjusted annually per changes in the construction price index) (Wisconsin DOT, 2000).

- Ohio - $25,000 / benefited receiver, using a unit cost of $17.50/sf. A benefited receiver is one receiving a 3 dBA or greater reduction in noise levels with the mitigation (ODOT, 2005).
- Nebraska - $18,000 to $30,000 / benefited receiver, however, several other factors are included in the reasonableness determination. A benefited receiver is one receiving a 3 dBA or greater reduction in noise levels with the mitigation (Nebraska Department of Roads, 1998).
- Montana – Uses the CEI which is dollars / average weighted insertion loss / number of benefited receivers in the study zone. The study zone includes receivers within 500 ft. of edge of pavement. Dollars includes costs of the noise barrier excluding ROW and utility relocations. If the CEI exceeds $4200, then the barrier is considered not to be reasonable. So if the average weighted insertion loss is 5 dBA, then the cost per benefited receiver is $21,000 (MDT, 2001).

Table VI.2
Items to Consider in Reasonableness Determination

(1) Noise Abatement Benefits
- (a) Amount of noise reduction provided
- (b) Number of people protected

(2) Cost of Abatement
- (a) Total cost
- (b) Cost variation with degree of benefits provided

(3) Views of the Impacted Residents
- (a) Community wishes
- (b) Aesthetic impacts (e.g., barrier height, material type, etc.)
- (c) Desire for a surrounding view

(4) Absolute Noise Levels
- (a) Existing noise levels
- (b) Future traffic noise levels
- (c) Context and intensity of noise levels (see 40 CFR, Part 1508.27)

(5) Change in Noise Levels
- (a) Difference between the future traffic noise levels and the existing noise levels.
- (b) Difference between the future traffic noise levels for the build alternative and the no-build alternative.

(6) Development Along the Highway
- (a) Amount of development that occurred before and after the initial construction of the highway.
- (b) Type of development (e.g., residential, commercial, mixed, etc.)
- (c) Extent to which zoning or land use is changing.
- (d) Effectiveness of land use controls implemented by local officials to prevent incompatible development.

(7) Environmental Impacts of Abatement Construction
- (a) Effects on the natural environment
- (b) Noise reduction during highway construction

Ref: Highway Traffic Noise Analysis and Abatement Policy and Guidance, FHWA, June 1995 (FHWA, 1995).

From a review of other states' policies, it is typical to: either fix the dollar value of the benefits and the costs of noise barrier construction; or escalate the dollar value of benefits and use current costs for the noise barrier cost estimate. FHWA's *Highway Traffic Noise Analysis and Abatement Policy and Guidance* (FHWA, 1995), states that an acceptable cost/residence index should be within the range of $15,000 - $50,000 / residence. The document also indicates that most states use a noise barrier cost in the range of $15 - $20 / sq foot for noise barrier posts and material in place.

Escalating the South Dakota value of benefits using the RS Means Historical Cost Index (RS Means, 2005), yields the following:

Means Historical Cost Index, January 1, 1993 = 100
Means Historical Cost Index, July 1996 = 110.2
Means Historical Cost Index, January 2005 = 148.5

$15,000 x [148.5 / 110.2] = $20, 213

Escalating the cost per benefited receiver to $20,213 is consistent with historic cost indices. However, since FHWA will be increasing their minimum to $25,000, SDDOT should increase the cost per benefited residential unit to a minimum of $25,000.

There are many variables that influence noise barrier costs. Ground mounted noise barriers are less expensive than bridge or retaining wall mounted noise barriers. Noise barriers located in areas where there are significant utilities and drainage features are more costly to construct. In addition, noise barriers located along the ROW typically involve lower maintenance and protection of traffic costs than edge of shoulder noise barriers. Without some consideration of differences in site conditions, site specific conditions may play a very significant role in determining whether noise barrier is judged to be reasonable. This is why some states fix the costs and the benefits of noise barriers in the determination of reasonableness. This ensures that the site specific conditions previously described, over which adjacent residents have no control, have little or no influence on the decision to construct a noise barrier.

Recommendation #5: SDDOT should adopt the proposed SDDOT noise policy, forward it to FHWA and distribute it to SDDOT main office, district office and consultants.

The proposed updated SDDOT noise policy has received extensive review by individuals on the Technical Panel, however, it must still be officially adopted by SDDOT's Executive Team. Following its adoption, the policy should be forwarded to the FHWA South Dakota Division Office and the Office of Planning, Environment and Realty at FHWA headquarters. Since the FHWA is presently updating its *Highway Traffic Noise Analysis and Abatement Policy and Guidance* (FHWA, 1995), FHWA review is especially important. Once adopted and reviewed by FHWA, the policy should be distributed as a new policy to SDDOT main office, district offices,

and consultants. To assist implementation of the policy, a rating form and procedures to guide determination of reasonableness on a more uniform basis should be developed. The policy itself should be reviewed and updated biennially.

ii. Pavement Design Practice

Recommendation #6: SDDOT should modify their PCC longitudinal tining specifications to require termination of longitudinal grooves at a minimum distance of 100 mm and a maximum distance of 380 mm from the transverse joints.

The SDDOT should utilize their presently specified surface textures for PCC pavements with the exception of transverse tining which should be limited to bridge decks and approach slabs. The SDDOT does not currently have a requirement in their specifications for terminating longitudinal tining a safe distance from roadway joint systems to prevent spalling at the joints. Therefore, it is recommended that the SDDOT create a requirement in their construction specifications that is similar to NYSDOT's.

Recommendation #7: SDDOT should change the bridge transverse tining specification to require a spacing pattern of: (1) 3mm wide (+/- 0.5mm) and 3 mm deep maximum; and (2) random spacing of either 13 mm or 26 mm average tine spacing. The 13 mm random tine spacing should have the following tine pattern (in millimeters): 10/14/16/11/10/13/15/16/11/10/21/13/10. The 26mm random tine spacing should have the following tine pattern (in millimeters): 24/27/23/31/21/34.

Other state DOT's, such as the NYSDOT, have changed their bridge deck specification requirement to include longitudinal tined texture surfacing instead of transverse tining based on research and testing by CalTrans, and Wisconsin DOT. However, it is recommended that the SDDOT retain its position of using random transverse tined surfacing on bridge decks based on safety considerations. Based on this recommendation, the SDDOT should review their existing transverse tining specification that defines the allowable transverse spacing, and consider changing it to the recommended pattern provided by the FHWA Technical Advisory T5040.36 to minimize tire-pavement noise (FHWA, 2005). The FHWA Technical Advisory: T5040.36 "Surface Texture for Asphalt and Concrete Pavements" may be found at the following link: http://www.fhwa.dot.gov/legsregs/directives/techadvs/t504036.htm

Recommendation #8: SDDOT should continue the practice of using the dense type hot mix asphalt (HMA) surface textures.

It is recommended that SDDOT continue the practice of using the dense type hot mix asphalt (HMA) surface textures (i.e. stone matrix asphalt, super pave asphalt, etc.).

Recommendation #9: SDDOT should include two alternative options for resurfacing PCC pavement where a quieter pavement is desired: resurface with Dense Graded Friction Course (DGFC) pavement or diamond grinding of the PCC pavement.

In areas where transverse tining already exists, and where resurfacing of PCC pavement is being considered, the SDDOT can include as alternative options either resurfacing with DGFC asphalt or diamond grinding of the PCC pavement.

Recommendation #10: For chip seal applications on road projects where quieter pavement is desired, SDDOT should use Type 1B aggregate for the upper course and Type 2A aggregate for the lower course.

For roadway projects using an application of asphalt covered with a spread of cover aggregate (or chip seal) it recommended that the SDDOT Type 1B, and Type 2A aggregates be used because of their smaller sieve requirements as per the SDDOT standard specifications. The smaller aggregate size results in reduced vehicle tire/surface noise.

Recommendation #11: SDDOT should continue to follow the progress of FHWA and state highway agency quiet pavement noise research programs and make adjustments to pavement surface finishes.

SDDOT should continue to follow the progress of quiet pavement noise research programs and make adjustments to their pavement surface finishes, consistent with other performance goals (ex. safety). SDDOT should not participate in pavement research involving its standard pavements, as their performance has been well documented by SDDOT. If SDDOT wanted to use a pavement surface finish that had limited acoustical, skid and durability test information, then the research team recommends SDDOT participates in that specific research.

iii. Shoulder Rumble Strips

Recommendation #12: SDDOT should provide public information and education about shoulder rumble strip policy.

The benefits of shoulder rumble strips are proven, and SDDOT policy has adopted their use on multiple highway types (i.e. 2-lane, 4-lane divided, interstate, etc.). Therefore, the SDDOT should provide public information and education regarding rumble strip policy and the highway safety benefit they provide.

Based on the lack of current references regarding adverse effects of shoulder rumble strips related to noise, it is recommended that the SDDOT follow up with future studies that may address issues of avoiding rumble strips in urban areas, and guidance on transition areas (rural to urban).

Recommendation #13: SDDOT should continue to use rumble strips in rural areas, avoid rumble strips in urban areas and provide guidance for transition areas between rural and urban areas.

Based on the lack of current references regarding adverse effects of shoulder rumble strips related to noise, it is recommended that the SDDOT continue to use them in rural areas, avoid using them in urban areas (or remove them in urban areas where highway improvements are being planned and designed) and develop guidance on their use in transition areas (rural to urban).

iv. Assistance Services for Local Governments

Recommendation #14: SDDOT should incorporate all elements of Level One and Level Two technical assistance services.

As noted in the Findings and Conclusions section, three levels of technical assistance to local governments were proposed. The Technical Panel agreed with the recommendation to provide all aspects of Level One and Level Two technical assistance services. The elements of technical assistance for Level One through Three are summarized in Table VI.3.

Table VI.3
Additional Assistance Services For Local Governments

Technical Assistance Level	Additional Elements of Assistance
Level One	1. Preparation and distribution of educational materials, including a 15-minute DVD, and tri-fold brochure to local units of governments and developers. 2. Preparation and delivery of annual training programs using the 3-hour PowerPoint slide presentation, and guidebook. 3. Development and distribution of the guidebook "Tools for Preventing Adverse Effects From Highway Noise" that includes model local planning, zoning, subdivision regulation and building code elements to enable noise compatible land use planning and mitigate highway noise impacts associated with noise sensitive development. 4. Provision of future condition noise contours defining an area adjacent to highways that is impacted by highway noise. 5. Ongoing response to technical assistance requests from local governments and developers. 6. Development of SDDOT technical standards for an approved local highway noise prevention land use planning and development regulation program.
Level Two	1. Provision of SDDOT ROW acquisition services for construction of noise barriers by developers or local governments. 2. Development of SDDOT standards for noise barriers. 3. Review and comment on proposed noise barrier specifications in particular locations by communities participating in the program. 4. Inspection of noise barriers during construction to assure conformance with SDDOT standards. 5. Inspection of noise barriers upon completion of construction to assure conformance with SDDOT standards.
Level Three	1. Acceptance of responsibility for long term maintenance of noise barriers constructed by others within the SDDOT ROW. 2. Cost sharing with local governments participating in the program on construction of certain Type II noise barriers.

Recommendation #15: SDDOT should determine which, if any, Level Two and Level Three services will be provided, and develop an implementation plan for the additional services.

This work element involves evaluation of the additional Level Two and Level Three assistance services listed in Table VI.3. We recommend that SDDOT perform this evaluation over the first three quarters of 2007 while the general technical assistance program is implemented. The need for some of these elements is not yet evident, and the legal and policy implications require further consideration by SDDOT.
After a decision is made on which elements of Level Two and Level Three assistance are to be provided, an implementation plan for each should subsequently be developed.

Recommendation #16: SDDOT should encourage local units of government to adopt the "quality of life" standards that define the highway noise overlay district for three types of noise sensitive land uses.

Noise standards are needed to define the area adjacent to highways that is impacted by highway noise and the limits of the highway noise overlay zoning district. Such standards should equal or exceed the FHWA standards, which only define a noise impact rather than a desired condition, and should be consistent with the L_{dn} standards used by other federal agencies. Local governments should use:

- The loudest hour L_{eq} of 61dBA as the recommended outdoor noise criterion. This preserves the yard area for conversational speech for NAC B (noise sensitive) land uses. The distance is measured from the centerline, or median, of the roadway to the nearest edge of the active use area.
- The loudest hour L_{eq} of 41dBA (corresponding to an outdoor loudest hour L_{eq} of 61dBA) as the noise criterion for buildings where people regularly sleep, and where there is infrequent or only transient outdoor use. The distance is measured from the centerline, or median, of the roadway to the nearest point of the principal building.
- The loudest hour L_{eq} of 51dBA (corresponding to an outdoor loudest hour L_{eq} of 71dBA) as the recommended indoor noise criterion for buildings where people do not regularly sleep, and where there is infrequent or only transient outdoor use. The distance is measured from the centerline, or median, of the roadway to the nearest point of the principal building.

The traffic volumes used to develop the distances to the 61 and 71 dBA noise contours are based on one of two methods. In locations where the existing highway capacity is significantly greater than the present conditions traffic volumes, the 20-year traffic projection, determined by the SDDOT, is used as the traffic volume. The operating speed used in the calculation is the posted speed limit. In locations where the existing traffic volumes are approaching the highway capacity for interstate and South Dakota state highway segments, the operational capacity of the highway and the operating speed associated with the operational capacity are used in the calculation.

The planning level calculation methodology provided in the TNM Look-up Tables, assuming acoustically soft ground, auto speed, auto volume, heavy truck speed,

heavy truck volume, are the only input variables needed. Variation in terrain, obstructions, grades, and natural barriers are ignored in the calculations.

v. SDDOT Program

These work elements can be implemented within the present SDDOT policies and programs, and require no involvement by local government. They are briefly summarized below, and listed in Table VI-1.

Recommendation #17: SDDOT should hire a full-time equivalent (FTE) Noise Specialist.

Implementing the recommendations of the research will require the hiring of 1.0 full-time equivalent FTE Noise Specialist. The Noise Specialist would be responsible for SDDOT's Type I noise policy and program, and would be the important resource person for local governments seeking to implement noise compatible land use planning in their communities. The SDDOT should develop a detailed job description, obtain hiring authorization, advertise for the position, evaluate candidates, and complete the hiring process in time so the noise specialist begins employment at the beginning of FY 2008. Once hired, the Noise Specialist should receive training in the FHWA TNM model, land use planning and zoning, and should participate in the Transportation Research Board's ADC40 Committee activities regularly.

Recommendation #18: SDDOT should incorporate GIS Noise Planning Tools into the SDDOT GIS platform, make the interstate highway noise contours available to local governments and use the GIS Distance Calculation Tool and Contour Calculation Tool to develop noise contours for other major South Dakota state highways.

This work element involves incorporating the GIS Noise Planning Tools, developed as part of the research project, into SDDOT's GIS platform; making the Interstate highway noise contours, developed as part of the research project, available to local units of government; and utilizing the GIS Distance Calculation Tool and Contour Calculation Tool, with traffic data provided by SDDOT's Office of Transportation Inventory Management, to develop noise contours for other major South Dakota state highways. We recommend that noise contours be made available only via SDDOT's web site so that changes to the noise contours that could occur based on changes in traffic projections, speeds or commercial truck volumes can be updated and communicated broadly and quickly. Procedures and protocols for making the Interstate highway noise contours and other SD highway noise contours available to local units of government should be developed. Traffic data used to develop the noise contours should be reviewed annually to verify that no significant changes have occurred to the traffic data. Also, changes to noise contours and roadways as a result of SDDOT Type I projects should be incorporated annually.

vi. Resources for Local Units of Government Work Elements

The following work elements involve the assistance services and their communication to interested local units of government. As the program is implemented, the means of communication and the tools themselves may be modified and new tools developed.

At the present time, there are two groups of local government representatives: local units of government who sent participants to one of the two April 2006 workshops; and those interested units of local government who have not had the opportunity to send participants to a workshop.

Recommendation #19: SDDOT should send the final report to participants of the April 2006 workshops.

Those local units of government who sent representatives to the April 2006 workshops should receive copies of the final report and electronic versions of the products of the research that will be made available by SDDOT.

Recommendation #20: SDDOT should hire the research team to conduct the 3-hour workshop for interested units of local government every year for the next 3 years.

For interested units of local government who have not participated in a workshop, the SDDOT should hold the 3-hour workshop on a regular basis for several years. As a part of this, the Power Point slide presentation should also be updated. Materials developed from the research, including the final report, DVD, brochure, and "Tools for Preventing Adverse Impacts from Highway Noise" should be distributed at the workshops. The workshop could be offered as part of another venue, such as the annual Statewide Planning Conference (usually held in October), or as a stand-alone workshop. For the first three years, this service should be provided by the Consultant Team, and in subsequent years by the Noise Specialist.

Recommendation #21: SDDOT should develop procedures and provide assistance for the coordinated review process for development projects along interstate and state highways.

Local units of government who adopt the highway noise overlay district provisions will require assistance and participation from SDDOT under the coordinated review and approval process for Interstate and State highways. SDDOT will need to develop the procedures of the coordination process, and the Noise Specialist should participate in the ongoing coordinated site plan review process.

Recommendation #22: SDDOT should provide ongoing technical assistance for the implementation of proactive noise avoidance and mitigation measures.

Planning department officials from local units of government will require ongoing technical assistance from the SDDOT to implement proactive noise avoidance and mitigation measures. This assistance will be provided by the Noise Specialist and may include:

- Answers to technical or procedural questions concerning implementation of "Tools For Preventing Adverse Effects From Highway Noise" in their communities;
- Technical assistance and guidance on site specific noise analysis questions;
- Reviewing qualifications and recommending qualified noise consultants;
- Technical reviews of site specific noise studies for proposed developments;

- Request for noise contours for a specific highway segment that have not already been provided by SDDOT.

As additional assistance services (Table VI.3) are agreed to be provided by SDDOT, this list of services will expand.

C. Performance Measures

i. Assessment of Program Effectiveness

Performance measures are necessary to evaluate the effectiveness of the program, to financially justify its continuation, and to identify improvements that may be needed to increase its effectiveness. Raw data used directly or indirectly as performance measures should not be too difficult to obtain, but should also be useful in identifying not only successes but shortcomings, so the program can be improved upon.

We recommend the following direct performance measures be compiled annually by the FTE Noise Specialist, and issued to the Secretary's Office and the Research Office:

- Number of participating communities;
- Percentage of participating communities statewide;
- Number of approved noise compatible development projects, and the distance along the development property boundary that is contiguous to South Dakota interstate and South Dakota arterial highway rights-of-way, for both participating and non-participating communities;
- Number of approved noise sensitive development projects (with noise mitigated development measures), and the distance along the development property boundary that is contiguous to South Dakota interstate and South Dakota arterial highway ROW, for both participating and non-participating communities; and
- Number of approved noise sensitive development projects (without noise mitigated development measures), and the distance along the development property boundary that is contiguous to South Dakota interstate and South Dakota arterial highway rights-of-way, for both participating and non-participating communities.
- Number of site specific noise analyses completed.
- Number of projects where noise impacts were considered during the scoping process.
- Number of corridor studies that analyzed noise impacts.

Using these direct performance measures, other indirect measures can be developed. The potential future savings from approval of noise compatible development or noise sensitive development (with noise mitigated development measures) can be calculated using a unit price per mile of noise barrier (Table VII.2). Similarly, the potential future costs from approval of noise sensitive development (without noise mitigated development measures) can also be calculated using Table VII.2. For example, assuming an average noise barrier cost of $30/sq. ft. and a 15 foot high noise barrier, approval of 12 miles contiguous to SDDOT ROW of noise compatible development or noise sensitive development with noise mitigated development measures yields a potential future savings of $28.8M.

SDDOT may also want to consider establishing a baseline condition for the miles of either presently developed or presently undeveloped land that is contiguous to South Dakota interstate and South Dakota arterial highway ROW. That information would identify the ultimate potential future savings or potential future liability for noise barriers.

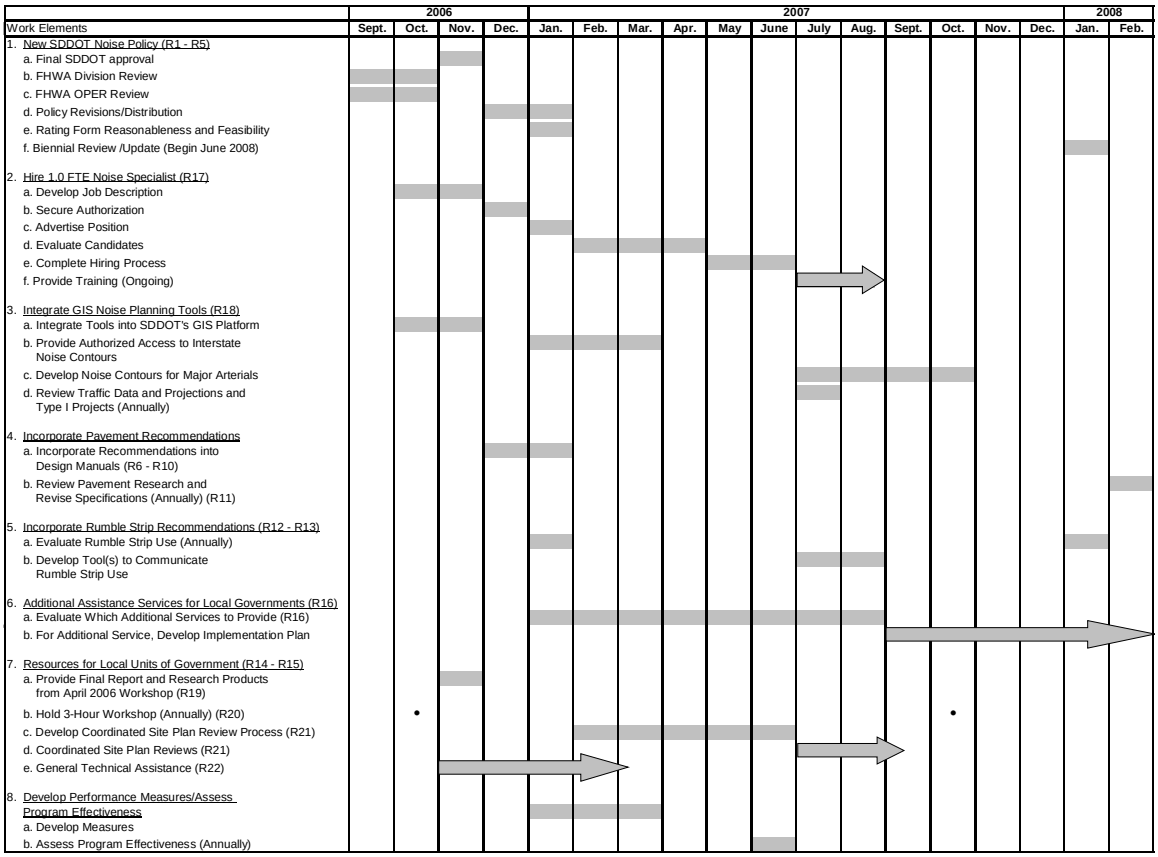
The following additional direct performance measures should be compiled annually by the FTE Noise Specialist, and issued to the Secretary's Office and the Research Office:

- Number and types of planning tools issued directly and as part of training workshops. Tools to track include: research report; tri-fold brochure; DVD and others as they are developed.
- Number of individuals invited to training workshops, their association, and number of individuals attending training workshops.
- Written evaluations for the training workshops to identify ways in which the training program can be improved upon to better meet the needs of attendees.
- Numbers of people requesting technical assistance, the type of technical assistance provided, and their association (local government, local planners, developers, citizens).

D. Implementation Plan

An implementation plan, shown in Table VI-4, includes all the recommendations of the research and performance measures with a schedule for their implementation.

Table VI.4
Implementation Plan Summary



R= Recommendation

VII. ANALYSIS OF RESEARCH BENEFITS

A. Introduction

The benefits of proactive noise mitigation and avoidance measures will stem from the

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partnership between SDDOT and local units of government that will guide future development adjacent to South Dakota highways so that it is compatible with highway noise. In this partnership, the Department proposes policies and provides resources to local governments, who in turn use those resources and the powers already granted to them to guide development in two ways: by encouraging noise compatible development adjacent to highways; and by guiding noise sensitive development to achieve development that is noise compatible.

The benefits of noise compatible land use planning will accrue to:

- People who live, work or visit lands adjacent to highways;
- Local communities
- The South Dakota DOT
- The traveling public

The benefits provided to each are summarized below.

B. Benefits to People Who Live, Work or Visit land Adjacent to Highways

The many effects of noise on humans have been widely studied. Effects may include noise-induced hearing loss, interference with communication, sleep interference, effects on performance or behavior, other health effects, and annoyance (Suter, 1992). The most significant effects of highway traffic noise on humans are in the areas of conversation, sleep and annoyance.

Where noise compatible land use planning is implemented the following benefits accrue to people living, working or visiting lands adjacent to highways:

i. Preserving Outdoor Conversational Speech.

The FHWA NAC L_{eq} of 67 dBA (L_{10} of 70 dBA) for residential land uses was established with the goal of preserving conversational speech during the loudest traffic hour of the day. The EPA's *Levels Document* determined that a yearly average outdoor L_{dn} of 55 dB would permit normal communication outdoors at a distance of about 10 feet (EPA, 1974). NCHRP Report 117 (NCHRP, 1971) identified the maximum L_{10} and L_{50} background noise levels that would generally permit acceptable speech communication for low, normal, raised and very loud voice levels and listener distances. L_{10} and L_{50} are defined as the noise level that is exceeded 10 and 50 percent, respectively, of the time. A summary is provided in Table VII.1. Normal conversational speech at 3 feet is often cited in the mid-60's dB range, while shouting at 3 feet is commonly cited as being in the upper 70's. Studies

Table VII.1 – Conversation Speech Interference
Maximum L_{10} A-Scale Noise Level

	Voice Level*, dBA			
Distance (m)	**Low**	**Normal**	**Raised**	**Very Loud**
0.3	**66**	**72**	**78**	**84**
0.6	**60**	**66**	**72**	**78**
1.0	**56**	**62**	**68**	**74**
1.2	**54**	**60**	**66**	**72**
1.5	**52**	**58**	**64**	**70**
1.8	**50**	**56**	**62**	**68**
3.6	**44**	**50**	**56**	**62**

MAXIMUM L_{50} A-SCALE NOISE LEVEL

	Voice Level*, dBA			
Distance (m)	**Low**	**Normal**	**Raised**	**Very Loud**
0.3	**60**	**66**	**72**	**78**
0.6	**54**	**60**	**66**	**72**
1.0	**50**	**56**	**62**	**68**
1.2	**58**	**54**	**60**	**66**
1.5	**46**	**52**	**58**	**64**
1.8	**44**	**50**	**56**	**62**
3.6	**38**	**44**	**50**	**56**

*** - Based on men's voices, standing face-to-face outdoors**

have shown that communication is impaired when noise levels exceed 66 decibels. Since normal conversational speech at a distance of 3 feet takes place in the mid-60 decibel range, when combined with 66 decibels of highway noise, speech interference is likely.

ii. Reducing Annoyance

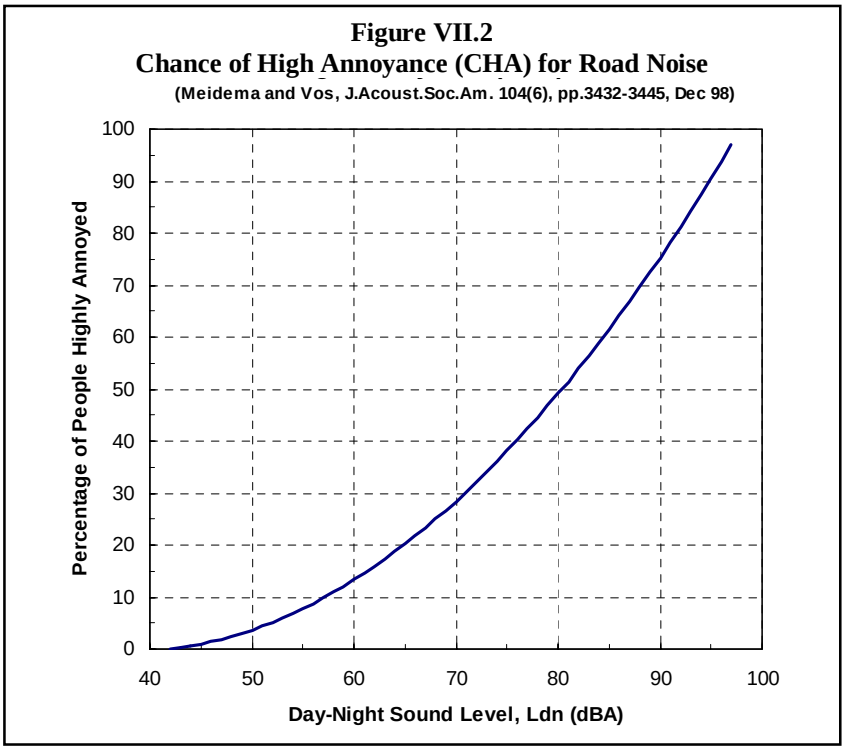
. Various researchers have developed relationships between L_{dn} noise levels and the degree of annoyance, expressed as a person's "average chance high annoyance" (%HA), based on attitudinal surveys. Schultz (1978) developed a relationship based on a combination of 21 data sets from attitudinal studies of road, aircraft and railway noise. Medema and Vos (1998), reviewed the data, augmented it with 34 datasets, and developed separate curves for road noise, aircraft noise and railway noise. The road noise relationship is expressed mathematically as:

$$\%HA = 0.03 (L_{dn} - 42) + 0.0353 (L_{dn} - 42)^2$$

The relationship is shown graphically in Figure VII.2.

Using Figure VII.2, L_{dn} of 65 dBA correlates with an average percentage chance highly annoyed of approximately 20%. Less than 10% average percentage chance highly annoyed correlates with an L_{dn} of 57 dBA.

Figure VII.2
Chance of High Annoyance (CHA) for Road Noise
(Meidema and Vos, J.Acoust.Soc.Am. 104(6), pp.3432-3445, Dec 98)



iii. Protecting Sleep

The EPA's *Levels Document* (EPA, 1974) determined an indoor L_{dn} of 45 dB as necessary to protect against sleep interference. Pearsons et al., (1989) reviewed and analyzed 21 studies, but were unable to derive relationships between the studies because of discrepancies between laboratory and field study results. Griefahn (1990) recommended, that nighttime average noise levels be kept below 45 dB in the sleeping quarters. She cited research by Eberhardt (1987 and 1990; Eberhardt et al., 1987;) and Vallet et al., (1976 and 1990) showing self-reported adverse effects from continual road traffic when the average noise level was 40 dB. An indoor noise level of 45 dB, established by EPA, can be thought of as a daytime (7:00 AM – 10:00 PM) noise level of 45 dB and a nighttime (10:00 PM – 7:00 AM) noise level of 35 dB.

C. Benefits to Local Communities

The benefits to local communities that guide future development to achieve noise compatible development include:

i. Preserving the Tax Base

Studies of the impact of highways, and the access they provide, on nearby land and house values have been performed since the beginning of the Interstate Highway Program. The hedonic pricing method, used for studies of this type, was formulated

by Rosen (1974). Hedonic pricing makes use of the fact that the price of a house or property reflects several attributes (eg. floor area, age, number of bedrooms, number of bathrooms, lot size). By decomposing a home's price into its various attributes, the effect of one single parameter may be estimated. The hedonic pricing method may be used to estimate economic values for environmental attributes that directly affect market prices. It is most commonly applied to variations in housing prices that reflect the value of local environmental attributes. By including a representative noise level (typically L_{dn}) as an environmental attribute, its effect on sale price can be included.

Huang (1994) performed a review of literature on hedonic price studies of the influence of highway access on house prices. He noted that for residential properties located close to a highway, noise and other adverse environmental factors reduced the value of locating close to a highway. Langley (1976, 1981) studied homes near the Washington, DC Beltway, and concluded that house prices increase with increasing distance from the highway out to a distance of 1,125 feet, and then decrease with increasing distance from the highway beyond that point. He interpreted this finding as evidence that the disamenities of highways dominate the value of access for distances of less than 1,125 feet. Nelson (1982) also found that certain land uses may be negatively impacted by noise and other disamenities.

Some researchers have quantified a relationship between noise levels and residential home sales prices. Nelson (1980) summarized 13 studies of airports and property values and found that airport noise discounts sales prices by between 0.4 and 1.1% per decibel. A study published by the Danish Department of the Environment (2003) found that the sale prices of homes affected by noise above 55 dB from high speed motorways decreases by 1.6% per decibel.

These studies indicate a quantifiable relationship between environmental noise and residential sale prices, and hence an effect on the tax base.

ii. Avoiding Future Corrective Actions

The SDDOT has not and has no future plans to participate in Type II (noise mitigation) projects, typically involving construction of noise barriers, along existing highways. Therefore, if noise complaints reach significant levels, local communities may need to fund noise mitigation projects. Local communities do not typically have capital improvement budgets large enough to cover the costs to construct noise barriers.

D. Benefits to the South Dakota DOT

If South Dakota implements noise compatible land use planning, when the South Dakota DOT constructs lane addition projects or significant modifications to its highway system (Type I projects), the increase in noise levels will typically not be large enough to result in noise impacts under the FHWA and SDDOT NAC. Therefore, expenditure of highway dollars to construct noise barriers will be less likely.

For the construction of new highways on new alignment, significant modifications of existing highways, or the addition of through travel lanes to an existing highway, the South Dakota DOT will determine if noise impacts would result from a project.

Following the SDDOT noise policy for Type I projects, a noise impact occurs when there is a 15 dBA increase in noise levels during the loudest traffic hour of the day, or when the future loudest hour noise level approaches, equals, or exceeds the FHWA NAC. The quality of life noise standard for outdoor residential land use is 61 dBA. The FHWA NAC for outdoor residential land use is 66 dBA. Since the recommended quality of life noise standard provides a 5 dBA higher (more protective) standard to begin with, it would take an existing noise level of 61 dBA and a 5 dBA increase in noise levels from the project to exceed the NAC of 66 dBA. The addition of through travel lanes to an existing highway, or modifications to an existing highway are unlikely in most instances to cause 5 dBA or greater increases in noise levels. Construction of new highways on new alignment is more likely to cause significant (15 dBA) increases in noise levels or noise levels that exceed the NAC.

The noise barrier costs avoided by implementing proactive noise mitigation and avoidance measures are illustrated in Table VII.2. Using a year 2006 average noise barrier cost of $30 per square foot, it costs $2.4M to construct one mile of 15 foot high ground mounted noise barrier on just one side of a highway. The money spent on noise barriers, which could have been avoided if proactive noise mitigation and avoidance measures were implemented, will not be available for highway and bridge improvements.

If educational and technical assistance resulted in local planning, zoning and development approval of noise compatible land development next to highways or, if noise sensitive land uses were permitted by local governments next to highways, but only with noise barriers or super-insulation in place so that there were no adverse highway noise impacts to address as noise levels rose, the costs would be more than justified.

Table VII.2: Noise Barrier Costs

Noise Barrier Unit Cost ($/sq. ft.)	Noise Barrier Height (ft.)	Cost/Mile ($/mile)
	10	$1.1 Million
$20 (low)	15	$1.6 Million
	20	$2.1 Million
	10	$1.6 Million
$30 (avg.)	15	$2.4 Million
	20	$3.2 Million
	10	$2.1 Million
$40 (high)	15	$3.2 Million
	20	$4.2 Million

E. Benefits to the Traveling Public

Expenditure of $2.4M to construct one mile of 15 foot high ground mounted noise barrier, on just one side of a highway, may benefit up to 500 residences. By comparison, for $2.4M, the South Dakota DOT could benefit many by: resurfacing just over 20 miles of two-lane roadway; replacing six 100-foot long, 2-lane bridges; or fully regrading and providing new pavement for over 2 miles of two lane highway. The traveling public will therefore also benefit from the implementation of proactive noise mitigation and avoidance measures by traveling on smoother and safer highways.

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Appendix A:
Glossary

Glossary

A-Weighted sound level (dBA) – A number representing the sound level that is frequency weighted (the "A-Scale") according to a prescribed frequency response established by the American National Standards Institute (ANSI S1.4-1971) and accounts for the response of the human ear.

Attenuation – Factors that mitigate (or reduce) the noise emissions in the environment from a noise source to a receiver. These include distance, obstacles (or ground obstructions), trees and other natural features, and man-made devices (i.e. mufflers, insulations, sound walls, etc.).

Barrier– A natural or man-made object that interrupts the path of sound from the sound source to the sound receiver.

Barrier Insertion loss – the reduction in sound level at a particular location achieved by the erection of a barrier.

Brushing – The surface texture obtained by stroking patterns with a broom or brush-type device over freshly placed concrete. A sandy texture is obtained by this method over the surface of freshly placed or slightly hardened concrete.

Day-Night Equivalent Sound Level (L_{dn}) – Equivalent A-weighted sound level for a 24-hour period, with an additional 10 dB weighting imposed on levels between 10 p.m. and 7 a.m.

Daytime Equivalent Sound Level (L_d) – Equivalent A-weighted sound level between 7 a.m. and 10 p.m.

Decibel (dB) – A measure used to express the relative level of a sound in comparison with a standard reference level.

Dragging – A Surface texture achieved by trailing a moistened coarse material (i.e. burlap) from a device that allows control of the time and rate of texturing.

Equivalent Sound Level (L_{eq}) – The dBA level of a steady state sound which has the same dBA weighted sound energy as that contained in the actual time-varying sound being measured over a specific time period.

Exterior Wall Noise Rating – A designed rank-order system that actually defines the level of noise reduction achieved.

Grinding – The process used to remove the upper surface of a concrete pavement to remove bumps and restore pavement rideability. For example, equipment used includes diamond-impregnated saw blades on a shaft or arbor to shave the surface of concrete slabs.

L_{10} – The A-weighted noise level that is exceeded 10% of the time. Thus the L_{10} level is an indication of the peak levels of the intruding noise.

L_{50} – The A-weighted noise level that is exceeded 50% of the time. Thus the L_{50} level is an indication of the average levels of the intruding noise.

$L_{eq(h)}$ – The hourly value of L_{eq} (based upon the peak-hour percentage of the annual average daily traffic).

Line of Sight – An uninterrupted visual path between two points.

Nighttime Equivalent Sound Level (L_n) – Equivalent A-weighted sound level between 10 p.m. and 7 a.m.

Noise Abatement Criteria (NAC) – FHWA established noise levels to determine noise impacts for given land use activity categories. These are the absolute levels that abatement must be considered. For example, Activity Category B (residences, picnic areas, parks, etc…) has an NAC for exterior land use set at 67 dBA.

Tining – Textures formed on concrete roadway surfaces to enhance traction. These texture patterns are made up of small ridges, and can be placed straight across a road (transverse), or with the flow of traffic (longitudinal), or at an angle (skewed).

TNM (Traffic Noise Model) – FHWA's computer program for highway traffic noise prediction and analysis, and the evaluation of noise barriers.

Medium Trucks – all cargo vehicles with two axles and six tires – generally with gross vehicle weight between 4,500 kg (9,900 lb) and 12,000 kg (26,400 lb).

Heavy Trucks – all cargo vehicles with three or more axles – generally with gross vehicle weight greater than 12,000 kg (26,400 lb).

Type I Project – A proposed Federal, Federal-aid, or State-funded highway project for the construction of a highway on a new location or the physical alteration of an existing highway which significantly changes either the horizontal or vertical alignment or increases the number of through-traffic lanes.

Type II Project – A proposed Federal, Federal-aid, or State-funded project for noise abatement on an existing highway. Local financial support is also required.

Appendix B:
Abbreviations

Abbreviations

AADT	Average Annual Daily Traffic
ACPA	American Concrete Paving Association
ADT	Average Daily Traffic
ARFC	Asphalt Rubber Friction Course
AZDOT	Arizona Department of Transportation
CDOT	Colorado Department of Transportation
CEI	Cost Effectiveness Index
CFR	Code of Federal Regulations
CIP	Capital Improvement Program
CPX	Close Proximity
DGFC	Dense Graded Friction Course
DNL	Day – Noise Level or L_{dn}
DOT	Department of Transportation
DVD	Digital Versatile Disk
EPA	Environmental Protection Agency
FHWA	Federal Highway Administration
FTE	Full Time Equivalent
GIS	Geographic Information System
HMA	Hot Mix Asphalt
HVAC	Heating, Ventilating and Air Conditioning
IGGA	International Grooving and Grinding Association
LOS	Level of Service
MDOT	Michigan Department of Transportation
MDT	Montana Department of Transportation
MPO	Metropolitan Planning Organization
NAC	Noise Abatement Criteria
NCHRP	National Cooperative Highway Research Program
NRC	National Research Council
NYSDOT	New York State Department of Transportation
ODOT	Ohio Department of Transportation
OGFC	Open Graded Friction Course
PCC	Portland Cement Concrete
QPPP	Quiet Pavement Pilot Program
ROW	Right of Way
SD	South Dakota
SDDOT	South Dakota Department of Transportation
SDL	South Dakota Law
SHA	State Highway Agency
TDR	Transfer of Development Rights
TNM	Traffic Noise Model

Appendix C:
Stakeholder Survey

Stakeholder Survey

The South Dakota Department of Transportation (SDDOT) is interested in the mitigation and avoidance of highway noise through shared responsibility between the SDDOT and local governments, community leaders and developers.

Noise avoidance and mitigation begins with an examination of land uses and noise generators. Major roadways need to be examined for their compatibility with existing, planned or zoned noise compatible land uses. In rural or suburban areas, noise compatible land uses are largely agricultural, forest management, industrial, commercial or office uses. If land adjacent to highways is planned and zoned for noise compatible land uses, most of the potential noise pollution problems will be inconsequential. However, if land adjacent is planned or zoned for noise sensitive land uses like residences, schools, hospitals, churches, or senior living complexes, highway noise may be considered a nuisance.

SDDOT is undertaking a research project with three major objectives:

1. To educate local governments on the application, advantages and public and private benefits of noise mitigation and avoidance measures
2. To recommend policies and guidelines for SDDOT to use to determine appropriate design and roadway surfaces in noise sensitive areas
3. To define performance measures, identify sources of supporting data and validate the State's ability to assess the effectiveness of noise avoidance and mitigation measures applied in South Dakota

The purpose of this questionnaire is to identify background and key issues related to noise pollution and determine potential mitigation measures that can be used by SDDOT and local stakeholders.

I. Interviewee Information

Name:
Organization:
Address:
Phone:
Email Address:
Role in Organization:
Years in Present Position:

Organizational Jurisdiction:
___Federal ___State ___ MPO __ County City/Town/Village

Percent of time working on noise concerns: _____
Approximately how many people live in your jurisdiction?

___ < 1,000 ___<5,000 ___<10,000 ___<20,000
___ <50,000 ___ <100,000 ___ >100,000

II. Community Noise Impacts

1. In your opinion, what is the biggest source of noise pollution in your jurisdiction?

2a. In relation to all noise pollution issues, is traffic noise a problem in your jurisdiction?

2b. If so, what experiences have prompted your concerns?

2c. If it is a problem, is the impact experienced inside or outside either homes or businesses?

3 Please rate each of the following in the list of possible highway noise sources, with **1 being a primary concern, 2 being a secondary concern and 3 being a tertiary concern**.

a. ____ Annoyance from rumble strip noise
b. ____ Annoyance from pavement surface textures
c. ____ Construction noise
d. ____ Future traffic noise resulting from construction of new Federal or State highways, significant alternation of existing highways, or capacity expansions of existing highways
e. ____ Future traffic growth along existing highways
f. ____ Large trucks and engine (Jake) brake noise
g. ____ Motorcycles
h. ____ Other: _____

III. Current and Potential Regulatory Tools to Reduce Noise Impacts

4. Which of the following roads should the research team focus on for proactive noise mitigation measures? **Please answer yes or no**.

a. ____ Freeways (limited access)
b. ____ Major arterials/state highways
c. ____ County or City arterials and collectors

5. Should the research team study only noise sensitive land uses such as residences, schools, hospitals, churches, or senior living complexes, or should the research study team also focus on all land uses (noise sensitive *and* noise compatible land uses)?

6. Please rate each of the following in the list of noise mitigation tools in terms of usefulness, with **1 being a primary (most useful) tool, 2 being a secondary tool and 3 being a tertiary tool**.

a. ____ Information about existing and/or future noise levels adjacent to highways
b. ____ Guidelines on recommended separation distances from highways to various noise level contours for recommended land uses.
c. ____ Model local land use controls that could be used and amended as required by individual communities
d. ____ Means to prevent the need to erect future noise barriers

e. ____ Noise mitigation measures (other than noise barriers) along existing highways
f. ____ Noise barriers constructed along existing highways

7. What responsibilities should local units of government have in promoting noise compatible land use planning and development?

8. Does your jurisdiction have any local noise regulations in place currently?

9. Are you aware of any examples of noise compatible development in your jurisdiction? Please give specific locations.

10. Rate each of the following tools, assistance, information or incentives you are most interested in exploring to promote more noise compatible development, with **1 being very interested, 2 being a secondary interest, and 3 being a tertiary interest?**

a. ____ Allow residential developers to build close to highways only if he/she pays the cost for a noise barrier or berm
b. ____ Develop General Nuisance Noise Ordinance
c. ____ Develop regulations to require site plan review for noise-incompatible uses
d. ____ Develop design guidelines to include window/door upgrade, superinsulation, central heating, ventilation and air conditioning (HVAC), and no windows facing the road in noise sensitive areas
e. ____ Allow noise sensitive development closer to the highway if approved noise mitigation measures are provided
f. ____ Build locally-funded noise barriers or berms to protect new development from noise impacts
g. ____ Permit noise sensitive land uses with adequate separation distances between highways and noise sensitive land uses
h. ____ Strongly encourage only noise compatible land use adjacent to highways
i. ____ Provide open space as a noise buffer
j. ____ Provide training/Information (video/DVD, brochure, web site, public meetings)
k. ____ Allow transfer of development rights (TDR) for developers to transfer density or to transfer use between two parcels he/she owns to keep land adjacent to the highway vacant
l. ____ Other: _____

11. Which of the tools, assistance, information or incentives listed in question #10 should **not** be pursued and why?

Appendix D:
State DOTs Survey

State DOT Interview Questionnaire

The South Dakota Department of Transportation (SDDOT) is interested in the mitigation and avoidance of highway noise through shared responsibility between the SDDOT and local governments, community leaders and developers.

Noise avoidance and mitigation begins with an examination of land uses and noise generators. Major roadways need to be examined for their compatibility with existing, planned or zoned noise compatible land uses. In rural or suburban areas, noise compatible land uses are largely agricultural, forest management, industrial, commercial or office uses. If land adjacent to highways is planned and zoned for noise compatible land uses, most of the potential noise pollution problems will be inconsequential. However, if land adjacent is planned or zoned for noise sensitive land uses like residences, schools or churches, highway noise may be considered a nuisance.

SDDOT is undertaking a research project with three major objectives:

1. To educate local governments on the application, advantages and public and private benefits of noise mitigation and avoidance measures
2. To recommend policies and guidelines for SDDOT to use to determine appropriate design and roadway surfaces in noise sensitive areas
3. To define performance measures, identify sources of supporting data and validate the State's ability to assess the effectiveness of noise avoidance and mitigation measures applied in South Dakota

SDDOT does not have a Type II noise barrier program, therefore, this survey is focused on innovative state highway agency Type I programs and policies, and on initiatives that state highway agencies have undertaken in cooperation with local communities to proactively mitigate or avoid highway noise impacts.

The purpose of this questionnaire is to identify:

1. What techniques (other than constructing noise barriers) has your State DOT implemented (or is considering implementing) to avoid, control or abate highway noise?
2. What tools or incentives have been provided to local communities (or what tools or incentives have local communities requested) to improve their noise compatible land use planning and land development regulation activities?

IV. Interviewee Information

Name: _____
Organization: _____
Address: _____
Phone: _____
Email Address: _____
Role in Organization: _____
Years in Present Position: _____
Percent of time working on noise concerns: _____

V. DOT Implemented Techniques/Actions

2. Has the Department implemented or is the Department considering implementing any of the following actions specifically to avoid, abate or control highway noise? (**I** (Implemented) or **C** (Considering), or leave blank.)

___ Repaving highway segments in populated areas using quieter pavement.
___ Conducting or sponsoring research on quiet pavements
___ Type II noise barrier program using Federal aid matching funds for constructing earth berms or noise barriers
___ Noise insulation of buildings
___ Restricting use of shoulder rumble strips in populated areas
___ Restricting use of rumble strips across travel lanes
___ Restricting use of engine (jake) brakes
___ Reducing the posted speed limit by 10 mph or more
___ Restricting commercial traffic from noise sensitive areas
___ Making changes to the State Highway Noise Policies to address these or other actions
___ Purchase of easements for future noise mitigation
___ Other

2. For any of the above listed items marked with **I** or **C** provide additional information (discussion, printed literature, web pages, hard copies, etc.)

VI. DOT Assistance to Local Governments

3. Has the Department provided, or has the Department received requests from local governments for any of the following types of assistance to improve noise compatible land use planning in their communities? (**P** (Provided) or **R** (Requested), or leave blank.)

___ Noise contours or recommended separation distances from busy highways (for existing or future conditions)
___ Information (brochures, web pages, videos) on traffic noise fundamentals, noise abatement and Department policies
___ Information (brochures, web pages, videos) on noise compatible land use planning
___ Model local land use controls (Municipal Zoning Ordinance, Municipal Subdivision and/or PUD Regulations) that could be used and amended as required by individual communities
___ Model highway noise ordinance
___ Standards for design and construction of walls and earth berm noise barriers
___ Design standards for window/door upgrades, super-insulation, central heating, ventilation and air conditioning (HVAC), and other actions to improve building sound insulation
___ Training in noise compatible land use planning and the use of local land use controls

4. For any of the above listed items marked with **P** or **R** provide additional information (discussion, printed literature, web pages, hard copies, etc.)

Appendix E:
GIS Noise Contour Planning Tools

Bergmann Associates
Planning & Zoning Center

I. Introduction

SDDOT is interested in the mitigation and avoidance of highway noise through shared responsibility between the SDDOT and local governments, community leaders and developers. This appendix describes one component of this project: the creation of GIS Noise Contour Tools for South Dakota's Interstate Highways. These tools were written as an ArcGIS 9.1 extension and consist of two distinct functions:

1. The *Calculate Distance to Noise Contours Tool* - uses the road median and traffic information (heavy truck and auto design hour volumes per segment and operational speed per segment) to calculate distances at user specified noise (dBA) levels. This information is stored for each road segment within the road median shapefile or feature class.

2. The *Noise Contour Calculation Tool* - given that the distances have been calculated by the *Calculate Distance to Noise Contours Tool*, this tool calculates contours based on these distances for the road median. The contours are created on both sides of the road segments.

This appendix provides documentation on the methodology used to create the road median data and both the GIS Noise Contour tools. In addition, documentation is provided on how to use these tools to generate noise contours for road medians.

II. Data Development – Road Median creation

a. Background

SDDOT provided the following information to the research team:

1. A shapefile of road segments where each feature is a road segment between interchanges;
2. Each of the interstate road segments has the following attributes: beginning MRM; end MRM; operating speed for autos; operating speed for heavy trucks; projected 20-year peak hour auto volume or peak hour auto volume at the operational capacity; projected 20-year peak hour heavy truck volume or peak hour heavy truck volume at the operational capacity.
3. The attributes for the roadway segments were the same for each parallel segment.
4. There was a feature for eastbound and a feature for westbound (or northbound and southbound) and these were manually edited to create a median feature for each set of line segments. This median feature inherited the sum of traffic volumes for autos and heavy trucks and the speed values from one of the segments.
5. The provided road segment information was used to create a set of features representing the road median and containing the attributes described above. The auto and heavy truck volumes for each segment were summed; the auto and speed values remained the same. This process is documented in the next section.

Please Note: All data development procedures were completed using ArcGIS Desktop (ArcCatalog or ArcMap), as well as Microsoft Excel.

b. Data Preparation – *Preparing the traffic data and geometry attributes for joining*

1. Loaded the adt_insterstate.shp file (the parallel road segment shape file) into a personal geodatabase called SouthDakotaDOT.mdb (renamed the file Step01_interstate).
2. Created a unique ID, called SegmentID, in the Step01_interstate feature class, as well as in the adt_interstate.xls file, which is an Excel file that contains the associated attribute information (heavy truck volumes and operating speeds) for the selected interstate highway road segments. The SegmentID is a concatenation of the highway_su and end_mrm fields. This step was necessary in order to join the Excel file to the feature class in Step b.6.
3. Created a new field in both the "20-yr_free_flow_data" worksheet, as well as the "Operational_capacity_data" worksheet in the adt_interstate.xls called begend_mrm, which is a concatenation of the beg_mrm and end_mrm fields and the word "to" (e.g. 000.98 to 002.48). This step was done so the segments could be merged appropriately in step b.4 and labeled as such in ArcMap.
4. Merged the "20-yr_free_flow_data" worksheet with the "Operational_capacity_data" worksheet in the adt_interstate.xls spreadsheet, such that the operational capacity data overrode the data for the same segments in the "20-yr_free_flow_data" worksheet. This step was done manually by filling the Operational_capacity_data cells with the color yellow. Then this data, along with the 20-yr_free_flow_data, was copied to a new worksheet called "Combo20yr_OpCapacity." Next, both sets of data were sorted by begend_mrm and where there were multiple records for a road segment (indicated in yellow), the records from the 20-yr_free_flow_data were deleted. Finally, this "Combo20yr_OpCapacity" worksheet was saved as a .dbf file (DBF 4 (dbase IV)) called noisedata.dbf.
5. Next, Step01_interstate was exported as a new feature class called Step02_ interstate_cleared. All unnecessary fields were then deleted with the exception of SegmentID.
6. Next, Step02_interstate_cleared feature class was joined with the noisedata.dbf table using the SegmentID field and exported as a new feature class called Step03_interstate_joined.

c. Data Cleanup and Conversion – *Creating & rectifying the road geometry*

1. The Step03_interstate_joined feature class was then examined and it was observed that some road segments were missing a parallel road segment that began and ended at the same mile markers. Step03_interstate_joined feature class was then exported to a new feature class called Step04_interstate_tocollapse (this was done in order to preserve Step03_interstate_joined as a back up).

2. Step04_interstate_tocollapse was then cleaned up such that each road segment had a corresponding parallel segment. The following images outline this “cleanup” process.

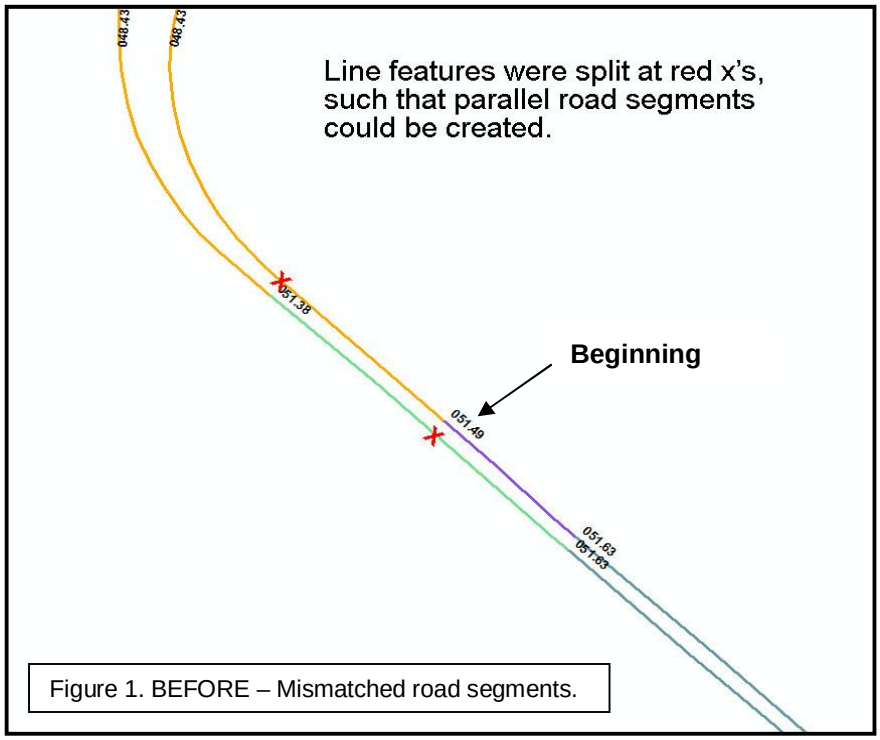


Figure 1. BEFORE – Mismatched road segments.

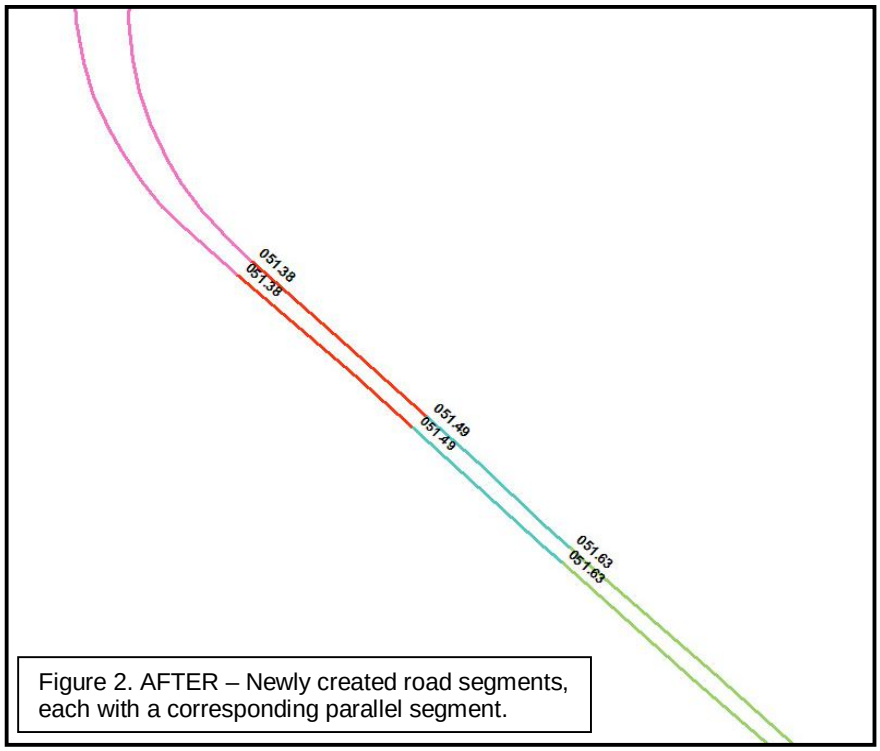
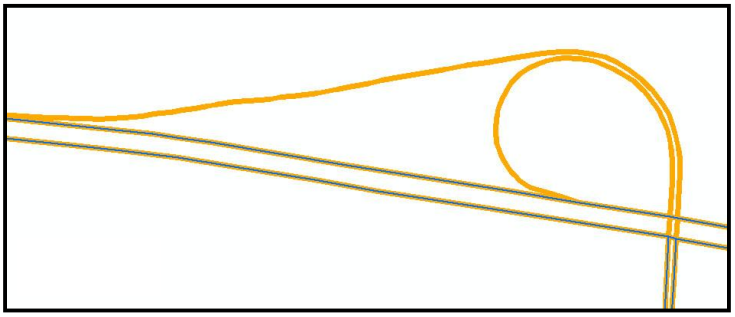


Figure 2. AFTER – Newly created road segments, each with a corresponding parallel segment.

3. The attribute information of each newly created road segment was then modified such that the BEG_MRM, END_MRM, and BEGEND_MRM fields matched those of the corresponding parallel line segment. For each segment that was modified, the initials KB were added to the SegmentID field in order to track where modifications were made to the data.

4. After the mismatching road segment issues were resolved, it was observed that there were overlapping line segments at a couple of interchanges, which would present an issue for the "Collapse Tool" in Step c.5. So, the ramps were deleted from the Step04_interstate_tocollapse feature class as shown in the figures below.



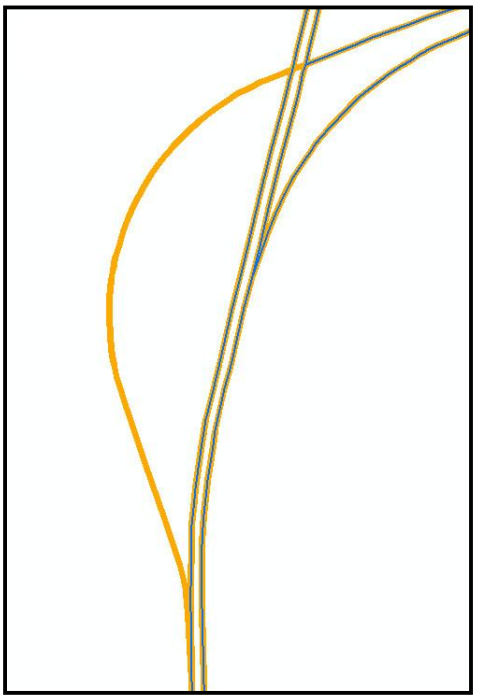


Figure 3. Above: 190 N to 90 W and 90 W to 190 S.

Figure 4. At Left: Interstate 229 S to 29 S.

The orange lines represent the road segments before deleting the ramps; the blue lines represent the road segments after deleting the ramps.

5. (A) After the Step04_interstate_tocollapse feature class was cleaned it was exported to a coverage file called **interstate** using ArcCatalog.

   (B) The coverage was then run through the "Collapse Dual Lines to Centerline" tool in ArcToolbox. This tool can be found under **Coverage Tools>Generalization> Collapse Dual Lines to Centerline**.

   This tool outputs a centerline file in the form of a new coverage file without any attributes of the input file. (Note: A maximum gap width of 650 meters was used - based on the fact that the widest gap between two parallel road segments was approximately 630 meters.) Coverage had to be used because currently this tool does not work with shapefiles or geodatabase feature classes. After the tool was run, a coverage file was created called **intercenter**.

   (C) This coverage, intercenter, was then exported to a geodatabase feature class called Step07_centerline using ArcCatalog.

6. The resultant centerline file, Step07_centerline, was then examined and it was observed that the geometry of the new file was not entirely consistent with the geometry of the original Step04_interstate_tocollapse feature class. Essentially, the **Collapse Dual Lines to Centerline** tool created extra small line segments that needed to be split and merged with adjacent line segments. These small line segments were a result of how the **Collapse Dual Lines to Centerline** interpreted the given input features and could not be avoided.

   This centerline file was therefore cleaned to match the parallel road segments of the Step04_interstate_tocollapse feature class. This cleanup process involved several steps, which are described below. (Please note, the method below was used in order to create the most accurate road segments possible, however other, less accurate methods could also be used.)

   (A) Vertices of the Step07_centerline feature class were converted to points using the "Feature Vertices To Points" tool in ArcToolbox. This tool can be found under **Data Management Tools>Features> Feature Vertices To Points.** The resultant feature class was named Step08_centerline_vertices. *(Note: The Feature Vertices To Points tool is only available at an ArcInfo license level.)*

   (B) Vertices of the Step04_interstate_tocollapse feature class were converted to points using the "Feature Vertices To Points" tool in ArcToolbox. This tool can be found under **Data Management Tools>Features> Feature Vertices To Points.** The resultant feature class was named Step09_interstate_vertices. *(Note: The Feature Vertices To Points tool is only available at an ArcInfo license level.)*

   (C) In the geodatabase, a new polyline feature class was created called Step10_VerticalSlices.

(D) Next, where incorrect vertices were found, a "vertical slice" was snapped and drawn from the nearest vertex on the top interstate line segment to the nearest vertex on the bottom interstate line segment. Then, the small line segment (shown in light blue below) was split where the vertical slice crossed it. The two resulting halves were then merged with the adjacent centerline line segment (to the left or right). The image below outlines this "cleanup" process.

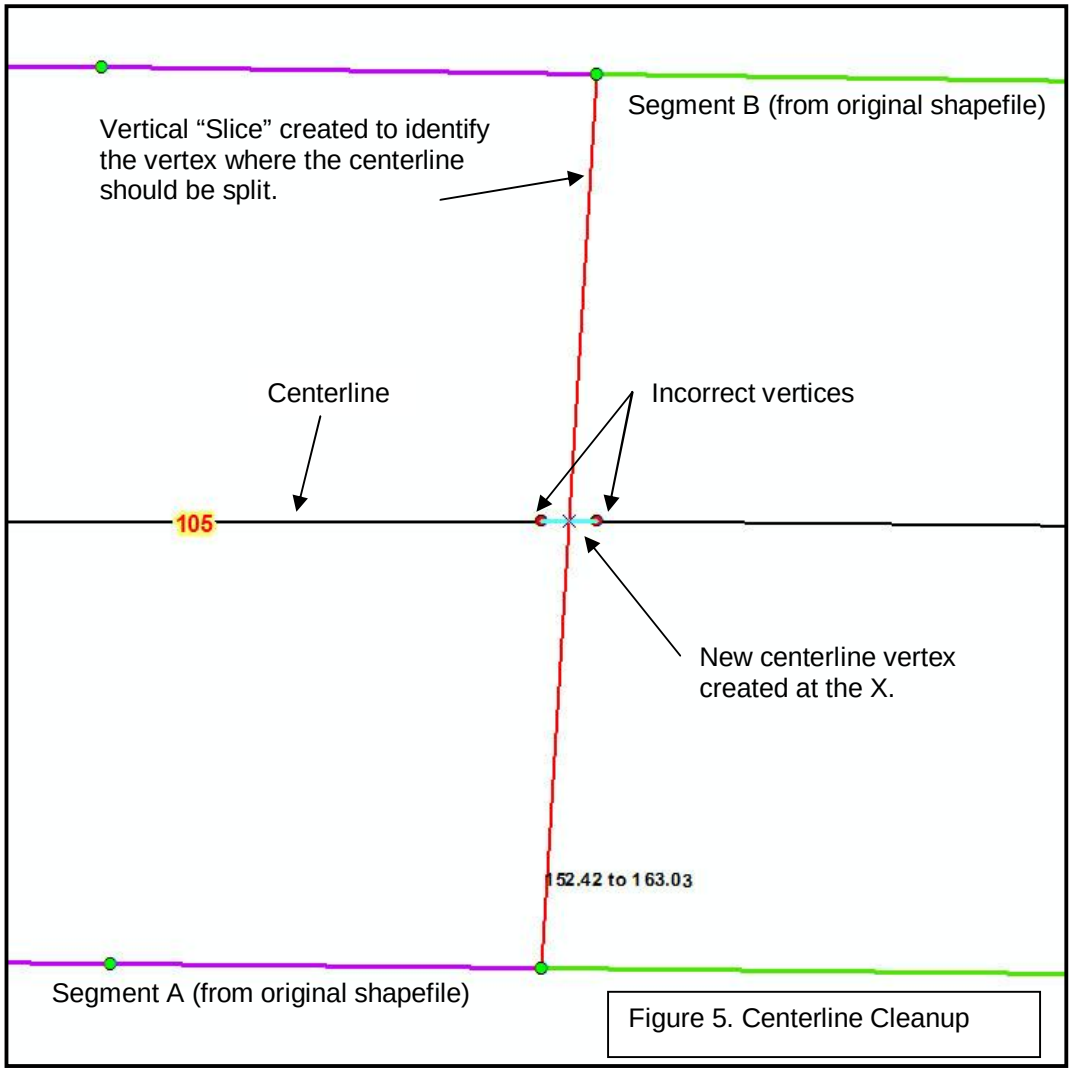
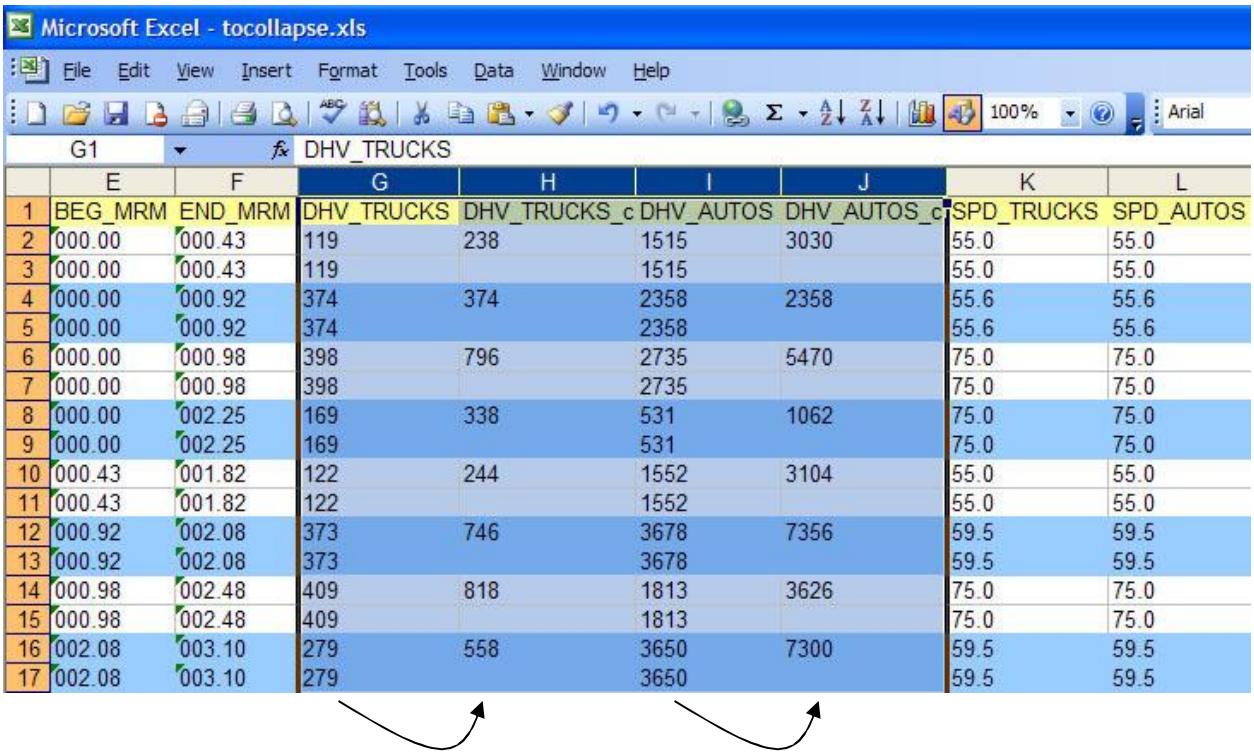


Figure 5. Centerline Cleanup

d. Merging and Joining – *Calculating the traffic attributes & joining to the road geometry*

1. The next step in the process was to export the attributes from the Step04_interstate_tocollapse feature class to Excel. The Excel file was named tocollapse.xls.

2. (A) Once in Excel, the traffic volumes for each pair of parallel segments were summed together for heavy trucks and autos respectively, while the speed limit values remained the same (see Figure 6. below).



Microsoft Excel - tocollapse.xls

File Edit View Insert Format Tools Data Window Help

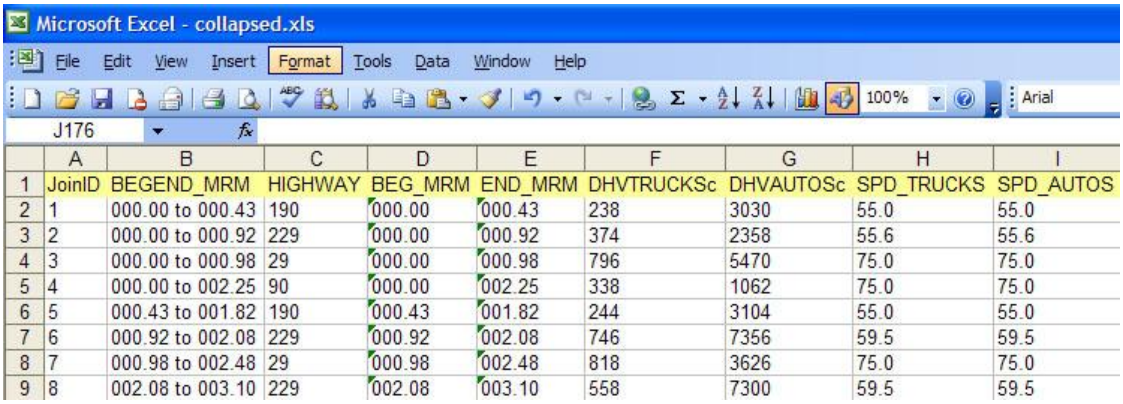
G1 DHV_TRUCKS

	E	F	G	H	I	J	K	L
1	BEG_MRM	END_MRM	DHV_TRUCKS	DHV_TRUCKS_c	DHV_AUTOS	DHV_AUTOS_c	SPD_TRUCKS	SPD_AUTOS
2	000.00	000.43	119	238	1515	3030	55.0	55.0
3	000.00	000.43	119		1515		55.0	55.0
4	000.00	000.92	374	374	2358	2358	55.6	55.6
5	000.00	000.92	374		2358		55.6	55.6
6	000.00	000.98	398	796	2735	5470	75.0	75.0
7	000.00	000.98	398		2735		75.0	75.0
8	000.00	002.25	169	338	531	1062	75.0	75.0
9	000.00	002.25	169		531		75.0	75.0
10	000.43	001.82	122	244	1552	3104	55.0	55.0
11	000.43	001.82	122		1552		55.0	55.0
12	000.92	002.08	373	746	3678	7356	59.5	59.5
13	000.92	002.08	373		3678		59.5	59.5
14	000.98	002.48	409	818	1813	3626	75.0	75.0
15	000.98	002.48	409		1813		75.0	75.0
16	002.08	003.10	279	558	3650	7300	59.5	59.5
17	002.08	003.10	279		3650		59.5	59.5

Figure 6. DHV_TRUCKS_c and DHV_AUTOS_c represent the summed (c for combined) values from each pair of parallel road segments (shown here in groups of two in blue or white).

2. (B) Next, half of the road segments (one segment from each pair of parallel road segments) were deleted from the worksheet (along with other unnecessary fields), such that all that remained was one record per road segment that corresponded with one road segment feature in the Step07_centerline feature class. This was done manually by selecting and deleting every other record in the table. A new unique ID was then created (JoinID).

3. This worksheet was then saved as a .dbf file (DBF 4 (dbase IV)) called collapsed.dbf (see figure 7 below).



	A	B	C	D	E	F	G	H	I
1	JoinID	BEGEND_MRM	HIGHWAY	BEG_MRM	END_MRM	DHVTRUCKSc	DHVAUTOSc	SPD_TRUCKS	SPD_AUTOS
2	1	000.00 to 000.43	190	000.00	000.43	238	3030	55.0	55.0
3	2	000.00 to 000.92	229	000.00	000.92	374	2358	55.6	55.6
4	3	000.00 to 000.98	29	000.00	000.98	796	5470	75.0	75.0
5	4	000.00 to 002.25	90	000.00	002.25	338	1062	75.0	75.0
6	5	000.43 to 001.82	190	000.43	001.82	244	3104	55.0	55.0
7	6	000.92 to 002.08	229	000.92	002.08	746	7356	59.5	59.5
8	7	000.98 to 002.48	29	000.98	002.48	818	3626	75.0	75.0
9	8	002.08 to 003.10	229	002.08	003.10	558	7300	59.5	59.5

Figure 7. A sample of the final traffic attribute data that was merged to the Step07_centerline feature class in Step d.5.

4. Next, a new JoinID field was created in the Step07_centerline feature class and then each road segment was manually assigned the corresponding JoinID from the collapsed.dbf Excel table. This was necessary because all attributes are lost when the "Collapse Dual Lines to Centerline" tool is run (see step c.5(B). This was done manually by turning on the Step04_interstate_tocollapse feature class in ArcMap and labeling it with the begend_mrm values, viewing the collapsed.dbf table in Excel, and through visual inspection, inputting each JoinID associated with each begend_mrm value into the Step07_centerline feature class.

5. Lastly, the Step07_centerline feature class was joined with the collapsed.dbf table based on the JoinID and a final, complete centerline shapefile was exported with all the proper traffic attributes called Step11_centerline_final feature class.

III. Calculate Distance to Noise Contours and Noise Contour Creation Tools

a. Background

The noise distance calculation and noise contour creation tools are part of an extension written for ArcMap 9.1. They are resident on a custom toolbar within ArcMap and will be displayed once the software is installed. The noise distance calculation tool uses the FHWA Traffic Noise Model (TNM) (U.S. Department of Transportation, Federal Highway Administration, Final Report July 1998, FHWA-PD-98-047, DOT-VNTSC-FHWS-98-5) to calculate a distance to a given noise level (dBA).

This model requires auto and heavy truck volume/hour counts and auto and heavy truck speed data. Heavy trucks are defines as cargo vehicles with three or more axels, generally with a gross vehicle weight more than 26,400 lbs. Automobiles are defines as vehicles with two axels and four tires, primarily designed to carry nine or fewer people (passenger cars, vans) or cargo (vans, light trucks) generally with a gross vehicle weight of less than 9,900 lbs.

The speed data range is 0 to 80 mph. The vehicle count data must be in the range such that the output distance is between 33 and 984 feet. This vehicle count data range within the TNM lookup table is different for each speed.

Note: for roads with very little traffic and that result in a distance that is below the threshold in the TNM Lookup table of 33 feet a distance of 30 feet will be output. In general this falls within the right-of-way of the road and should be recognized as "no contour."

The vehicle count and speed limit information needs to be defined for each road segment. For each segment and a given noise level (dBA) the distance will be calculated and stored in the attribute table for each segment. Distances for several noise levels can be stored within the same shapefile or feature class that holds the traffic input data.

The distance that is calculated assumes that the noise propagation is over level acoustically soft ground, with no barriers or obstructions between the noise source and the receiver.

Once the noise distance has been calculated the noise contour creation tool uses the centerline geometry and the noise distances to create the noise contours. For each noise level a pair of contour lines is created, one on each side of the road segment. These are stored in a separate shapefile or feature class.

Note: contours cannot be calculated for segments that are 5 feet or less in length. Before any contours are calculated all segments are checked to see if they are above this threshold. If not, a dialog box is displayed that specifies the segments, by object-id that do not meet this criterion. These must be deleted or merged into other segments before contours can be calculated.

For the SDDOT data, the tool was used to calculate the 61, 66 and 71 dBA noise contours.

b. Installation Prerequisites

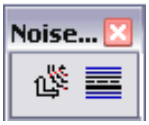
You must have administrative privileges on the installation machine in order to install the tool. The tool requires that ESRI ArcGIS desktop software is installed. The lowest license level of ArcView is appropriate.

This tool also requires that .NET 1.1 be installed on your machine. Please note that .NET 2.0 does NOT include .NET 1.1 and that it is fine to have both installed simultaneously.

c. Installation

1. To install the tool run the Setup.exe on the installation disk. It is recommended that when asked for whom you should install the software you choose Everyone (the default is "Just Me").

2. To turn on the toolbar, open ArcMap and go to the View Menu à Toolbars and select Noise Calculations. The following toolbar will be displayed:



d. Uninstall

4. To uninstall the software go to the Start Menu on the Task Bar and click on **Control Panel**.
5. On the **Control Panel** double click on **Add/Remove Programs**
6. On **Add/Remove Programs** click on **Noise Calculations** and then **Remove**.

III. Noise Distance Calculation Tool

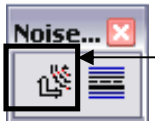
e. Background

The noise distance calculation tool processes a line feature class or shapefile representing a road centerline where each feature has the following attributes:

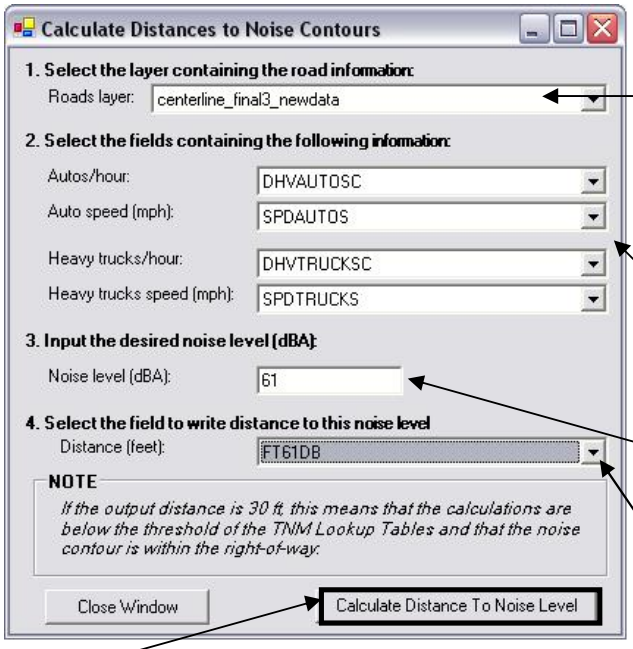
i. heavy truck peak hour volume
ii. heavy truck operating speed, mph
iii. auto peak hour volume
iv. auto operating speed, mph

In addition, the user defines fields to hold the calculated noise distances; for example, FT61DB (number of feet to 61 dBA) and FT66DB (number of feet to 66 dBA), etc. The traffic volume and speed attributes are used along with the FHWA TNM lookup table algorithm to calculate the distance, in feet, to a given noise level (dBA). For each feature, this distance is written into the previously defined field. One can create as many columns of distances-to-noise-level as desired.

f. Using the Distance Calculation Tool



Click on the distance calculation tool to activate



1. Select the layer that contains the road centerline geometry and the traffic data for each feature in this layer.

2. Indicate the fields in which each type of traffic information can be found.

3. Specify the noise level for which the distance will be determined.

4. Indicate the field where the distance information will be written. Please note that this field will be overwritten.

5. Click this button to calculate the distance to noise level for each feature.

After you click the button you will be alerted that the distance field will be overwritten and will be asked to continue.

If you select No, you will return to the tool's dialog box. If you select Yes the distance to the noise level indicated will be calculated for each feature in the roads layer and will be stored in the indicated distance field.

§ The distance is calculated in feet.

Note: for roads with very little traffic and that result in a distance that is below the threshold in the TNM Lookup table of 33 feet a distance of 30 feet will be output. In general this falls within the right-of-way of the road and should be recognized as "no contour."

g. Example Input and Output Data

Here is a portion of an attribute table from a line feature class that was used in the noise calculation tool. The input fields and output fields are indicated.

Attributes of centerline_final3_newdata

DHVTRUCKSC	DHVAUTOSC	SPDTRUCKS	SPDAUTOS	FT61DB
312	624	75	75	521
322	646	75	75	528
232	764	75	75	463
236	778	75	75	467
228	752	75	75	460
242	794	75	75	472
283	820	75	75	504
306	1220	75	75	528
326	1292	75	75	541
290	1154	75	75	516
340	1352	75	75	550
530	1266	75	75	649
516	1874	75	75	650
632	3320	75	75	715
628	3292	75	75	713
514	1908	75	75	650
412	1816	75	75	597

Output data

Input data

IV. Noise Contour Creation Tool

h. Background

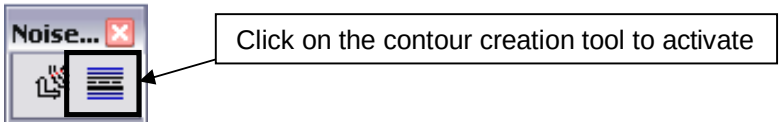
The noise contour creation tool takes as its input a line feature layer with a field indicating distance. It will output a new line feature class, or shapefile, with lines parallel to each input line feature at this distance stored in the distance field. Two lines are created, one on either side of the input line feature.

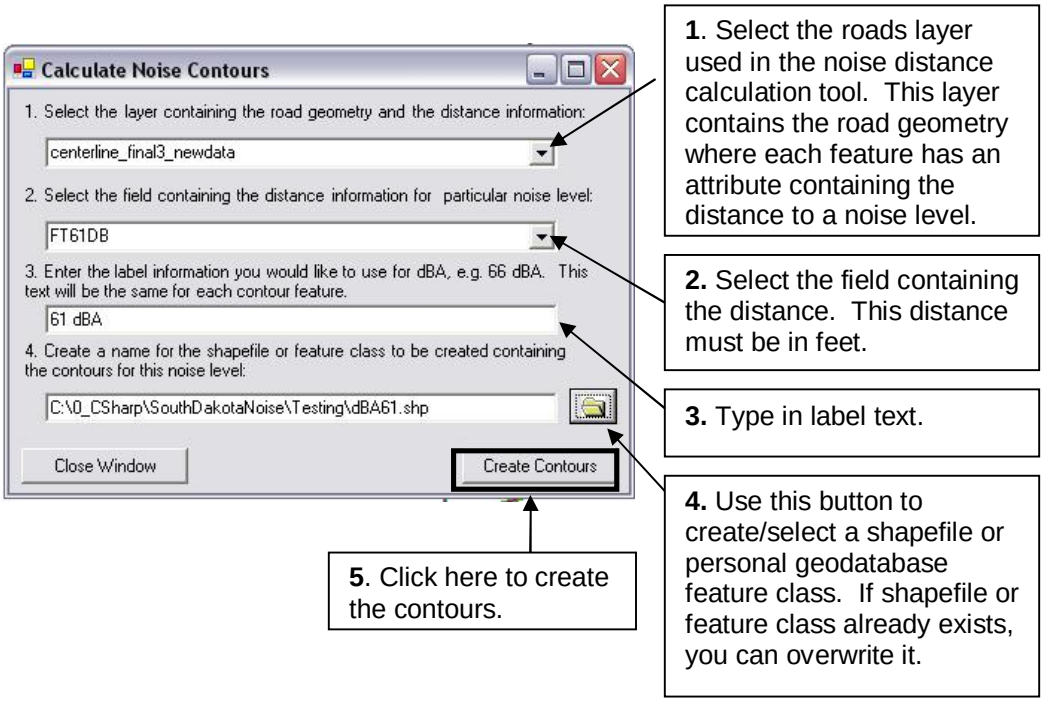
Note: contours cannot be calculated for segments that are 5 feet or less in length. Before any contours are calculated all segments are checked to see if they are above this threshold. If not, a dialog box is displayed that specifies the segments, by object-id, which do not meet this criterion. These must be deleted or merged into other segments before contours can be calculated.

The tool is designed to work with the Noise Distance Calculation tool which calculates a noise distance for each feature in a line feature class. This distance becomes the input to the contour tool and the resulting feature class or shapefile represents the noise contour at that noise level. This tool will create a separate feature class or shapefile for each noise level. For example, a new feature class

or shapefile will be created which will contain a pair of contour lines for each road segment for the distances calculated for 61 dBA and a different shapefile or feature class will be created for the pair of contour lines for each road segment for the distances calculated for 66 dBA.

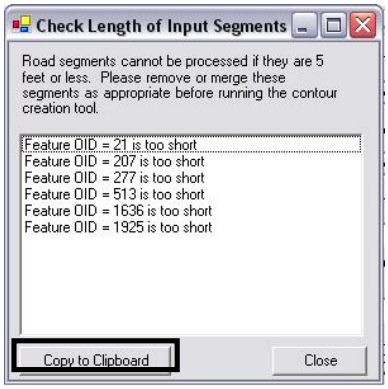
i. Using the Contour Creation Tool





The new shapefile or feature class is created and the distance information is copied, from the input feature class, for each feature.

Before the contours are created all line segments are checked to make sure that their length is 5 feet or greater. If there are line segments that do not meet this criterion the following dialog box is displayed.



Click on the "Copy to Clipboard" button to copy the contents of the list box to the clipboard and then paste this information into any word processor. This information can now be used as reference when you close this dialog box and the noise contour dialog box to have access to the roads segment feature layer. These segments must be deleted or merged as is appropriate for your application before the contours can be created.

j. Example Output Data

The following figure shows the results of running the contour tool for three noise levels. Each of the three resulting feature classes contains a pair of parallel lines around the road centerline. Please note that the contours were labeled by the GIS analyst using annotation and feature masking (available in ArcInfo only).