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16. Abstract

This project will provide the Texas Department of Transportation (TxDOT) with information about the effects of the current cost-effectiveness criterion. The project has reviewed (1) the cost-effectiveness criteria used by other states, (2) the noise barrier construction history of the other states, and (3) the effect the cost-effectiveness criteria has had on noise barrier construction. The researchers examined the effect of the Texas' cost-effectiveness criterion on decisions regarding noise barrier construction during recent years. Typical residential scenarios where highway noise impacts residences were also evaluated to determine when the cost-effectiveness criterion would indicate the need for constructing a noise barrier. Recommendations are made concerning the optimum monetary level for that criterion.

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VALIDATION OF COST-EFFECTIVENESS CRITERION FOR EVALUATING NOISE ABATEMENT MEASURES

by

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Research Report Number 7-3965-1

Project 7-3965

Cost-Effectiveness Criterion for Evaluating Noise Abatement Measures

Conducted for the

TEXAS DEPARTMENT OF TRANSPORTATION

by the

CENTER FOR TRANSPORTATION RESEARCH
Bureau of Engineering Research
THE UNIVERSITY OF TEXAS AT AUSTIN

April 1999

IMPLEMENTATION RECOMMENDATIONS

This project provided a detailed review of the relation between the history of noise barrier construction and the cost-effectiveness criterion. It examined the history of the cost-effectiveness criterion in other states, as well as how the cost-effectiveness criterion has affected noise barrier construction in Texas. In addition, this report discusses how the cost-effectiveness criterion impacts typical cases where noise abatement is modeled using the newest Federal Highway Administration (FHWA) noise model. Based on the information obtained through this study, the researchers recommend the following:

1) There is no indication or evidence at this time that the cost-effectiveness criterion of $25,000 should be adjusted either higher or lower.

2) The suitability of the cost-effectiveness criterion should be evaluated every 5 years. If local construction costs change significantly, evaluations could be made more often. Such an evaluation need not be a formal project, but could be accomplished through informal investigation by the staff at TxDOT's Environmental Affairs Division (ENV). To assist in this evaluation, several tasks are recommended:

    a) Complete records of TxDOT traffic noise analyses, including tables of the model results and detailed maps of the receiver and recommended barrier locations, should be maintained at TxDOT/ENV.

    b) The barrier construction activity of other states should be monitored for any trends in the use of their cost-effectiveness criteria. Toward this goal, it is important that TxDOT/ENV maintain close liaison with noise representatives from state highway agencies nationwide.

    c) A comprehensive database of TxDOT's completed noise barriers should also be maintained in TxDOT/ENV. This database should include overall design characteristics/specifications for each noise barrier, an evaluation of noise level reductions achieved by each of the various types of noise barriers, and a summary of any associated lessons learned.

DISCLAIMERS

The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Texas Department of Transportation. This report does not constitute a standard, specification, or regulation.

There was no invention or discovery conceived or first actually reduced to practice in the course of or under this contract, including any art, method, process, machine, manufacture, design or composition of matter, or any new and useful improvement thereof, or any variety of plant, which is or may be patentable under the patent laws of the United States of America or any foreign country.

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CHAPTER 1. INTRODUCTION — COST-EFFECTIVENESS CRITERION

A fair and reasonable cost-effectiveness criterion is essential for the operation of a noise abatement program. The cost-effectiveness criterion is the guideline used to judge if a noise abatement project will produce a benefit for the affected residences that is commensurate with the cost of the project. Such assessments are necessary, given that the funding for noise abatement projects originates from the same limited funding pool used for highway construction. Assigning a value to the benefit of noise abatement projects allows individual projects to be objectively evaluated with regard to cost versus benefit. Setting that value at the proper level helps to ensure that noise abatement measures will be taken when they represent the greatest benefit available to the public for the amount of funds expended.

The purpose of this study was to determine if the monetary level of the noise abatement cost-effectiveness criterion for the state of Texas is valid or if it should be changed. Further, this study will recommend how the criterion should be applied to individual cases. In nearly all instances, noise abatement has taken the form of a highway noise barrier. Accordingly, this study will concentrate on the cost-effectiveness of noise barrier construction. In all cases, the decision to build a noise barrier is made after consideration of cost-effectiveness and other criteria.

Project Cost Determination Method. An essential part of every noise barrier project is the method used to determine if noise mitigation is feasible and cost-effective and, if so, what is necessary to provide that noise mitigation. Because nearly all noise abatement is accomplished by constructing noise barriers, this report examines the method used to determine (1) if a noise barrier will be effective at providing substantial noise reduction and (2) how large (length and height) the noise barrier must be in order to accomplish that noise reduction. There are two main parts to the methods currently used that have a direct effect on the cost per benefited residence. First, the project is computer modeled to determine the size of the barrier. Second, a cost per square foot is used to determine the estimated cost of the noise barrier.

Currently, computer modeling may be performed using one of two software models, STAMINA or Traffic Noise Model (TNM). STAMINA has been in use for many years as the FHWA-approved model, while TNM is the new FHWA model. Eventually, TNM will replace STAMINA as the FHWA-required model for noise mitigation design. The new model, TNM, has many improvements, including better user interface, intuitive data entry, a parallel barrier design calculation, and more sophisticated noise calculation algorithms. TNM results also compare more favorably to actual noise measurements (Ref 1). The user interface and data entry improvements should result in more accurate modeling, especially in complicated highway designs. The use in TNM of different algorithms from STAMINA was expected to produce negligible difference in the results for an identical situation modeled with both STAMINA and TNM. In fact, that situation is often the case. However, it appears that in some cases, the results from the two programs have significant differences. In most of these cases, TNM predicts that an identical barrier would be somewhat more effective than when the same barrier is modeled with STAMINA. Alternately, compared to a barrier modeled with STAMINA, a barrier modeled with TNM that is slightly less tall or long would produce the same noise reduction.

Since build decisions are made based on the model results, it is possible to have a situation where modeling with TNM would result in a barrier that meets the cost-effectiveness criterion, while the same barrier modeled with STAMINA may exceed the cost-effectiveness criterion. This result is significant because, in examining cost-effectiveness, we will evaluate past cases that were modeled with STAMINA, yet make a recommendation for a cost-effectiveness criterion that will be used in cases modeled with TNM. Fortunately, initial evaluation of TNM by the FHWA has indicated that the model is accurate and can be expected to produce good results for situations normally encountered in noise mitigation design.

Over the next several years TNM will be reevaluated as actual projects that were modeled with TNM are completed. At a later date, a reevaluation of the cost-effectiveness criterion can be made where both past and future projects are modeled with the same computer program.

To arrive at an estimated barrier cost, the engineer will normally determine what size barrier will produce the desired, or at least the minimum, noise reduction, and then multiply the size by the estimated cost per square foot of barrier. The cost per square foot for a noise barrier is normally determined by the cost of past projects. Here again, good judgment is essential. While the choice of material has a strong impact on cost, experience has shown that, even with similar materials, construction costs vary considerably from one project to another. Accordingly, the modeling engineer must research each case to calculate the best estimate of cost per square foot. Use of historical data, especially recent data from similar or proximally located projects, is the best guide for arriving at a cost per square foot value.

These two factors — model used and cost per square foot for noise barriers — will determine the cost of a noise barrier. That cost divided by the number of benefited residences will determine if a proposed noise barrier is cost-effective. Thus, it is essential that both factors undergo periodic evaluation in order to ensure that the most accurate methods are being used to determine for any particular project what amount of noise mitigation will be in the best interest of the state and its residents.

Overview of this Report. The evaluation of the cost-effectiveness criterion was conducted across three broad areas: (1) Cost-effectiveness criteria of other states were evaluated, along with the states' history of noise barrier construction. (2) The historical results in Texas for noise barrier construction in relation to cost-effectiveness were evaluated. Several particular projects that illustrate how the cost-effectiveness criterion has been used in Texas were examined in detail. (3) Multiple typical project scenarios were modeled with TNM to precisely determine what level of noise mitigation can be achieved with the current and a modified cost-effectiveness criterion. Finally, based on the results of the above-mentioned investigation and on a consideration of TXDOT requirements and guidance, conclusions and recommendations are made toward establishing and evaluating the cost-effectiveness criterion.

CHAPTER 2. ANALYSIS OF THE COST-EFFECTIVENESS CRITERION IN PLACE AT OTHER HIGHWAY AGENCIES

A major part of this study involved gathering information about the noise abatement programs of all the other state highway agencies (SHAs). In particular, information on the cost-effectiveness criteria for all the states was obtained. This information was examined in relation not only to the amount of actual barrier construction in the state, but also to the cost of construction. An obvious goal of surveying other states is to find programs that are successful at satisfying the needs of the affected residents in a cost-efficient manner. In conjunction with another investigation, questionnaires regarding the states' cost-effectiveness criteria were sent to all fifty states. The survey was followed by a telephone interview of all SHAs, even if they had returned the questionnaire. A quick summary of the results is provided in Table 2.1. Some states use a formula instead of a fixed number to calculate the cost-effectiveness criterion. For those states, an average project case was used to arrive at a cost-effectiveness criterion value.

Table 2.1 shows that the cost-effectiveness criteria for the different SHAs span from $15,000 – $50,000. Texas has a cost-effectiveness criterion of $25,000, which is the median value for all the states. The two major factors that will influence the cost of noise abatement projects are the actual cost of construction in a given area of the country and the approach that the SHA takes toward noise abatement construction. Construction costs throughout the United States vary by as much as a factor of 2. Certainly, this accounts for some of the differences in the cost-effectiveness criteria. However, it is also clear that a large portion of the difference in the index derives from differing policies and approaches toward noise abatement. For example, some states may be more inclined to offer noise mitigation to impacted residences and, therefore, willing to spend more per benefited residence. All states try to design noise mitigation to provide a minimum of 5 dB in noise reduction. However, a few states, New York and Maryland, for example, strive for a minimum of 7 dB noise reduction. The extra protection will normally result in higher barriers and higher costs per benefited residence. Also, many of the states have had little or no noise barrier construction and therefore have not utilized the cost-effectiveness criterion sufficiently to perform a comprehensive evaluation of the index. For that reason, Texas and the ten states having the most barrier construction will be examined more closely.

The combination of the cost-effectiveness criterion and local construction costs determines how much construction can be built per resident to mitigate noise impact. That is, assuming comparable types of barrier construction, the analysis determines how many square feet of barrier wall can be built for each resident. Table 2.2 lists the relative cost percentage of the national average for masonry construction for selected cities in the eleven states being examined (Ref 3). The table shows that costs can vary considerably in the same region of the country and even in the same state. These are comparative costs for identical masonry work. Depending on state policy, funds available, and neighborhood influence, different types of construction with varying costs will be used.

TABLE 2.1. COST-EFFECTIVENESS CRITERIA OF THE SHAs

State	Cost Criteria ($)	State	Cost Criteria ($)
Alabama	20,000	Montana	25,000
Alaska	25,000	Nebraska	25,000
Arizona	15,000	Nevada	25,000
Arkansas	20,000	New Hampshire	30,000
California	35,000	New Jersey	40,000
Colorado	15,000	New Mexico	40,000
Connecticut	50,000	New York	50,000
Delaware	40,000	North Carolina	25,000
Florida	25,000	North Dakota	20,000
Georgia	50,000	Ohio	25,000
Hawaii	35,000	Oklahoma	30,000
Idaho	15,000	Oregon	20,000
Illinois	30,000	Pennsylvania	50,000
Indiana	20,000	Rhode Island	25,000
Iowa	20,000	South Carolina	15,000
Kansas	25,000	South Dakota	15,000
Kentucky*	12,000	Tennessee	25,000
Louisiana	25,000	Texas	25,000
Maine	20,000	Utah	20,000
Maryland	50,000	Vermont	20,000
Massachusetts*	24,000	Virginia	20,000
Michigan	27,000	Washington	20,000
Minnesota*	23,000	West Virginia	15,000
Mississippi	20,000	Wisconsin	40,000
Missouri	30,000	Wyoming	15,000

* Based on a formula using an average case

The last column of Table 2.2 shows how cost-effectiveness relates to relative cost for selected cities in the ten states having the most barrier construction. A relative cost-effectiveness ratio level of 1 has been chosen for a state that has a cost-effectiveness criterion of $25,000 and a relative masonry cost percentage of 100 (average for the country). Higher ratios signify a relatively higher cost-effectiveness criterion after adjustment for local construction costs. For example, Norfolk, Virginia, has a ratio of 1.2, while Detroit, Michigan, has a ratio of 0.9, which means that, using the same type of construction, more construction of a similar nature can be undertaken per resident in Norfolk than in Detroit even though the state cost-effectiveness criterion is lower in Virginia. Ratios below 0.8 indicate a relatively low amount of construction available per impacted resident. States with low ratios often have used less expensive methods for barrier construction (e.g., wood or basic concrete block). States with high ratios are less cost constrained in their construction options and have tended to use more costly construction for noise barriers. The fact that Texas has construction costs lower than the national average results in an adjusted relative cost-effectiveness criterion of 1.2 for Dallas and 1.3 for Houston. This means that after adjusting for local construction costs, the cost-effectiveness criterion for Texas is in effect higher than average.

TABLE 2.2. COST-EFFECTIVENESS CRITERIA VERSUS RELATIVE COST FOR SELECTED CITIES

State	City	Cost-Effectiveness Criteria ($)	Relative Cost Percentage of Average for US (%)	Relative Cost-Effectiveness Criteria Ratio
California	Oakland	35,000	131.5	1.1
	Los Angeles	35,000	118.1	1.2
Virginia	Fairfax	20,000	80.3	1.0
	Norfolk	20,000	69.3	1.2
New Jersey	Jersey City	40,000	113.8	1.4
Minnesota	Minneapolis	23,000	122.4	0.8
Colorado	Denver	15,000	88.8	0.7
New York	Long Is. City	50,000	151.3	1.3
	Buffalo	50,000	119.2	1.7
	Syracuse	50,000	98.9	2.0
Pennsylvania	Philadelphia	50,000	114.2	1.8
	Pittsburgh	50,000	102.0	2.0
Oregon	Portland	20,000	113.0	0.7
Michigan	Detroit	27,000	115.2	0.9
	Flint	27,000	100.6	1.1
Maryland	Baltimore	50,000	80.0	2.5
Texas	Dallas	25,000	74.7	1.3
	Houston	25,000	81.7	1.2

Table 2.3 lists the linear miles, square feet, and cost in 1995 dollars for barriers constructed for the same eleven states (Ref 4). Table 2.3 shows that the average actual construction cost per square feet varies from $11 to $28, more than a factor of 2. The particularly low cost in Minnesota and Colorado is due to a large percentage of wood construction, while low costs in Oregon are due partly to the use of earth berms for part of many barriers. Considering only concrete or masonry-type construction and ignoring a few exceptions, the cost per square feet is concentrated in a smaller range of approximately $16 to $23. Not unexpectedly, the states that have the highest cost-effectiveness criterion also

have the highest cost per linear mile and per square meter. The relationship of cost-effectiveness criterion to barrier cost per linear meter is shown in Table 2.4.

TABLE 2.3. NOISE BARRIER CONSTRUCTION AND COST FOR TEN MOST ACTIVE STATES

State	Linear Miles	Square Feet (thousands)	Total Cost 1995 Dollars ($) (millions)	Cost Per Linear Mile ($) (thousands)	Cost Per Square Foot ($)
California	435.6	27,220	438.7	1,007	16
Virginia	72.6	6,440	106.0	1,460	16
New Jersey	70.8	7,020	163.9	2,315	23
Minnesota	61.5	5,120	58.3	948	11
Colorado	57.4	3,060	33.9	591	11
New York	55.9	4,210	78.5	1,404	19
Pennsylvania	46.7	3,130	76.8	1,645	25
Oregon*	39.9	2,130	26.5	664	12
Michigan	38.9	2,360	52.0	1,337	22
Maryland	34.2	3,210	89.6	2,620	28
Texas	33.2	2,100	33.0	994	16

*Barriers constructed cost-free to DOT omitted

TABLE 2.4. AVERAGE LENGTH OF BARRIER IN FEET THAT CAN BE BUILT PER RESIDENCE BASED ON THE COST-EFFECTIVENESS CRITERION

State	Cost-Effectiveness Criteria	Cost Per Linear Mile ($ thousands)	Cost-Effectiveness/ Cost Per Linear Foot ($)
California	35,000	389	17.04
Virginia	20,000	564	6.71
New Jersey	40,000	894	8.47
Minnesota	23,000	366	11.90
Colorado	15,000	228	12.46
New York	50,000	542	17.48
Pennsylvania	50,000	634	14.93
Oregon*	20,000	257	14.76
Michigan	27,000	516	9.90
Maryland	50,000	1,012	9.36
Texas	25,000	385	12.31

*Barriers constructed cost-free to DOT omitted

Table 2.4 gives an average indication of how long a barrier can be built per benefited residence when limited by the cost-effectiveness criterion. Note that although Colorado has a very low cost-effectiveness criterion, the state can still build about 135 ft of barrier per benefited residence, which is above the median for the eleven states covered in Table 2.4. Colorado achieves this because most of the barriers constructed to date are made of wood and therefore have a low cost per linear mile. Minnesota has also used wood construction frequently, while Oregon's barrier construction often has made use of berms. On the other hand, Virginia has predominately used precast concrete, a relatively expensive construction method, resulting in a low value of 70 ft of barrier per benefited residence. New York, with a high cost-effectiveness criterion and a high average construction cost value, is able on average to build over 190 ft of barrier per benefited residence. At 130 ft per residence, Texas is slightly above the median for the ten states having the most barrier construction. Thus, Texas can provide slightly longer barriers per benefited residence. This result is in agreement with the results of Table 2.2. These results appear to indicate that under similar conditions in a noise-impacted area, based on the cost-effectiveness criteria, some states would provide noise abatement while others would not. While this is no doubt true, it is important to keep in mind that these tables deal with average costs. In any given state, construction costs for different projects in the state vary more than average costs vary among states.

In summary, the review of the overall data from the fifty states and the specific data from Texas and the ten states having the most barrier construction leads to several broad conclusions.

1. Cost-effectiveness criteria for the fifty states vary by more than a factor of 3, from $15,000 to $50,000.
2. States with higher average construction costs tend to have higher cost-effectiveness criterion. However, even after adjusting for construction costs, there is a wide variation in the cost-effectiveness criterion.
3. States with low adjusted cost-effectiveness criterion tend to use less expensive construction techniques to serve the noise-impacted residences. States with a high cost-effectiveness criterion often use relatively expensive construction techniques.
4. Based on the cost-effectiveness criterion, the average length of noise barrier that can be built per benefited residence varies from 70 to 190 ft, with a median value of approximately 130 ft. This number gives an indication of the maximum spacing between residences that can be accommodated and the minimum number of residences that can be served by one barrier while still keeping barrier cost per residence below the cost-effectiveness criterion. The maximum spacing between residences and the minimum number of residences served by one barrier are examined in the following chapters.
5. Texas' ability to provide noise abatement for impacted residences is slightly higher than the median of the ten states with the most barrier construction. Texas has a median cost-effectiveness criterion that is slightly above average when adjusted for local construction costs. The historical construction costs per noise barrier square meter in Texas reflect local construction costs. Based on historical construction data and on the cost-effectiveness criterion, the length of noise barrier that can be

constructed per benefited residence in Texas is slightly above the average for the ten most active states.

CHAPTER 3. ANALYSIS OF THE COST-EFFECTIVENESS CRITERION REGARDING NOISE BARRIER CONSTRUCTION IN TEXAS

This chapter examines the role of the cost-effectiveness criterion in noise abatement project decisions in the recent history of noise barrier construction in Texas. A total of 172 noise impact studies resulting from new construction undertaken from 1995 through 1998 were examined to identify general trends in noise abatement decisions in Texas. Also, several highway capacity improvement projects that had a noise impact and in which noise abatement was considered are examined in some detail. The impact of the cost-effectiveness criterion on these projects is examined to illustrate how cost-effectiveness is used in specific cases. A total of seven specific cases are examined, three of which resulted in no noise abatement action, while four resulted in some noise barrier construction.

RECENT HISTORY ABOUT HIGHWAY NOISE IMPACT STUDIES IN TEXAS

The record of noise impact studies in Texas reveals some of the reasons why noise barriers are built or not built. Among the criteria considered by the Texas Department of Transportation (TxDOT) in building a noise barrier for residents, the most common reasons why noise abatement was not recommended included access requirements, excessive cost, and inability to achieve the required noise reduction. In 125 cases, access requirements prevented construction of noise barriers. For many of these cases, access required numerous gaps in the barriers that made the walls ineffective in noise reduction. In addition, in some of the cases, the residents did not want the noise barriers proposed by TxDOT because the barriers blocked the visibility and some access. In twenty-two cases, barriers were not built because the cost exceeded the cost-effectiveness criterion. In some instances the cost exceeded the $25,000 per resident criteria by just a few thousand dollars, while in other instances the cost was more than 2 to 3 times the $25,000 criteria. In three cases the noise barriers were not built because the location of the residences in relation to the proposed barrier location was such that the predicted noise reduction was less than the 5 dB minimum required.

In cases in which the recommendation was made for building noise barriers, the barrier model indicated that the barrier would clearly be feasible and achieve a minimum of a 5 dB noise reduction. A total of twenty-two projects resulted in some noise barrier construction. Table 3.1 shows the consolidated data for the noise impact studies resulting in no-build decisions, while Table 3.2 shows the consolidated data for the build cases. More detailed summaries are provided in Appendix A.

EXAMPLE NOISE IMPACT STUDIES IN WHICH NOISE ABATEMENT ACTION WAS NOT TAKEN

Three specific projects are examined to illustrate common situations where noise abatement in an impacted residential area is deemed not feasible or not reasonable. The first case involves several reasons for not constructing noise abatement, including access requirements (causing a noise barrier to be ineffective) and wide residential separation (resulting in noise abatement exceeding the cost-effectiveness criterion). The second case illustrates the problems often associated with trying to provide noise abatement for a one- or two-residence location. The third case illustrates how the cost of a barrier for multiple residences can often exceed the cost-effectiveness criterion and result in a decision to not build noise barriers.

TABLE 3.1. SUMMARY OF CASES RESULTING IN NO-BUILD DECISIONS

District	Counties	Cost	Access	Noise Level	Opposed by Public
Atlanta	Upshur, Bowie, Cass, Harrison	1	4		
Austin	Travis, Hays	1	2		
Beaumont	Orange, Jasper, Jefferson, Hardin		7		
Bryan	Brazos, Washington		5		
Corpus Christi	Aransas	1	4		
Dallas	Dallas, Collin, Ellis, Denton, Rockwall, Kaufman	9	26	1	1
El Paso	El Paso	2	3		
Fort Worth	Tarrant, Hood, Wise, Johnson, Erath		12		
Houston	Galveston, Harris, Fort Bend, Brazoria	2	12		
Laredo	Maverick, Webb		5		
Lufkin	Angelina, Polk, Shelby	3			
Odessa	Ector		3		
Pharr	Hidalgo, Cameron, Brooks,		16		
San Angelo	Tom Green, Menard, Comal, Guadalupe, Bear	5	4		
Tyler	Smith, Henderson		2		
Waco	McLennan, Coryell, Hill, Bell	1	1		
Yoakum	Wharton, Calhoun, DeWitt, Gonzales		5		

TABLE 3.2. SUMMARY OF CASES RESULTING IN BUILD DECISIONS

District	County	Highway	Number of Benefited Residences	Length (ft)	Height (ft)	Cost ($)	Cost Per Benefited Residence ($)
Corpus Christi	Nueces	Ennis Joslin	21	2140	10	320,702	15,271
Dallas	Dallas	FM 1382	50	4505	8–12	842,910	10,300–22,825
Dallas	Denton	FM 3040	50	4920	7	169,920	11,271–16,531
Dallas	Dallas	Jupiter	35	1110	9–11	164,720	2,280–12,760
Dallas	Denton	SH 114	50	2245	12	561,000	11,220
Dallas	Dallas	FM 1382	53	5035	10	906,300	17,100

TABLE 3.2. SUMMARY OF CASES RESULTING IN BUILD DECISIONS (CONTINUED)

District	County	Highway	Number of Benefited Residences	Length (ft)	Height (ft)	Cost ($)	Cost Per Benefited Residence ($)
Dallas	Collin	Plano Parkway	10	820	10	147,600	14,760
Dallas	Collin	SH 78	23	1200	9–10	162,135	6,750–17,100
Dallas	Dallas	SH 190 (toll)	668	40710	6.5–15	9,126,000	9,450–24,387
Dallas	Collin	Spring Creek	123	5155	8–9	818,408	2, 460–10, 024
Dallas	Dallas	SH 66	9	870	12	187,920	20,880
Fort Worth	Tarrant	SH 199	23	1935	10–12	386,600	16,383–20, 880
Fort Worth	Tarrant	IH-35W	18	560	16	161,568	8,976
Fort Worth	Tarrant	Green Oaks	87	7780	8	1,245,600	14,317
Fort Worth	Tarrant	BUS 114	6	250	6	35,500	5,917
Houston	Harris	IH-610W	114	16625	16–18	2,711,400	23,784
Houston	Fort Bend	Dairy Ashford	82	5700	8–10	551,565	4,796–10, 269
Houston	Fort Bend	West Airport	59	5475	8	506,627	6,678–12, 597
San Antonio	Guadalupe	IH-410	24	7090	11	403,920	16,830

Consideration of Barriers to Protect Widely Spaced Residences Requiring Access: Dallas District Case 0442-02-087 on IH-35E

This case concerns noise abatement for twenty-three noise impacted residences and one church. The highway improvement project was approximately 4.84 miles in length on IH-35E, with a southern limit just to the north of Parkerville Road and a northern limit just to the north side of IH-20 interchange in Dallas. The project route was directed mainly through a residential area with single family houses, a church, and a small commercial area. The project involved widening a section on IH-35E from a four-lane controlled access freeway to a six-lane controlled access freeway for part of, the project transitioning to eight-lanes for the remainder. Figure 3.1 shows the residences affected by the project. All the receiver positions along the route were predicted to either approach or exceed the noise abatement criteria (NAC) level. The results of the noise analysis for residences south of Danieldale Road are shown in Table 3.3. Despite the noise level, barriers for the residences covered by those receiver positions were not considered reasonable for two reasons. First, the houses were widely spaced, necessitating a barrier having a high length-to-benefited-resident ratio; second, the existence of a creek and several streets would require that the barrier have many gaps, thus reducing its noise abatement effectiveness.

The reasonableness of constructing a noise barrier near the southwest quadrant of the IH-20/IH-35 interchange — a barrier that would protect twenty-four residences (receivers 57 to 81 in Figure 3.1) — was also evaluated, with the results of the noise analysis provided in Table 3.4. The modeled barrier was 15 ft (4.56 m) high and 2,673 ft (812.6 m) long. At a cost of $17.25 per square foot, the estimated cost per residence was $30,075. The wall would have reduced the noise level by 5.2 dB to 7.1 dB at all residences but one, where the noise level achieved a reduction of only 3.3 dB. The construction of this wall was not recommended because the cost exceeded the $25,000 cost-effectiveness criterion.

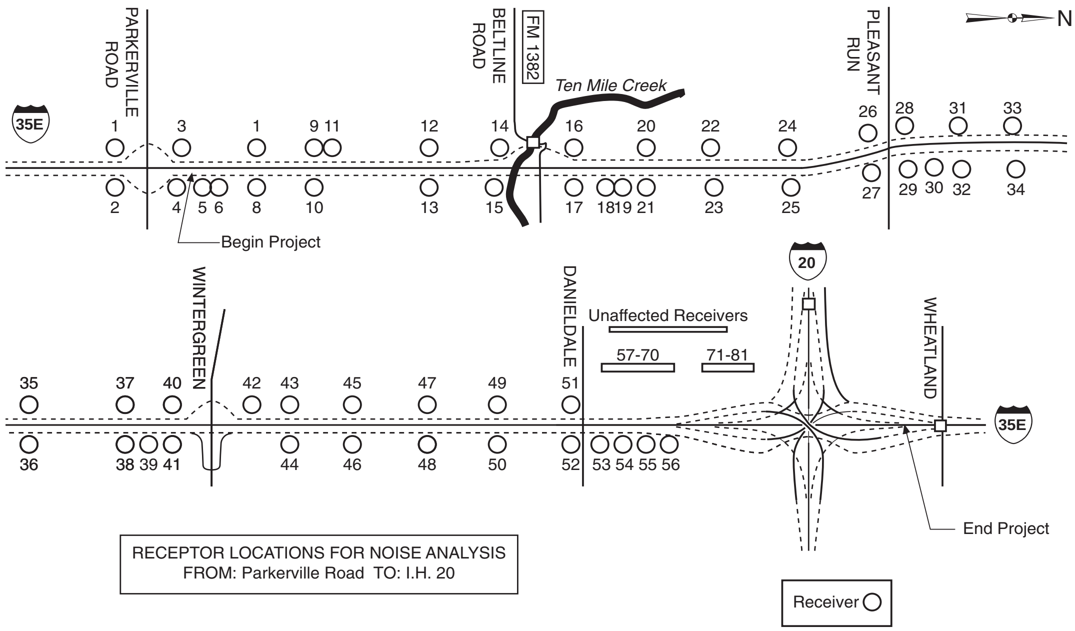

Figure 3.1. Drawing of noise analysis of a proposed widening of IH-35E from Parkerville Road to IH-20 in Dallas County, Dallas District

TABLE 3.3. NOISE ANALYSIS SUMMARY FOR RECEPTOR LOCATION SOUTH OF DANIELDALE ROAD: DALLAS DISTRICT CASE 0442-02-087 ON IH-35E

Receiver	NAC Level	Without Mitigation			
		1995	Status	2020	Status
4	B	75.2	Exceeds	82.1	Exceeds
8	B	75.3	Exceeds	76.9	Exceeds
9	C	75.8	Exceeds	77.5	Exceeds
10	C	75.0	Exceeds	76.6	Exceeds
12	C	72.8	Exceeds	75.5	Exceeds
14	C	72.9	Exceeds	75.6	Exceeds
16	C	75.1	Exceeds	76.9	Exceeds
17	C	76.8	Exceeds	78.6	Exceeds
22	C	76.6	Exceeds	78.4	Exceeds
23	C	75.2	Exceeds	77.0	Exceeds
27	C	73.3	Exceeds	75.1	Exceeds
29	C	72.7	Exceeds	74.5	Exceeds
33	C	74.8	Exceeds	76.6	Exceeds
34	B	76.1	Exceeds	77.9	Exceeds
40	C	76.0	Exceeds	78.2	Exceeds

Receiver	NAC Level	Without Mitigation			
		1995	Status	2020	Status
41	C	74.6	Exceeds	76.4	Exceeds
42	C	76.4	Exceeds	78.2	Exceeds
47	C	77.2	Exceeds	78.8	Exceeds
48	C	76	Exceeds	76.9	Exceeds
51	C	73.6	Exceeds	75.4	Exceeds
52	C	75.1	Exceeds	76.8	Exceeds

TABLE 3.4. NOISE ANALYSIS SUMMARY FOR RECEPTOR LOCATION NORTH OF DANIELDALE ROAD: DALLAS DISTRICT CASE 0442-02-087 ON IH-35E

Receptor	NAC Level	Without Sound Walls				With Sound Walls		Drop in dB (A) with Walls
		1995	Status	2020	Status	2020	Status	
53	67	75.5	Exceeds	76.7	Exceeds	76.6	Exceeds	0.1
56	67	75.3	Exceeds	76.5	Exceeds	76.5	Exceeds	0.0
57	67	66.2	Approaches	67.5	Exceeds	60.4	Under	7.1
64	67	67.8	Exceeds	69.1	Exceeds	63.4	Under	5.7
70	67	68.0	Exceeds	69.3	Exceeds	63.4	Under	5.5
71	67	68.3	Exceeds	69.5	Exceeds	63.4	Under	6.1
75	67	67.8	Exceeds	68.8	Exceeds	63.4	Under	5.4
81	67	68.3	Exceeds	69.7	Exceeds	66.4	Approaches	3.3

Consideration of Barriers to Protect One- and Two-Residence Locations: Austin District Case 3417-03-002 on Parmer Lane

In this case, two barriers for noise abatement were considered: one for two adjacent residences and the other for a single residence. The project involved laying out a new four-lane extension of FM734, Parmer Lane. The environmental review completed in April 1995 covered a 2-mile stretch of the highway extension. The route was primarily through an unimproved rural area but did pass close to one residential subdivision and one isolated residence. For this highway section, the predicted 67 dB noise level contour encompassed a portion of the property of two residences in the subdivision, as shown in Figure 3.2. To obtain the minimum 5 dB noise reduction, the required barrier would have to have been 14 ft tall and 453 ft long. Based on a $20 per square foot ($215 per square meter) construction cost, the barrier would cost $126,840, or $63,420 per residence. Because the barrier cost exceeded the cost-effectiveness criterion of $25,000 by over a factor of 2, barrier construction was not recommended.

The main factor that prevented this project from being cost-effective was the length of barrier required to achieve the required noise reduction. The long barrier was required because the residential property was quite far (over 100 ft) from the highway right-of-way and on lots that were nearly 100 ft wide at their widest point. Also note that the majority of the residential property was outside the 67 dB contour, and thus the impact just barely met the noise abatement criteria guidelines.

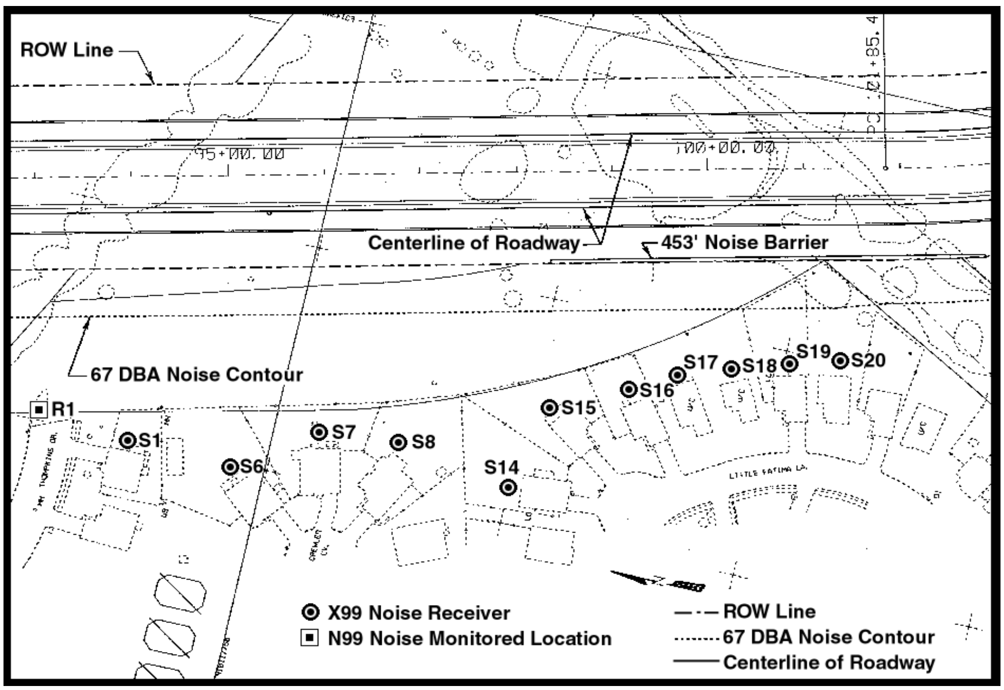

Figure 3.2. Drawing of noise analysis of a proposed new road construction for FM 734 in Austin, Texas (noise abatement for the residences at S19 and S20 was considered)

The 67 dB contour also encompassed the isolated residence shown in Figure 3.3. This residence was almost completely inside the 67 dB contour and was within 75 ft of the highway right-of-way. In this case, a 12 foot tall and 120 foot long barrier would achieve a 5 dB noise reduction. The barrier was estimated to cost $28,800. While this cost per residence was much lower than that for the other barrier, it still exceeded the cost-effectiveness criterion. The barrier was not constructed.

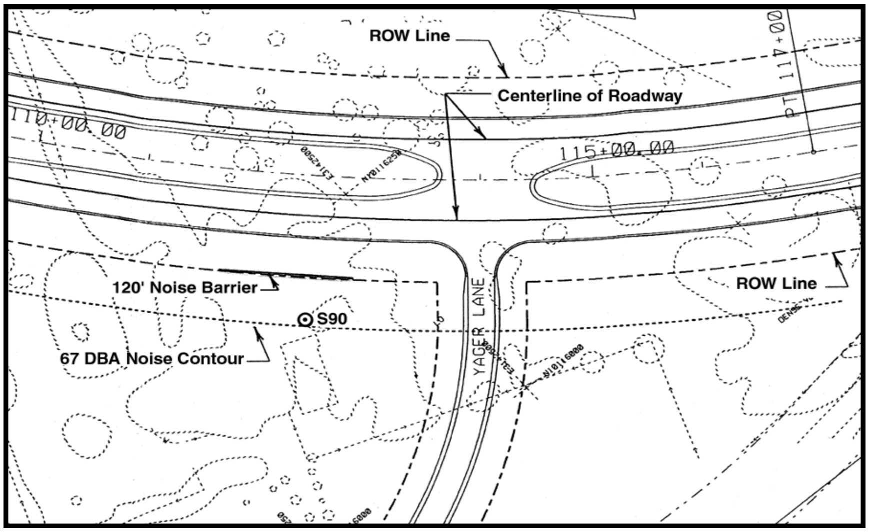

Figure 3.3. Drawing of noise analysis of a proposed new road construction for FM 734 in Austin, Texas (noise abatement for the residence at S 90 was considered)

Case Analyzing Building Barriers to Protect Multiple Residences That Exceeded Cost-Effectiveness Criterion: Dallas District Case 8075-18-006 on Spring Valley Road

The scope of this project was to widen Centennial Boulevard from a four-lane divided roadway to a six-lane divided arterial between Sherman and Grove. The length of the project was approximately 1.3 miles. The project is routed primarily through residential (activity category B) and some retail/commercial (activity category C) areas. The noise level in many residences approached or exceeded the NAC, as shown in Table 3.5. All no-build decisions were based on construction costs exceeding the cost-effectiveness criterion of $25,000.

Five barriers were modeled to a height of 11 ft, while one was modeled to a height of 16 ft. Table 3.6 summarizes the noise abatement analysis in terms of cost, number of units attenuated, the height and length of the modeled barriers, the total cost of each barrier, and the cost per benefited residence. Figure 3.4 shows the position of the noise receivers used in the model. The longest barrier would have benefited forty residents by lowering the noise level by at least 5 dBA for all residences and by as much as 8 dBA for some residences. However, the cost per residence is over 44 percent above the cost-effectiveness criterion.

TABLE 3.5. NOISE ANALYSIS SUMMARY OF SPRING VALLEY RD./CENTENNIAL BLVD. IN DALLAS DISTRICT

Receptor	Activity Category	NAC Level	Without Mitigation			With Mitigation	
			Existing	Future	Status	Future	Status
1	C	72.0	72.5	72.8	Exceed	72.8	Exceed
2	C	72.0	73.1	73.3	Exceed	63.5	Under
3	C	72.0	75.5	75.8	Exceed	64	Under
4	C	72.0	65.2	65.3	Under	65.3	Under
5	C	72.0	70.2	70.3	Under	63.5	Under
6	B	67.0	73.8	73.3	Exceed	63	Under
7	B	67.0	67.1	67.5	Exceed	64.7	Under
8	B	67.0	60.0	60.7	Under	59.1	Under
9	C	72.0	68.0	69.3	Under	59.5	Under
10	B	67.0	67.9	68.7	Under	60.8	Under
11	C	72.0	70.2	71.8	Under	60.1	Under
12	B	67.0	64.0	64.7	Exceed	57.8	Under
13	C	72.0	69.9	71.4	Approach	60.1	Under
14	B	67.0	64.0	65.0	Under	57.8	Under
15	C	72.0	70.9	72.6	Exceed	58.8	Under
16	B	67.0	66.0	66.9	Approach	60.7	Under
17	C	72.0	74.1	76.2	Exceed	60.9	Under
18	B	67.0	63.1	64.1	Under	58.4	Under
19	B	67.0	69.0	71.1	Exceed	61.6	Under

TABLE 3.6. COST-EFFECTIVENESS ANALYSIS SUMMARY OF SPRING VALLEY RD./CENTENNIAL BLVD. IN DALLAS DISTRICT

Receptor	Noise Barrier			Residences Benefited	Cost/Residence ($)
	Length (ft)	Height (ft)	Cost ($)		
6, 7	880	11	158,400	4	39,600
11	600	11	108,000	2	54,000
13	650	11	117,000	3	39,000
10, 12, 14, 16, 18	3105	16	1,441,500	40	36,038
15	675	11	121,500	2	60,750
17	175	11	31,500	1	31,500

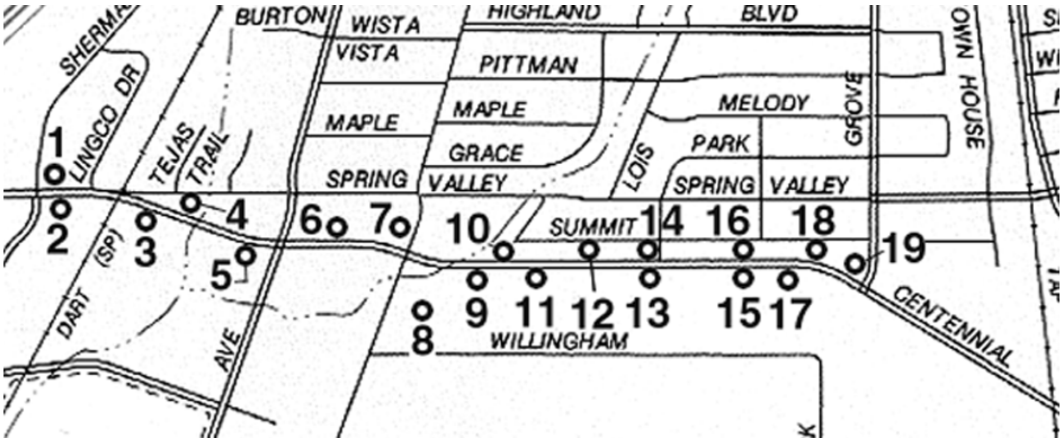

Figure 3.4. Drawing of the map used for the noise analysis of a proposed widening of Spring Valley/Centennial Road from a six-lane to an eight-lane arterial

EXAMPLE NOISE IMPACT STUDIES IN WHICH NOISE ABATEMENT ACTION WAS TAKEN

Two specific projects are examined to illustrate how the cost-effectiveness criterion was used in common situations when judging the reasonableness of noise abatement for an impacted residential area. The first case is a typical example in which the use of long barriers to protect multiple residences results in a relatively low cost per residence. The second case illustrates the same economy of scale with very long barriers and, in several cases, very tall barriers that protected a densely populated residential area.

Case Analyzing Building Barriers That Are within the Cost-Effectiveness Criterion to Protect Multiple Residences: Dallas District Case 1047-02-022 on FM 1382

This project involved noise mitigation on FM 1382 from US 67 to Hampton Road. The project sought to expand a two-lane rural road to a four-lane urban road. The route is mostly through a residential area that also contains a few churches. Noise barriers were not planned for the churches because access was required to a number of driveways. Shown in Figure 3.5, five noise walls were planned for the residential areas. Details of the cost analysis of the barriers are given in Table 3.7. These walls were predicted to have a noise reduction of 6 dB to 7 dB. The most expensive barrier per benefited residence is 650 ft long and 12 ft high and had an estimated cost per benefited residence of $22,825. Two of the barriers (2 and 3) benefited residences that were relatively closely spaced, and as a result, the barriers had a very low cost per residence of less than $11,000. As shown in Table 3.7, in this case it was possible to construct all the noise barriers well within the cost-effectiveness criterion.

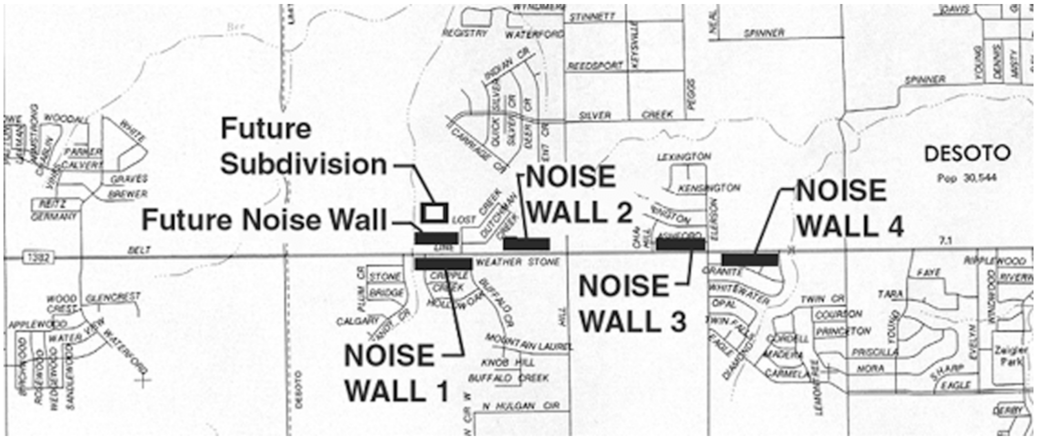

Figure 3.5. Locations of noise wall on FM 1382 from US 67 to Hampton Road

TABLE 3.7. COST-EFFECTIVENESS ANALYSIS TABLE, HIGHWAY FM 1382 IN DALLAS DISTRICT, DALLAS COUNTY

Noise Barrier Number	Number of Benefited Residences	Length (ft)	Height (ft)	Cost ($)	Cost/Benefited Residence ($)
1	11	1115	12	248,400	22,582
2	9	515	10	92,700	10,300
3	11	945	8	131,760	11,978
4	13	1296	10	233,100	17,931
5	6	633	12	136,950	22,825
Total	50	4505		842,910	

Case Analyzing Building Barriers That Are within the Cost-Effectiveness Criterion to Protect Multiple Residences

This project's purpose was to construct SH 190 between IH-35E and SH 78. There are a total of 600 impacted residences along the route. Predicted noise levels for the residences ranged from 64 dBA to 74 dBA. Also, an elementary school is predicted to have a 73 dBA noise level. Fifteen noise barriers listed in Table 3.8 were recommended along this proposed project. The heights for the suggested walls ranged from 9 ft to 15 ft and their lengths from 1400 ft to 5600 ft. The walls provide a 4 dBA to 10 dBA insertion loss for 668 residences. The cost per residence ranged from $9,237 to $24,300, based on $18 per square foot construction costs. Barrier 11 shown in Figure 3.6 is a good example of the ability to provide noise abatement at a very low cost per residence. The low cost was possible because of the high number of residences benefited per length of highway barrier and because a long barrier could be constructed without breaks for access.

TABLE 3.8. COST-EFFECTIVENESS ANALYSIS TABLE, HIGHWAY SH 190 (TOLL) IN DALLAS DISTRICT, DALLAS COUNTY

Noise Barrier Number	Number of Benefited Residences	Length (ft)	Height (ft)	Cost ($)	Cost/Benefited Residence ($)
1	34	3400	9	550,800	16,200
2	30	2100	9	340,200	11,340
3	13	1900	9	307,800	23,677
4	17	1700	9	275,400	16,200
5	29	2400	9	388,800	13,407
6	15	1700	9	275,400	18,360
7	27	2500	12	540,000	20,000
8	40	3600	15	972,000	24,300
9	31	2800	15	756,000	24,387
10	32	2300	15	621,000	19,406
11	152	5200	15	1,404,000	9,237
12	24	1400	15	378,000	15,750
13	48	2200	15	594,000	12,375
14	48	1900	15	513,000	10,688
15	128	5600	12	1,209,600	9,450
Total	668	40710		9,126,000	

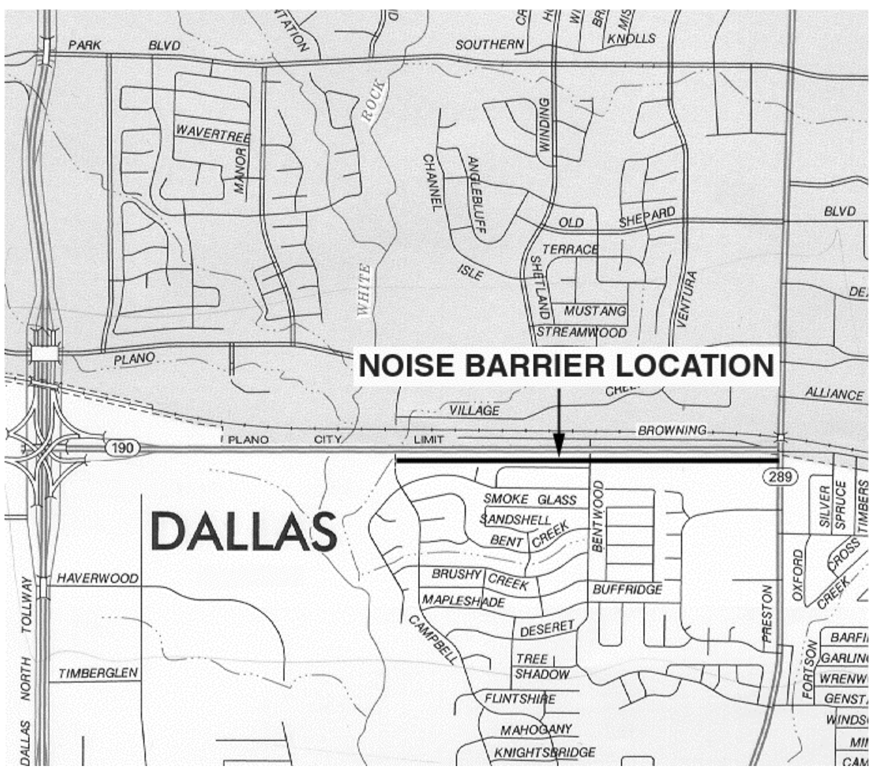

Figure 3.6. Map showing the project location along SH 190 in Dallas

SUMMARY OF THE EFFECT OF THE COST-EFFECTIVENESS CRITERION ON HIGHWAY NOISE BARRIER CONSTRUCTION IN TEXAS

This examination of the application of the cost-effectiveness criterion in Texas has shown that in most cases in which noise mitigation is feasible, it can be accomplished within the costs specified by the criterion. In the vast majority of cases in which noise barriers were not constructed, access requirements were the main reason for the no-build decision. Exceeding the cost-effectiveness criterion was the second major reason for not building a noise barrier. In many of the cases, the costs were so high that even a higher cost-effectiveness criterion would not have resulted in a build decision.

Specific cases have shown that when multiple residences can be protected by a single barrier, the cost per residence is usually well within the cost-effectiveness criterion. In cases where a barrier is used to protect only one or two residences, the barrier is invariably more expensive per residence and will typically exceed the cost-effectiveness criterion.

CHAPTER 4. ESTIMATION OF THE RESULTS OF THE COST-EFFECTIVENESS CRITERION ON NOISE BARRIER CONSTRUCTION DECISION MAKING THROUGH MODELING VARIOUS RESIDENTIAL SCENARIOS

Previous chapters included a comparison of the noise abatement programs in other states, and noise abatement program results detailing specific cases in Texas. The new FHWA computer program, TNM, was used to model typical example project scenarios. Examples were designed to be near the limits of the cost-effectiveness criterion in order to determine under what circumstances residences would receive noise abatement. Cases were analyzed using an average cost per foot for concrete construction in Texas; however, the results can easily be adjusted for a different cost (Ref 3). Only first-row-benefited residences were considered, although it is understood that sometimes second- and even third-row residences may benefit from noise barriers.

All cases were run with a traffic mix of 80 percent automobiles, 10 percent medium trucks, and 10 percent heavy trucks with all vehicles moving at 60 mph. This vehicle mix represents the worse case for a commercial highway. Reducing the percentage of trucks would create a roadway profile that more closely simulates a residential boulevard and would, consequently, lead to slightly different noise abatement results for the same noise barrier. Thus, a boulevard case with no trucks was run (along with the standard case) for the long continuous barrier to show the effect on the results. A barrier cost of $27 per square foot — a worse case construction cost for concrete or masonry construction — was used to calculate the cost-effectiveness of the barriers.

Five different noise barrier and residence scenarios were examined. The spacing of receiver locations was done in 5, 10, or 15-meter increments but all barrier heights were in feet. They were chosen to simulate common scenarios encountered when considering the benefits of constructing noise barriers. The first scenario covers the long continuous barrier, including the noise reduction (or barrier insertion loss) near the end of the barrier. The second examines the problems encountered when attempting to provide noise reduction for a single residence. The third scenario examines the results of noise abatement provided for a small group of residences, such as two or three residences in a row. The fourth scenario investigates how a gap in a long barrier might affect noise abatement. Finally, the last case examines protecting residences on multiple streets that join a highway at a right angle. This common situation has the sides of two residences facing the highway between each street, with such a scenario meant to investigate barriers for a small group of residences and the effects of gaps in the barrier. In each analysis, the roadway was extended 500 ft beyond the end receivers, a point at which traffic noise no longer contributes to the overall results.

In an effort to identify which barrier dimensions are capable of achieving a substantial noise reduction for the maximum number of residences, parameters were varied to determine optimum height and width of a single barrier or a combination of barriers. These results were used to determine if the current cost-effectiveness criterion is a reasonable limit, and to identify what effect changes in the cost-effectiveness criterion would have.

COST-EFFECTIVENESS FOR RESIDENCES PROTECTED BY A LONG CONTINUOUS BARRIER

In a case in which the barrier is continuous for at least a few hundred feet, the only noise that reaches the residents on the other side is that which travels over the barrier. This type of barrier — the long continuous barrier — provides the most economical method of noise reduction. In many situations, however, it is necessary to leave gaps in the barrier for access, for drainage, or for other requirements. At the point where a barrier ends, noise can travel not only over the barrier, but also around the end. In such cases, the barrier needs to extend beyond the direct path from highway to residence to reduce the noise level of the sound coming around the side of the barrier. Figure 4.1 shows a model of a straight continuous highway, one end of a long continuous barrier, and multiple possible residence locations spaced in meters. Table 4.1 gives the results of the TNM modeling.

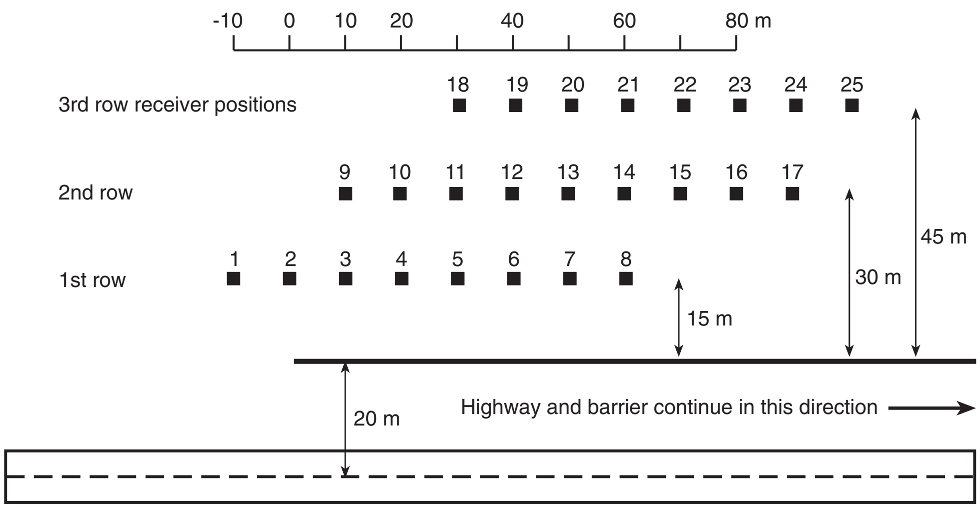

Figure 4.1. The end of a long continuous noise barrier and possible residence locations

This scenario was run with barrier height varied from 6.5 ft to 13 ft. Also, two different traffic cases were run: one with 80 percent automobiles, 10 percent medium trucks, and 10 percent heavy trucks; and a second with 100 percent automobiles and no trucks. The two traffic cases were designed to simulate a typical urban commercial highway and a residential boulevard. The residential locations furthest to the right for all rows in Figure 4.1 were far enough from the barrier end that they had an insertion loss typical for a barrier with no end.

TABLE 4.1. INSERTION LOSS AT RECEIVER POSITIONS IN FIGURE 4.1

Receiver	Noise Barrier Height (ft)						
	6.5		8		10	11.5	13
	Highway	Boulevard	Highway	Boulevard	Highway	Highway	Highway
1	0.6	0.6	0.8	0.7	0.8	0.9	0.9
2	1.8	1.8	2.1	2.1	2.3	2.4	2.5
3	3.4	3.6	4.1	4.2	4.5	4.7	**5.0**
4	4.3	4.5	**5.3**	**5.5**	**6.0**	**6.4**	**6.8**
5	4.7	4.9	**5.9**	**6.0**	**6.7**	**7.3**	**7.8**
6	4.8	**5.0**	**6.1**	**6.2**	**7.0**	**7.7**	**8.2**
7	4.9	**5.1**	**6.3**	**6.3**	**7.2**	**7.9**	**8.5**
8	4.9	**5.1**	**6.3**	**6.3**	**7.3**	**8.0**	**8.7**
9	1.9	2.2	2.5	2.7	2.9	3.2	3.4
10	2.5	2.7	3.3	3.3	3.8	4.2	4.5
11	2.8	3.1	3.8	3.9	4.5	**5.0**	**5.4**
12	3.0	3.2	4.1	4.2	4.9	**5.5**	**6.0**
13	3.1	3.4	4.3	4.4	**5.2**	**5.9**	**6.4**
14	3.2	3.4	4.4	4.4	**5.4**	**6.1**	**6.7**
15	3.2	3.4	4.5	4.4	**5.4**	**6.2**	**6.9**
16	3.2	3.5	4.5	4.6	**5.5**	**6.3**	**7.0**
17	3.2	3.4	4.5	4.5	**5.6**	**6.4**	**7.0**
18	1.8	2.0	2.6	2.6	3.2	3.7	4.1
19	2.0	2.2	2.9	2.9	3.6	4.1	4.6
20	2.1	2.3	3.1	3.1	3.8	4.5	**5.0**
21	2.1	2.4	3.2	3.2	4.0	4.7	**5.3**
22	2.2	2.4	3.3	3.2	4.1	4.9	**5.5**
23	2.2	2.4	3.3	3.3	4.2	**5.0**	**5.7**
24	2.2	2.4	3.4	3.3	4.3	**5.1**	**5.8**
25	2.3	2.5	3.4	3.3	4.3	**5.1**	**5.9**

The base case for a commercial highway and no barrier end achieved a noise reduction of 5 dB or greater for locations behind the barrier at 50 ft (15m), 100 ft (30m), and 150 ft (45m), with an 8, 10, and 11.5 ft high barrier, respectively. A 10 ft high barrier costs $270 per foot of length. Thus, residences up to 100 ft (30m)) from the barrier can be separated by up to 90 ft (27m) along the length of the barrier to stay at the $25,000 cost-effectiveness criterion. If the residences are nearer than 50 ft (15m) from the barrier, an 8 ft barrier will suffice at a cost of $216 per foot of length, in which case residences can then be up to 110 ft (33m) apart. The boulevard traffic case showed that for a 6.5 ft high barrier, residences receive a slightly higher insertion loss of approximately 0.2 dB, while the differences in insertion loss for a given barrier 8 ft or higher is nearly identical for the two traffic cases. Thus, for the boulevard traffic case, it is possible to achieve a 5 dB insertion loss with a 6.5 ft high barrier if the residences are 50 ft (15m) from the barrier. A 6.5 ft high barrier costs $176 per foot of length, and therefore, residences could be up to 135 ft (41m) apart and still meet the cost-effectiveness criterion. Residences farther out from the barrier had similar results in both the commercial highway and boulevard cases.

Near the end of the barrier, as expected, residences experience less insertion loss from noise coming around the barrier. Generally speaking, if the end of the barrier is at a 60° angle to the side of the residence location, then the insertion loss is within 1 dB of the level for a continuous barrier. This ratio is the same as the often quoted 4-to-1 rule, which says that a barrier should be four times longer than the distance from the barrier of the residence. The 4-to-1 rule results in extending both ends of the barrier to a 60° angle. For residence locations close to the barrier — in this example 50 ft (15m) — extending the barrier to a 50° angle is sufficient.

Depending on the height of the barrier, it is possible to achieve a substantial noise reduction (5 dB) with a shorter length barrier, but normally more barrier area is required thereby resulting in higher costs. For example, in the scenario of Figure 4.1, a 13 ft high barrier results in 5 dB or greater insertion loss for all shown possible residence locations except the first two on the left of each row. This height equates to an angle of about 45°, or about a 33 ft (10m) shorter length barrier to protect the same residences. In a design for residences at 100 ft (15m) from the barrier, 325 ft^2 of barrier is saved from the reduced length, while 860 ft^2 are added from the increased height. Materials and costs increase by about 20 percent for the last 300 ft (100m) of barrier. There is also the less tangible drawback of a barrier that is taller near the end, which may be aesthetically undesirable.

For the above reasons, the most economical approach to protect residences near a barrier end is to extend the barrier at the same height to about a 60° angle past the residence. The extra cost of extending the barrier is averaged into the cost of the entire barrier resulting in a barrier cost per residence that is higher than for the continuous barrier and is directly related to the number of residences protected. The single residence case is the limit of the finite length barrier scenarios and the most expensive per residence.

COST-EFFECTIVENESS FOR A SINGLE RESIDENCE PROTECTED BY A BARRIER

The single residence is usually the most difficult to protect from traffic noise using a barrier that stays within the cost-effectiveness criterion. That case was examined to determine what is required to protect a single residence and what are the costs. Figure 4.2 shows the model for the single residence barrier. Two rows of possible residence locations are shown. One row is at the center of the barrier length, and one is 33 ft (10m) to the right, both starting 15 ft (5m) and extending to 100 ft (30m) from the barrier. Table 4.2 shows the insertion loss predictions for several noise barrier heights.

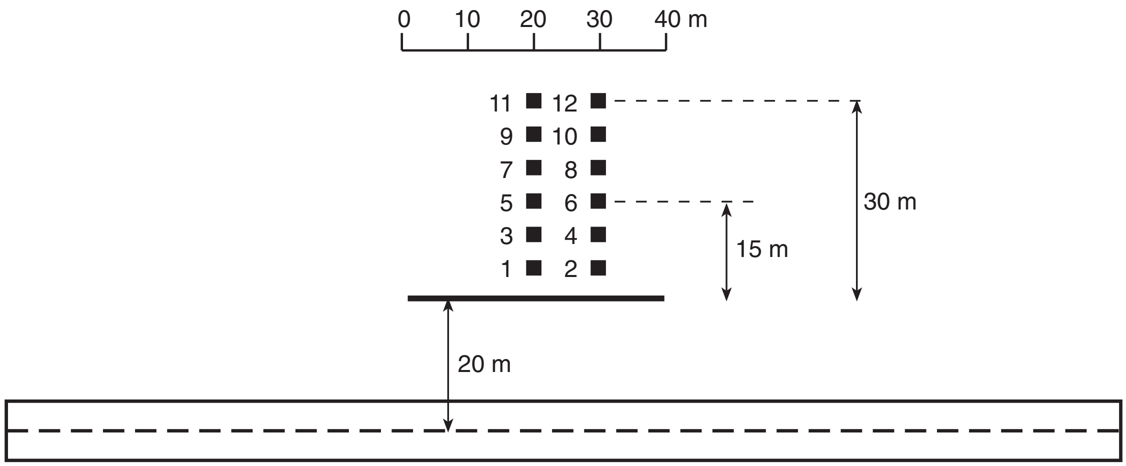

Figure 4.2. A noise barrier serving a single residence with possible residence locations

TABLE 4.2. INSERTION LOSS AT RECEIVER POSITIONS IN FIGURE 4.2

Receiver	Noise Barrier Height (ft)				
	6.5	8	10	11.5	13
1	**7.2**	**8.8**	**10.1**	**10.5**	**11.5**
2	**6.6**	**7.9**	**8.7**	**9.1**	**9.6**
3	**5.2**	**6.2**	**6.8**	**7.4**	**7.7**
4	4.4	**5.2**	**5.7**	**6.0**	**6.3**
5	3.9	4.6	**5.1**	**5.4**	**5.6**
6	3.3	3.9	4.3	4.5	4.7
7	2.9	3.5	3.9	4.2	4.4
8	2.5	3.0	3.3	3.5	3.6
9	2.4	2.9	3.3	3.5	3.6
10	2.0	2.5	2.8	3.0	3.1
11	1.9	2.4	2.7	2.9	3.1
12	1.7	2.1	2.4	2.5	2.7

The model predicted that for a 130 ft (40m) barrier a 5 dB insertion loss could be achieved on the line perpendicular to the center of the barrier out to 50 ft (15m) by using a 10 ft high barrier. Under those conditions, the position 33 ft (10m) to the right receives an insertion loss of slightly less than 5 dB. The result is that a residential area, such as a backyard, centered behind the barrier, is protected out to 50 ft (15m) and for a width of almost 65 ft (20m). Increasing the barrier height above 10 ft resulted in only a very small increase in insertion loss for all receiver positions. Similar to the case for noise reduction near the end of a continuous barrier, in the single residence case, the barrier must extend out to a 50° angle past the residence to achieve 5 dB of noise reduction. In this case, that means both sides, which results in a barrier slightly less than 3 times longer than the residence-to-barrier distance.

The resulting barrier is 130 ft (40m) long and 10 ft high, resulting in a cost of $36,000 — a figure 44 percent higher than the $25,000 cost-effectiveness criterion. If the residence area to be protected is only 33 ft (10m) from the barrier, a 8 ft high barrier will protect an area 65 ft (20m) wide. In that case, the cost will be $30,000, which is substantially less, yet still above the cost-effectiveness criterion. If the residence were farther from the barrier, say 80 ft (25m), the barrier would have to be 200 ft (60m) long and 12 ft high, costing $72,000.

These scenarios illustrate why it is difficult to stay within costs when protecting a single residence.

COST-EFFECTIVENESS FOR TWO OR THREE RESIDENCES PROTECTED BY A BARRIER

The next scenario examined is a noise barrier designed to protect two or three residences. Figure 4.3 shows a barrier 200 ft (60m) in length alongside a highway tangent, with several possible residences located behind the barrier. Six possible locations are at the barrier midpoint, while nine others are to the right of midpoint. Because of the symmetry of the layout, the insertion loss of points to the left of the midpoint can be surmised from those on the right. Table 4.3 provides the insertion loss predictions for this scenario.

A barrier 8 ft high provides a minimum of 5 dB protection for all locations out to the second row, or 33 ft (10m) from the barrier. This means two residences separated by about 100 ft (30m) could be protected out to 33 ft (10m) from the barrier. The cost per residence is then $22,500 — a figure safely within the cost-effectiveness criterion. If the same residences needed to be protected out to 50 ft (15m) from the wall, an 11.5 ft high barrier is required to protect the entire residential area, resulting in a cost per residence of $31,500. A less expensive option not shown in the table is to lengthen the barrier by 33 ft (10m), which would result in a cost per residence of $26,250. Alternately, as a compromise, a 10 ft high barrier would provide protection for the majority (but not all) of two 65 ft (20m) wide residential lots, resulting in a cost of $27,000 per resident. Clearly, if feasible, lengthening the barrier is the better choice. If the barrier cannot be lengthened because of a particular requirement (such as access), the barrier height must be increased, which would result in a cost somewhat over the $25,000. To protect residences separated by 65 ft (20m) to 100 ft 30m), the least expensive option would be to make the barrier at least 65 ft (10m) longer (260 ft (80m) total length), which would result in a cost-per-residence figure of $30,000.

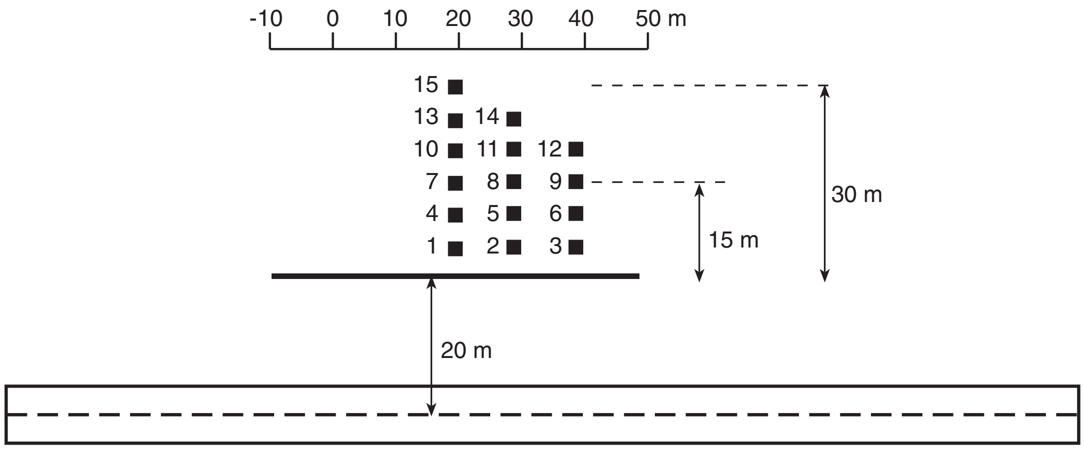

Figure 4.3. A noise barrier serving two or three residences with possible residence locations

TABLE 4.3. INSERTION LOSS AT RECEIVER POSITIONS IN FIGURE 4.3

Receiver	Noise Barrier Height (ft)				
	6.5	8	10	11.5	13
1	**7.5**	**9.2**	**10.6**	**11.3**	**12.3**
2	**7.3**	**9.0**	**10.3**	**11.0**	**11.9**
3	**6.6**	**7.9**	**8.8**	**9.3**	**9.8**
4	**5.6**	**7.0**	**7.8**	**8.6**	**9.1**
5	**5.4**	**6.7**	**7.5**	**8.1**	**8.6**
6	4.5	**5.3**	**5.8**	**6.2**	**6.5**
7	4.6	**5.7**	**6.4**	**6.9**	**7.3**
8	4.4	**5.4**	**6.0**	**6.4**	**6.7**
9	3.4	4.1	4.5	4.7	4.9
10	3.6	4.5	**5.2**	**5.6**	**5.9**
11	3.4	4.2	4.8	**5.2**	**5.4**
12	2.7	3.3	3.7	3.9	4.1
13	3.0	3.8	4.4	4.8	**5.1**
14	2.8	3.6	4.1	4.4	4.7
15	2.5	3.3	3.8	4.1	4.4

In general, for the two-residence case, it is possible to protect the residences and stay within the cost-effectiveness criterion, but only if the houses are separated by 100 ft or less and if the area to be protected is 50 ft (15m) or less from the barrier. For three residences in a row, the costs become more favorable. In fact, the costs begin to approach those for a continuous barrier. An 8 ft high, 330 ft (100m) long barrier can protect out to a distance of 50 ft (15m) three residences that have a lateral spacing of 100 ft (30m) or less. The cost per residence is $25,000.

For comparison, an 8 ft high continuous barrier costs $22,500 per residence. If three residences are to be protected out to a distance of 65 ft (20m), the barrier must be made 360 ft (108m) long with a resulting cost per residence of $27,500. Any additional residences in the row will add 100 ft (30m) of barrier at a cost of $22,500 per additional residence.

Of course, residences more closely spaced can result in cost-effective solutions. For example, houses closely spaced at 65 ft (20m) per house allow a 300 ft (100m) barrier to protect three residences at a cost of $22,500 per residence. The above results show that if residences can be protected in groups of three or more, the costs often can be kept within the $25,000 cost-effectiveness criterion.

COST-EFFECTIVENESS FOR RESIDENCES NEAR A GAP IN THE BARRIER

Up to this point, the cost-effectiveness of barriers has been considered for single barriers that protect any number of residences. The frequently encountered case of a gap in a barrier is now considered. The most common reason for a gap in a barrier is vehicle access, although other reasons, such as drainage requirements or terrain features, can also require a gap. The extent of the gap normally ranges from 33 ft (10m) for access to an alley to 100 ft (30m) for vehicle access and driver visibility requirements. The gap can always be assumed to degrade the performance of the barrier in comparison with a continuous barrier. Historically in Texas and in other states, access requirements represent a major reason why barriers are not considered to be either feasible or cost-effective and, consequently, why they are not installed. The following analysis indicates the degree of the degradation caused by a gap in the barrier, along with how the gap affects the project cost-effectiveness. A drawing of the analysis scenario is shown in Figure 4.4, and the results are given in Table 4.4.

The most obvious result of a gap in a barrier is the loss of protection for residences near the gap. With no gap and a 8 ft high barrier, residences located 50 ft (15m) and 100 ft (30m) behind the barrier receive 6.6 dB and 4.8 dB of noise reduction, respectively. This protection is greatly reduced for residences located directly behind the gap; although they do receive some protection from the barriers on either side of the 65 ft (20m) gap shown in Figure 4.4, noise reduction at receiver position 6 is 1.8 dB. For a 100 ft (30m) gap, that protection is reduced to 1 dB, while for a 33 ft (10m) gap the benefit rises to 3 dB. These figures result from the fact that the noise levels at the residences are the average of the noise coming from the entire length of the highway, not just from the part of the highway directly in front of the residence. The effect of the barrier is reduced as the distance from the barrier to the residence increases. For example, with a 65 ft (20m) long gap in a barrier 8 ft high in front of a residence, the difference between gap and no-gap is 4 dB at 50 ft (15m) behind the barrier and only 2 dB further back at 100 ft (30m) behind the barrier. This finding reflects the fact that, for locations farther back, the height of the barrier has a greater influence on the noise levels.

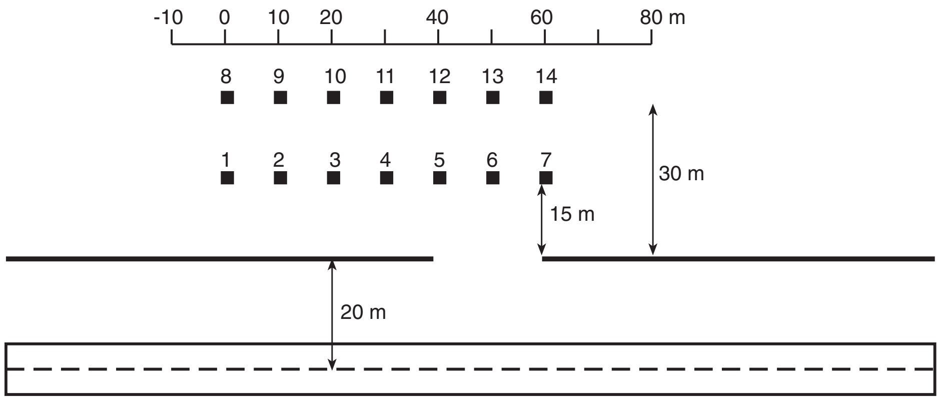

Figure 4.4. A noise barrier, continuous except for one gap, serving multiple residences with possible residence locations (shown with a 65 ft (20m) gap)

TABLE 4.4. INSERTION LOSS AT RECEIVER POSITIONS IN FIGURE 4.4

Receiver	Noise Barrier Height (ft)				
	6..5	8	10	11.5	13
1	4.9	**6.5**	**7.6**	**8.4**	**9.1**
2	4.7	**6.2**	**7.2**	**8.0**	**8.5**
3	4.3	**5.6**	**6.4**	**7.0**	**7.5**
4	3.6	4.5	**5.1**	**5.4**	**5.7**
5	2.2	2.7	3.0	3.2	3.3
6	1.5	1.8	2.0	2.2	2.3
7	2.2	2.7	3.0	3.2	3.3
8	3.1	4.6	**5.7**	**6.5**	**7.2**
9	2.9	4.2	**5.2**	**6.0**	**6.5**
10	2.7	3.8	4.7	**5.3**	**5.8**
11	2.3	3.3	4.0	4.4	4.8
12	1.9	2.7	3.3	3.6	3.9
13	1.9	2.6	3.1	3.4	3.7
14	2	2.8	3.3	3.7	4.0

As the length of the gap increases, the noise reduction results approach those obtained by analyzing the barriers as separate entities. As shown in Figure 4.5, for a 100 ft (30m) gap in a barrier 8 ft high, the residence location from the end of the barrier needs to be at about a 55° angle to the side. That is, a residence 50 ft (15m) behind the barrier needs to be 65 ft (20m) laterally from the gap. Recall that this distance is approximately the same as that relating to residences located near the end of a continuous barrier. Therefore, when a gap is over 100 ft (30m), the two sides of the barrier are basically separate and acoustically independent barriers. With a much smaller gap of 33 ft (10m), the two sides of the barrier provide mutual protection, such that 5 dB or greater insertion loss is received for a residence that is located only 35° to the side, or for 50 ft (15m) back, 33 ft (10m) to the side.

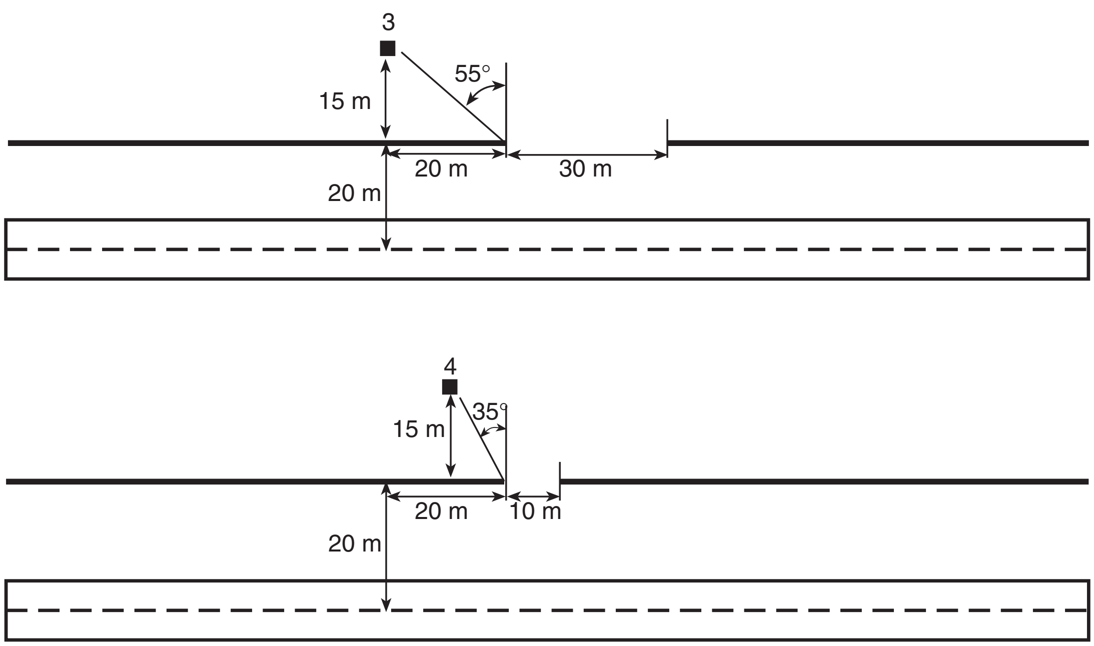

Figure 4.5. Protected area behind gap in barrier

The cost-effectiveness of a barrier with gaps is essentially the same as two separate barriers. Although, it might be possible to slightly reduce cost by using narrow gaps between barriers, that practice is highly discouraged due to the associated degradation of the acoustical benefits. Keeping the number of benefited residences high is important in keeping within the cost-effectiveness criterion. The loss of protection for residences near the gap reduces the ability of the barrier to be cost-effective.

COST-EFFECTIVENESS FOR THE CASE OF PROTECTING RESIDENTS ON STREETS THAT ACCESS THE HIGHWAY

Environmental engineers frequently encounter projects involving capacity improvement on a highway that is accessed by multiple residential streets. This case is illustrated in Figure 4.6. In this scenario, the engineer is faced with the task of reducing noise levels while providing access.

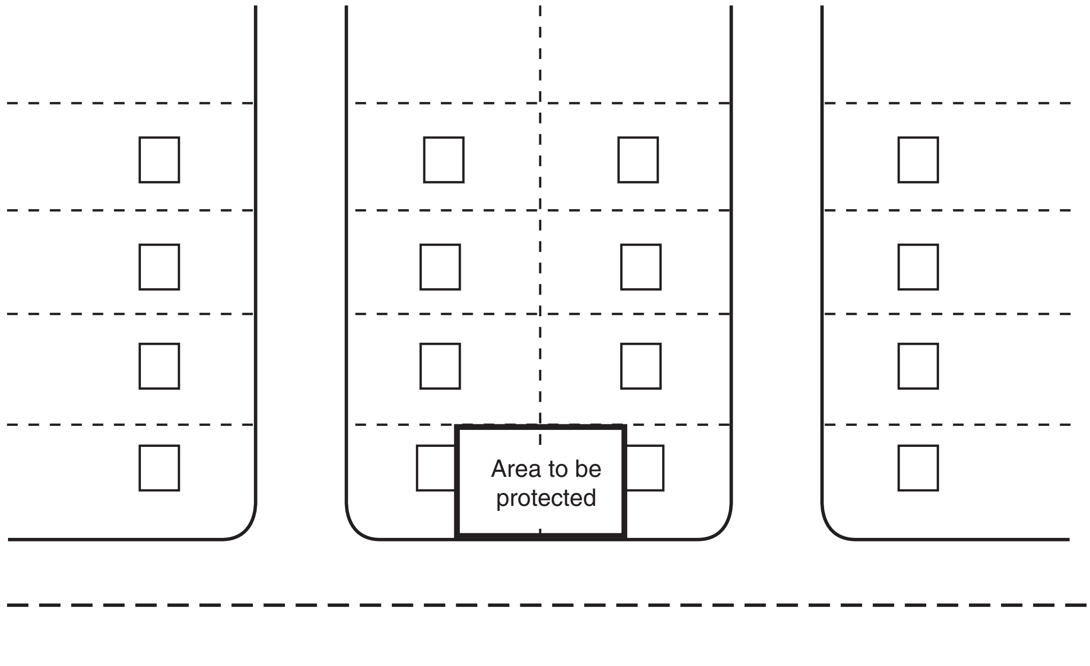

Figure 4.6. Illustration of residences on streets joining a highway

Often, the residences' backyards are considered the outdoor activity location that should be protected. A typical case would involve residential lots 165 ft (50m) deep and 100 ft (30m) wide. Such dimensions would normally put the two adjoining backyards for each pair of houses starting 80 ft (25m) from the side streets or access road, for a total protection area of 165 ft (50m) by 100 ft (30m), as shown in Figure 4.6. In order to provide sufficient line of sight for vehicles on the side street, it is normally advisable to have any noise barriers end 33 ft (10m) prior to the side street. For the distances given, each barrier would be 260 ft (80m) long, with a gap of approximately 100 ft (30m) between barriers.

Given such a large gap, the barriers protecting each pair of houses in the first row can be analyzed separately. Because the houses themselves provide some protection on the sides, to reduce costs the barrier can be somewhat shorter length and still protect the backyards. For this case an 8 ft high and 215 ft (65m) long barrier will work at a cost per resident of $24,750. The receiver and barrier locations are shown in Figure 4.7, while the results of the calculations are given in Table 4.5. The barrier provides at least 5 dB of insertion loss at backyard receivers out to 80 ft (25m) from the barrier. Note that some receiver locations near the house (locations 12 and 15) are shielded from highway noise by the structure of the house. These receiver locations already have a significant noise reduction and are little affected by the barrier.

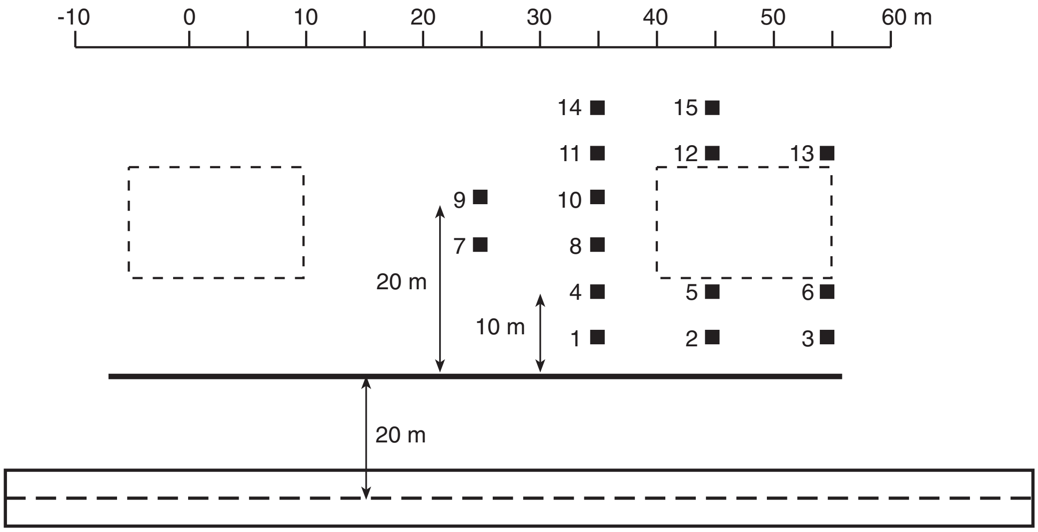

Figure 4.7. Receiver and barrier locations for two residences on streets joining a highway

Unfortunately, many similar cases also require access for an alley between the two backyards. Such access destroys the protection for the backyard. In those cases, it is almost always impossible to provide cost-effective protection.

TABLE 4.5. NOISE LEVELS AND INSERTION LOSS FOR RESIDENCES IN FIGURE 4.6 FOR A 8 ft HIGH BARRIER, 215 ft LONG

Receiver	Noise Level Without Barrier	Noise Level with Barrier	Insertion Loss
1	73.1	63.9	**9.2**
2	73.1	64.6	**8.5**
3	73.1	68.4	4.7
4	71.2	64.3	**6.9**
5	71.2	65.2	**6.0**
6	71.2	67.9	3.3
7	69.9	64.0	**5.9**
8	69.7	63.6	**6.1**
9	68.4	62.8	**5.6**
10	67.7	62.3	**5.4**
11	66.1	60.9	**5.2**
12	48.5	48.5	0
13	64.7	64.3	0.4
14	64.9	60.6	4.3
15	61.1	59.1	2.0

SUMMARY OF THE RESULTS FROM THE EXAMPLE TNM CALCULATIONS

The results of the five different TNM calculations are consistent with the records of actual cases in Texas presented in the previous chapter. In brief, the results indicated the following:

1. A long continuous barrier is the most cost-effective barrier.
2. Isolated single or double residences can be protected while staying within the cost-effectiveness criterion only under ideal conditions.
3. A gap in a barrier for access causes a significant reduction in barrier effectiveness.
4. The cost-effectiveness criterion of $25,000 per benefited receiver is a valid measure of the cost-effectiveness of noise barriers for the typical residential layouts in Texas.

CHAPTER 5. CONCLUSIONS AND RECOMMENDATIONS

Previous chapters have evaluated the cost-effectiveness criterion by examining state guidance, by reviewing historical noise barrier construction data, and by modeling typical noise impact scenarios using the latest FHWA noise model. States were surveyed for information on their cost-effectiveness criteria and their noise barrier construction history. This information was then compared with Texas data to determine how the cost-effectiveness criterion used by Texas compares with that used by the other states, in particular those states that have completed substantial noise barrier construction. The historical results in Texas for all noise barrier construction and several specific case histories in relation to cost-effectiveness were examined to determine the major causes for noise barrier build or no-build decisions, as well as what effect changes in the cost-effectiveness criterion would have on those decisions. Finally, typical highway noise mitigation project scenarios were modeled with TNM to precisely determine what level of noise mitigation could be achieved with the current and modified cost-effectiveness criterion. Based on the results of this investigation, conclusions and recommendations are presented in an effort to set and evaluate the cost-effectiveness criterion.

CONCLUSIONS

The results of this investigation indicate that Texas is able to provide noise abatement for impacted residences at a level slightly higher than the median of the ten states having the most barrier construction. Texas has a median cost-effectiveness criterion that is slightly above average when adjusted for local construction costs. In Texas, based on historical construction data and on the cost-effectiveness criterion, the length of noise barrier that can be constructed per benefited residence is slightly above the average for the ten most active states. In other words, on average, when compared with residents in other states, a Texas resident impacted by new highway construction is slightly more likely to receive some noise abatement from the construction of a noise barrier.

This examination of the application of the cost-effectiveness criterion in Texas has shown that in most cases in which noise mitigation is feasible, it can be accomplished within the costs specified by the criterion. In the vast majority of cases in which noise barriers were not constructed, access requirements were the main reason for the no-build decision. Exceeding the cost-effectiveness criterion was the second major reason for not building a noise barrier. In many of the cases, the costs were so high that even a higher cost-effectiveness criterion would not have resulted in a build decision.

Specific cases have shown that when multiple residences can be protected by a single barrier, the cost per residence is typically well within the cost-effectiveness criterion. In cases in which a barrier is used to protect only one or two residences, the barrier is invariably more expensive per residence and will typically exceed the cost-effectiveness criterion.

The results of the five different TNM calculations are consistent with the records of actual cases in Texas. The TNM calculations showed that when closely located residences are protected by a single continuous barrier, costs are typically well within the cost-effectiveness criterion.

RECOMMENDATIONS

1) There is no indication or evidence at this time that the cost-effectiveness criterion of $25,000 should be adjusted either higher or lower.

2) The suitability of the cost-effectiveness criterion should be evaluated every 5 years. If local construction costs change significantly, evaluations could be made more often. Such an evaluation need not be a formal project, but could be accomplished through informal investigation by the staff at TxDOT's Environmental Affairs Division (ENV). To assist in this evaluation, several tasks are recommended:

   a) Complete records of TxDOT traffic noise analyses, including tables of the model results and detailed maps of the receiver and recommended barrier locations, should be maintained at TxDOT/ENV.

   b) The barrier construction activity of other states should be monitored for any trends in the use of their cost-effectiveness criteria. Toward this goal, it is important that TxDOT/ENV maintain close liaison with noise representatives from state highway agencies nationwide.

   c) A comprehensive database of TxDOT's completed noise barriers should also be maintained in TxDOT/ENV. This database should include overall design characteristics/specifications for each noise barrier, an evaluation of noise level reductions achieved by each of the various types of noise barriers, and a summary of any associated lessons learned.

REFERENCES

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2. "Guidelines for Analysis and Abatement of Highway Traffic Noise," Texas Department of Transportation (TxDOT), June 1996.
3. Means, R. S., "Building Construction Cost Data," 55th Annual Edition, R. S. Means Company, Inc., 1996.
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APPENDIX A

DETAILED SUMMARY OF HIGHWAY NOISE MITIGATION ANALYSIS FROM ENVIRONMENTAL IMPACT STUDIES FOR HIGHWAY CAPACITY IMPROVEMENT PROJECTS IN TEXAS

Table A.1 shows the consolidated data for the noise impact studies resulting in no-build decisions, while Table A.2 shows the consolidated data for the build cases. These tables are an expansion of the data presented in Chapter 3, Tables 3.1 and 3.2. In Table A.1 each individual case that resulted in a no-build decision is listed with the reason given for the decision. In Table A.2 — the list of build cases — the information on each case is expanded to give detailed information on all the individual barriers that were recommended for construction. The data in these tables were obtained from records maintained at the Environmental Affairs Office (ENV) of the Texas Department of Transportation (TxDOT).

TABLE A.1. DETAILED SUMMARY OF CASES RESULTING IN NO-BUILD DECISIONS

District	County	Case	Highway	Reason for No-Build		
				High Cost	Access Required	Low Noise Level
Atlanta	Upshur	0392-02-056	US 259		X	
Atlanta	Bowie	0010-13-058	US 67		X	
Atlanta	Cass	0062-04-037	US 59		X	
Atlanta	Harrison	0402-040-19	SH 154		X	
Austin	Travis	0113-03-072	US 290/SH 71		X	
Austin	Hays	0061-03-064	IH-35		X	
Austin	Travis	0062-04-037	US 59	X		
Beaumont	Orange	0306-01-041	SH 87		X	
Beaumont	Orange	0028-09-087	IH-10		X	
Beaumont	Jasper	0065-03-030	US 96		X	
Beaumont	Orange	0710-02-044	FM 105		X	
Beaumont	Jefferson	1075-01-009	Spur 93		X	
Beaumont	Jefferson	1075-01-011	Spur 93		X	
Beaumont	Hardin	0200-09-063	US 69		X	
Beaumont	Jasper	0244-03-039	US 190			X
Bryan	Brazos	0017-02-028	SH 21		X	
Bryan	Brazos	0117-01-023	SH 21		X	
Bryan	Brazos	0116-04-067	SH 21		X	
Bryan	Washington	0315-07-010	SH 105		X	

TABLE A.1. (CONTINUED)

District	County	Case	Highway	Reason for No-Build		
				High Cost	Access Required	Low Noise Level
Bryan	Brazos	0050-01-060	BS 6		X	
Corpus Christi	Aransas	0180-04-054	SH 35		X	
Corpus Christi	San Patricio	3026-01-015	FM 2986		X	
Corpus Christi	Nueces	0916-35-041	Greenwood		X	
Corpus Christi	Nueces	0102-01-083	SH 44		X	
Corpus Christi	Nueces	0373-01-031	US 77	X	X	
Dallas	Dallas	2964-01-014	SH 161, 183		X	
Dallas	Dallas	0581-01-090	Loop 12		X	
Dallas	Denton	0196-02-078	IH-35E			X
Dallas	Dallas	1068-04-092	IH-30		X	
Dallas	Dallas	0092-02-090	IH-45		X	
Dallas	Dallas	0047-07-176	US 75		X	
Dallas	Collin	N/A	Dallas N. Toll.	X		
Dallas	Ellis	0172-04-028	US 287	X		
Dallas	Denton	0135-10-023	US 380		X	
Dallas	Rockwall	0009-04-039	SH 66	X		
Dallas	Dallas	2374-01-069	IH 635,US 75	OPPOSED BY PUBLIC		
Dallas	Dallas	0095-02-085	US 80		X	
Dallas	Kaufman	1091-02-012	FM 740/FM 548		X	
Dallas	Dallas	2964-03-006	SH 190		X	
Dallas	Dallas	0918-45-243	Marshall	X		
Dallas	Collin	0364-03-067	SH 121		X	
Dallas	Collin	0135-03-029	US 380		X	
Dallas	Dallas	0048-01-035	Corinth		X	
Dallas	Dallas	0918-45-222	Keller Springs		X	
Dallas	Dallas	0430-01-034	SH 352		X	
Dallas	Denton	0353-02-055	SH 114		X	
Dallas	Dallas	0196-06-017	Harry Hines		X	
Dallas	Dallas	0353-05-083	Loop 12		X	
Dallas	Dallas	0442-02-087	IH-35E	X		
Dallas	Dallas	8050-18-027	Belt Line		X	
Dallas	Dallas	0009-11-167	IH 30		X	
Dallas	Collin	0135-11-012	US 380		X	
Dallas	Collin	0619-03-034	FM 544		X	
Dallas	Navarro	0092-06-083	IH-45		X	
Dallas	Collin	0047-06-089	US 75		X	

TABLE A.1. (CONTINUED)

District	County	Case	Highway	Reason for No-Build		
				High Cost	Access Required	Low Noise Level
Dallas	Collin	0047-09-019	SH 5	X		
Dallas	Dallas	8075-18-006	Sp Valley Centennial	X		
Dallas	Rockwall	1014-03-033	FM 740		X	
Dallas	Collin	2056-01-024	FM 2170		X	
Dallas	Collin	8014-18-001	FM 2478	X		
Dallas	Collin	0091-05-029	SH 289	X		
Dallas	Dallas	8050-18-034	Belt Line		X	
El Paso	El Paso	3592-01-001	Artcraft	X		
El Paso	El Paso	3451-01-012	FM 1281		X	
El Paso	El Paso	0374-02-050	US 62/180		X	
El Paso	El Paso	3572-01-001	FM 3500		X	
El Paso	El Paso	2121-01-046	IH-10	X		
Fort Worth	Tarrant	0172-01-042	East Rosedale		X	
Fort Worth	Hood	0080-08-017	FM 4		X	
Fort Worth	Tarrant	0902-48-188	Handley-Ederville		X	
Fort Worth	Tarrant	0902-48-195	Wilson		X	
Fort Worth	Tarrant	0902-48-189	Broadway		X	
Fort Worth	Wise	0134-07-044	US 380		X	
Fort Worth	Johnson	0260-01-034	US 67		X	
Fort Worth	Tarrant	8649-02-004	East Rosedale		X	
Fort Worth	Tarrant	8648-02-011	Rosedale		X	
Fort Worth	Erath	0079-05-033	US 67/377		X	
Fort Worth	Tarrant	8352-02-001	Debbie		X	
Fort Worth	Tarrant	0094-02-075	SH 10		X	
Houston	Galveston	1607-02-008	FM 1764		X	
Houston	Harris	1685-02-033	FM 1960		X	
Houston	Harris	8170-12-003	Hempstead		X	
Houston	Harris	0912-71-532	Ley		X	
Houston	Harris	0508-01-218	IH-10		X	
Houston	Fort Bend	0027-12-062	US 59S		X	
Houston	Brazoria	0111-08-089	SH 288		X	
Houston	Harris	8144-21-006	Mykawa		X	
Houston	Harris	8004-12-003	Little York		X	
Houston	Brazoria	0179-01-028	SH 35		X	

TABLE A.1. (CONTINUED)

District	County	Case	Highway	Reason for No-Build		
				High Cost	Access Required	Low Noise Level
Houston	Fort Bend	0027-12-088	US 59S		X	
Laredo	Maverick	0276-09-005	FM 3443		X	
Laredo	Maverick	0299-13-009	Bus 277N		X	
Laredo	Maverick	0299-04-042	US 277		X	
Laredo	Webb	0086-01-042	SH 359		X	
Laredo	Webb	0086-14-015	Loop 20		X	
Lufkin	Angelina	0176-03-097	US 59	X		
Lufkin	Polk	0176-04-056	US 59	X		
Lufkin	Angelina	2553-01-067	US 59		X	
Lufkin	Shelby	0175-01-005	US 84	X		
Odessa	Ector	0906-06-022	University		X	
Paris	Franklin	0190-01-021	SH 37		X	
Paris	Grayson	2453-02-010	FM 1417		X	
Paris	Fannin	0045-20-004	US 82		X	
Pharr	Hidalgo	0039-04-082	Bus 83		X	
Pharr	Hidalgo	0921-02-901	Trenton		X	
Pharr	Cameron	2717-01-013	FM 3248		X	
Pharr	Hidalgo	2094-01-029	FM 2220		X	
Pharr	Cameron	1140-01-014	FM 802		X	
Pharr	Cameron	0220-04-030	US 281		X	
Pharr	Brooks	0255-03-021	US 281		X	
Pharr	Cameron	0873-01-020	FM 507		X	
Pharr	Hidalgo	0865-01-065	FM 495		X	
Pharr	Hidalgo	1429-02-020	FM 1426		X	
Pharr	Cameron	0339-19-033	US 83		X	
Pharr	Hidalgo	1228-03-015	FM 1015		X	
Pharr	Hidalgo	0039-17-118	US 83		X	
Pharr	Hidalgo	0865-01-063	FM 495		X	
Pharr	Cameron	1425-03-037	FM 106		X	
Pharr	Hidalgo	0621-01-058	SH 336		X	
San Angelo	Tom Green	0069-07-080	US 87		X	
San Angelo	Tom Green	0077-06-064	US 67		X	
San Angelo	Menard	0035-05-042	US 83		X	
San Antonio	Comal	0016-05-088	IH-35	X		
San Antonio	Guadalupe	0216-02-028	SH 46	X		
San Antonio	Bexar	2452-01-021	Loop 1604	X		

TABLE A.1. (CONTINUED)

District	County	Case	Highway	Reason for No-Build		
				High Cost	Access Required	Low Noise Level
San Antonio	Bexar	0521-03-049	Loop 13			X
San Antonio	Bexar	0915-12-122	Eisenhauer		X	
San Antonio	Bexar	0915-12-170	Montgomery		X	
San Antonio	Bexar	0915-12-161	Hildebrand	X		
San Antonio	Bexar	1478-01-007	FM 1517	X		
Tyler	Smith	2075-02-033	Loop 323		X	
Tyler	Henderson	0697-02-028	SH 334		X	
Tyler	Smith	0492-01-020	FM 14		X	
Waco	McLennan	0258-09-092	SH 6/Loop 340		X	
Waco	Coryell	0231-02-035	Copperas Cove	X		
Waco	Bell	0836-02-044	SH 195		X	
Waco	Hill	0121-03-048	SH 22		X	
Waco	McLennan	0833-03-027	FM 1637		X	
Waco	McLennan	0209-01-046	US 77		X	
Waco	Bell	2304-02-027	FM 2410		X	
Waco	McLennan	0049-01-061	SH 6		X	
Waco	Bell	0836-02-028	SH 195		X	
Waco	Bell	1835-02-036	FM 1741		X	
Yoakum	Wharton	1412-03-029	FM 1301		X	
Yoakum	Calhoun	0179-10-092	SH 35		X	
Yoakum	Calhoun	0144-03-029	US 87		X	
Yoakum	DeWitt	0269-04-030	US 77		X	
Yoakum	Gonzales	0025-07-049	SH 97		X	

TABLE A.2. SUMMARY OF CASES RESULTING IN BUILD DECISIONS

District	County	Case Number	Highway	Barrier Number	Number of Benefited Residences	Length (ft)	Height (ft)	Cost ($)	Cost per Benefited Residence ($)
Corpus Christi	Nueces	3596-01-002	Ennis Joslin	1	11	1565	10	234,614	21,329
				2	10	574	10	86,088	8,607
				Total	21	2139		320,702	15,271
Dallas	Dallas	1047-02-022	FM 1382	1	11	1115	12	248,400	22,582
				2	9	515	10	92,700	10,300
				3	11	945	8	131,760	11,978
				4	13	1296	10	233,100	17,931
				5	6	633	12	136,950	22,825
				Total	50	4505		842,910	
Dallas	Denton	3088-01-015	FM 3040	1	18	1640	7	206,640	11,480
				2	22	1969	7	247,968	11,271
				3	10	1312	7	165,312	16,531
				Total	50	4921		169,920	
Dallas	Dallas	0918-45-190	Jupiter	1	24	374	10	54,720	2,280
				2	6	344	9	46,200	7,700
				3	5	390	11	63,800	12,760
				Total	35	1109		164,720	
Dallas	Denton	0353-02-027	SH 114	1	50	2244	12	561,000	11,220
Dallas	Dallas	1047-03-038	FM 1382	9	53	5036	?	906,300	17,100
Dallas	Collin	0918-24-047	Plano Pky	1	10	820	10	147,600	14,760
Dallas	Collin	0281-02-035	SH 78	1	7	400	9	54,135	7,734
				2	16	801	9	108,000	6,750
				Total	23	1201		162,135	
Dallas	Dallas	-	SH 190	1	34	3402	9	550,800	16,200
				2	30	2100	9	340,200	11,340
				3	13	1900	9	307,800	23,677
				4	17	1699	9	275,400	16,200
				5	29	2402	9	388,800	13,407
				6	15	1699	9	275,400	18,360
				7	27	2500	12	540,000	20,000
				8	40	3602	15	972,000	24,300
				9	31	2802	15	756,000	24,387
				10	32	2300	15	621,000	19,406
				11	152	5200	15	1,404,000	9,237

TABLE A.2. (CONTINUED)

District	County	Case Number	Highway	Barrier Number	Number of Benefited Residences	Length (ft)	Height (ft)	Cost	Cost per Benefited Residence
				12	24	1400	15	378,000	15,750
				13	48	2200	15	594,000	12,375
				14	48	1900	15	513,000	10,688
				15	128	5600	12	1,209,600	9,450
				Total	668	40700		9,126,000	
Dallas	Ellis	0048-03-049	US 77	N/A					
Dallas	Dallas	0581-01-068	Loop 12	1	Apts	620	9	84,000	
Dallas	Collin	8024-18-002	Spring Cr.	1	12	663	8	95,328	7,944
				2A	8	417	8	80,192	10,024
				2B	8	315	8	45,360	5,670
				2C	8	226	8	32,544	4,068
				3	12	377	8	81,648	6,804
				4	12	636	8	91,584	7,632
				5	24	1302	8	187,632	7,818
				6	24	410	8	59,040	2,460
				7	15	807	10	145,080	9,672
				Total	123	5154		818,408	
Dallas	Dallas	0009-03-025	SH 66	1	9	869	12	187,920	20,880
Fort Worth	Tarrant	0171-04-035	SH 199	1	11	951	10	190,000	17,273
				2	12	984	10	196,600	16,383
				Total	23	1936		386,600	
Fort Worth	Tarrant	0014-16-189	IH-35W	1	18	561	16	161,568	8,976
Fort Worth	Tarrant	8679-02-003	Gr. Oaks	1	5	420	8	67,200	13,440
				2	13	971	8	155,200	11,938
				3	3	351	8	56,000	18,667
				4	3	279	8	44,800	14,933
				5	1	108	8	17,600	17,600
				6	2	230	8	36,800	18,400
				7	2	230	8	36,000	18,000
				8	4	518	8	83,200	20,800
				9	2	200	8	32,000	16,000
				10	14	1030	8	164,800	11,771
				11	7	591	8	94,400	13,486

TABLE A.2. (CONTINUED)

District	County	Case Number	Highway	Barrier Number	Number of Benefited Residences	Length (ft)	Height (ft)	Cost	Cost per Benefited Residence
				12	3	240	8	38,400	12,800
				13	5	479	8	76,800	15,360
				14	1	98	8	16,000	16,000
				15	2	180	8	28,800	14,400
				16	5	459	8	73,600	14,720
				17	1	141	8	22,400	22,400
				18	4	328	8	52,800	13,200
				19	2	210	8	33,600	16,800
				20	2	220	8	35,200	17,600
				21	4	299	8	48,000	12,000
				22	1	98	8	16,000	16,000
				23	1	98	8	16,000	16,000
				Total	87	7779		1,245,600	14,317
Fort Worth	Tarrant	0353-07-012	BUS 114	1	6	249	6	35,500	5,917
Fort Worth	Tarrant	0902-48-964	Arkansas - Bowen	1	4	312	6	33,480	8,370
				2	10	669	7	84,420	8,442
				3	1	98	6	10,800	10,800
				4	2	240	6	25,920	12,960
				5	1	98	8	14,400	14,400
				6	3	361	6	38,880	12,960
				7	1	112	7	13,860	13,860
				8	2	220	7	27,720	13,860
				9	8	361	6	38,880	4,860
				10	2	279	6	30,240	15,120
				11	1	98	6	10,800	10,800
				12	4	161	6	17,280	4,320
				13	2	269	8	38,880	19,440
				14	2	299	8	43,200	21,600
				15	3	325	7	40,900	13,633
				16	1	144	6	15,660	15,660
				17	1	69	7	8,820	8,820
				18	1	131	7	16,380	16,380
				19	2	210	6	22,680	11,340
				Total	51	4455		533,200	10,455

TABLE A.2. (CONTINUED)

District	County	Case Number	Highway	Barrier Number	Number of Benefited Residences	Length (ft)	Height (ft)	Cost	Cost per Benefited Residence
Houston	Harris	0271-17-063	IH 610W	1	19	2641	16	422,400	22,232
				2	16	2208	16	364,000	22,750
				3	8	1040	16	166,400	20,800
				4	6	440	16	70,400	11,733
				5	School	1572	14	219,800	NA
				6	School	741	14	103,600	NA
				7	7	1040	16	166,400	23,771
				8	23	2628	16	420,800	18,296
				9	17	2047	18	369,000	21,706
				10	11	1119	18	201,600	18,327
Houston	Fort Bend	0912-34-070	Dairy Ashford	1	4	315	10	41,075	10,269
				2	5	318	10	41,502	8,300
				3	4	400	8	37,033	9,258
				4	2	171	8	15,785	7,892
				5	17	925	8	85,602	5,035
				6	1	85	8	7,892	7,892
				7	15	778	8	71,942	4,796
				8	10	587	8	54,336	5,434
				9	8	597	8	55,246	6,906
				10	10	955	8	88,334	8,833
				11	6	571	8	52,818	8,803
				Total	82	5702		551,565	
Houston	Fort Bend	0912-34-069	West Airport	1	2	272	8	25,195	12,597
				2	4	472	8	43,711	10,928
				3	9	876	8	81,048	9,005
				4	5	423	8	39,158	7,832
				5	5	361	8	33,391	6,678
				6	13	1273	8	117,778	9,060
				7	16	1388	8	128,402	8,025
				8	5	410	8	37,944	,7589
				Total	59	5476			
San Antonio	Guadalupe	0521-04-187	IH 410	1	24	7087	11	403,920	16,830