Method To Determine Reasonableness and Feasibility of Noise Abatement at Special Use Locations

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Most states have policies in place that determine whether noise abatement is necessary and reasonable/feasible for Type I projects. These policies mirror federal guidance and apply to various land uses near the proposed project. Special land use facilities such as parks, churches, and schools are included in the policy as far as when abatement may be necessary (i.e., FHWA noise abatement criteria), but the determination of whether the abatement is reasonable or feasible may not be adequately addressed. A survey of state Departments of Transportation (DOTs) indicated that states are dealing with this need for reasonable/feasible determination for special land uses but do not have formal policies in place to address the issue. A systematic procedure would eliminate arbitrary decisions. A methodology developed for the Florida DOT to aid in the development of a procedure for special land use cases is presented. This methodology includes a feasibility flowchart that leads an individual through the process of determining whether abatement at a special land use site is feasible. The feasibility flowchart directs the individual to cease analysis because abatement is not feasible or to continue onto a reasonableness worksheet that determines whether abatement at the site is reasonable. The reasonableness worksheet leads the individual through site-specific calculations to derive an "abatement cost factor" used to determine reasonableness of abatement at the site.

Most states have policies in place that determine whether noise abatement is necessary and reasonable/feasible for Type I projects. These policies mirror federal guidance and apply to various land uses near the proposed project. Special land use facilities such as parks, churches, and schools are included in the policy as far as when abatement may be necessary (i.e., FHWA noise abatement criteria), but the determination of whether the abatement is reasonable or feasible may not be adequately addressed. A survey of state Departments of Transportation (DOTs) indicated that states are dealing with this need for reasonable/feasible determination for special land uses but do not have formal policies in place to address the issue. Often, it may be feasible to provide abatement for these special land uses but is it reasonable to use limited funds for noise abatement? A systematic procedure would eliminate arbitrary decisions.

The purpose of this research was to develop a methodology for the Florida DOT (FDOT) that would help it develop a procedure for special land use cases. The proposed procedure will provide a decision process by using a systematic approach to determine whether abatement is reasonable for special land uses. The development process of the reasonableness worksheet for special land uses is explained and an overview of the finalized policy along with details concerning the development of the methodology is presented.

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TECHNICAL SUMMARY

Survey

The first phase of methodology development was to assess the current state policies on special land use. This was accomplished by mailing a survey to noise representatives from each state DOT. Additional surveys were mailed to other groups and individuals to develop more insight into the problem. For nonresponding state DOTs, follow-up telephone calls were made requesting completion of the survey. Table 1 presents a summary of the survey questions.

The survey was designed to determine whether any formal policies on special land use existed. If there were none, the survey sought to ascertain what the respondents considered to be key items for a policy of this type. For example, Question 7 of the survey asked the respondents to choose from a list of items they considered to be important when determining abatement feasibility and reasonableness. Question 8 asked the respondents to rank the items they chose in Question 7. Question 8 was later used as a key indicator of which items should be included in the feasible/reasonable determination for special land uses. The survey also asked the respondents to provide some methodology for the items they chose as most important for this task. This information was invaluable in development of a worksheet and methodology to assess the feasibility/reasonableness of a special land use site.

Survey Response

Thirty-five states responded to the survey along with three environmental professionals. Results from two survey questions are presented in Table 2.

Table 2 indicates that about one-half of the states are coping with the problem and the other one-half are having difficulties; it shows there may be a need for a formal noise-abatement policy for special land uses. Four states reported they had a formal policy for special land uses, but upon review of their policies it was found that the policies were actually for residences. No states currently have a formal policy for special land uses and the majority of states responding have had difficulty in determining reasonableness for these land uses. Twenty-seven respondents did not answer the question of how they determined reasonableness/feasibleness of special land uses. The remainder of the respondents generally stated that they evaluated special land use sites on a case by case basis.

Question 8 of the survey asked the respondents to list what they believed to be the top three criteria for determining abatement reasonableness. Table 3 presents a summary of the responses to this question.

TABLE 1 Summary of Survey Questions

Number	Question
1	Has your agency had trouble identifying the appropriate procedure for determining if abatement is reasonable and feasible for special land uses in the past?
2	In your opinion, what are the key details in determining if abatement is reasonable and feasible for special land uses?
3	Has any formal policy been established by your agency to determine if special land use noise abatement is reasonable and/or feasible?
4	Would you supply a copy of this document to the research team?
5	What is the name of this document?
6	How has your agency handled determination of reasonable and feasible noise abatement for special land uses?
7	In your opinion, what are reasonable and feasible indicators for determining if noise abatement is needed for special land uses? [Check all that apply.] Cost, Noise Abatement Criteria, Land Use, Noise Level Increase, Facility Type, New Developments, Time of Use, Amount of Use, Type of Use, Developed After Highway
8	Which are the most important three items listed in Question number 7?
9	For the items checked or listed in Question number 7, how would these be used in determining reasonable and feasible abatement strategies for special land uses?
10	Are you aware of any information (studies, documents, reports, etc.) that may be helpful in determining if abatement is reasonable and/or feasible for special land uses?

Table 3 indicates that the respondents consider abatement cost to be the most important criteria for reasonableness. Whether the site approaches or exceeds noise-abatement criteria levels received the second highest response, followed by noise level increase. The land use of the site and the amount of time the site was used were also mentioned by several respondents as important items. Several respondents stressed the importance of the issue of site development after date of public knowledge of the transportation project and its relevance to reasonableness. Question 9 asked the respondents to suggest a methodology to determine reasonableness for the top items they selected in Question 8. These top items and the suggested methodologies were incorporated in the development of the feasible/reasonable decision process as described below.

Development of Methodology

The results presented in Table 3 and the suggested methodologies from Question 9 were used as a starting point to develop the feasible/reasonableness methodology. In addition, 15 states provided their reasonable/feasible policies for residences. The residence policies of the 15 states were reviewed and summarized along with the responses to other survey questions. These state policies identified several common themes among states such as barrier cost per benefited receiver. Some state policies included reasonableness items that may also be applicable to a special land use policy. The guidance of existing state and federal policies, the survey responses, and the guidance provided by the FHWA regulations (Code of Federal Regulations Part 772, 23CFR772) were used along with the guidance of FDOT and the authors' experience to develop the feasibility flowchart and reasonableness worksheet for special land uses indicated in Figure 1.

Abatement cost had the highest priority according to the survey when considering reasonableness. The first draft methodology contained a cost value that included many considerations and concepts such as amount of use at the special facility, size of a barrier necessary to abate the traffic noise, and activity areas protected. This led to a cost scheme that takes into account the time that people actually use the site, considers the areas receiving significant abatement, and equates a cost to the barrier size. The result of this led to development of a special land use "abatement cost factor."

The methodology of determining the abatement cost factor uses currently accepted residential abatement cost scenarios in scenarios and extrapolates that information into a cost for special land use sites. Development of the abatement cost factor followed these steps:

1. Use FDOT accepted barrier cost per residence ($30,000).
2. Assume residences are used 24 h/day.
3. Determine average frontage of a residence (30.5 m; 100 ft).

TABLE 2 State Survey Responses

Question	Yes	No
Has your state had difficulty in determining reasonableness for special land uses?	18	17
Does your state have a policy for special land uses?	4[a]	31

[a]These policies were determined to be for residences.

TABLE 3 Top Criteria for Abatement Reasonableness (DOT Response)

Criteria	Responses
Cost	25
Approach or exceed Noise Abatement Criteria (NAC) levels	18
Noise Level Increase	15
Type of Use	9
Amount of Use	7
Development after Highway date of public knowledge	6

(a)

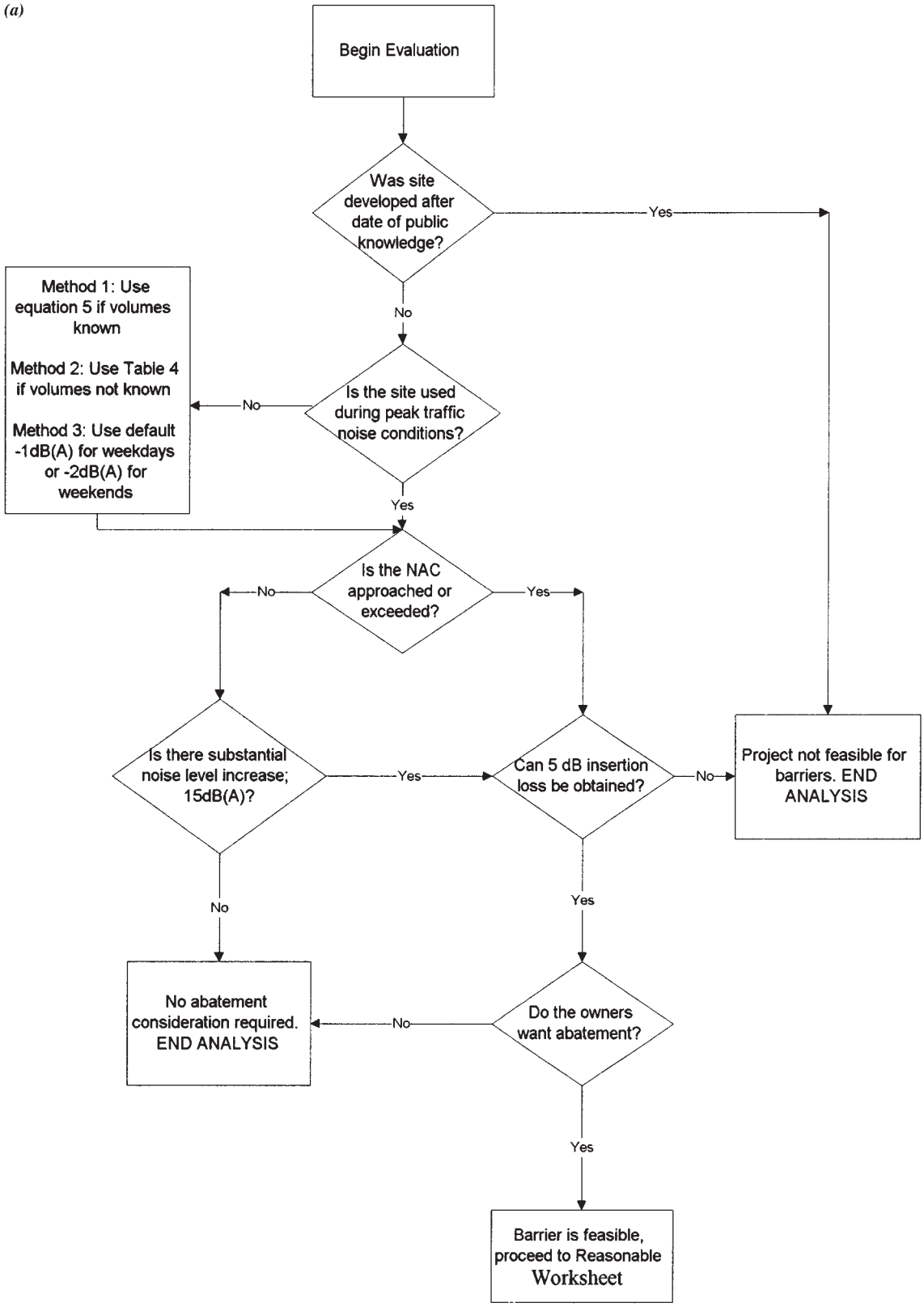

FIGURE 1 (*a*) Feasibility flowchart; (*b*) reasonableness worksheet.

(b)

Item	Criteria	Input (English units)	Input (SI Units)
1	Enter length of proposed barrier	ft	m
2	Enter height of proposed barrier	ft	m
3	Multiply item 1 by item 2	ft^2	m^2
4	Enter the average amount of time that a person stays at the site per visit	hours	hours
5	Enter the average number of people that use this site per day that will receive at least 5 dB(A) benefit from abatement at the site	people	people
6	Multiply item 4 by item 5	person-hr	person-hr
7	Divide item 3 by item 6	ft^2/person-hr	m^2/person-hr
8	Multiply $30,000 by item 7	$/person-hr/$ft^2$	$/person-hr/$m^2$
9	Does item 8 exceed the "abatement cost factor" of English units = $711,382/person-hr/$ft^2$? or SI units = $66,083/person-hr/$m^2$?		
10	If item 9 is no, abatement is reasonable		
11	If item 9 is yes, abatement is not reasonable		

FIGURE 1 (*continued*)

4. Determine the average height of a barrier (4.3 m; 14 ft).
5. Use the average frontage of a residence and barrier height to determine the area of a hypothetical barrier per residence frontage.
6. Determine state average number of people per dwelling unit.
7. Use these data to determine a criteria barrier cost per hour of usage and area of barrier.

The values shown were chosen from current FDOT policy, FDOT guidance, census data, and experience of the authors.

The abatement cost factor derivation quantifies typical residential usage and considers a hypothetical barrier section that would occupy the frontage of a typical residence. Note that this is purely a hypothetical situation and does not imply that this barrier section would provide adequate abatement at the residence; instead, it estimates the size of a barrier that would occupy the frontage property of a typical residence.

The typical residential usage and hypothetical barrier size per residence are combined with the FDOT barrier cost per residence to provide a basis for the abatement cost factor based on person-hours of usage and barrier area. Assumptions were made on input values specific for Florida that may not be sufficient for other states. If better data are available replacement may be made depending on administrative decision. Individual states may also change values to be state specific.

The typical residence usage is derived from census (*1*) data for the state of Florida, which reports that the number of persons per residence ranges from 2.18 in Pinellas County to 3.00 in Baker County, with an overall state average of 2.46. This average value was used to derive the person-hours of usage for a typical residence. A conservative assumption was that the residences are in use 24 h/day. It was also assumed that all individuals should receive equal treatment. The FDOT barrier cost per benefited residence is divided by the number of persons per residence per day and the hours of usage per day, which gives a preliminary "abatement cost factor" based on hours of usage. This calculation is depicted below in English units.

$$\text{preliminary cost factor} = \frac{\$30\text{k}}{\text{residence}} \times \frac{\text{residence}}{2.46\ \text{persons}} \times \frac{\text{usage}}{24\ \text{hours}}$$

$$= \$508.13/\text{person-hour} \quad (1)$$

Equation 1 provides a preliminary abatement cost factor based on hours of usage only. Note that if this abatement cost factor were derived for a special land use site with the hours of usage in Equation 1, a lower cost factor occurs as the number of on-site usage hours increases. This preliminary abatement cost factor varies inversely with hours of usage. The preliminary abatement cost factor must be adjusted to account for actual size of the proposed barrier; otherwise a barrier of any size will be deemed reasonable as long as the site has high usage.

Barrier size is included in the abatement cost factor by first determining the hypothetical size of a barrier that would occupy the frontage of a residence. The assumption is made that a typical residence has 30.5 m (100 ft) of frontage and that an average barrier has a height of 4.3 m (14 ft) in Florida. These two values are used to obtain the surface area of this hypothetical barrier and are then applied to the abatement cost factor equation as indicated below in English units.

$$\text{abatement cost factor} = \frac{\$30\text{k}}{\text{residence}} \times \frac{\text{residence}}{2.46\ \text{persons}} \times \frac{\text{usage}}{24\ \text{hours}} \times (14 \times 100\ \text{ft})$$

$$= \$711,382/\text{person-hour}/\text{ft}^2 \quad (2)$$

This further derived abatement cost factor contains additional units of square feet (or square meters) and now considers actual barrier size. Once again, this abatement cost factor is simply a derivation of a value that can give a comparative measure of cost associated with the proposed abatement. This abatement cost factor should not be confused with real abatement costs (i.e., barrier project costs).

At this point we have taken the FDOT barrier cost per residence and translated this cost into a factor that accounts for site usage and barrier size. This criteria abatement cost factor can now be compared with an abatement cost factor derived for special land use sites.

Abatement cost is considered reasonable if the calculated abatement cost factor is below the criteria abatement cost factor of Equation 2 ($711,382/person-hour/ft^2 or $66,083/person-hour/m^2).

The reasonableness worksheet leads the preparer through the calculation of the site-specific abatement cost factor. It is important to note that the reasonableness worksheet considers the percentage of land protected by abatement criteria by including only those individuals who receive at least 5 dB(A) of benefit from abatement. Abatement at the site is more reasonable when the protected land area encompasses greater numbers of persons using the site. The section "Receiver Placement for Noise Impact Analysis" contains a detailed explanation of two methods for determining the number of benefited receivers.

PROPOSED FINAL METHODOLOGY

As previously noted, the process of determining abatement feasibility/reasonableness for a special land use is divided into two parts. The first is to assess feasibility of abatement for the site, and the second part of the analysis is assessment of abatement reasonableness. The reasonableness methodology uses a worksheet process whereby the preparer can systematically perform a step-by-step analysis of the special land use site. The preparer first establishes feasibility of abatement with a simple flowchart. The results of the feasibility flowchart specify whether the preparer should cease the analysis and that no abatement is required or possible. If abatement is feasible, the preparer should complete the reasonableness worksheet. The reasonableness worksheet leads the preparer through a list of questions and calculations that establish whether abatement is reasonable based on criteria such as barrier cost and usage of the site. The feasibility flowchart and reasonableness worksheet are designed to be completed with minimum effort and extra information.

The feasibility flowchart and reasonableness worksheet are presented in Figure 1.

ANALYSIS DEFINITIONS AND EXAMPLES

This section provides some detailed explanations of items necessary to complete the feasibility flowchart and reasonableness worksheet.

Definition of Special Land Use

The term special land use applies to those land uses that are not residential. This type of land use does not include dwelling residences or land use Category C as defined by 23 CFR Part 772. Land use Category D would occur only if there were endangered species or unusual land uses. Some examples of special land uses are church, school, park, and amphitheater.

Receiver Placement for Noise Impact Analysis

Receiver placement for special land use sites is similar to that of the residential analysis. Receivers should be placed at the closest location to the highway right-of-way (ROW) line where outdoor activity normally occurs to determine whether the noise-abatement criteria (NAC) are exceeded. In addition, receivers should be placed at locations away from the ROW line to determine the extent of impact and to consider sensitive receptors if the NAC are exceeded at the ROW line. The definition of a noise-sensitive receiver is "any property where frequent exterior human use occurs and where a lowered noise level would be of benefit. In those situations where there are no exterior activities affected by the traffic noise, the interior of the building shall be used to identify a noise sensitive receiver" (*2*).

In some cases, the decision to place receivers may be simple, as in the case of an amphitheater. In the case of a park, it may be more complex because people can use the park over a wide area. The reasonableness methodology must address this concern because it asks questions about sound levels at all site receivers. The following general guidelines may be used to determine receiver placement and the number of receivers that receive 5-dB insertion loss (IL) with a barrier in place at special land use sites.

Do Not Consider Parking Lots for Receiver Placement

These are not noise sensitive areas.

Define the Areas of Frequent Human Activity for the Special Land Use Site and Place Receivers

This includes areas that people use for a significant period of time. This does not usually include transition areas from parking facilities to other facilities.

In some cases, this demarcation is obvious, such as playgrounds at schools and pavilions or beaches at parks. The following examples illustrate the demarcation of frequent use areas at special land use sites.

Consider the school site presented in Figure 2. Both playground areas are deemed to have frequent human activity and so both of them are marked (dashed boundary) as areas where receivers can be placed. The next step is to place the receivers; they should first be placed near the ROW line to determine whether the NAC is approached or exceeded and, if so, they should be placed at greater distances from the roadway to determine the extent of exceedance. This is indicated in Figure 3.

It should be noted that the receivers in Figure 3 at the boundaries of the nearest frequent activity area and closest to the ROW line were evaluated first to determine whether the NAC was exceeded. If indoor use was considered, receivers should be placed at the building and transmission loss considered. The analysis is conducted with these receivers to determine impact from the nearby road; the interior receiver sound levels are further abated by the building and the common value of 20-dB(A) attenuation is used in this case.

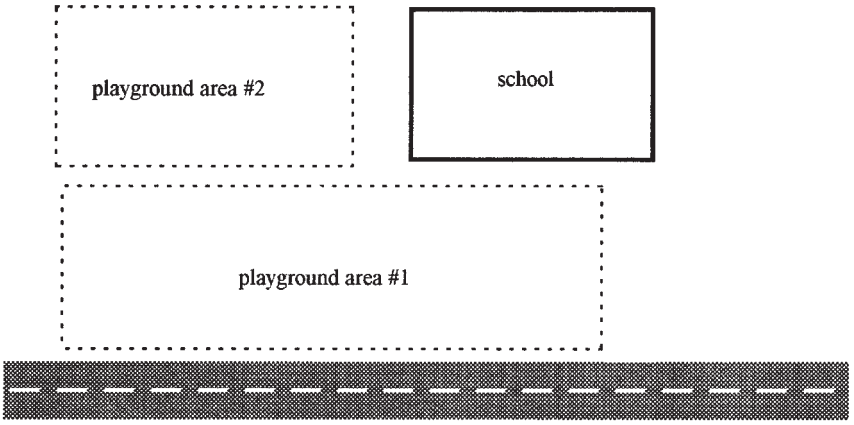

FIGURE 2 Areas of frequent human activity at a school.

After receiver placement to determine the extent of noise impact on a site (whether NAC levels are approached or exceeded) has been assessed and confirmed, abatement is proposed. At this point there is a further need to evaluate receivers that will benefit from proposed abatement. Benefited receiver determination is based on the number of people who use areas protected by abatement. This topic is discussed in the next section.

Place Receivers To Evaluate Barrier IL

The process of adding additional receivers placed at successive distances from the noise source to evaluate IL is needed for determination of the benefited receivers mentioned in reasonableness worksheet item 5. A benefited receiver is a receiver that receives at least a 5-dB(A) noise level reduction with the proposed abatement in place. Placing receivers in a grid fashion is the most effective method but it requires the most receiver placement. Using noise contours is also very effective. An example of receiver placement to establish the number of benefited receivers is presented in Figure 4.

The grid of receivers in Figure 4 can provide an indication of the portion of the area of frequent human use that receives at least 5-dB(A) IL from a proposed barrier. Let us assume that a noise impact assessment for this site predicted the IL values noted in Figure 4.

The ILs in Figure 4 indicate that five of the nine receivers meet the 5-dB(A) IL criteria. To relate this information back to the number of actual receivers in the park we need to know the average number of persons that use this field area daily. If exact numbers of people are known by location, they should be used. If there is no information on use areas, a default approximate method would be to assume equal usage throughout the area.

Determine Approximate Method of Benefited Receiver

Assume usage of the site is evenly distributed. As such, that portion of the site receiving more than 5-dB(A) IL is protected and the fraction of people receiving protection is equal to the fraction of land protected. With that assumption, we can determine the number of benefited receivers to be

$$\text{benefited receivers} = PLP \times ADP \tag{3}$$

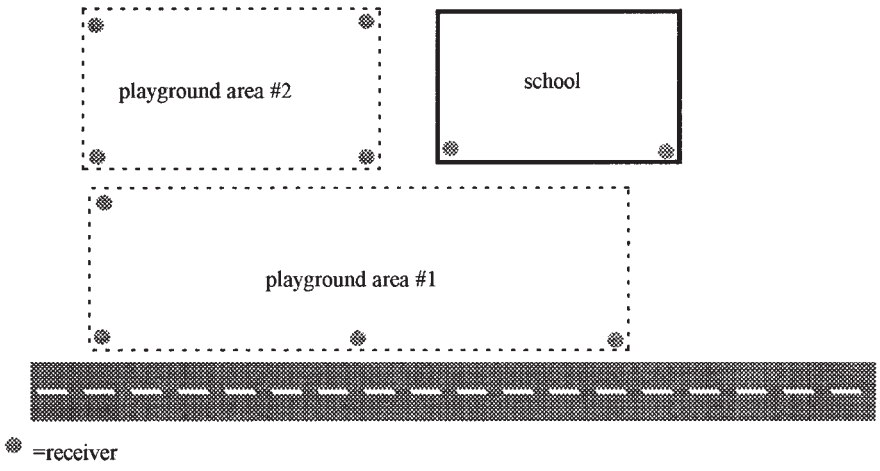

FIGURE 3 Receiver placement at a school.

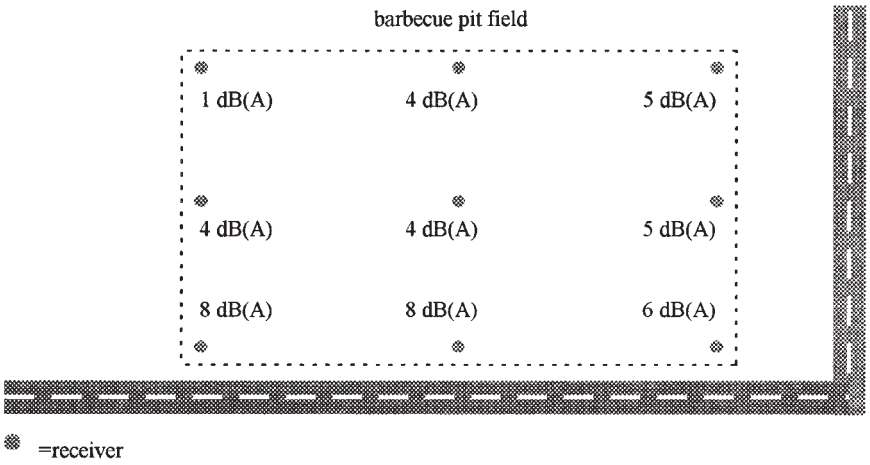

FIGURE 4 Receiver placement to evaluate barrier IL.

where

PLP = fraction of total land area protected [5-dB(A) IL or more], and
ADP = average number of persons using the area daily.

The percent of land use is derived by evaluation of the receiver grid as indicated in Figure 4. A more exact method of determining benefited receivers can be used if more information is known about the site.

Determine More Exact Method of Benefited Receiver

The percentage of land protected—that is, receiving 5 dB(A) or more of IL—is determined from the receiver grid evaluation indicated in Figure 4. A more exact number of benefited receivers can be determined if the number of people who use the protected areas is known. The number of benefited receivers can then be determined by summing the number of people per day who use the protected areas of the special land use site.

$$\text{benefited receivers} = \Sigma \text{ persons using protected areas [5-dB(A) IL or more]} \quad (4)$$

This number of benefited receivers, whether by exact location or fraction of total land protected and average number of persons using the site daily, is then used for item 5 of the reasonableness worksheet.

Feasibility Flowchart Items

The following discussion provides additional information for each of the feasibility flowchart items.

Feasibility Item 1: Was the Site Developed After Date of Public Knowledge?

It is less reasonable to provide abatement for a site that was developed after public knowledge of the roadway construction. The developers were aware of the increased noise and chose to build at the site regardless.

Feasibility Item 2: Is the Site Used During Peak Traffic Noise Conditions?

If the site is operated primarily during off-peak traffic conditions, it is not reasonable to predict sound levels based on peak traffic conditions. There are three possible ways to adjust for off-peak traffic volumes and they depend on the amount of information known by the preparer.

Method 1: Direct Calculation If Off-Peak Volumes Are Known The peak-hour levels can be adjusted by use of the following formula if the off-peak volumes are known:

$$L_{eq}\,(\text{off-peak hour}) = L_{eq}\,(\text{peak hour}) + 10\log\left(\frac{N}{N_o}\right) \quad (5)$$

where

N_o = peak-hour traffic volume, and
N = off-peak traffic volume.

Method 2: Adjustment Table If Off-Peak Volumes Are Not Known Table 4 presents a list of adjustment factors for peak-traffic volume data with quick response techniques when the reduced traffic volume is not known.

TABLE 4 Traffic Volume Adjustment Factors for Weekdays (*3*)

time	hr/peak hr	10*log(hr/peak hr) dB(A)
5-9 am	0.55	-2.6
9 am-2 p.m.	0.64	-1.9
2 p.m.-8 p.m.	1.00	0
8 p.m.-12 p.m.	0.29	-5.4

Method 3: Default dB(A) Offset for Off-Peak Use Realizing that only peak traffic data may be available, a default correction can be applied by subtracting 1 dB(A) from predicted levels if the site is operated off peak during the week or 2 dB(A) from predicted levels if the site is operated primarily on weekends. If a site is operated off peak during the week and also on weekends, subtract 1 dB(A) from predicted noise levels. It should be noted that this correction should not be used for Interstate highways because of the high truck volumes and relatively constant noise levels.

Feasibility Item 3: Is the NAC Level Approached or Exceeded?

It is stated in 23CFR 772.5(g) that traffic noise impacts are those that approach or exceed the NAC for the site or when the predicted noise levels substantially exceed the existing noise levels, and in these cases abatement must be considered. Feasibility flowchart items 4 and 5 address this requirement. If the predicted noise levels at the site approach or exceed the NAC then the preparer proceeds to flowchart item 5; otherwise the preparer must answer the substantial increase criteria question located in flowchart item 4.

Feasibility Item 4: Is There a Substantial Noise Level Increase [15 dB(A)]?

This item completes the "or" statement of 23CFR772.5(g) that states that traffic noise impacts are those that approach or exceed the NAC or have a substantial increase for the site or when the predicted noise levels substantially exceed the existing noise levels. If the predicted sound levels for the site are greater than 15 dB(A) over the existing levels then the preparer continues the feasibility analysis; otherwise the site is deemed not appropriate for abatement.

Feasibility Item 5: Can 5-dB IL Be Obtained?

This item is included in Chapter 17 of the FDOT Project Development and Environment Manual (*2*). In addition, 23CFR772.11(d) states that "when noise abatement measures are being considered, every reasonable effort shall be made to obtain substantial noise reductions." The manual interprets "substantial noise reduction" as an effort to reduce traffic noise impacts at benefited receptors by 10 dB(A) or more if possible, with a minimal acceptable level of reduction of no less than 5 dB(A). If this 5-dB(A) criteria cannot be met the analysis is finished because abatement is not feasible.

Feasibility Item 6: Do the Owners Want Abatement?

The owners of the property (i.e., church administrators or State Park officials) are those persons that most closely fit the title of owners of the property. If the abatement measure is unwanted no further analysis is required. This flowchart item is meant to include all issues of owner opinion about abatement. If the owners are in favor of the abatement measure this flowchart item directs the preparer to proceed to the reasonableness worksheet.

Reasonableness Worksheet Items

The reasonableness worksheet presented in Figure 1b asks the preparer to input site-specific data into the worksheet and perform simple calculations that result in an abatement cost factor for the site that is compared with the value shown above. Abatement at the site is reasonable if the abatement cost factor is below \$711,382/person-hour/ft^2 or \$66,083/person-hour/m^2; otherwise it is deemed not reasonable. This abatement cost factor does not relate to the actual cost of abatement but is simply a number that normalizes the analysis, permitting comparisons.

The reasonableness worksheet is simple and straightforward to use. It requires knowledge of the size of the proposed abatement and information about site usage. Determining the benefited receivers for the site requires some analysis and this was discussed in the section "Receiver Placement for Noise Impact Analysis." The following examples provide guidance on using the reasonableness worksheet.

Selected Example Calculations

Traffic Volume Determination: Church Example

Consider the traffic volume calculation at a church site. Peak traffic data for the roadway is 1000 vehicles/h. The primary use of the church occurs at from 9 a.m. to noon on Sunday. Application of the traffic volume adjustment factor for this site is as follows:

$$\text{traffic volume} = \text{peak volume} \times \text{adjustment factor}$$

$$= 1000 \text{ vehicles/h} \times 0.32 = 320 \text{ vehicles/h}$$

$$\text{dB offset} = 10 \times \log(0.32) = -4.9 \text{ dB(A)}$$

Alternatively, this example could have followed the feasibility flowchart and subtracted 2 dB(A) from the predicted receiver levels. The calculation shown above illustrates that 2 dB(A) is a conservative value for weekend use.

A traffic volume of 320 vehicles/h would now be used to predict existing noise levels if the preparer chose to use actual traffic volume instead of the decibel offset. Future traffic volume would also be estimated in this manner.

Abatement Cost Factor Calculations: School Example

Consider the school site indicated in Figure 3. We want to determine the abatement cost factor to complete the reasonableness worksheet. The following data (input parameters) are known about the school and the proposed barrier and are used as input to the abatement cost factor equation.

1. Number of people per week = 600 people;
2. Average time per person using playground = 1 h;
3. Proposed barrier height = 3.96 m (13 ft);
4. Proposed barrier length = 305 m (1000 ft);
5. Number of benefited receivers = 300 receivers; and
6. Number of daily benefited receivers = 300/7 = 43.

Now we enter the required parameters in the reasonableness worksheet (Table 5). The reasonableness worksheet analysis indicates that abatement for the school site is not reasonable.

TABLE 5 Reasonableness Worksheet for School Example

Item	Criteria	Input (English units)	Input (SI Units)
1	Enter length of proposed barrier	1000 ft	m
2	Enter height of proposed barrier	13 ft	m
3	Multiply item 1 by item 2	13,000 ft^2	m^2
4	Enter the average amount of time that a person stays at the site per visit	1.0 hours	hours
5	Enter the average number of people that use this site per day that will receive at least 5 dB(A) benefit from abatement at the site	43 people	people
6	Multiply item 4 by item 5	43 person-hr	person-hr
7	Divide item 3 by item 6	302 ft^2/person-hr	m^2/person-hr
8	Multiply $30,000 by item 7	9,069,767 $/person-hr/$ft^2$	$/person-hr/$m^2$
9	Does item 8 exceed the "abatement cost factor" of English units = $711,382/person-hr/$ft^2$? or SI units = $66,083/person-hr/$m^2$?	YES	
10	If item 9 is no, abatement is reasonable		
11	If item 9 is yes, abatement is not reasonable	√	

NOTE: 1 ft = 0.3 m.

This research has shown that there may be a need among state DOTs for a formal noise-abatement decision policy concerning special land uses such as churches, parks, and schools. If a state DOT elects to develop a special land use abatement policy, this should include a formal process to evaluate whether abatement is reasonable and feasible so that the process is not capricious or arbitrary. This research has established a method to determine whether abatement is reasonable or feasible for special land uses. The methodology was derived based on an extensive survey that included responses from 35 states:

- Telephone interviews,
- Personal contacts,
- Existing state and federal policies,
- Guidance by FDOT, and
- The expertise of the authors.

This resulted in a Phase I methodology that underwent a thorough review by the FDOT noise task team. Based on these comments, a final procedure was developed that includes a flowchart to determine feasibility and a worksheet to determine reasonableness. The final report completely defines this process and provides several examples.

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