



**COLORADO DEPARTMENT OF TRANSPORTATION**  
**NOISE ANALYSIS AND ABATEMENT GUIDELINES**

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This document supersedes CDOT Noise Analysis and Abatement Guidelines  
dated December 1, 2002

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# Noise Analysis and Abatement Guidelines

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# Noise Analysis and Abatement Guidelines

## 1. INTRODUCTION

Pursuant to requirements set forth by the Federal Highway Administration (FHWA), the Colorado Department of Transportation (CDOT) *Noise Analysis and Abatement Guidelines* provide the procedural and technical requirements for the evaluation of highway project traffic noise and consideration of noise mitigation alternatives where noise impacts are identified. The resultant goal of these guidelines is to provide the citizens of the State of Colorado with as compatible a relationship as possible between highway improvements and noise sensitive land uses. CDOT understands the importance of the issue of highway traffic noise and is committed to evaluating traffic noise impacts during the planning, design, and construction of highways and transportation improvements.

The following guidelines are intended to provide a consistent, equitable approach in addressing highway traffic noise and to foster a rational abatement decision-making process for highway projects within the State of Colorado. In addition, the guidelines include the protocol for providing thorough documentation of these activities in technical noise study reports as a part of National Environmental Policy Act (NEPA) documents.

This document supersedes the December 1, 2002 CDOT *Noise Analysis and Abatement Guidelines*. Projects which have a signed decision document (Signed Categorical Exclusion (CE) Form 128, Finding of No Significant Impact (FONSI) or Record of Decision (ROD)) prior to July 13, 2011 will remain under the authority of the 2002 guidelines.

These guidelines are based on currently accepted practices and procedures used by Federal and state transportation agencies and will be subject to review every three years. Interim amendments to these guidelines will be made on an as needed basis and will be considered, when approved, to be an integral part of these guidelines. An addendum to these guidelines will subsequently be prepared to document the changes.



## 2. APPLICABILITY AND SCOPE

### 2.1 Purpose

The regulations that govern highway traffic noise for Federal-aid and Federal action projects are contained in Part 772 of Title 23 of the Code of Federal Regulations (23CFR772), which is the Federal highway noise standard. The CDOT guidelines describe the CDOT policy and program to implement 23CFR772. Where FHWA has given the highway agency flexibility in implementing the noise standard, these guidelines describe CDOT's approach to implementation.

### 2.2 Federal Requirements

The NEPA process provides broad authority and responsibility for evaluating and mitigating adverse environmental effects of transportation projects, including highway traffic noise, but it was the Federal-Aid Highway Act of 1970 that mandated FHWA develop noise standards for the mitigation of highway traffic noise.

23CFR772 describes the methods that must be followed in the evaluation and abatement of highway traffic noise in Federal-aid and Federal action highway projects. FHWA will not approve the plans and specifications for any federally-aided or Federal action highway project unless the project includes noise abatement measures that are deemed to be feasible and reasonable to adequately reduce noise impacts. When warranted, noise abatement is to be considered as an integral component of the total project development process and incorporated as such.

The final amended 23CFR772 requires each state highway agency to prepare and adopt written guidelines specific to that state which must demonstrate compliance with 23CFR772. State highway agencies are allowed flexibility to establish their own definitions and quantifications of different criteria and decision items that are used in the guidelines to make noise abatement determinations. All highway projects that are developed in conformance with the CDOT guidelines will be deemed to be in conformance with the Federal regulations and with FHWA noise standards.

### 2.3 State Requirements

In addition to the Federal regulatory requirements, the CDOT guidelines are also required to be in accordance with CDOT Policy Directive 1601, Interchange Approval Process. The 1601 process applies to governmental and quasi-governmental (e.g., E-470) entity projects which require a new interchange on the system or major modifications to an existing interchange. Included in the 1601 process is the provision that potential environmental impacts must be evaluated, including those from projected traffic noise. The noise regulation broadens the general definition of Type I projects as defined in Section 2.4.1, to include not only Federal-aid projects, but also state, local, and public-private partnership projects overseen by CDOT and requiring CDOT and FHWA approval. The 1601 process also requires compliance with NEPA.

To assure the citizens of Colorado are afforded consistent application and implementation of noise analyses and abatement consideration, the CDOT *Noise Analysis and Abatement Guidelines* is intended to include not only Federal-aid and Federal action projects as Type I



projects, but also includes state, local, and public-private partnership projects overseen by CDOT or requiring CDOT approval.

## 2.4 *Project Classification*

The following discussion describes which CDOT highway projects require a noise analysis.

### 2.4.1 **Type I Projects**

Under 23CFR772, it is mandatory for all states to comply with the regulations for projects that are classified as Type I projects that may result in increased noise levels at sensitive receptors. Some projects may cause noise reductions; however, analyses are required to assess the exact nature of noise level changes resulting from a Type I project. The CDOT guidelines are applicable to all Type I projects. Type I projects include, but are not limited to, the following activities:

- ▶ Construction of a roadway on a new location.
- ▶ Addition of through-travel lane(s) by new construction or restriping an existing highway. This includes the addition of a through-traffic lane that functions as a high-occupancy vehicle lane, high-occupancy toll lane, bus lane, or truck climbing lane.
- ▶ Addition to a highway of an auxiliary lane by new construction or restriping, including lanes that function as passing lanes, continuous access lanes, acceleration and deceleration lanes, except for when the auxiliary lane is a turn lane. See **Appendix A** for lane-specific determinations and definitions.
- ▶ Addition of new interchanges or alterations of existing interchanges. This includes the addition or relocation of ramps, or ramps added to a quadrant to complete an existing partial interchange.
- ▶ A project which consists of a substantial change in vertical profile of 5 feet or more.
- ▶ A project which removes or alters shielding (either natural or man-made) thereby exposing the line-of-sight between the receptor and the traffic noise source. An example of this would be a case where, to improve sight distance on a highway, an existing earth berm or hillside is flattened, resulting in a direct line-of-sight between the highway and an existing residence. Vegetation does not have sufficient noise abatement properties, and thus cannot be considered for these shielding effects.
- ▶ Alteration of highways such that the horizontal distance between the nearest edge of travel lane and existing sensitive receptors is approximately halved.
- ▶ Addition of a new or substantial alteration of a weigh station, rest stop, ride-share lot, or toll plaza.

In general, actions such as the above are considered to be Type I projects due to capacity increases, alignment changes, or addition of weigh stations, rest stops, ride-share lots, and toll plazas. In all cases in which a project is identified as Type I, a noise analysis study is required if noise sensitive receptors are present within the project study zone. This study zone is defined as the area contained within the environmental study or a 500-foot distance in all directions from the proposed edge of traveled lane(s) throughout the extents of the project, whichever is larger.



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This 500-foot halo defines the extents for the noise analysis and shall include receptors on all sides of the highway. The 500-foot study zone represents the minimal noise study zone, so that if there is a reasonable expectation that noise impacts would extend beyond that boundary, the study zone must be expanded to include those receptors. This concept also includes addressing upstream or downstream resultant traffic changes where a doubling of volume would occur as a result of the project, but are located outside the traditional study zone for noise.

### 2.4.2 Type II Projects

23CFR772 defines Type II projects as projects that provide noise abatement on an existing highway (retrofit noise barrier) in a location where there will not be any new highway construction.

Type II noise abatement projects were constructed on an existing federal or federal-aid highway. Projects were proposed for federal-aid participation based upon the outcome of a noise analysis and prioritization, at the option of the highway department. The monies spent on the Type II abatement were to be deducted from the funds which otherwise be available for highway construction. This was a voluntary program in which FHWA funded 80% of the cost of Type II barrier construction. The state portion of Type II projects are funded through the Colorado Transportation Commission.

The Colorado Transportation Commission had participated in the Type II Noise Barrier Program beginning in the 1970's; however, state funding has been unavailable for this program since 1999. Thus, Colorado currently has no active Type II program or projects.

### 2.4.3 Type III Projects

All projects that do not meet the Type I or Type II criteria are Type III projects and are not required to undergo noise analysis. Such projects and activities would include many roadway maintenance operations, bridge rehabilitations, resurfacing or white-topping projects, adding shoulders, and ride-sharing programs that pair riders with carpools, commuting assistance, etc. Minor operational projects, such as the changing of a speed limit (that does not involve other construction activity), would not require a noise analysis.

The following template language should be used for Type III documentation:

*This project meets the criteria for a Type III project established in 23CFR772. Therefore, the project requires no analysis for highway traffic noise impacts. Type III projects do not involve added capacity, construction of new through lanes or auxiliary lanes (other than turn lanes), changes in the horizontal or vertical alignment of the roadway, exposure of noise sensitive land uses to a new or existing highway noise source, or any other activity classified as a Type I or Type II project. CDOT acknowledges that a noise analysis is required if changes to the proposed project result in reclassification to a Type I project.*



### 2.5 Project Timing

Each state highway agency is required to identify when the public is officially notified of the adoption of a location of a proposed highway project. CDOT, within the scope of these guidelines, defines the “date of public knowledge” as the date on which the final environmental project document (signed CE Form 128, Finding of No Significant Impact, or Record of Decision) is approved. After this date, CDOT will be responsible for analyzing and documenting changes in traffic noise impacts, but will not be required to provide noise abatement for new development which occurs adjacent to the proposed highway project. Decisions concerning such noise abatement are left to the local government agencies and private developers. Section 7.2 contains further discussion concerning noise-compatible land use planning and development.

### 2.6 Noise Sensitive Receptors

A noise sensitive receptor is any location where highway traffic noise may be detrimental to the enjoyment and functional use of the property as defined by the Noise Abatement Criteria (NAC). The residential outdoor activity and areas of frequent human use, such as schools, parks, hotels, and commercial centers, are considered for evaluation (**Exhibit 1**). All dwelling units on all floors of multifamily dwellings that have an outdoor activity area, such as a balcony, and are exposed to traffic noise are considered to be noise sensitive receptors.

Normally, these uses must be in existence at the time of the project construction, but special provisions can apply to undeveloped lands if applicable (Section 2.6.2).

#### 2.6.1 Currently Developed Lands

All properties within the study zone are to be considered as existing receptors in the noise analysis. Each property must be classified as to the type of land use and the extent of the activity (Section 4.1). As mentioned above, all sensitive receptors present within the defined study zone must be included in the analysis.

#### 2.6.2 Permitted Development

Normally, the noise analysis does not consider lands that are not developed, except to provide noise impact contours for local planning agencies; however, noise analysis is required for undeveloped lands for which development has been permitted before the date of public knowledge. This indicates that a definite commitment, with official public knowledge, has been made to develop the property in question and has reached a point where the developer’s plans can no longer be changed in a practical manner. Any area which fits this category must be treated in the noise analysis as though the development has already been constructed.

The State of Colorado will consider a proposed development as being permitted when a formal building permit has been issued to the developer by the local agency of authority. During the NEPA re-evaluation process, if undeveloped land was not permitted for development by the date of public knowledge, FHWA and CDOT financial participation in abatement measures will no longer be considered for that property.

For example, when a project re-evaluation for NEPA is undertaken after a project has been shelved for more than 3 years, noise impacts will be re-analyzed and will include any new



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receptors built or permitted after the original NEPA document date of public knowledge, however; no new abatement analysis will be required for those receptors built or permitted after the original date of public knowledge. FHWA and CDOT will participate in noise abatement only for those receptors that were previously identified in the original NEPA noise study. FHWA and CDOT will not participate in abatement measures for new receptors which were not in existence or permitted prior to the original NEPA document date of public knowledge.

If a re-evaluation initiates a new NEPA document with a second, new NEPA decision document, all receptors identified within the new study zone up to the second date of public knowledge, will be analyzed for traffic noise impacts and considered for abatement measures.

There is no date of public knowledge for a Tier I document. The date of public knowledge is considered in the Tier II stage of NEPA documentation. Tiered NEPA documents such as Tier I Environmental Impact Statements (EISs) are discussed in Section 5.8.



### 3. NOISE FUNDAMENTALS AND TRAFFIC NOISE IMPACT CRITERIA

Sound can be defined as mechanical energy generated by movement or vibration from a source that can be sensed by the ear. Noise, generally, is defined as unwanted sound, and is the description usually given to sound that emanates from highway traffic. Each sound (noise) can be expressed in terms of three primary characteristics: magnitude, frequency, and time element.

The magnitude of a sound event can be measured in terms of its acoustic pressure. Because the range of absolute pressure values can vary over several orders of magnitude, the unit typically used to describe sound levels is the decibel (dB), which is a relation of the sound pressure level to a standard reference pressure. This ratio is then converted to a more compact logarithmic scale.

Since sound travels in waves, there are also varying frequencies associated with each sound event. The human ear does not respond equally to all frequencies, however, and filtering of these frequencies must be done in order to obtain accurate measurements and descriptions of highway traffic noise, as this noise is comprised of many frequencies. The filtering (weighting of frequencies) of the “A” scale on sound-level meters most closely approximates the average frequency response of the human ear, and is the scale that is used for traffic noise analyses. Decibel units described in this manner are referred to as A-weighted decibels, or dBA.

As sound intensity tends to fluctuate with time, a method is required to describe a noise source, such as a highway, in a steady state condition. The descriptor most commonly used in environmental noise analysis is the equivalent steady state sound level, or Leq. This value is representative of the same amount of acoustic energy that is contained in a time-varying sound measurement over a specified period. For highway traffic noise analyses in Colorado that time period is one hour, and the value then reflects the hourly equivalent sound level, or Leq(h).

For highway projects that require noise analyses in Colorado, the accepted noise descriptor is the worst-hour Leq(h) for determining existing and future noise levels and impacts. The worst-hour is specified and defined as such to reflect the conditions that will produce the worst traffic noise. In general, this is highest traffic volume traveling at the highest possible speed. If traffic volume continues to increase past these conditions, the traffic is eventually forced to slow down, which in turn decreases the noise levels generated.

A traffic noise impact is considered to occur when any noise sensitive receptor is subjected to either 1) future noise levels that approach or exceed the Noise Abatement Criteria (NAC), or 2) future noise levels that substantially exceed the existing noise levels. Both of the above must be analyzed to adequately assess the noise impact of a proposed project. When noise sensitive receptors are present and are found, during the course of the analysis, to be impacted under either case, noise abatement measures must be considered and evaluated for those receptors under the feasibility and reasonableness factors as described in Sections 5.4 and 5.5.



### 3.1 Approach or Exceed Noise Abatement Criteria

The NAC are noise levels which are compared to existing or future levels to determine impact threshold. The levels that are specified are based on the certain types of existing activities that are present.

CDOT defines “approach” as noise levels that are 1 dBA less than the national NAC specified in 23CFR772. The values shown in **Exhibit 1** reflect the values that CDOT considers when evaluating noise levels for each corresponding activity category.

Any receptor that is subjected to noise levels that either currently reach or are predicted to reach the values stated in **Exhibit 1** are considered to be impacted by noise. It is important to note that these values do not have to be exceeded to result in an impact, and there is no difference in the severity of the impacts in either case.

The levels expressed in **Exhibit 1** are intended to strike a balance between noise levels that are desirable and those that are feasible. Numerous approaches were considered in establishing the criteria, to include hearing impairment, annoyance, sleep interference, and speech communication interference. Highway traffic noise levels do not normally reach the levels that result in hearing damage, and what constitutes an annoyance or hindrance to sleep is very difficult to quantify on a large scale. Speech impairment, however, was usefully applied as a condition that reflects a compromise between noise levels that are desirable and those that are achievable and was found not to be arbitrary or capricious.

It is very important to understand that the CDOT NAC are impact criteria only; the absolute threshold levels for which abatement consideration must take place. There is not a specific *absolute* noise level that abatement measures must reach for noise impacts to be considered successfully mitigated.

When evaluating abatement, the NAC activity category Leq(h) values are not to be considered as the goals for which abatement must be designed. The overall objective of mitigation is to obtain the noise reduction design goal (Section 5.5.1), which may or may not result in noise levels below the NAC levels.

NAC Activity Category A receptors are extremely rare and apply only to extraordinary special public needs where the existing environment is of a serene nature that needs to be preserved to allow the area to continue to serve its purpose. Determination of whether or not a specific receptor qualifies as a NAC Activity Category A will be made on a case-by-case basis in consultation with CDOT and FHWA.

Most sensitive receptors that will be encountered on highway traffic noise analysis efforts will be categorized as NAC Activity Category B (residential) receptors and NAC Activity Category C receptors, which are both subject to the 66 dBA approach criterion. NAC Activity Category D describes criteria for interior evaluations when all exterior analytical methods have been exhausted, and then only applies to certain NAC Activity Category C uses.

NAC Activity Category E describes lands that are commercial in nature, and exhibit characteristics less sensitive to traffic noise. It should be cautioned that hotels and motels often have permanent residential occupation and should be surveyed for such before designating the



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appropriate categorical criterion of NAC Activity Category C or E. NAC Activity Categories F and G receptors are non-sensitive to traffic noise or undeveloped land uses, and are not subject to a NAC value.

### Exhibit 1. CDOT Noise Abatement Criteria

Activity Category	Activity Leq(h)*	Evaluation Location	Activity Description
A	56	Exterior	Lands on which serenity and quiet are of extraordinary significance and serve an important public need and where the preservation of those qualities is essential if the area is to continue to serve its intended purpose.
B <sup>1</sup>	66	Exterior	Residential
C <sup>1</sup>	66	Exterior	Active sport areas, amphitheatres, auditoriums, campgrounds, cemeteries, day care centers, hospitals, libraries, medical facilities, parks, picnic areas, places of worship, playgrounds, public meeting rooms, public or nonprofit institutional structures, radio studios, recording studios, recreational areas, Section 4(f) sites, schools, television studios, trails, and trail crossings.
D	51	Interior	Auditoriums, day care centers, hospitals, libraries, medical facilities, places of worship, public meeting rooms, public or nonprofit institutional structures, radio studios, recording studios, schools, and television studios.
E <sup>1</sup>	71	Exterior	Hotels, motels, offices, restaurants/bars, and other developed lands, properties or activities not included in A-D or F.
F	NA	NA	Agriculture, airports, bus yards, emergency services, industrial, logging, maintenance facilities, manufacturing, mining, rail yards, retail facilities, ship yards, utilities (water resources, water treatment, electrical), and warehousing.
G	NA	NA	Undeveloped lands that are not permitted for development.
<sup>1</sup> Includes undeveloped lands permitted for this activity category. * Hourly A-weighted sound level in dBA, reflecting a 1-dBA approach value below 23CFR772 values			

When determining impacts, primary consideration is to be given to exterior areas of frequent human use where a lowered noise level will be of benefit. CDOT will consider interior noise abatement only for NAC Activity Category D facilities (Section 5.7).



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### ***3.2 Substantial Increase over Existing Noise Levels***

The second manner in which a noise sensitive receptor can be impacted by highway traffic noise is to be subjected to a substantial increase of noise due to a highway project.

CDOT defines that a noise impact occurs if a receptor is to receive an increase in noise levels of at least 10 dBA over the existing noise levels. This impact criterion takes effect regardless of the absolute noise levels. For example, an increase of noise from an existing 45dBA to a predicted build condition of 57 dBA for a NAC Activity Category B receptor will result in a noise impact, as the net noise increase of 12 dBA is greater than the 10 dBA substantial increase threshold. A change in noise levels from 62 to 69 dBA for NAC Activity Categories B or C would not be an impact under the substantial increase criteria, but would still result in an impact as the NAC of 66 dBA has been exceeded.

As long as one of the impact criteria is met for a receptor, abatement must be considered for that receptor. No subjective descriptor terms are used to describe traffic noise impacts.



### 4. HIGHWAY TRAFFIC NOISE ANALYSIS

The main purpose of the highway traffic noise analysis is to identify noise sensitive receptors that will be subjected to traffic noise impacts. Any and all receptors that are identified as impacted must be considered for noise abatement. The abatement alternatives must be evaluated under the feasibility and reasonableness criteria. The noise analysis technical report (**Appendix B**) serves as proof that the analysis was performed and provides all necessary documentation as required by the regulations.

As early as is reasonably possible in the process, an initial assessment must be made to determine whether or not the project will require a detailed noise analysis as described in Section 4.1. This is best done in conjunction with the environmental scoping of the project.

The analysis consists of two major parts. The first consists of identification of noise sensitive receptors, assessment of the noise levels that these receptors are currently experiencing and are predicted to experience in the future, and determination of whether or not traffic noise impacts exist. If no traffic noise impacts are found, the analysis is then considered to be complete with no further evaluation required. If traffic noise impacts are expected, then the second part of the analysis, abatement consideration and evaluation, must be performed. The requirements for the first part of the analysis will be described below, while the mitigation consideration protocol will be discussed in Section 5.

Common misunderstandings arise when the subject and requirements of performing noise analyses are discussed. The requirement to perform a noise analysis, in and of itself, does not imply that impacts are present or that any other future actions are inevitable. The analysis will identify any noise impacts, which will then be considered for noise mitigation. Noise abatement will be provided if it is determined to be both feasible and reasonable.

#### 4.1 *Identification of Land Uses*

The proper identification and quantification of the noise sensitive receptors adjacent to a highway improvement project is essential to the success of the analysis. Each receptor that is present within the extents of the project study zone must be examined in accordance with the regulations. The study zone has been defined to encompass the most likely area within which, a receptor may experience impacts resulting from project related traffic noise.

A project that does not border any existing or permitted noise sensitive land use area will not require a noise analysis. Receptors that are outside of the study zone of 500 feet around the extents of work for the individual project do not need to be considered for analysis, unless there is a reasonable expectation that noise impacts would extend beyond that boundary. The CDOT Environmental Programs Branch (EPB) noise specialist should be consulted for clarification as necessary.

The primary focus with the noise sensitive receptors is the exterior areas of frequent human use that are adjacent to the individual properties. For identified receptors, the consideration point will be the outside area that is immediately facing the highway, which in most cases will be the front/back yard, communal gathering/activity area, or porch area. To summarize the land-use



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activities that are present, each NAC Activity Category should be listed and the number of receptors identified in the project documentation.

The following metrics are intended to provide guidelines to facilitate statewide consistency of receptor identification. Coordination among CDOT, federal land management agencies and local jurisdictions is encouraged to provide appropriate context for and resolve identification of complex receptor-land use issues. (See **Exhibit 1** for tabulation of activity types and land uses.)

### 4.1.1 NAC Activity Category A

Determination of whether or not a specific receptor qualifies as a NAC Activity Category A will be made on a case-by-case basis in consultation with FHWA.

### 4.1.2 NAC Activity Category B

This NAC includes residential and multiple family dwellings, which includes mobile home parks and apartment buildings. All apartments that have an outdoor activity area, such as a balcony, and with exposure to traffic noise should be considered in the noise analyses – regardless of floor. Evaluation of the upper floors in multi-storied buildings is required to provide a basis for reasonable expectation of effective noise abatement for impacted receptors. Pragmatically, for a multi-storied residential building, the evaluation can be undertaken in multi-floor increments until no impacted dwelling is detected on that floor. Note that multi-family common areas belong to NAC Activity Category B. Special attention should be given to identify permanent or long-term residences that may be incorporated in hotels (NAC Activity Category E) or RV parks (NAC Activity Category C), as these should be evaluated under NAC Activity Category B.

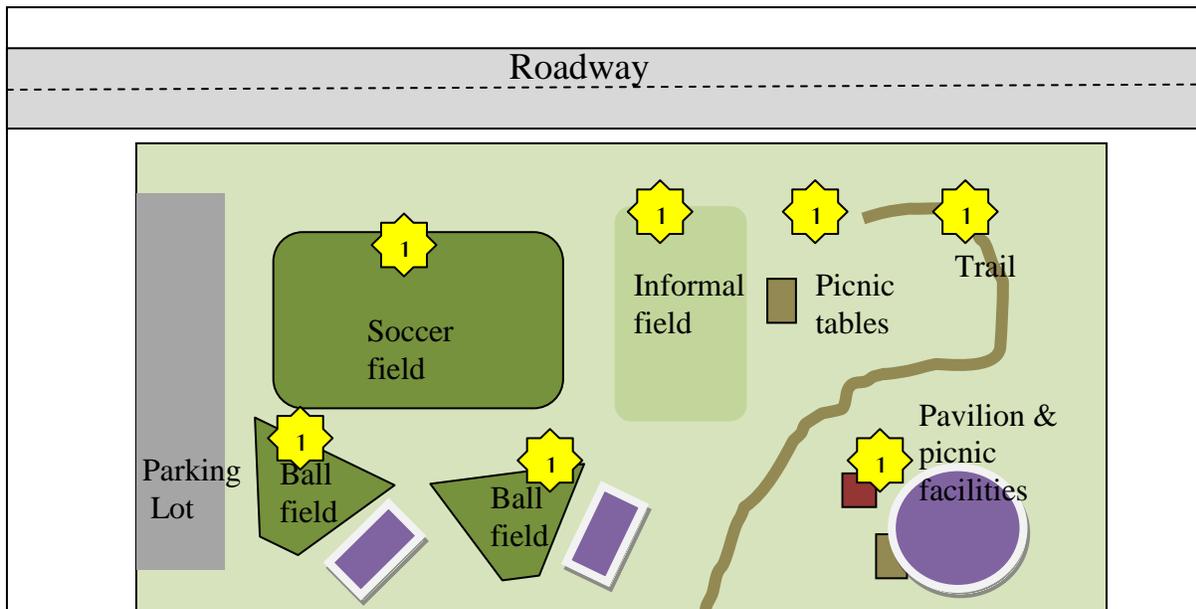
If a group of individual receptors share similar acoustical properties and settings, a representative, consolidated receptor site may be used in modeling. The total number of individual receptors represented by the consolidated receptor site must be clearly documented in the impact tables and reporting.

### 4.1.3 NAC Activity Category C

NAC Activity Category C land uses are identified as either individual sites, such as buildings, or can involve properties with multiple areas of diverse activity and usage characteristics, such as parks. The receptor identification metrics defined for NAC Activity Category C are purposely general to allow easy identification and inclusion of noise sensitive receptors, yet includes enough specific parameters to remove ambiguity in receptor site quantification.

This category follows an activity focused theme, using consolidated facilities and related uses as the basis of receptor identification. Communal or recreational properties may be divided into individual receptors based on individual activity areas (**Exhibit 2**); however multiple receptors must not be counted for individual pieces of a single common activity functional area. For activity areas that are spread across a property or for properties that lack defined facilities or formalized activity areas, a single generalized receptor should be placed within the property that best represents the worst expected traffic noise condition, based on professional judgment of the noise specialist. Consultation with the local jurisdiction is recommended to best resolve these issues.

## Exhibit 2. Illustration of Park or Recreation Area Receptor Identification



Note: This hypothetical property would have a total of seven receptors based upon activity area identification.

**Parks and Recreation Areas** – Parks range in size and amenities from neighborhood pocket parks, to linear green belts accommodating drainages or trails, to large regional parks and natural preserves with multiple trails and outdoor use facilities. Recreation areas may also encompass multiple activity areas within a large parcel of land. Receptors should be located within the park or recreation area boundary for each area with a discrete outdoor activity as conceptually defined under this section. If the park or recreational area has no discernable formal activity areas (trails, camping facilities, picnic areas, ball fields, etc.) as defined within this section, a minimum of one (1) receptor should be sited to be representative of typical traffic noise on the property by using best professional judgment and by consultation with the jurisdictional authority for the property.

**Picnic Areas and Fire Pits** – One (1) receptor should be counted for each area of clustered tables and/or fireplaces which could be considered oriented or situated as a single functional area.

**Campgrounds** – One (1) receptor should be counted for each formal campsite or camping cabin capable of human occupation. Informal campsite areas located within formalized campgrounds should be counted as 1 collective receptor per separated area.

**Pavilions** – One (1) receptor should be counted for each complex of tables, outdoor cooking facilities, covered pavilions, gazebos; etc. that could be considered oriented or situated to provide a single use area.

**Sporting fields** – One (1) receptor should be counted for each formalized sporting field inclusive of its associated seating, access, pathways, and/or stadium complex which could be considered oriented or situated to facilitate use of the sporting field. Less formalized activity



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areas such as grassy areas of a park or recreation area, which are commonly utilized for informal sporting activity, should be counted as one (1) receptor per area which has been observed or exhibits attributes that demonstrate common active use.

**Golf Courses** – One (1) receptor should be placed within each hole (tee-off areas or fairway-green combination) of the golf course that best represents the worst expected traffic noise condition, based on professional judgment of the noise specialist. If other outdoor activity areas exist within the course such as practice areas, picnic facilities, restaurant outdoor area, etc., each course segment and formalized activity area shall be identified with a separate receptor.

**Jurisdictionally-Controlled Forests and Other Areas Officially Managed for Outdoor Recreational Activity** – Jurisdictionally controlled managed areas generally are federal lands that must have a management plan including defined outdoor activity use. Receptors should be located within the activity managed area boundary for each identified management area that defines outdoor activity areas as conceptually defined under this section. If the management area has no discernable activity areas (trails, camping facilities, picnic areas, etc.) as defined within this section, a minimum of one (1) generalized receptor shall be placed no closer than 50 feet from the edge of pavement within the management area that best represents the worst expected traffic noise condition, based on professional judgment of the noise specialist. Consultation with the local jurisdiction is recommended to best resolve these issues.

**Trails/Trail crossings** – One (1) receptor should be counted for each formal trail crossing regardless of the pathway orientation. The receptor should be placed no closer than 50 feet from the edge of pavement on the trail that best represents the worst expected traffic noise condition, based on professional judgment of the noise specialist.

Individual trails that course parallel to a roadway should be assessed for usage – formal or informal, recreational or transportation – to provide a basis for receptor siting. Estimations should incorporate a frequency of use estimate that includes germane user information estimated number and mode of users, and daily or seasonal factors. Stopping places along a trail, such as rest areas with benches or scenic viewing areas, should each be assigned a receptor. Consultation with the local jurisdiction is recommended to best resolve these issues.

**Community activity areas** – Apartment and residential community common areas may include pools, ball courts, or other formalized outdoor activity areas. Each of these outdoor activity areas should be counted as one (1) receptor.

**Cemetery** – One (1) receptor should be counted for each area of a formalized memorial gathering facility. Individual grave sites, access ways, and informal activity areas are not considered individually sensitive receptors; however, each section of the cemetery as defined through consultation with the operator, which may have informal gathering areas, should be assigned a receptor. If there are no formalized or operator defined informal gathering areas, a generalized receptor shall be placed within the property that best represents the worst expected traffic noise condition, based on professional judgment of the noise specialist.



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**Section 4(f) Sites** – Section 4(f) sites encompass three types of sites – parks and recreation areas, wildlife refuges, and historic sites:

- ▶ Parks and Recreation Areas – addressed above.
- ▶ Wildlife Refuges – wildlife or wildfowl refuges or preserves typically have limited or no human activity area and thus would not be subject to noise analysis. However, on-site trails or observation areas should be considered under NAC Activity Category C as defined in this section.
- ▶ Historic Sites – For historic sites that have exterior areas with frequent human use (historic houses), one (1) receptor should be counted for each site with such use. For historic sites without frequent human use, no noise analysis is necessary.

When no noise analysis is necessary for a site due to an absence of an exterior area with frequent human use, this finding should be documented in the project file or noise report.

## 4.1.4 NAC Activity Category D

This activity category includes the interior impact criteria for certain land use facilities. CDOT would conduct an indoor analysis only for Activity Category D receptors after first examining if there are potential exterior areas of frequent human use.

Unless an actual interior noise measurement has been taken, the interior building noise level predictions shall be calculated by subtracting noise reduction factors from the predicted exterior levels for the building in question, using the information in **Exhibit 3**. Noise analysts should take interior noise measurements for the final noise analysis and abatement design for locations where noise insulation is being considered as an abatement measure.

### Exhibit 3. Building Noise Reduction Factors for Interior Noise Evaluation

Building Type	Window Condition	Noise Reduction Factor (Due to Exterior of Structure)
All	Open	10 dB
Light Frame	Ordinary Sash (closed)	20 dB
	Storm windows	25 dB
Masonry	Single Glazed	25 dB
	Double Glazed	30 dB

The windows shall be considered open unless there is firm knowledge that the windows are in fact closed almost every day of the year. See FHWA-DP-45-1R, *Sound Procedures for Measuring Highway Noise: Final Report*

Source: FHWA A-HEP-10-025 *Highway Traffic Noise: Analysis and Abatement Guidance* (2010)

## 4.1.5 NAC Activity Category E

This activity category contains receptors which are less sensitive to highway traffic noise. These include hotels, motels, offices, and other developed lands not included in NAC Activity Categories A-D, and F. Special attention will be given to ascertain if motel/hotel properties could include permanent or long term residents, thus qualifying as NAC Activity Category B.

## 4.1.6 NAC Activity Category F

This activity category includes industrial, commercial and other land uses that are not sensitive to noise. Some examples are agricultural uses, airports, maintenance yards, warehousing, emergency services, mining, rail yards, and utility facilities (water treatment, water resources, electrical). These uses are not considered noise sensitive, and no noise analysis is required for these locations.

## 4.1.7 NAC Activity Category G

This activity category includes all undeveloped lands which do not have a building permit prior to the date of public knowledge. These uses are not considered noise sensitive, and no noise analysis is required for these locations. However, noise impact contours for these properties should be provided to the local jurisdictional agency, including local planning, zoning and/or building permit offices, and where applicable, metropolitan planning organizations and transportation planning regions, for future land use planning purposes.

## 4.2 *Determination of Existing Noise Levels*

The next step in the analysis is to quantify the existing noise environment by determining the noise levels that the identified receptors are currently experiencing. Determination of existing noise levels shall be made by field measurement and use of the most current version of the TNM noise prediction modeling software. Protocol for the use of TNM for CDOT projects can be found in the *Traffic Noise Model User's Guide for Colorado DOT Projects* (2006). All measurement procedures must be performed by an ANSI Type I or Type II integrating sound meter in accordance with report FHWA-PD-96-046, *Measurement of Highway Related Noise*.

Although TNM analytical results are expressed to the nearest tenth decimal, all noise levels shall be rounded to the nearest whole number for reporting purposes in both the NEPA documentation and supporting technical reporting. (Technical modeling appendices including TNM output files should retain their original decimal format.)

### 4.2.1 **New Roadway at New Location.**

Data siting the proposed new alignment and construction footprint should be superimposed on a base map illustrating existing and permitted buildings, features and facilities to define the appropriate noise study zone and identify noise sensitive receptors. Field measurements will provide the basis of existing noise conditions for projects involving the construction of a new highway in a new location. Noise field measurements at existing and permitted receptors (or representative receptors) located within the study zone of the project will be taken to a) provide adequate context for existing noise levels and b) to provide sufficient information to compare sensitive receptor noise levels to future noise levels derived from analytical modeling for the purposes of defining substantial noise impacts along the proposed highway corridor study zone.

### 4.2.2 **Modifications to Existing Roadways.**

Field measurements should be sufficient to provide adequate definition of the existing noise condition to validate the TNM model for existing conditions (Section 4.2.1.).

A minimum of two (2) existing field measurements are required within the study zone. Field measurements should represent sensitive receptors best illustrating the existing traffic noise environment, as free from the influence of local non-traffic generated noise sources and shielding as practical. Measurements can be taken at any time; however, it is best to measure when traffic is relatively free flowing at or near the posted speed limit. For high-volume roads, a 10-minute sample is usually statistically accurate enough to obtain a good measurement, but sample times of 30 minutes but not more than 1 hour may be needed for measurements along lower volume roads. A directional count of all automobile, medium truck and heavy truck traffic should be taken for relevant roadways adjacent to the measurement site. Tabulation of motorcycle and bus counts is also desirable. Determination of the approximate speed that the vehicles were traveling can be determined by either driving a test vehicle through the traffic stream or by use of a radar gun.

### **4.3 TNM Model Validation**

Most often, the purpose for taking field measurements will be to gather data that is used to develop a comparison between those measurements and results obtained with the noise prediction model. This exercise is performed to validate the model so that it can be used with confidence to determine the worst-hour existing noise levels and predict the future noise levels. It is not required to perform measurements at each individual receptor; however, enough representative measurement locations (a minimum of two measurements) in the project area must be utilized in order to reasonably characterize conditions for the validation effort. Once these data have been collected, each of the locations is then input into the model for comparison purposes.

In order to arrive at a valid comparison between measured and modeled results, traffic and speed data must be collected at the measurement locations at the same time the noise measurements were taken. This will involve actual counting of vehicles, being sure that truck (heavy and medium) counts are taken separately, and a determination of the approximate speed that the vehicles were traveling. For the purposes of validation, field measurement data should be normalized to an hourly basis as that will be needed for input into the computer model. The collection of relevant data will allow the modeling of the same conditions as was observed during the measurement exercise and does not require the analyst to attempt to measure during the worst noise hour. This effort is to be thoroughly documented within the noise study report.

The maximum acceptable difference between the actual noise measurements and the modeling results is 3 dBA. If the difference between the measured and predicted levels is not within 3 dBA, an examination of the measured and modeled data shall be performed to determine the reason for the difference and shall be adequately explained in the noise technical report. This may require that a second measurement be taken in some instances. Standard validation practices are described in **Appendix C** and in *Traffic Noise Model: Frequently Asked Questions FAQs* at [www.fhwa.dot.gov/environment/noise/traffic\\_noise\\_model/tnm\\_faqs/faqs06.cfm#miroadways1](http://www.fhwa.dot.gov/environment/noise/traffic_noise_model/tnm_faqs/faqs06.cfm#miroadways1).

### **4.4 Noise Modeling for Existing Conditions**

Unless the project involves the construction of a new highway on a new location, the worst-hour noise levels are determined by the validated TNM computer model.



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In selecting model locations, each individual receptor does not have to be modeled separately. A modeling location can be chosen that represents several actual receptors. This is acceptable as long as all the identified sensitive receptors are represented in the analysis. The number of the actual modeling points that are used will vary depending on the nuances of the individual project. For each modeled location, a table that shows the location identification and exactly how many receptors are being represented by that location must be included in the noise study report. These locations are then modeled at a height of 5 feet (1.5 meters) above the ground level elevation to approximate the height of the average human ear. For analysis of areas above the ground level, those locations shall be modeled at a height 5 feet above the elevation level of the use area.

To perform the noise modeling for the existing conditions, the analyst will need to gather the following input data:

- ▶ Current roadway alignment for roadways in the immediate area which may contribute to the noise environment. For areas containing roadways of a minor residential nature, only throughways carrying substantial traffic volume need be modeled (on a professional judgment basis).
- ▶ Existing traffic volumes, which include a breakdown of numbers of automobiles, medium trucks (2-axle, 6-tire), and heavy trucks (3+ axles) for all roadways.
- ▶ Current posted speed limit for all roadways.
- ▶ Receptor locations.
- ▶ Terrain features, such as natural berms.
- ▶ Other features which result in a shielding effect (i.e. buildings).
- ▶ Any existing noise barriers present.
- ▶ Other TNM parameters such as pavement type can be utilized as a TNM option in existing condition modeling; however, the default average pavement type must be utilized in future condition modeling.

To model the worst hour existing condition, the traffic data that shall be used are the highest volume of traffic that can travel at the highest relevant speed for the particular roadway. In the past, this situation has often been represented by the Design Hour Volume of the roadway modeled at the posted speed limit. A new approach was evaluated (**Appendix E**) to identify the worst-hour traffic noise that is based on methodology found in the *Highway Capacity Manual* (2000). **Exhibit 4** summarizes the highest traffic volumes per lane at various posted speed limits for different highway classifications that were found to produce the loudest noise conditions.

For TNM modeling, the estimated traffic volumes from the project traffic analysis are to be used if they are less than the volumes presented in **Exhibit 4**. If the estimated traffic volumes for a project roadway are higher than the corresponding volumes shown in **Exhibit 4**, the traffic volumes from **Exhibit 4** are to be used in the noise analysis because added traffic would cause speeds to slow which in turn will reduce noise levels. Proper documentation of the source of the traffic volumes is required to be included in the noise study.



## Exhibit 4. Suggested Maximum Traffic Volumes for Worst Noise Hour

Posted Speed Limit (MPH)	Maximum Traffic Volumes by Facility Type (vehicles/lane/hour) <sup>1</sup>		
	Freeway	Non-Freeway Multiple Lane	Two-lane Roadway
75 or above	1600	NA	NA
70	1700	NA	NA
65	1800	1700	1300
60	1900	1800	1300
55	2000	1900	1300
50	2100	2000	1400
45	2200	2100	1500
40	Not applicable	2200	1600
35 or below	Not applicable	2200	1600

<sup>1</sup> Appendix E contains technical support documentation for worst noise hour equivalent capacity.

It is critical in the TNM modeling to account for all features affecting the noise environment, such as existing noise walls, partial barriers, jersey barriers, solid panel bridge walls, landscape berms, and other features that contribute to reduction, shielding or reflection of traffic noise.

### 4.5 Existing Noise Barriers and Privacy Fences

A situation where a barrier is already present can be confusing. To be considered a noise barrier, the structure must be solid and designed specifically to abate noise. Wooden privacy fences, which are not normally constructed to abate noise, are not considered to be noise barriers, because they generally do not provide an appreciable amount of noise reduction. These fences contain many gaps, each of which allows transmission of noise, and often are not made of sufficiently dense material to provide negligible noise transmission through them.

When privacy or other development-related fences are present, consideration shall be given as to whether the fence is a continuous, double-sided-wooden, masonry or composite-material fence and whether the fence will remain in good condition over the life of the project (20 years for projected future noise levels). If there is doubt as to the durability of the fence, it should not be modeled as a barrier providing noise abatement.

When a noise barrier is currently in place, the existing conditions noise model must have the barrier included. The noise levels that are then reported for the existing conditions are those calculated with the barrier included in the model. Additionally, if the existing barrier can be shown to meet the 7-dBA noise reduction design goal (Section 5.5.1) for the affected receptors in the future, then effective noise abatement has already been provided and no additional noise abatement is required from the proposed project. If the existing barrier is to be demolished under the new project, a replacement barrier meeting should be constructed as a part of the project (Section 5.3).

### ***4.6 Prediction of Future Noise Levels***

Once the existing noise levels have been determined, the future design-year noise levels for each receptor are calculated. The future model shall reflect the design year conditions (usually 20 years post-construction) into the future (traffic counts and speeds, roadway alignments, changes to terrain) for the worst-hour noise condition. Each alternative alignment being considered for the project must be examined, including the no-action alternative. Although no analysis of the future no action alternative is required by 23CFR772, for the purposes of NEPA, CDOT requires that a no action scenario noise analysis is conducted. For minor projects, there will likely only be one alternative, but in the cases of projects which are either part of an Environmental Assessment (EA) or EIS, there may be several alternatives to consider and analyze.

Although TNM analytical results are expressed to the nearest tenth decimal, noise values shall be rounded to the nearest whole number for reporting purposes (impact tables) in both the NEPA documentation and supporting technical reporting. (Technical modeling, Cost-Benefit Index calculations, and appendices including TNM output files should retain their original decimal format.)

The traffic projections that are used must be consistent with the applicable adopted long-range plan traffic model, if available. When a long-range plan traffic study is not available, the best available data shall be used. Annual average daily traffic volumes and truck compositions for most state highways are located at <http://apps.coloradodot.info/dataaccess/Traffic>. In the absence of any better traffic data, the traffic volumes used shall be the applicable volumes from **Exhibit 4** at the recommended future posted speed conditions for the new highway design.

The same traffic noise prediction modeling software that was used in the determination of the existing conditions shall also be used for future modeling, with the modeled receptors in the same locations as they were for the existing model, as appropriate. Receptors which are identified as potential ROW takes will not normally need to be included in the future modeling, but do need to be included in the no-action case. As was the case in the existing condition evaluation, if a noise barrier is currently present it must also be included in the analysis of the future conditions, unless it will be demolished as part of future condition.

### ***4.7 Determination of Traffic Noise Impacts***

The final step in the first part of the noise study is to compare the future predicted noise levels to the applicable NAC and to the existing noise levels to determine traffic noise impacts. As discussed earlier, any receptor which either equals or exceeds the NAC (**Exhibit 1**) under the existing or future conditions or is subjected to a 10 dBA substantial increase in noise levels is considered to be impacted by highway traffic noise. This is to be done for each alternative, including the no-action alternative.

It is important to remember that the determination of traffic noise impacts only results in consideration of abatement for the receptors, which will be performed in the next part of the analysis. It is not a guarantee that abatement will be provided.

If no traffic noise impacts are identified under the future conditions for any of the proposed alternatives, as defined by the provisions set in these guidelines, the analysis is considered



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complete and further consideration of noise abatement is not required. This determination, if applicable, shall be stated as such in the final noise study report.

To provide for a detailed and thorough review of all noise modeling efforts and inclusion of analyses done to predict the future noise levels as described in Section 4.3, the noise study must either include a electronic media copy of the TNM model files or a computer printout of TNM input and results tables generated during the modeling analysis.

### 5. EVALUATION OF HIGHWAY TRAFFIC NOISE ABATEMENT

Any and all receptors which were determined to be impacted by noise must be evaluated for traffic noise abatement. This requires that the overall social, economic, and environmental effects of the abatement be evaluated against the benefits. When determining abatement measures, primary consideration is to be given to exterior areas surrounding residential areas or areas of frequent human use for other uses such as parks and commercial districts where a reduced noise level would be of benefit. All feasible and reasonable mitigation measures are required to be included in the highway project. It is not considered to be a prudent investment of public funds to consider construction of a noise barrier that will not result in at least a readily perceptible noise reduction.

#### 5.1 *Abatement Options*

The following are common abatement measures that may be incorporated in highway projects to reduce traffic noise impacts.

- ▶ Traffic management measures, such as lane-use restrictions, designated truck routes, and speed limit reductions. Measures such as these may or may not be beneficial or possible given the constraints of the project and the immediate area. While lesser speeds do decrease noise levels, it generally will take a reduction in speed of approximately 20 miles per hour to achieve a readily perceptible (5 dBA) reduction of noise at its source.
- ▶ Alteration of horizontal and vertical alignments to reduce noise impacts, where practical.
- ▶ Acquisition of undeveloped land for buffer zone creation. While buffer zones are a very good strategy in overall noise compatible land use planning, it is often not a practical solution, due to the large amount of land that must be purchased. In many instances, the existing developments already border the highway. Vegetation and/or landscaping are not considered viable abatement measures.
- ▶ Noise insulation, but for NAC Activity Category D structures only.
- ▶ Construction of noise barriers within highway right-of-way, or acquisition of property rights for construction of noise barriers outside of the highway right-of-way.

A related topic that has been researched for many years is the noise emissions that are due to the tire-pavement interaction. While it is accepted that different tires, pavements, and pavement surfacing textures do result in varying noise levels, it is difficult to forecast the overall pavement surface condition 20 years into the future. Due to this fact, and the requirement that noise mitigation must provide a readily perceptible reduction in noise levels over a long period of time (i.e., permanent), the use of different pavement types or surface textures cannot be considered as a noise abatement measure.

#### 5.2 *Noise Barriers*

There are two common abatement measures employed by CDOT: the vertical noise wall and the earthen berm. Both barriers work by blocking the path of sound waves from the highway, forcing the sound to travel around or over the barrier. If a noise barrier is tall enough to break the line of



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sight between the highway and the receptor, constructed of sufficiently dense material (4 pounds per square foot minimum density), and does not have any openings or gaps, a noise reduction will be possible that will range from being readily perceptible to less than half as loud (5-15 decibels for most barriers) depending on the height and location of the barrier. CDOT has determined that a barrier design must achieve a minimum 7 dBA noise reduction design goal (Section 5.5.1) for at least one receptor and at least a readily perceptible noise reduction (5 decibels) at one or more receptors to be considered reasonable and feasible, respectively, for construction as a prudent investment of public funds.

The most common types of highway noise barriers are vertical walls, which can be constructed out of a variety of materials: concrete, masonry block, composite synthetic materials, as well as transparent acrylic/plastic products.

The primary purpose of traffic noise barriers is to reduce noise levels at sensitive receptors behind the barrier; however, under some conditions, barriers may reflect traffic noise and negatively affect the noise conditions at other nearby receptors. Generally, this occurs when there are receptors on the opposite side of the subject road from the noise barrier. In these circumstances, the barrier is acting as a secondary noise source because of the reflected sound. A reflective barrier could increase noise levels by 3 dBA at most, but in practice will normally change noise levels by 1 dBA or less. Some of the more common situations where reflective barriers may be a concern include:

- ▶ Sensitive receptors are present across the subject road from a proposed barrier, but are not being considered for a separate noise barrier.
- ▶ A frontage road is located between the proposed barrier and the sensitive receptors.
- ▶ Parallel barriers would be present on each side of a road and the ratio of the distance between the barriers versus the height of the barriers is 10:1 or less. (See **Appendix C** Transportation Noise Modeling Users Manual for CDOT Projects.)
- ▶ A large building or other man-made reflective surface is immediately across the subject road from a proposed barrier.
- ▶ A large rock cut or other natural reflective surface is immediately across the subject road from a proposed barrier.

In these kinds of situations, surface treatment of the proposed barrier to reduce reflections may be beneficial. Such treatments could include sound-absorptive surfacing or an irregular barrier surface. Therefore, CDOT will consider special barrier surface treatments for projects where a sensitive receptor or a large sound-reflecting object is present across the subject road from a proposed noise barrier and at a distance no greater than 10 times the proposed barrier height. Decisions regarding barrier materials and finishes will be made in compliance with CDOT's materials selection process.

Reflective and absorptive material criteria are defined in CDOT sound wall materials specifications, located at <http://apps.coloradodot.info/apl/SearchRpt.cfm?cid=5&scid=37>.

An earthen berm is essentially a linear natural or man-made soil or soil/debris mound. Berms, while more natural in appearance, do require a great deal of land and a very large footprint.



Noise walls require much less space to be constructed, but may be subject to height limits due to structural and aesthetic reasons. Barriers have also been constructed by placing walls on top of berms to create a combination barrier. More detailed information concerning design, structural, and aesthetic considerations of noise barrier construction at CDOT can be found in the Chapter 18 of the CDOT Roadway Design Guide, 2005 at:

[www.coloradodot.info/business/designsupport/bulletins\\_manuals/roadway-design-guide](http://www.coloradodot.info/business/designsupport/bulletins_manuals/roadway-design-guide).

### ***5.3 Noise Barrier Abatement Evaluation***

Evaluations of possible noise barriers are to be conducted using the most current, FHWA approved TNM software using the future conditions data. Various locations and heights of barriers can be input into the model, which will calculate the noise levels with the barrier. The amount of reduction, also known as insertion loss, is defined as the future barrier noise levels subtracted from the future no-barrier condition.

Acoustically, the most effective noise barriers are generally located closest to the source (i.e. highway) or closest to the receptors. As a result, initial barrier placement should be considered and evaluated for either of these locations. In many cases, however, the CDOT right-of-way line is the most practical location for the barrier. Multiple barrier locations should be considered in the analysis if more than one effective location can be used within the right-of-way. Barrier locations should first be evaluated within the CDOT right-of-way. If effective noise reduction cannot be achieved by a barrier located within the right-of-way, adjacent or nearby land can be evaluated for placement of an abatement measure.

The overall length of barrier, different barrier heights, and design compensation for situations that require breaks in the barrier (overlapping or wrapped end-segment barriers) should also be considered in abatement analyses. Performing this evaluation is an iterative process, done by altering certain inputs and barrier siting. The best judgment of the noise analyst should be used to determine the optimal feasible and reasonable barrier dimensions and location. As always, this process needs to be documented in the noise analysis report.

In a case where a noise barrier is already present in the study area, an assessment must be made of the existing barrier in terms of both effectiveness and remaining service life. The remaining service life of the existing barrier as defined within an engineering evaluation must also be considered to ensure that it is a permanent solution as required by FHWA. If the existing barrier poses ongoing functionality or maintenance problems, it should be replaced with currently acceptable materials as a part of the Type I highway project. An example case is where an older, wooden noise barrier has been installed but deteriorated over time. Decisions concerning these situations will be made on a case-by-case basis. Federal funds can be used only if there will be impacts in design year caused by Type I project and replacement barrier is reasonable/feasible.

Effectiveness of the existing barrier will be assessed through the noise modeling software by calculating the noise reduction from the barrier for the project design year with the proposed improvements in place. If the existing barrier is found meet the noise reduction design goal, no further action is necessary for the existing barrier. If the barrier will not meet the design goal, examination of alterations to the existing barrier so that it will meet the current noise reduction design goal (Section 5.5.1) will be necessary and appropriate recommendations made to improve



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the barrier. If structural integrity, inadequate footing design, load carrying capacity, or other construction issues prevent the existing wall from being adequately modified and no remedy is readily found, consultation with FHWA and CDOT Project Management Team will determine whether a replacement wall shall be built to meet the 7 dBA noise reduction design goal. At a minimum, any existing noise barrier removed for construction of a new transportation project shall be replaced in kind at a new location. All noise abatement analyses recommendations must be documented on a CDOT Form 1209, the Noise Abatement Determination Worksheet (**Appendix D**).

As noise abatement measures other than the construction of noise barriers are not usually practical, the following discussions concerning feasibility and reasonableness are presented in the context of considering noise barriers and noise barrier construction.

### **5.4 Feasibility**

Feasibility criteria describe the physical considerations and concerns with the construction of an acoustically effective noise barrier at a particular site and project. If a noise barrier that has been evaluated for a particular location is deemed not to be feasible, an assessment of the reasonableness criteria is not required and the noise abatement analysis is considered complete. This analysis and decision is to be fully discussed and documented in the noise study technical report.

#### **5.4.1 Noise Reduction**

The major feasibility criterion that is to be considered is whether or not a substantial noise reduction can be obtained based on constraints that are inherent to the individual project. If a reduction of 5 dBA cannot be provided to at least one impacted receptor, the abatement measure is not considered a feasible mitigation and will not be recommended for inclusion in the project.

A very common issue to consider in this case is the ability to construct a continuous barrier for the entire length of the impacted area. A barrier is typically not effective if built with frequent breaks for driveways, sidewalks, streets, utilities, drainage facilities or streams as the resultant short wall lengths may drastically reduce the barrier's acoustic performance. One possible solution in a case such as this is to consider wrapping barrier end-segments or overlapping the barriers. The analysis indicating that a 5 dBA feasible noise reduction cannot be achieved must be documented in the technical report.

#### **5.4.2 Safety and Maintenance Considerations**

As is the case with any structure, there are obvious engineering, safety and maintenance issues that must be considered to determine its feasibility. If any of these issues are significant enough to cause a fatal flaw condition, then the barrier is deemed to not be feasible. The geographic setting and weather conditions inherent to Colorado dictate very different feasibility concerns when it comes to winter maintenance. Four-fifths of Colorado is non-urban/non-suburban in nature and most roadways are situated at altitudes from 4000 feet to 9800 feet. Many highly traveled roadways traverse terrain that is mountainous, steep valley sided with limited sun exposure. In these cases, there is little room to negotiate noise barrier locations within the physical constraints of the terrain.



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Examples of situations which can be considered fatal flaws include, but are not limited to, the following:

- ▶ Excessive reduction of sight distance.
- ▶ Creation of a continuous shadowing condition that may cause excessive icing of driving lanes through the winter months.
- ▶ Inability to provide for adequate snow/debris removal or snow storage during winter months.

CDOT uses consultation with maintenance and traffic engineering staff to determine when these types of maintenance/safety issues can be redesigned to an acceptable level, can safely incorporate transparent barriers, or are severe enough to cause a feasibility fatal flaw to noise barrier installation at any project site.

### 5.4.3 Constructability

If reliable and common engineering practices could be employed to construct a noise barrier, then that barrier is considered feasible. If it is obvious that the constructability of a noise barrier due to location limitations, critical environmental factors or engineering considerations is not possible without major modifications to the site or technological efforts, or extraordinary costs, the barrier can be considered not to be feasible and no further analysis is required. However, this should only be used for situations that are very clear. Decisions such as these shall be thoroughly documented and justified in the noise study report.

A special constructability consideration is when the minimum barrier height required to achieve the noise reduction design goal (Section 5.5.1) for at least one receptor is found to be greater than 20 feet. CDOT has determined that for Colorado terrain and weather conditions, including common high wind events, 20 feet is the maximum allowable height without compromising structural integrity under typical construction design specifications. CDOT views this condition as infeasible and the barrier will be re-evaluated for feasibility at a lower wall height (possibly sited at a different location).

Feasible constructability extends to extraordinary costs related to implementation of engineering design, structural reinforcement, or right-of-way purchase for the purpose of noise abatement implementation. Typically these types of extraordinary costs are not identified until final design has been rendered.

### 5.4.4 Considerations for Berms

Most of the above feasibility discussions have focused on the construction of noise barrier walls. Berms, however, can be considered as an alternative to walls where possible, as they are generally more aesthetically pleasing and have a more natural appearance. Limitations with berms do need to be considered in the feasibility evaluation, because a much larger footprint is required. Ideally, berm flanks will be no steeper than a 3:1 slope. A earthen berm is deemed not feasible if the necessary slope ratio is steeper than 2.5:1 or adequate ROW cannot be acquired to construct the berm to safety or slope ratio specifications.

## 5.4.5 Considerations for Parallel Barriers

Due to multiple sound reflections, performance degradation of parallel barriers needs to be investigated if the width-to-height ratio is less than 10:1 (distance between the barriers is less than 10 times the height of the barriers) or if the barriers are closer together than 200 feet. Analysis of individual walls under these specific parallel configurations could lead to incorrect abatement calculations (**Appendix C**). Possible solutions include raising the height of the barriers to overcome the degradation or investigating the use of absorptive treatments on either or both barriers to reduce the reflections. In these cases, retaining walls or vertical rock face cut slopes, if they are present, should be treated as barriers in the analysis.

## 5.5 Reasonableness

Reasonableness of abatement measures evaluates the combination of environmental, economic, and social factors affected by the noise abatement measure. This analysis ensures a prudent use of public funds.

Reasonable noise abatement must at a minimum collectively achieve the criteria of the noise reduction design goal, the cost-benefit evaluation and the benefited receptors desire for an abatement measure. Failure to achieve all of these criteria (Sections 5.5.1 through 5.5.3) will result in the noise abatement measure to be deemed unreasonable.

### 5.5.1 Noise Reduction Design Goal

CDOT defines the noise reduction design goal as the insertion loss that is predicted to result from a barrier that results in a 7 dBA noise reduction at a minimum of one benefited receptor. The initial barrier evaluation shall be performed to determine what dimensions and siting will be required to achieve a 7 dBA reduction.

Barrier dimensions must be optimized in terms of overall noise reduction and cost-benefit, which are two of the factors for reasonableness. It is desirable that a design be identified where a potential noise barrier provides the best balance between cost and noise reduction benefit. This is not a trivial task, as the benefit versus cost relationship is not linear and a point of diminishing returns will be reached. An iterative process, however, can result in a barrier that will provide optimal benefit with a noise reduction design goal of at least 7 dBA.

A benefited receptor, whether impacted or not, is one that receives at least 5 dBA of noise reduction. This 5 dBA reduction is based on the addition of the noise barrier only, and is only considered after any shielding effects, such as for rows of buildings, are taken into account.

Often times, noise sources such as aircraft, rail, ground transit modes, or industrial noise contribute substantially to the noise environment. The quantitative context of these non-roadway noise sources is not addressed within the approved FHWA TNM modeling software. Therefore, in cases where substantial noise contribution is expected from other transportation (or non-transportation) noise sources, consultation among CDOT noise specialist(s), CDOT project manager, local agency project sponsor(s) (if applicable), and FHWA is required to resolve the noise impact and abatement evaluation methodologies.



## Noise Analysis and Abatement Guidelines

Other considerations that need to be taken into account are situations where a barrier will shield a main highway, but not a frontage road. In these cases, the overall noise environment shall be the basis for the determination if the noise reduction design goal is possible.

### 5.5.2 Cost Benefit Index

In consideration of the cost of each potential noise barrier segment, the barrier cost benefit index shall be calculated based on an estimate of cost per receptor per decibel of reduction caused by the abatement. This will determine the cost-reasonableness of the abatement measure. To be considered reasonable, the cost benefit index must calculate to a dollar value no more than **\$6,800** per receptor per decibel of reduction.

The cost benefit index, calculated as a ratio, is *not* intended to function as an accurate cost itemization for the design and construction of a noise barrier, but rather to provide a consistent level of consideration that will be used for CDOT noise abatement decision-making under these guidelines. The genesis of this cost-benefit baseline derives from the average wall dimensions necessary to provide prudent noise reduction benefit to a suburban/urban neighborhood housing density.

The cost benefit index value will be determined by dividing the approximate cost of the barrier (length \* height \* unit cost) by the total decibel reduction that is predicted to occur for all benefiting receptors of 5 dBA or more. For purposes of the abatement evaluation, the unit cost that will be used for this cost calculation will be a generic wall cost of \$45 per exposed square foot (on one-side of feature), which approximates the typical costs in construction of a standard concrete/masonry barrier that does not require special site considerations. This cost is based on an average of 2005 to 2009 noise wall square footage costs collected from CDOT cost tabulations.

If berms are potentially feasible, use the unit cost of \$15 per cubic yard of earth for the berm portion of the calculation. If the berm will be constructed utilizing on-site excess materials or recycled excess roadside sand, resulting in a trivial cost or a net benefit to the project, a unit cost of \$2.50 per cubic yard shall be used in the calculation. It will be a matter of CDOT noise specialist discretion to determine which berm unit cost will be utilized in the cost-benefit calculation.

For example, consider a barrier 10 feet high and 1000 feet long to protect a development of 16 homes. If 6 receptors are predicted to receive a 5 dBA benefit and 10 are predicted to receive a 7 dBA benefit, the cost benefit index value will be calculated as follows:

- ▶ Cost = (10 ft. ht.) \* (1000 ft. l.) \* (\$45/sq. ft) = \$450,000;
- ▶ Benefit = (6 rec. \* 5 dBA) + (10 rec. \* 7 dBA) = 100 total dBA reduction;
- ▶ Cost-Reasonableness Value = \$450,000/100 dBA = \$4500/receptor/decibel.

This example barrier would be considered reasonable because when the cost of the barrier (\$450,000) is divided by the total amount of decibel reductions for the 16 benefitted receptors (100 dBA), the cost per benefitted receptor, per dBA (\$4,500) is less than the cost per benefitted receptors allowance of \$6,800.



## Noise Analysis and Abatement Guidelines

As mentioned earlier, receptor points that were used in the modeling usually represent several actual receptors. It is very important to properly quantify these receptors to obtain an accurate count of the benefits achieved and used for the calculation. For the calculation, each benefited individual residence, business, etc. is to be counted as one receptor. For multi-family residences, each dwelling unit adjacent to the highway should count as one receptor. If the multi-family structure is represented by a single modeled receptor and it is predicted to receive an overall benefit of 8 dBA, for example, but there are 4 separate units, then an overall benefit of 32 dBA (4\*8) must be used in the calculation. Receptor identification for special land uses captured under the NAC is described in Section 4.1.

### 5.5.3 Benefited Receptor's Desires

The opinions and desires of the benefited community must be considered in the evaluation of reasonableness of a noise barrier. The decision to build or not build noise abatement measures recommended from noise mitigation analysis should result from a simple majority response consisting of greater than 50% of the responding benefited property owners and residents. The CDOT or consultant noise specialist shall identify the applicable benefited receptors within each abatement analysis. A benefited receptor is any property containing a noise sensitive receptor(s) that receives 5 dBA or more noise reduction caused by the abatement measure.

In order to take both owner and resident desires into account, each dwelling unit is provided two votes – one for the owner and one for the resident. For owner-occupied dwellings, both votes would be cast by the same individual(s). For owners of multiple dwelling units (e.g. apartment buildings), the owner would have the same number of votes as the number units that are benefited. Each residential unit would get one vote. In the instance with multiple owners or multiple residents of a single dwelling unit, a consensus is required.

#### Initial Benefited Receptor Preference Survey

CDOT shall solicit current residential occupants and property owners' opinions to build or to not build the abatement measures recommended for the preferred alternative through the NEPA public involvement process, which can include, but is not limited to, open houses, public hearings and/or neighborhood mailers. A noise abatement station providing noise abatement displays and analyses adequate to inform the public on the recommendations shall be present at NEPA-related public venues to solicit and receive votes from benefited receptors. The benefited receptor preference survey process must be thoroughly documented and attached to the CDOT Form 1209 for that abatement measure. A vote of equal standing will be provided one resident and one owner per benefited dwelling unit as described above. Whichever option (for or against the abatement action) that receives the most votes will become the stated preference of the affected persons and the answer for this reasonableness criterion. This recommendation will be documented in the NEPA noise technical documentation and Statement of Likelihood (Section 5.6).

The noise barrier preference survey is normally based on residential areas; however, mitigation for commercial and special-use areas would be based on a survey of the business operators and property management/owners and/or the officials with jurisdiction.



## Noise Analysis and Abatement Guidelines

### **Final Benefited Receptor Preference Survey**

Once final design of the project and the re-evaluated abatement analyses are completed, a renewed public involvement process shall be utilized to solicit the views of current residential occupants' and property owners' on whether to build noise abatement or not. This final design public involvement process shall be devised by CDOT Project Management and coordinated with the noise specialist responsible for the re-evaluation analyses of the final abatement design. The final benefited receptor preference survey process must be thoroughly documented and attached to the Form 1209 for that abatement measure. A vote of equal standing will be provided one resident and one owner per benefited dwelling unit as described above. Whichever option (for or against the abatement action) that receives the most votes will become the stated preference of the affected persons and determine whether or not the abatement is built.

### **Special Circumstance – Categorical Exclusion**

In the special case of the Categorical Exclusion project where there is typically only one build alternative under consideration, public involvement may be limited, and the timeframes between NEPA noise analyses, engineering design and construction are generally more compressed, a single survey as outlined in the *Final Benefited Receptor Preference Survey* will constitute the only survey required for public preference for the noise abatement measure(s). This single survey process would also apply to final NEPA abatement measures identified for design-build construction projects (Section 5.7).

### **Receptor Preference Survey Example**

As an example of the voting process, suppose an Environmental Assessment recommends sound walls at 2 different locations within the project area. The noise specialist identified 60 dwelling units benefited from Noise Wall #1 and 25 benefited dwelling units from Noise Wall #2. An Initial Benefited Receptor Preference Survey was conducted over the final NEPA public comment period, where 2 public meetings were held resulting in 35 votes (25 affirmative, 10 negative) from benefited owners/residents received for Noise Wall #1 and only 5 affirmative and 11 negative votes received for Noise Wall #2.

The decisions would be as follows:

- ▶ Noise Wall #1 received 35 total responses- a total of 25 of 35 or 71% affirmative votes and 10 of 35 or 29% negative votes. The decision would be to recommend construction of Noise Wall #1. This wall would be included in final design of the project.
- ▶ Noise Wall #2 received 16 total responses - a total of 5 of 16 or 31% affirmative votes and 11 of 16 or 69% negative votes from benefited owners/residents. The resulting decision is to not recommend construction of Noise Wall #2. This wall does not meet the required reasonableness criterion because of this vote and would not be recommended. However, this wall would be re-evaluated during final design of the project.
- ▶ These voting results would be documented in the Statement of Likelihood (Section 5.6) of the NEPA decision document and would be attached to the appropriate CDOT Form 1209 (**Appendix D**).

At the final design project stage, both wall locations would undergo a noise abatement re-evaluation to reflect potential changed conditions for impacted receptors, and a new public



## Noise Analysis and Abatement Guidelines

involvement process, the Final Benefited Receptor Preference Survey, would be initiated for those benefited receptors associated with Noise Wall #1 and #2.

- ▶ Under this re-evaluation public involvement process survey Noise Wall #1 received 100 responses from the benefited dwelling unit owners/residents. The final results tabulate 82 of 100 or 82% affirmative votes and 18 of 100 or 18% negative votes. The decision is to build the noise abatement as verified at final design.
- ▶ Noise Wall #2 received 29 responses from the benefited owners and residents. The final results tabulate 15 of 29 or 52% affirmative votes and 14 of 29 or 48% negative votes. The final decision is to build the noise abatement as verified at final design.
- ▶ These decisions would be documented and attached to the appropriate CDOT Form 1209 in the project file and NEPA administrative archive.

### ***5.6 Statement of Likelihood***

The environmental document shall identify (1) locations where noise impacts are predicted to occur, (2) where noise abatement appears feasible and reasonable, (3) locations with impacts that have no feasible or reasonable noise abatement alternative, and (4) the recommendations for construction of noise abatement measures. For an environmental decision, this analysis shall be completed to the extent that design information is available at the time the environmental decision document is completed. A Statement of Likelihood shall be included in the environmental document since feasibility and reasonableness determinations may change due to changes in final project design after approval of the environmental document. The Statement of Likelihood shall include the preliminary location and physical description of noise abatement measures determined to be feasible and reasonable in the preliminary analysis. The final noise abatement decision will be made during the completion of the project's final design and the public involvement processes.

To aid in this documentation, completion of CDOT Form 1209 is required and is to be included within the noise study report (**Appendix D**). This form is to be filled out for each barrier segment or each distinct area of the project that were evaluated in the abatement analysis.

### ***5.7 Special Insulation Abatement Considerations***

Noise insulation of NAC Activity Category D land use facilities, such as places of worship and schools, may be considered for noise insulation in accordance with 23CFR772.13(c)(5). This evaluation will be made on a case-by-case basis. Any decisions in this regard must be thoroughly and completely documented in the text of the noise report. Post-installation maintenance, repair and operational costs for noise insulation are not eligible for Federal-aid or CDOT funding.

### ***5.8 Tiered Environmental Impact Statement***

Tiered EIS documents are a special case requiring consultation with FHWA. The level of noise analyses required for a Tier 1 EIS would be more general in nature, deferring a Type I project noise analysis, as described herein, for a subsequent Tier 2 NEPA study. CDOT and FHWA will jointly determine the appropriate scope of noise analysis for the Tier 1 EIS. When the Tier 1 EIS is intended to narrow the range of alignment alternatives and/or modal alternatives, the Tier 1 EIS may provide more general estimates of future noise levels than a project-specific Tier 2

analysis. The Tier 2 analysis will generally include more detailed information about the design concept and scope and surrounding land uses than Tier 1.

## 5.9 *Design-Build Project Implementation*

The preliminary technical noise study shall document all considered and proposed noise abatement measures for inclusion in the NEPA document (EIS, EA or CE). Design-build noise abatement measures shall be based on the preliminary noise abatement design developed in the technical noise analysis for the Preferred Alternative design. Noise abatement measures shall be considered, developed, and constructed in accordance with this standard and in conformance with the provisions of 40CFR1506.5(c) and 23CFR636.109.

The following items should be included in all Type I design-build bid engineering design plan sets and/or specifications to provide consistency and clarity to the contractor. All items listed below must be compiled by the CDOT Project and Noise Teams and clearly documented in the Bid Package.

- ▶ Definition of geographic siting, dimensions and material requirements of the recommended noise abatement measures.
  - Aesthetic treatments
  - Absorptive treatment if required
  - Materials selection
  - Construction method (e.g. post and panel, pour in place)
  - Any required structural element
- ▶ Definition of the alignment shifts and profile elevation tolerances triggering a re-analysis of noise impacts and abatement. Definition of process for re-evaluation of original recommended abatement in response to alignment shifts or profile changes.
  - Identification of phasing issues where salient features such as existing noise walls or existing shielding once removed during construction would trigger temporary noise abatement requirements during construction period until final abatement measure is re-evaluated and/or constructed.
- ▶ A ***Benefited Receptor Preference Survey*** shall be conducted for abatement recommended for the final alternative in the NEPA process as defined in Section 5.5.3 Special Circumstance. If new abatement is added to the design-build project, the Project Management Team in conjunction with the contractor noise analyst shall initiate a new ***Benefited Receptor Preference Survey*** for any new abatement measure(s).
- ▶ A final noise analysis will be conducted to determine effectiveness of constructed or proposed abatement measures. This includes evaluation of new impacts and new abatement as a result of design changes.
- ▶ Clear responsibility of contractor for monitoring and reporting of alignment and profile changes; communication chain and authority to instigate new noise impact and abatement evaluation.



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- ▶ Clear responsibility of conducting, reporting, recommending, and documenting of new noise impact evaluation in the office.
- ▶ Clear responsibility for development, siting and communicating construction requirements for new abatement measures in the field.

As design-build project construction proceeds, noise abatement measures shall be carefully monitored to document barrier inclusion and barrier placement. Noise abatement measures recommended by the CDOT noise specialist cannot be removed or ‘value engineered’ from a project as a cost-savings device. Adequate abatement must be provided to sensitive receptors as identified in CDOT noise abatement analysis. Altered barrier conditions will be evaluated on an ongoing basis to assure that abatement is constructed that continues to meet noise 7 dBA reduction design goals at one receptor at each recommended feasible and reasonable barrier location. Alterations in dimensions and deviations from proposed siting plans should be well-documented. Larger or more complex projects, which are likely to result in modified roadway horizontal or vertical alignments during the design-build process, should develop an abatement verification procedure to formalize and document changes and alterations to the preliminary recommended abatement parameters and siting.

### ***5.10 Noise Impact Compensation and Third Party Funding***

Property owners or residents cannot receive Federal funds as monetary compensation in lieu of noise abatement. Neither can property owners and residents receive direct monetary compensation for unmitigated damages caused by highway traffic noise impacts.

Third party funding is not allowed on a Federal or Federal-aid Type I or Type II project if the noise abatement measure would require the additional funding from a third party to be considered feasible and/or reasonable. Third party funding can be used on such projects to make functional enhancements, such as adding absorptive treatment, access doors, or aesthetic enhancements, to a noise abatement measure already determined to be feasible and reasonable. Private funding cannot be used to augment the dimensions or change the cost-benefit index of abatement measures recommended in a federal project.

Under current Federal-aid law and regulation, there is no preclusion of multiple parties and/or private funding for project design or construction, such as construction of an interchange or roadway widening, which would include project noise abatement measures.

In regards to CDOT Sound Wall Policy Directive 1900.0 and Implementation of Sound Wall Procedural Directive 1900.1, local agency sponsored and privately funded noise abatement can be constructed on CDOT right of way if the abatement is determined to be feasible and reasonable and meets the requirements of the CDOT directives.

## 6. CONSTRUCTION CONSIDERATIONS

The approach to this discussion in the project report should be general in scope and consider the temporary nature of construction activities. Included should be the types of activities that are expected to be performed and the equipment that will be used. If desired, noise levels that are associated with these activities can be researched through product or process literature and presented in the report. Computerized prediction models have been developed for the calculation of noise from construction but are very sophisticated and require a great deal of construction staging and planning input that is not available to CDOT during the NEPA process. As a result, use of these models to analyze construction noise is not required.

### 6.1 *Construction Noise*

All Type I and II projects will identify land uses or activities that may be affected by construction noise caused by the project. No detailed analysis is required; however, CDOT recommends use of the FHWA construction noise model and suggested mitigations, which can be found at [www.fhwa.dot.gov/environment/noise/construction\\_noise](http://www.fhwa.dot.gov/environment/noise/construction_noise). The noise analysis must at a minimum identify low-cost, readily implemented abatement measures that can be included on the project. Examples are limitations of work to daytime (or specified) hours, ensuring that equipment utilized properly maintained mufflers, modification of backup alarm systems, location of haul roads, and public outreach.

A construction noise plan may be developed to detail mitigation needs and abatement measures employed during construction activities, especially in large, complex projects in major urban areas that are anticipated to have duration of one year or more. In these cases, a more detailed discussion of the impacts and mitigation measures is necessary for the project. This type of mitigation plan could include, but is not limited to construction noise monitoring, heavy truck routing, temporary noise abatement measures, noise complaint hotlines, establishing project construction noise limits and violation procedures. This plan should be identified as a NEPA mitigation strategy for noise or construction, and be fully developed and approved prior to final project design implementation (pre-construction).

### 6.2 *Construction Vibration*

A vibration analysis is generally not necessary for construction activities unless there are vibration-sensitive businesses in the area and high vibration construction methods are proposed. Before construction begins, each vibration-sensitive area must be identified and a temporary vibration mitigation plan be developed.

### 6.3 *Local Ordinances*

Some local governments have passed local noise ordinances which may restrict the amount of noise that can be emitted from a construction operation during certain hours or in certain areas (i.e. residential neighborhoods). Although CDOT is ultimately responsible to assure that local noise ordinances are observed by the contractor, acquisition of noise related permits and variances required by the local ordinances are the responsibility of the contractor. This is something that may be needed if the work is envisioned to be very extensive or lengthy in nature. County, city or local noise ordinances and noise control plans should be investigated with local



## Noise Analysis and Abatement Guidelines

agencies and variances fully resolved with identified jurisdictional authorities, councils and/or boards prior to commencing work.



## 7. COMMUNITY CONSIDERATIONS

### 7.1 *Public Involvement*

Decisions concerning noise abatement should include involvement from the public, in particular the citizens who reside or perform business adjacent to the proposed noise barrier. Education should also be provided to members of the general public within the scope of public meetings and publications that describe noise, noise-related impacts, traffic noise mitigation, and enforcement issues. Various publications that explain many of these concepts are available on the FHWA web site [www.fhwa.dot.gov/environment/noise.htm](http://www.fhwa.dot.gov/environment/noise.htm). Section 5.5.3 outlines the public involvement requirements for a Benefited Receptor Preference Survey.

### 7.2 *Coordination with Local Agencies*

Upon completion of the noise study technical report, information shall be provided to local government agencies within whose jurisdiction the highway project is located as to the traffic noise implications of the project on that particular local community in the future. The overall goal of this effort will be to prevent future traffic noise impacts on currently undeveloped lands and to promote noise compatible land use planning.

Proper noise compatible land use planning is very likely the best approach in dealing with the issue of highway traffic noise. The premise is very simple: Refrain from placing noise sensitive developments adjacent to highways. In reality, this is very difficult to do. As the jurisdiction over most of the land in these cases belongs to local governments, it is up to them to determine what activities to pursue in consideration of the best interests of their citizens. While the State of Colorado encourages local governments to plan their developments in such a manner to minimize the impacts of highway traffic noise, such as the creation of buffer zones or placing less sensitive land uses near the highway, there are no mandates currently in effect that prohibit noise sensitive development adjacent to highways.

Information shall be provided to the local officials as to the best estimation of future noise levels at various distances away from the centerline of the project for both un-developed and developed lands. In particular, the distance estimate of the projected 66 dBA contour (related to NAC Activity Categories B and C) should be emphasized. Noise contour maps of the project area clearly delineating the future 66 dBA and 71 dBA contours on the most current available base mapping or aerial photography of the CDOT project including the surrounding community shall be supplied to the local agency planning department, the zoning department and the building permit department. The noise study report should be forwarded to the local authorities, as well as any other explanation or information that will aid the local officials in planning for future traffic noise impacts, such as the FHWA publications *The Audible Landscape: A Manual for Highway Noise and Land Use* and *Guidelines for Considering Noise in Land Use Planning and Control*. Upon request, CDOT will provide additional available material and technical support and guidance which may be of assistance.



### 8. NEPA DOCUMENT REQUIREMENTS

All Type I projects, regardless of which level of documentation (CE, EA, or EIS) is being used for that particular project, a detailed noise study report will be required to be submitted for CDOT review and comment. This finalized report will be submitted and included with all project information and documentation.

#### 8.1 *Categorical Exclusions*

For CE projects, there is usually no published environmental document. Rather, CDOT CE Form 128 is used to document the environmental decisions, to include noise. Completion of the detailed noise technical report, which has addressed the comments and concerns of the CDOT environmental review process, will suffice as far as project documentation is concerned. This documentation can be used in the public desires survey and for notification of public planning agencies and departments of future noise levels on undeveloped lands. The date that the noise analysis and abatement analysis have been accepted will be noted on the CE Form 128. The final approval of the CE Form 128 represents the date of public knowledge.

#### 8.2 *Environmental Assessments and Environmental Impact Statements*

EAs and EISs will provide a summary of the noise technical report within the body of the document. In particular, this summary will include the impacts that are expected and an evaluation of any potential abatement measures. Although final design information is not available at the early stages of the environmental analysis and documentation effort, every effort must be made to make an initial determination of impacts and evaluation of abatement measures, even though final decisions will not be made until the final design process for the project.

Before the adoption of the decision document, noise abatement measures which are reasonable and feasible and are likely to be incorporated into the project and noise impacts for which no apparent solution is available must be identified by a Statement of Likelihood (Section 5.4). This information should be included to the extent practicable in all NEPA documentation, and must be included in the final environmental document. The purpose of this requirement is that the intentions concerning noise abatement must be made as early as possible in the process. If it is determined that mitigation cannot be provided, the decision must be thoroughly documented with strong supporting evidence provided.

The noise study report shall be available for review within the technical appendix section of the environmental document. The noise study report must be finalized and approved by the CDOT EPB noise specialist before the environmental decision document is approved and signed.

#### 8.3 *Noise Abatement Measure Reporting*

In accordance with 23CFR772.13(f), prescribed FHWA requirements to report a triennial inventory of noise abatement measures and their characteristics, each project shall report the following information on all constructed noise abatement measures. Each region shall report the following information to CDOT EPB noise specialist as each project incorporating a noise abatement measure is constructed.



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The inventory shall include the following parameters:

- ▶ Type of abatement (wall, berm, composite);
- ▶ Cost (overall cost, unit cost per square foot);
- ▶ Average height (feet);
- ▶ Length (feet);
- ▶ Location (county, city, route, and GPS coordinates with identified datum and projection system if appropriate, for wall end points);
- ▶ Year of construction;
- ▶ Average noise reduction as reported by the model in the noise analysis;
- ▶ NAC Activity Category(s) protected;
- ▶ Material(s) used (precast concrete, berm, block, cast in place concrete, brick, metal, wood, fiberglass, combination, plastic [transparent, opaque, other]);
- ▶ Features (absorptive, reflective, surface texture);
- ▶ Foundation (ground mounted, on structure);
- ▶ Project type (Type I, Type II, and optional project types such as State funded, county funded, toll way/turnpike funded, experimental, unknown).

CDOT will report this information to FHWA every three years, in accordance with Office of Management and Budget's Information Collection Requirements.



# Noise Analysis and Abatement Guidelines

## APPENDIX A DEFINITIONS

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## Noise Analysis and Abatement Guidelines

**23CFR772**—Title 23, Code of Federal Regulations, Part 772 (the FHWA Noise Regulation).

**Abatement**—Measures used to substantially reduce traffic noise levels.

**Approach**—Noise levels which are within 1 dBA of the Noise Abatement Criteria for a corresponding NAC Activity Category.

**Automobiles**—All vehicles with 2 axles and 4 tires. Includes passenger cars, vans, and light panel and pick-up trucks.

**Auxiliary Lane** – Auxiliary lanes are not intended to increase road capacity, but to facilitate the operations of the roadway. Examples include, but are not limited to, any lanes that connect the on-ramp of one interchange with the off-ramp of the next interchange, truck climbing lanes, passing lanes, acceleration and deceleration lanes, and turn lanes. Auxiliary lanes which are turn lanes are exempt from Type I projects (see turning lane definition).

**Background Noise**—The total of all noise in a system or situation, independent of the presence of the source of interest (ambient noise).

**Benefited Receptor**— A receptor that is calculated to receive a noise reduction of at least 5 dBA from an abatement action.

**Berm**— An earthen mound constructed for use as a noise barrier.

**CDOT**— Colorado Department of Transportation.

**CDOT Form 1209**—Noise abatement determination worksheet is required to be filled out for each noise analysis for CDOT projects.

**Cost Benefit Index**—A value used to determine the cost-reasonableness of noise abatement based on an average barrier cost per unit area.

**Date of Public Knowledge**—The date of approval of the appropriate environmental decision document for a highway project (signed CE Form 128, FONSI, or ROD).

**Decibel**—The basic unit for measuring the difference of sound pressure levels of a sound event from a reference pressure. To approximate the range of frequencies of sound most audible to the human ear, an A-weighting factor is applied. Sound levels are usually reported in A-weighted decibels, abbreviated dBA.

**Design Year**—The future year used to estimate the probable traffic volume for which a highway is designed (usually 20 years from start of construction). This year is used as the basis for calculating the predicted future noise levels.

**Existing Noise Levels**—The level of noise measured or modeled at a receptor for the pre-construction condition of the highway project area.

**Feasibility** - The combination of acoustical and engineering factors considered in the evaluation of a noise abatement measure.

**Federal Action** – A Federal action includes actions with effects that potentially subject Federal control and responsibility to projects, programs, funding, or regulatory application.



## Noise Analysis and Abatement Guidelines

**FHWA**—Federal Highway Administration.

**Heavy Trucks**—Any vehicle with three or more axles.

**Impacted Receptor**—Any receptor which, under future conditions, is either subjected to noise levels that approach or exceed the noise abatement criteria or a substantial increase in noise levels.

**Insertion Loss**—The predicted reduction in noise levels resulting from implementation of noise abatement measures.

**Leq(h)**—Hourly Equivalent Noise Level; the equivalent steady-state sound level that contains the same amount of acoustic energy as the time-varying sound level over a one hour period; the noise descriptor that is used for all traffic noise analyses for CDOT projects.

**Loudness**—The perceived assessment of the intensity of sound/noise.

**Medium Trucks**—Any vehicle with 2 axles and 6 tires.

**Multifamily Dwelling** - A residential structure containing more than one residence. All dwelling units on all floors of multifamily dwellings that have an outdoor activity area, such as a balcony, and are exposed to traffic noise, are considered noise sensitive receptors.

**NEPA**—National Environmental Policy Act.

**Noise**—Unwanted sound; any sound that is generally considered annoying or offensive.

**Noise Abatement Criteria (NAC)**—Absolute noise levels used to determine that a noise impact occurs when the level is equaled or exceeded.

**Noise Barrier**—A solid structure (wall or berm) constructed between a noise source and noise impacted receptors to abate the highway traffic noise.

**Noise Reduction Design Goal** - The optimum desired dBA noise reduction determined from calculating the difference between future build noise levels with abatement, to future build noise levels without abatement. The noise reduction design goal shall be at least 7 dBA.

**Parallel Barriers**—Two barriers which face each other on opposite sides of a highway.

**Permitted**—Planned development on currently undeveloped land that has obtained a formal building permit.

**Predicted Noise Levels**—Post-construction noise levels as determined via use of a traffic noise prediction model for the design year.

**Privacy Fence**—Fence constructed on private property or edge of development that is primarily used to separate individual lots from a roadway, and not constructed for noise abatement purposes.

**Property Owner** - An individual or group of individuals that holds a title, deed, or other legal documentation of ownership of a property or a residence.



## Noise Analysis and Abatement Guidelines

**Reasonableness** - The combination of social, economic, and environmental factors considered in the evaluation of a noise abatement measure.

**Receptor**—Any location of an outdoor area where frequent human activity occurs that may be impacted by highway traffic noise and may benefit from reduced noise levels.

**Shielding**—Noise reduction attributable to any structures or terrain features which are located between a noise source and receptor. The presence or absence of landscaping or vegetation does not affect shielding.

**Sound**—Mechanical energy produced by pressure fluctuations in a medium (air, water, etc.) that travels in waves and can be detected by the human ear.

**Statement of Likelihood** - A statement provided in the environmental decision document based on the feasibility and reasonableness analysis completed at the time the environmental document is being approved.

**Substantial Noise Increase**—For a Type I project, the predicted noise levels increase by 10 dBA or more over the existing noise levels as a result of a highway project.

**Study Zone**—The area encompassed within a 500 foot halo around the extents of a project which must be considered in the noise analysis. The 500 foot halo is measured from the edge of the roadway pavement, not the highway centerline. If there is a reasonable expectation that noise impacts would extend beyond 500 feet from the edge of the travel way, the study zone will be expanded to include those receptors.

**Through Lane** – A through lane is any general purpose or managed lane that provides capacity to the roadway.

**Traffic Noise Model (TNM)** - Current FHWA approved traffic noise prediction software for use on CDOT projects. Former noise modeling program, STAMINA 2.0 has been superseded and is no longer applicable for project analyses.

**Traffic Noise Impacts**—Impacts which occur when the predicted traffic noise levels approach or exceed the noise abatement criteria or when the predicted traffic noise levels substantially exceed the existing noise levels.

**Turn Lane** – For the purposes of noise analysis, a turn lane is considered to be the amount of roadway lane required to complete a turning motion. The addition of turn lanes would be a Type III project. Freeway turning lanes are considered ramps.

**Type I Projects**—A proposed Federal action or Federal-aid highway project for the construction of a highway on new location or the physical alteration of an existing highway which significantly changes either the horizontal or vertical alignment or increases the number of through traffic lanes. See full criteria identified in Section 2.3.1.

**Type II Projects**—A proposed Federal action or Federal-aid highway project for noise abatement on an existing highway. No active Type II program currently exists in Colorado.



## Noise Analysis and Abatement Guidelines

**Type III Projects** - A Federal action or Federal-aid highway project that does not meet the classifications of a Type I or Type II project. Type III projects are not required to undergo noise analysis.

**Undeveloped Lands**—Lands on which no current human activity areas already exist or are not currently permitted for future development.

**Worst Traffic Noise Condition**—Traffic conditions that yield the highest absolute noise levels by consisting of the highest volume of traffic traveling at the highest possible speed. In general, this is the roadway design hour traffic volume at the posted speed limit.



# Noise Analysis and Abatement Guidelines

## APPENDIX B NOISE TECHNICAL REPORT REQUIREMENTS

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## Noise Analysis and Abatement Guidelines

The purpose of the noise technical report is to provide complete documentation of a highway traffic noise analysis. The noise analysis shall include the following steps for each alternative under detailed study, to include the no-action alternative:

- ▶ Identification of existing activities (receptors), developed lands, and undeveloped lands for which development is permitted,
- ▶ Determination of existing noise levels,
- ▶ Prediction of future noise levels,
- ▶ Identification of traffic noise impacts, and, if necessary,
- ▶ Documentation of the evaluation of noise abatement measures.
- ▶ Development of mapped noise contours to identify future noise impact levels for local land use planning agencies.

Within the body of the report, the above steps taken shall be documented in a manner which allows clear comprehension to the reader of what analysis was done and its underlying reasoning.

The noise report shall include the following (this does not necessarily have to be in the following order and can be included as appendices where appropriate):

- ▶ **Introduction and Study Area.** Describe in detail the project location, project purpose, and project alternatives that are being proposed and the study zone that is being considered.
- ▶ **Noise Basics and Applicable Guidelines.** Describe general sound and noise terminology and the guidelines and regulations that are being adhered to in the development of the noise analysis.
- ▶ **Measurement Procedures.** Describe where and when noise measurements were taken and report the results. List in a table each measurement location and the corresponding results. Not every receptor needs to be measured individually, but enough locations are required in representative points throughout the project. Collect traffic data during the measurements to be used in the validation step.
- ▶ **Measurement/Model Comparison (Validation).** Compare the measurement results with the results obtained using the computer model. Report this data in tabular form as well. In general, agreement within 3 dBA will be acceptable. If the difference for any locations is more than 3 dBA, an explanation must be provided as to the reasons for the difference. This may require that the field measurements be repeated.
- ▶ **Model Input Data.** Describe the data that is to be included in the modeling of the existing and future conditions. Include and quantify all receptors which are within the study zone of the project. Include and describe which roadways, terrain features, buildings, and ground conditions are present. Describe in detail which traffic data are to be used for the modeling, to include the speeds. Generally, this will be the design hour volume for the roadway. If the design traffic year volumes are higher, use the volumes as



## Noise Analysis and Abatement Guidelines

shown in **Exhibit 4**. If they are less, then use those values (do not model to actual capacity of the highway unless the traffic is projected to meet or exceed that capacity). Be sure to obtain as accurate a split as possible on medium truck and heavy truck volumes.

- ▶ **Modeling.** For all receptors, model the noise levels for the existing, all future alternatives being considered, and the future no-action alternative. List all data in tabular form for easy comparison. All receptors shall be identified with an address, business name, or location illustrated on a reasonably legible map in addition to whatever modeling convention is used (i.e. R1-1200 Oak Street) and to which activity category they were classified. If any modeled receptors represent more than one actual property, the representative information also needs to be included (R1, 1200 Oak Street, NAC Activity Category B, 5 residences).
- ▶ **Mitigation Analysis and Evaluation.** If noise impacts are identified, mitigation must be evaluated under the feasibility and reasonableness guidelines. Evaluate abatement first to attempt to achieve a 7 dBA minimum reduction for at least one receptor (CDOT noise reduction design goal). At least two barrier placements and heights should be analyzed unless it is very obvious that only one location/height will be possible. The goal of this effort is to attempt to optimize the barrier given the feasibility and reasonableness factors.
- ▶ **Mitigation Recommendation and Statement of Likelihood.** Explain in detail the final recommendations concerning noise mitigation. This information will also be used in the environmental document, if applicable.
- ▶ **Construction Noise.** A brief discussion of the implications of construction noise and typical mitigation measures that can be used is also required.
- ▶ **Maps.** To aid in visualization of the project and provide definition of receptor locations, maps should be included as appendices to the noise study report that locate the project, modeled receptors, measurement locations, and barrier locations.
- ▶ **CDOT Form 1209.** A copy of a CDOT Noise Abatement Determination Worksheet for each evaluated abatement site should be filled out and attached as an appendix as well. Fill out one form for each barrier segment or project area analyzed.
- ▶ **Noise Modeling Data.** A copy of the input and output data can either be included in the appendix, or preferably, submitted with the report on electronic media.



## **Noise Analysis and Abatement Guidelines**

# **APPENDIX C TRAFFIC NOISE MODEL USER'S GUIDE FOR CDOT PROJECTS**

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# Noise Analysis and Abatement Guidelines

## APPENDIX D NOISE ABATEMENT WORKSHEET

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# Noise Analysis and Abatement Guidelines

## COLORADO DEPARTMENT OF TRANSPORTATION NOISE ABATEMENT DETERMINATION WORKSHEET

Instructions: To complete this form refer to CDOT Noise Analysis Guidelines

STIP # \_\_\_\_\_ Date of Analysis: \_\_\_\_\_

Project Name & Location: \_\_\_\_\_

A. FEASIBILITY:

1. Can a 5dBA noise reduction be achieved by constructing a noise barrier or berm?  
 YES  NO
2. Are there any fatal flaw drainage, terrain, safety, or maintenance issues involving the proposed noise barrier or berm?  
 YES  NO
3. Can a noise barrier or berm less than 20 feet tall be constructed?  
 YES  NO

B. REASONABLENESS:

1. Has the Design goal of 7 dBA noise reduction for abatement measure been met for at least one impacted receptor?  
 YES  NO
2. Is the Cost Benefit Index below \$6800 per receptor per dBA?  
 YES  NO
3. Are more than 50% of benefited resident/owners in favor of the recommended noise abatement measure?  
 YES  NO

C. INSULATION CONSIDERATION:

1. Are normal noise abatement measures physically infeasible or economically unreasonable?  
 YES  NO  
If the answer to 1 is YES, then:
2. a. Does this project have noise impacts to NAC Activity Category D?  
 YES  NO
- b. If yes, is it reasonable and feasible to provide insulation for these buildings?  
 YES  NO

D. ADDITIONAL CONSIDERATIONS:

E. STATEMENT OF LIKELIHOOD:

- |                                                                                                                         |                                                                                                            |
|-------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------|
| 1. Are noise mitigation measures feasible?<br><input type="checkbox"/> YES <input type="checkbox"/> NO                  | 2. Are noise mitigation measures reasonable?<br><input type="checkbox"/> YES <input type="checkbox"/> NO   |
| 3. Is insulation of buildings both feasible and reasonable?<br><input type="checkbox"/> YES <input type="checkbox"/> NO | 4. Shall noise abatement measures be provided?<br><input type="checkbox"/> YES <input type="checkbox"/> NO |

F. ABATEMENT DECISION DESCRIPTION AND JUSTIFICATION:

Completed by: \_\_\_\_\_ Date: \_\_\_\_\_



# Noise Analysis and Abatement Guidelines

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# Noise Analysis and Abatement Guidelines

## APPENDIX E TECHNICAL SUPPORT DOCUMENTATION

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# **CDOT White Paper: Review of General Barrier Cost/Benefit Data for CDOT Noise Guidelines**

The purpose of this memorandum is to document TNM Version 2.5 modeling and associated analyses that were performed in support of CDOT staff as the agency updated the traffic noise analysis guidance document to comply with changes made in 2010 by FHWA to 23CFR772. Specifically, this memo addresses evaluations of barrier cost/benefit as it relates to barrier “reasonableness” assessments under the new regulations.

## **OVERVIEW**

The evaluation of noise barriers for highway projects as specified by 23CFR772 consists of two primary considerations—feasibility and reasonableness. One of several criteria under reasonableness is an examination of the cost/benefit ratio of the noise abatement from a proposed barrier (i.e., wall). The new CDOT guidance must set the threshold for this criterion to allow comparisons and decisions during environmental analysis of future CDOT projects.

CDOT’s previous guidance (2002) specified that costs of \$4,000/receptor/decibel or higher were unreasonable. This assumed a barrier cost of \$30/square foot and counted all receptors receiving at least 3 dBA of noise reduction. The numeric values for the new guidance needed to be updated for 2011 and beyond construction costs while also recognizing the regulatory change that benefiting receptors must now receive at least 5 dBA of noise reduction. The consensus among the CDOT staff participating in the guidance update was that the 2002 cost/benefit threshold had worked well and that a comparable threshold under the new guidelines was appropriate.

To facilitate setting the new cost/benefit threshold, several real-world situations were examined through TNM modeling to evaluate several cost and benefit situations. The examination focused on residential receptors (Land Use Category B) because this is by far the most common situation involving noise barrier evaluations that CDOT has faced. Varying densities of receptors (i.e., neighborhoods) with similarly-performing barriers were combined with updated construction costs to build comparative data (Table 1) to support the selection by CDOT of a new cost/benefit threshold.

## **TNM MODELING REVIEW**

Three example situations were selected from recent past professional experience for examination. The situations are illustrated in Figures 1 through 3. The situations were selected to represent a range of common receptor densities—denser receptor situations would be expected to give better cost/benefit results while lower receptor density would give worse results.

TNM software was used and the modeling processes followed those currently in use for CDOT projects. The actual terrain elevations for the sites were used to ensure realism. The modeling was intended to establish the most compact noise barrier that would provide at least 7 dBA of noise reduction (a simple size optimization of each barrier was included) for the front row receptors so that a matrix of benefits and costs for these neighborhoods could be developed and compared (Table 1).

Separate research for the guidance update, that is not detailed here, reviewed recent CDOT noise barrier construction costs to establish a new barrier cost basis. A new value of \$45/square foot

was chosen—up from the previous \$30/square foot. (Note: earth berms were not examined in this exercise.)

**RESULTS**

Using the new barrier cost basis along with the “optimized” barrier sizes, the performance of each example barrier was calculated and the results are summarized in Table 1.

Table 1. Example Situation Noise Barrier Cost/Benefit Results

Situation	Benefitting Receptors	Total Noise Reduction (in dBA)	Estimated Cost of Barrier	Cost/Benefit Ratio
Example 1	20	142	\$464,000	\$3,270
Example 2	57	508	\$1,820,000	\$3,580
Example 3	21	153	\$2,920,000	\$19,100

The examples fell into two basic groups: those under \$5,000/receptor/dBA and those above. For comparison, the outcomes appeared to be similar to those that would have been expected under the 2002 guidelines, which was viewed favorably by the CDOT panel.

Based on these results, the participating CDOT and FHWA staff felt that an appropriate \$/dBA threshold value would be between the \$4,000 allowed under the 2002 guidance and the \$19,100 exhibited by the poorest-performing example situation (which should not be recommended). A straight escalation of the 2002 threshold value that matched the increased construction cost basis (150%) would give a new threshold value of \$6,000. However, this value would not take into account that comparatively fewer receptors would be viewed as benefitting because the minimum noise reduction would increase from 3 dBA to 5 dBA under the new regulations—which affects the final cost/benefit value for a wall. Therefore, it was felt that a (relatively modest) 13% added cost allowance (\$800) was appropriate in the new threshold value to offset the loss of some receptors that “benefitted” under the old guidance.

This results in a final recommended cost/benefit threshold value of \$6,800/receptor/dBA for the new reasonableness criterion—potential barriers less than or equal to this cost/benefit value are considered to be “reasonable.”

**SUMMARY**

TNM modeling was performed for several example situations to “test drive” ideas regarding a new cost/benefit criterion for potential noise barriers required under the new traffic noise regulations. The results of the modeling fed into the selection by the CDOT panel of a new cost/benefit threshold value that partially determines the “reasonableness” of a potential noise barrier in a CDOT traffic noise abatement evaluation. The new threshold value selected for the CDOT criterion was \$6,800/receptor/dBA.

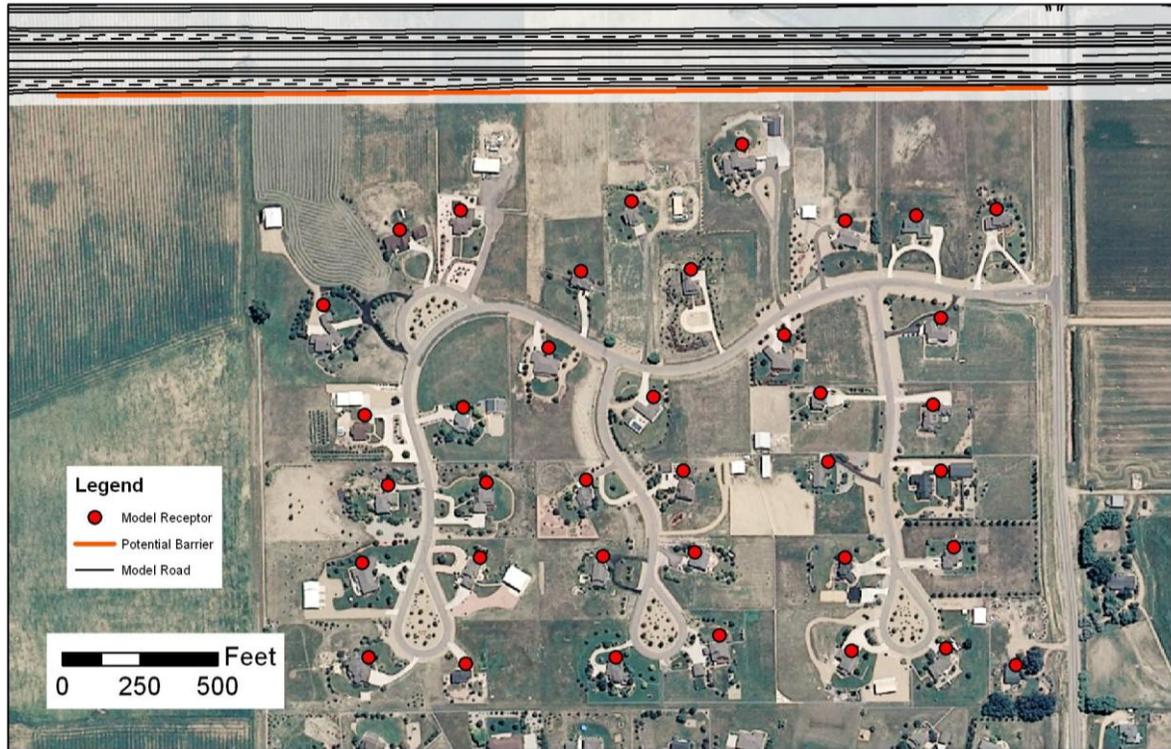
Figure 1. TNM Model Example 1



Figure 2. TNM Model Example 2



Figure 3. TNM Model Example 3



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## **CDOT White Paper: General Methodology for Determining Proper Traffic Volumes for use in Noise Analyses**

One of the requirements for predicting noise levels in highway traffic noise studies is to capture what is usually referred to as the “worst noise hour,” or the point in time where the traffic noise from a given system is at its highest (in the new 23CFR772.9 (d) the term used to describe this is officially “the worst traffic noise impact”). This will be when the highest volume of traffic is traveling at the highest possible speed, or typically just before or after the corresponding “rush” hour, when traffic on some facilities begins to slow with increasing volumes.

When attempting to predict noise under future conditions for highway projects, traffic volumes are either provided by a separate traffic study or derived from existing information. These volumes, however, are usually given as “peak-hour” volumes, which only represent the highest traffic throughput and are represent in many cases a congested situation. As such, it is not appropriate to use peak hour volumes in the noise analysis unless it can be shown that those volumes are below the threshold in which noise levels begin to decrease. Additionally, it is not valid to take those congestion-level peak hour volumes and model them at the peak speed limit.

For simplicity, many State Highway Agencies have defined the worst noise hour as the point in time where traffic Levels of Service (LOS), as described in the Highway Capacity Manual (HCM), are at a rating of between “C” and “D”. While this has been a functional approach, it does have limitations as the parameters that are used may not be something that can be universally used over all facilities. Based on this question, the Colorado DOT performed a general evaluation of highway traffic and corresponding noise levels.

The first task undertaken was to determine at what speeds different volumes (which will be based on vehicles per lane per hour) of traffic will be able to travel. The 2000 version of the HCM was used to investigate this question. Initially, freeway facilities were investigated, as it was the simplest methodology provided (Chapter 23 of the HCM) but also because most of the major noise impacts are associated with these facilities. Chapter 23 of the HCM shows the criteria for freeway facilities and is not included in its entirety here, but the basics of the methodology involve identifying a free-flow speed (FFS) for a facility and the traffic characteristics for that facility. The main calculation that is performed determines the actual vehicle speed based on the volume of traffic per lane per hour. Also determined is the LOS of a facility, which is based on traffic density (calculated by dividing the traffic per lane by the speed).

Based on the equations shown in the HCM, there are inflection points with traffic volumes where traffic will begin to slow. These range from 1150 vehicles/lane/hr. for a FFS=75 mph facility to 1750 vehicles/lane/hr. for a facility with FFS=55 mph. It is interesting to note that based on the LOS definitions in the HCM, the LOS levels for these inflection points (as shown on Figure 23-3 in the HCM) range from B to D. As such, this would indicate that a blanket LOS C or D approach may not result in the highest noise levels for all facilities.

Exhibit 1 illustrates the speeds by volume for different FFS facilities.

Exhibit 1.

VOLUME (vehicles/ln/hr)	Traffic Speed (mph)				
	FFS=75	FFS=70	FFS=65	FFS=60	FFS=55
1500	74.21	69.80	64.99	60.00	55.00
1600	73.48	69.43	64.88	60.00	55.00
1700	72.44	68.80	64.54	59.94	55.00
1800	71.04	67.85	63.90	59.66	54.99
1900	69.26	66.55	62.89	59.02	54.78
2000	67.05	64.85	61.45	57.93	54.18

These numbers illustrate that adding volume to a facility affects the speeds with higher FFS values to a greater extent than facilities with a lower FFS. Thus, it is possible to continue to increase volumes on some facilities more and still increase noise levels up to a certain point.

Exhibit 2 illustrates the approximate traffic volumes and corresponding speeds for the high end of the LOS C condition (defined as a facility density of 26 vehicles/hour/lane).

Exhibit 2.

FFS (mph)	Volume (vehicles/ln/hr)	Actual Speed (mph)
75	1832	70.52
70	1771	68.16
65	1680	64.63
60	1600*	60.00*
55	1750*	55.00*

\*Represents LOS D conditions, traffic will begin to slow with higher volumes

This table, when reviewed along with the volume/speed table, illustrates that a blanket consideration of LOS traffic volumes may not result in a true representation of the actual worst-noise hour conditions.

To determine the vehicle traffic/speed combination that would result in the worst-noise hour condition, the FHWA Traffic Noise Model (TNM) was used. For this analysis, a very basic model was constructed, which simulates the physical conditions of a rural interstate (2-lanes per direction with a median; receptor placed 50 feet from the nearest centerline). Traffic was input as all passenger vehicles, as the interest is not the actual noise levels but the combination of traffic/speed values that would result in the highest levels. By using TNM for this analysis the worst noise hour can be determined directly rather than anecdotally.

To perform the TNM analysis, the major assumption that was made was to treat the FFS of a particular segment as being equivalent to the posted speed limit. There are some drawbacks to performing the analysis in this manner, as for some facilities the FFS can be higher than the posted speed, especially if the engineered facility design speed is greater. This can result in potentially underestimating noise levels. However, for the purposes of this analysis it was felt that as volumes increase to the point of congestion, the overall speeds of the vehicles will tend to congregate around the posted speed limit. Traffic/speed combinations were input into TNM based on the HCM calculations.

Many model iterations were performed in TNM to determine the worst-noise hour levels; those values are shown in Exhibit 3.

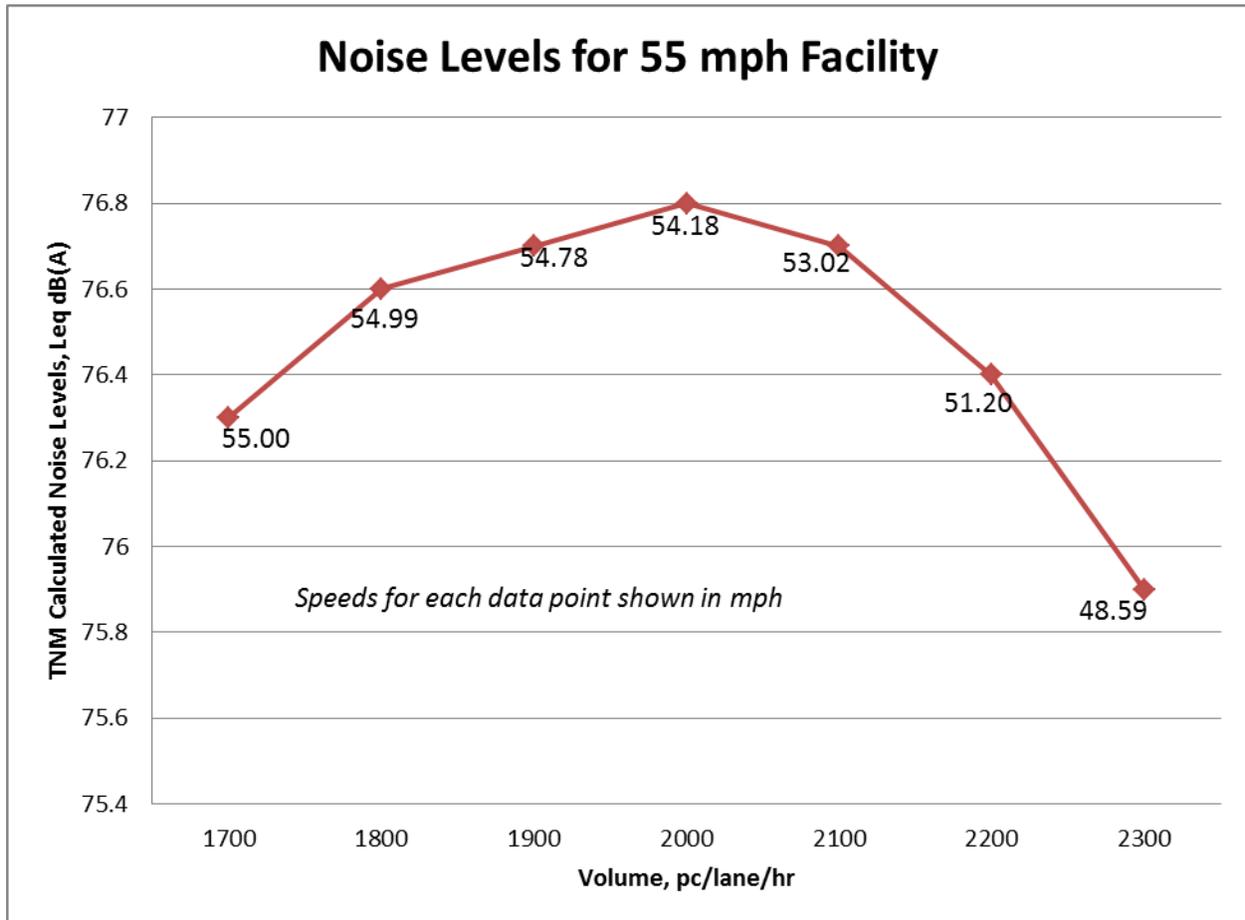
Exhibit 3.

FFS (mph)	Volume (vehicles/ln/hr)	Actual Speed (mph)	TNM Leq Value (dBA)*	LOS
75	1600	73.48	80.6	C
70	1700	68.8	79.8	C
65	1800	63.9	79.0	D
60	1900	59.02	78.0	D
55	2000	54.18	77.0	E

\* These values were obtained using the FFS, not the actual speed

For ease of use, CDOT recommends that, for freeway facilities, these volumes be used to represent the worst-noise hour for different facilities based on the posted speed limit. Additionally, although the worst-noise hour was calculated based on the actual speeds, for simplicity CDOT recommends using the posted speed and not the actual speed as calculated. This will increase the noise level that will be predicted by TNM, but this over-prediction ranges from only 0.2 dBA for FFS=55 to 0.3 dBA for FFS=75, which is not felt to be significant.

Exhibit 4. Volume/Speed vs. Noise Level Chart, Example illustrates FFS=55 mph



This detailed analysis was shown for freeway facilities. Additional analysis was also performed for multi-lane facilities (non-freeway) and 2-lane facilities. The methodology for multi-lane facilities is almost identical than that for freeways, and the base results were very similar. However, the impact of other factors with these facilities, for example at-grade intersections, resulted in lower recommended maximum volumes for the worst-noise hour. Two lane facilities utilize an entirely different approach for determining speed and LOS based on an overall capacity of 1600 vehicles/ln/hr. This methodology was combined with the freeway methodology to arrive at the recommended maximum volumes for those facilities.

Admittedly, this approach does not result in a major change in TNM calculated noise levels over the basic LOS approach and may appear to over-simplify some of these variables. Having performed this analysis, however, has provided the data that supports the overall approach. Having this data allows for an expansion on the LOS concept which identifies discrete values that can be easily used for the analysis so that the worse noise hour levels will be reasonably identified. This also allows noise analysts to concentrate on building their models without having to be experts in traffic analysis.