

Arizona Department of Transportation

Instruction on using FHWA TNM in noise analysis

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Contents

1. INTRODUCTION	3
2. REQUIRED QUALIFICATIONS FOR ANALYSIS.....	3
3. REQUIRED TNM MODELING INVENTORY	4
4. GENERAL	4
5. IMPORTING DXF FILES	6
6. INPUT ROADWAYS.....	6
7. TRAFFIC DATA	9
8. INTERVENING FEATURES.....	11
9. RECEIVERS PLACEMENT AND INPUT.....	14
10. NOISE IMPACT ANALYSIS	17
11. NOISE ABATEMENT MEASURES - BARRIERS	18
12. TNM LOW VOLUMES TOOL.....	25
13. FHWA TNM 3.0.....	25

1. INTRODUCTION

- Arizona Department of Transportation (ADOT) Noise Abatement Requirements demands use of the most current Federal Highway Administration (FHWA) Traffic Noise Model (TNM) for traffic noise analysis.
- ADOT EP Noise team is suggesting a default approach for modeling inputs, based on the environmental conditions and level of noise analysis.
- These instructions promote streamlining ([FHWA-HEP-17-061](#)), consistency and facilitating comparisons of modeling results between projects and alternatives.
- This document is dynamic and may change following the development of new noise modeling tools as approved by FHWA, such as [TNM 3.0](#) and [Low Volume Road Noise Calculation Tool](#).
- These recommendations rely on FHWA's reports [FHWA-HEP-16-018](#) (*Recommended Best Practices for the Use of the FHWA Traffic Noise Model (TNM)*) and [NCHRP Report 791](#) (*Supplemental Guidance on the Application of FHWA's Traffic Noise Model (TNM)*)

2. REQUIRED QUALIFICATIONS FOR ANALYSIS

[ADOT values](#), accountability, integrity, and respect are to be intertwined in all efforts, as we see transportation personal. ADOT is building engaged, empowered, problem-solving team members, in line with Continuous Improvement through [Lean](#) (*identifying and eliminating wasteful activities that do not further the mission*), consultants working on the noise analysis are encouraged to take part in implementing these principles as well through collaboration with EP Noise team. Example of the noise analysis project team, with pertaining qualifications is shown in the figure below.

PROJECT TEAM				
Name	Surname	Skills	Experience	Job title
John	Prof. Dr. Smith, PhD	LEAN management 23 CFR 772, ADOT NAP NEPA processes Traffic noise analysis	6 years - Company FHWA-NHI-142063	Project Manager person responsible for quality of submittals and correspondence
Mark	Markowski	FHWA TNM 2.5	FHWA-NHI-142051	Noise Specialist
Linda	Gonzales	ADOT NAP	FTA-VA-90-1003-06	
	Outsource	MicroStation, AutoCAD CADD, ArcGIS	(FTA) General Transit Noise Assessment	
Horacio	White	23 CFR 772, ADOT NAP	FHWA-NHI-142051	Noise technician
Jane	Johnson	Larson Davis 820 MS Office	FHWA-NHI-142063 FHWA-PD-96-046	
Janet	Jackson	FHWA TNM 2.5 MicroStation, AutoCAD CADD, ArcGIS, USGS MS Office		CADD technician
Taylor	Warren	23 CFR 772, ADOT NAP MS Office Logistics Communications		Admin support clerk

3. REQUIRED TNM MODELING INVENTORY

A model is only as good as pertaining information and assumptions made. The most important step before any modeling is commenced is to obtain all up to date and accurate data/information pertaining to:

1. roadway infrastructure, existing and future
2. land use within project area of concern, the two being absolutely crucial component, and
3. noise propagation intervening features within project area of concern

The extent of data requirements is commensurate with the effort and project's purpose, but in general the following is a must.

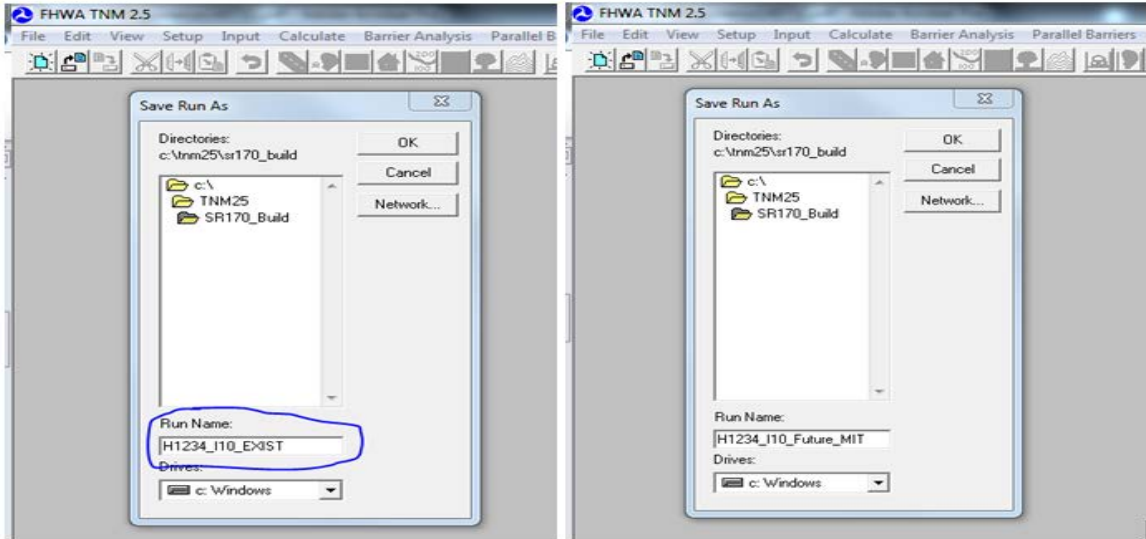
- Engineering Documents
 - Design Concept Report (DCR), existing roadway design drawings with stationing, horizontal and vertical alignment coordinates, drainage, contours, etc.
 - Traffic study, with Level of Service and/or Average Annual Daily Traffic (AADT), vehicle volumes and mix per lane and roadway, existing and future (scenarios)
 - Roadway design and inventory CADD files, with stationing and mile posts, existing and future – MicroStation (perhaps InRoads V8i), AutoCAD files (*.DWG to be converted to *.DXF, 2000 compatible for TNM 2.5), ESRI/GIS (Shapefile *.SHP)
- Mapping data
 - Make sure not to rely solely on aerial map to determine residences and properties, see [Land use instructions](#) (municipal GIS, County Tax Assessor, Google Earth, ESRI)
- Terrain files, such as Digital Terrain Model (DTM), ESRI (SHP)

All the information above is to be obtained and studied before [Methodology meeting](#).

4. GENERAL

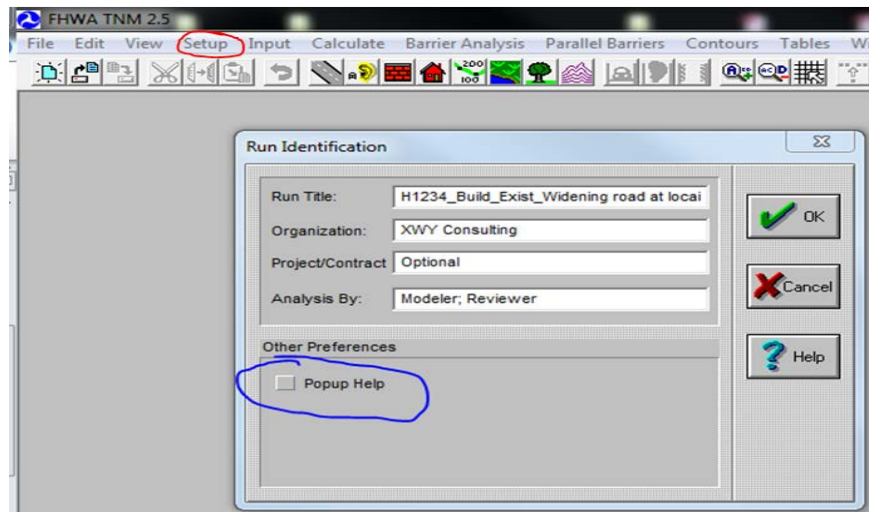
- When naming the TNM run use self-explanatory titles, short enough to fit in the window, Figure 1.
 - Tracks_Route_Scenario (H1234_I10_Exist), and/or
 - Tracks_Route_Scenario_Mitigation
 - When submitting TNM runs with Noise Technical Analysis Report (Report) provide details for every run submitted in a single table in appropriate Appendix.

Figure 1 - TNM run naming



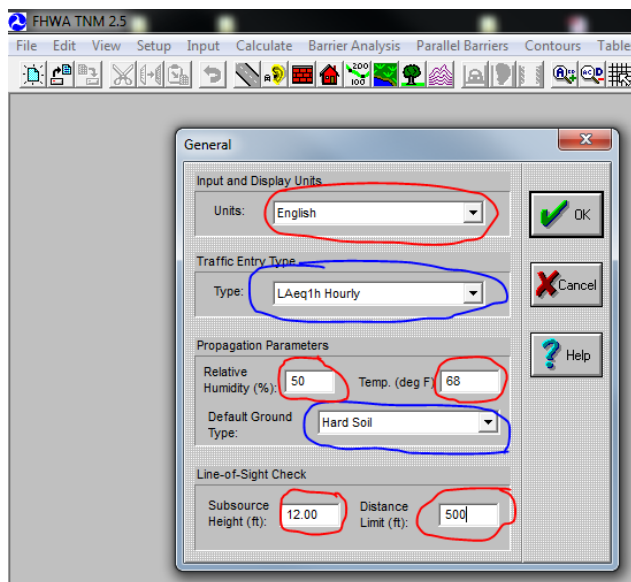
- Use Setup to enter project identification and project specific default details
 - o Run Identification should consist of the information as on Figure 2
 - o Unselect the Popup Help checkbox

Figure 2 - Run Identification required details



- o General default information should be used as shown on Figure 3. Items circled in red are to remain unchanged; items circled in blue may be changed to reflect the situational context.

Figure 3 - General Default Setup



5. IMPORTING DXF FILES

Noise analyst may import DXF files as a Background (like a *wallpaper*) or as Drawing objects that can later be converted into TNM objects such as roadways, barriers, etc., steps include:

1. Create a new run,
2. Export DXF File from CAD or GIS Program
3. Import the DXF file
4. Digitize TNM objects using *Convert DXF Segments to ...* (under Input)
5. Export coordinates to Text File (MicroStation® and AutoCAD®)
6. Comma-separated variable (CSV, TXT) file of coordinates of a specific CAD object
7. Copy and paste into TNM input tables, or
8. Create Shapefile DBF Table and calculate X and Y coordinates for a point object in ArcGIS®

Noise analyst needs to use AutoCAD 2000 compatible files, single layer, points, do not import text, or over detailed curvatures that may create too many closely placed points.

Noise analyst may use option under Edit Subdivide segments, or other, on TNM objects. This may be useful to create smaller segments for fine tuning and optimization of roadways, ramps and barriers. It is particularly important for proposed barriers to have same *Stationing* as shielded roadways for facilitating quality control. Ensure that the entire line is selected (double click), an entire DXF line, to become a TNM object, as otherwise only selected line will be converted.

6. INPUT ROADWAYS

Modeling Roadways and Traffic requirements may be summarized as below:

1. Every lane is to be modeled separately on Multilane highways

- a. If it is considered inconsequential, as determined during Methodology meeting, it is allowed to group up to 3 lanes (2 with traffic, 1 shoulder).
 - b. Extend roadways beyond last 1st row receiver, 4 times the distance to the edge of the roadway on both sides.
2. Traffic is to be laterally distributed across the highway, for every vehicle category, suggest the use of [Traffic lateral distribution tool](#), and FHWA information available [here](#), if information is not available.
3. Name of the roadway should reflect Route, Direction, Lane, and Purpose, Figure 6.
4. Ramp should be modeled as a flow control acceleration roadway that starts at the beginning of the ramp, with 100% Vehicles Affected. The Speed Constraint should be 10 mph, Figure 7. If the ramp carries less than 3% heavy trucks, the Speed constraint could be increased to 15 or 20 mph because automobiles can make the turn onto the ramp at a higher speed before beginning the acceleration along the ramp. Make sure the speed on ramps reflects the posted speed (+5 mph) which is in most cases different than the main roadway.
5. Deceleration is not computed by TNM (except for heavy trucks cruising up a grade >1.5%) Modeling of deceleration is generally not needed.
6. Signalized Interchanges, Intersections
 - Intersecting road: does not cross through intersection
 - Approach: constant-speed roadway at **posted** speed
 - Departure: flow control roadway with 50% Vehicles Affected and Speed Constraint = 20 mph
7. Roundabouts
 - Smaller diameter, speed at 15-20 mph
 - Larger diameter, with two or more lanes, combine, speed at 20-25 mph,

An Example of how to model a two-lane roadway with shoulder is shown below, Figure 5. Notice the Lane Number (1, 2 in line with ADOT numbering, available on [TDMS](#), Figure 4), percentage of trucks and automobiles, lane overlap, and placement of a receiver, while maintaining the width.

Figure 4 – ADOT Lane numbering conventions for modeling

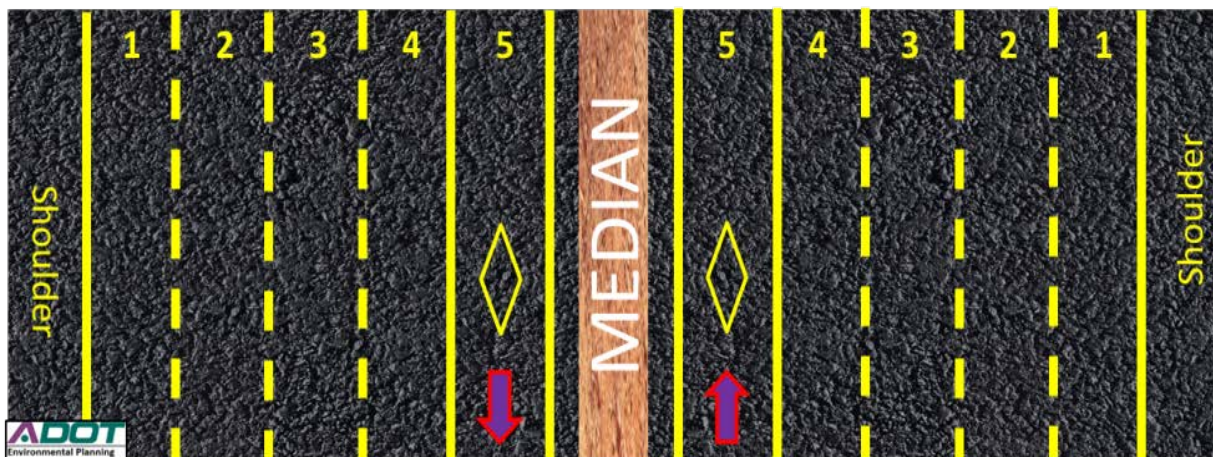
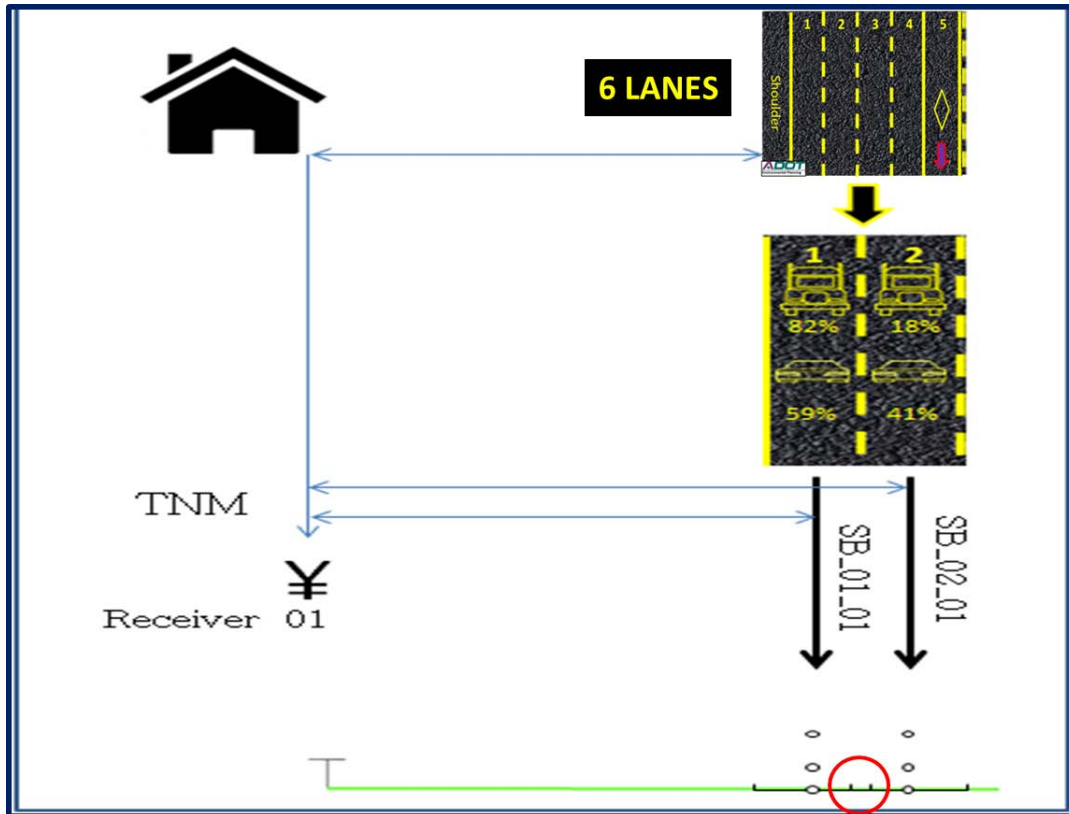


Figure 5 - Lanes grouping - Example



Roadway Input Table provides several Tabs (*General, LAeq1h, FlowControl, Notes*) and Fields for information to be filled in. When it comes to inputting information for the roadways please follow the following recommendations.

Under General tab, Figure 6:

1. Name: Name the roadway to reflect Route, Direction, Lane, and Purpose, as shown on the Figure 4 and 7.
Examples: I-10_WB_1, or RAMP_I-10_43AVE_ON_1
2. Use width to correspond to the roadway design data in DCR, and apply for every section of the roadway.
3. Point name of the roadway should be given to correspond to Stationing used in DCR /other engineering documents.
4. Vertical coordinate (Z), ensure it is same for that Point-Stationing, as used in engineering documents and files, for that particular lane
 - a. Make sure that super-elevation is considered for outside and HOV lanes, as it may easily be over 3 ft difference on multilane highway
5. Pavement remains Average

Under FlowControl, use Speed Constraints, Control Device, and Percentage based on the type of Control Device (Stop, Signal, Toll, Onramp), as shown on Figure 7, circled in red.

Figure 6 - Roadway input Table

Figure 6 shows the 'Roadway Input' dialog box in FHWA TNM 2.5. The 'Name' field is 'I-10 WB Inside_1', 'Width (ft)' is '36.00', and 'Pavement Type' is 'Average'. The table below lists 19 points with columns for Pnt.No, X (ft), Y (ft), Z(pavement) (ft), Pmnt Type, and On Struct?.

Pnt.No	X (ft)	Y (ft)	Z(pavement) (ft)	Pmnt Type	On Struct?
1	650,530.4	895,547.5	1,048.00	Average	
2	650,364.6	895,518.5	1,048.00	Average	
3	650,136.5	895,467.7	1,049.00	Average	
4	649,933.3	895,422.1	1,049.50	Average	
5	649,701.1	895,382.7	1,050.00	Average	
6	649,501.1	895,356.8	1,050.00	Average	
7	649,305.1	895,349.5	1,050.00	Average	
8	649,134.1	895,342.3	1,050.00	Average	
9	648,918.5	895,347.5	1,052.00	Average	
10	648,719.4	895,364.0	1,054.00	Average	
11	648,604.4	895,376.5	1,056.00	Average	
12	648,484.1	895,392.0	1,058.00	Average	
13	648,303.7	895,415.9	1,062.00	Average	
14	648,163.8	895,432.5	1,066.00	Average	
15	648,028.0	895,448.0	1,070.00	Average	
16	647,897.4	895,465.6	1,074.00	Average	
17	647,764.7	895,483.3	1,078.00	Average	
18	647,631.0	895,500.9	1,082.00	Average	
19	647,495.2	895,519.5	1,086.00	Average	

Figure 7 - On ramp traffic Example

Figure 7 shows the 'Roadway Input' dialog box in FHWA TNM 2.5 for an on-ramp. The 'Name' is '7th Ave WB On Ramp', 'Speed Constraint (mph)' is '10.00', and 'Vehicles Affected' is '100'. The 'Control Device' is 'Onramp'. The table below shows points 9, 10, 11, and 12 with Pnt.No and Pnt.Name values.

Pnt.No	Pnt.Name
9	0.22
10	0.20
11	0.19
12	0.16

7. TRAFFIC DATA

As in previous Chapter, every lane is to be modeled separately on Multilane highways. If it is considered inconsequential, noise-wise, as determined during Methodology meeting, it is allowed to group up to 3 lanes (2 with traffic, 1 shoulder). Traffic is to be laterally distributed across the highway, for every vehicle category, and depending on the available data, one may use [Traffic lateral distribution tool](#), and FHWA information available [here](#), if better information is not available.

It is essential that the traffic data used in modeling corresponds to the latest approved Traffic Analysis; this is particularly important when working on re-evaluation of environmental documents.

As a minimum traffic mix should represent automobiles, heavy, and medium trucks.

As per ADOT NAR traffic volumes used in noise analysis are representative of Level of Service C, or 10% or AADT. Peak traffic data is not necessarily representative of worst noise case scenario. On projects that do not have traffic information developed the best resources are ADOT [TDMS](#) and [ADOT Data and Analysis](#), PAG [TDMS](#), and MAG [TDMS](#).

Speed used in the analysis should be 5 mph higher than posted speed; heavy trucks should not be modeled at speeds higher than 75 mph.

8. INTERVENING FEATURES

INVENTORY OF INTERVENING FEATURES	
Intervening Existing Barriers	Median or shoulder safety barriers Large buildings Privacy walls Crash barriers
Intervening Terrain Lines	Ravines, washes, ditches, hills, berms
Intervening Ground Zones	Ponds, parking lots, grass fields, golf courts
Intervening Building rows	Height, width, 50-80 percent
Intervening dense Vegetation	Not likely

Jerseys, median barriers, existing barriers, privacy walls

Existing barriers are important for consideration in modeling the existing conditions and TNM model validation.

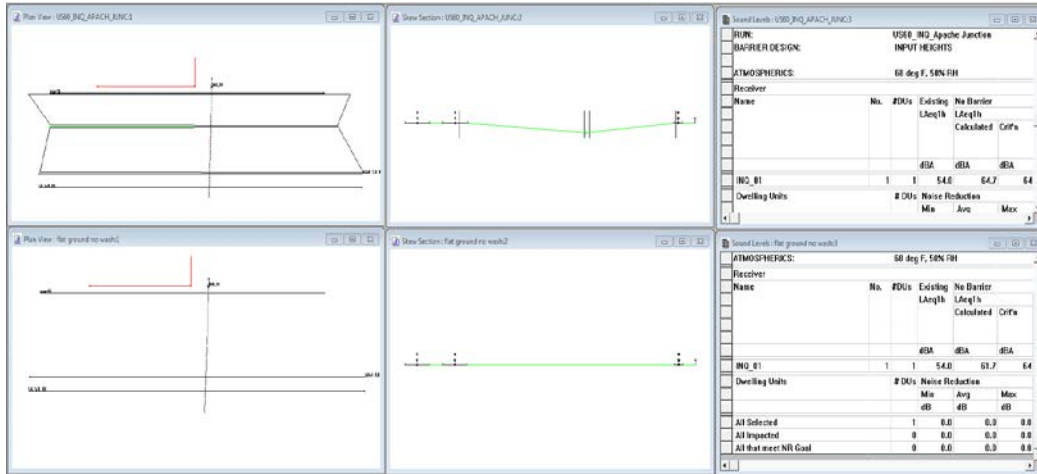
As a reminder, the users should model roadway medians when the median width is greater or equal to 10 ft. Jersey and median barriers may reduce traffic noise impacts from the lanes near to it, and it is particularly important to account them on on-structure ramps, HOV lanes and similar, as they will brake line of sight for the road surface level traffic generated noise. If they are at or over 4 ft model them as an existing wall.

For all roadways, it is necessary for the median to overlap the roadway edges as defined by their widths because TNM will default to the pavement until it reaches the edges of the roadways. For medians less than 10 ft, one may use 1 roadway without traffic to model the median or use 2 wide roadways that overlap. Additionally, please do not snap ground zone points to the roadway points when modeling the median. Often one may check that they are properly overlapping by using the Skew Section view or Input tables.

Terrain lines and Ground zones

The example below is an existing noise inquiry. Failure to incorporate terrain lines and ground zones may make a difference in determination if a receiver is impacted or not. Similar location would be the appropriate place to validate TNM model, and impact of terrain and ground feature verifying modeled versus monitored noise levels. One should not forget that the traffic conditions in course of noise measurements are corresponding to the traffic conditions in the TNM. However, it is not expected to capture every change in terrain, rather two most predominant features for a respective receiver.

Figure 8 - Terrain lines, ground type and impact determination



By default, Ground type is to be Hard soil, Pavement or Loose soil. Using any other type has to be substantiated. Table 2 provides noise reduction at different distances as a result of ground type selected, at various vehicle volumes, mix and speed, straight roadway, same vertical coordinates as receivers, and without intervening features. Therefore, selection of ground type should be adjusted, as per Table 2, to best capture noise propagation at the respective location of modeled receiver.

Table 1 - Terrain propagation test, based on [FHWA TNM 2.5](#)

EFR TEST	50	100	200	400	800	Average	Hourly volume	10000	%	mph
Reduction		3.6	3.8	4.2	4.8	4.1	Auto	90	80	
HARD SOIL	84.7	81.1	77.3	73.1	68.3		MedTruck	5	80	
Reduction		5.3	5.4	6	6.7	5.85	HevTruck	5	75	
LOOSE SOIL	80.8	75.5	70.1	64.1	57.4					
EFR TEST	50	100	200	400	800	Average	Hourly volume	10000	%	mph
Reduction		3.7	3.7	4.1	4.7	4.05	Auto	80	80	
HARD SOIL	86.1	82.4	78.7	74.6	69.9		MedTruck	5	80	
Reduction		4.9	5.1	5.6	7.1	5.93	HevTruck	15	75	
LOOSE SOIL	82.6	77.7	72.6	67	59.9					
EFR TEST	50	100	200	400	800	Average	Hourly volume	7500	%	mph
Reduction		3.6	3.7	4.2	4.8	4.075	Auto	90	80	
HARD SOIL	83.4	79.8	76.1	71.9	67.1		MedTruck	5	80	
Reduction		5.2	5.4	6	6.8	6.07	HevTruck	5	75	
LOOSE SOIL	79.5	74.3	68.9	62.9	56.1					
EFR TEST	50	100	200	400	800	Average	Hourly volume	5000	%	mph
Reduction		3.7	3.7	4.2	4.8	4.1	Auto	90	80	
HARD SOIL	81.7	78	74.3	70.1	65.3		MedTruck	5	80	
Reduction		5.2	5.4	6	6.7	6.03	HevTruck	5	75	
LOOSE SOIL	77.7	72.5	67.1	61.1	54.4					
EFR TEST	50	100	200	400	800	Average	Hourly volume	7500	%	mph
Reduction		3.5	3.7	4.1	4.7	4	Auto	90	70	
HARD SOIL	81.8	78.3	74.6	70.5	65.8		MedTruck	5	70	
Reduction		5	5.2	5.7	6.5	5.80	HevTruck	5	70	
LOOSE SOIL	78	73	67.8	62.1	55.6					

Edge of the road and possibly Right-of-Way line should be modeled as terrain lines. Placing terrain lines and ground zones needs to be not too close to the barriers. More information can be found here:

https://www.fhwa.dot.gov/environment/noise/traffic noise model/tnm_faqs/faq07.cfm

Buildings and building rows

There are analysts that prefer modeling every individual building as a fixed-height barrier; others may prefer to use building rows.

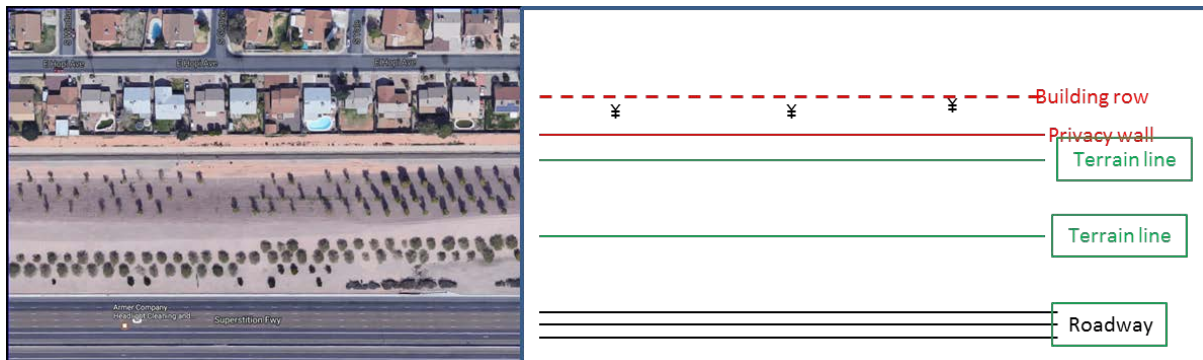
Figure 9, building and the privacy walls are to be modeled as a fixed-height barrier, as area of frequent human use is clearly in the back, shielded by privacy walls and the house itself. In case a receiver is shielded by a warehouse, mall or similar type of building, it is to be modeled as a fixed-height barrier.

Figure 10, front row residential premises are to be represented by building row, at 80%, while the line representing building row would be parallel to the noise dominant roadway, cutting the houses as a central line. Placing receivers would be in front of that line at the closest corner of the residence to the noise dominant roadway.

Figure 9 - Single isolated facility with a backyard



Figure 10 - Row of individual residential facilities



9. RECEIVERS PLACEMENT AND INPUT

[ADOT NAR Chapter 2 Analysis of Traffic Noise, 2.7 Areas of Use and Receiver Placement](#), provides detailed information on receiver placement representing different FHWA NAC Activity Categories. Although Methodology meeting is the venue for additional clarification, EP Noise staff will be available to assist and provide guidance through the course of noise analysis.

The compliance with the following instructions will be very much appreciated, as it would drastically streamline the noise abatement measures feasibility and reasonableness determination, model review process, and overall noise analysis.

1. First row receivers should be titled as

No	RECEIVER TITLE	DESCRIPTION
	R1_XX_IB	R1 stands for 1 st row, XX-any consecutive number, IB-Impacted-Benefited
	R1_XX_INB	R1 stands for 1 st row, XX-any consecutive number, INB-Impacted-NotBenefited
	R1_XX_NIB	R1 stands for 1 st row, XX-any consecutive number, NIB-NotImpacted-Benefited
	R1_XX_NINB	R1 stands for 1 st row, XX-any consecutive number, NIB-NotImpacted-NotBenefited
	RX_XX_IB	RX stands for X ^(nd,th) row, XX-any consecutive number, IB-Impacted-Benefited
	RX_XX_B	RX stands for X ^(nd,th) row, XX-any consecutive number, B-Benefited

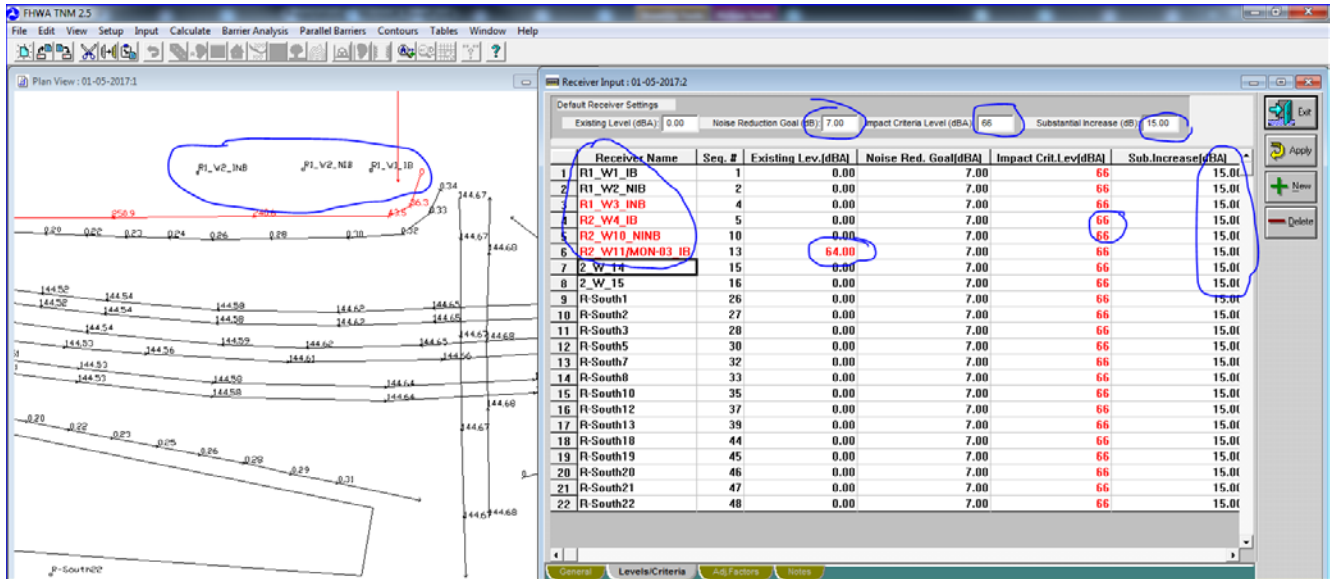
Receivers may be renamed after the analysis, as it is almost impossible to determine impacts determination before running the model, please do before submitting TNM files for review.

2. Insert Default Noise levels relevant for noise analysis for respective receivers, in line with ADOT NAR
 - a. Existing noise level for monitored receivers

- b. Noise design goal, at 7 dBA
- c. Noise impact criteria, at 66 dBA for Activity Category B and C
- d. Substantial increase at 15 dBA

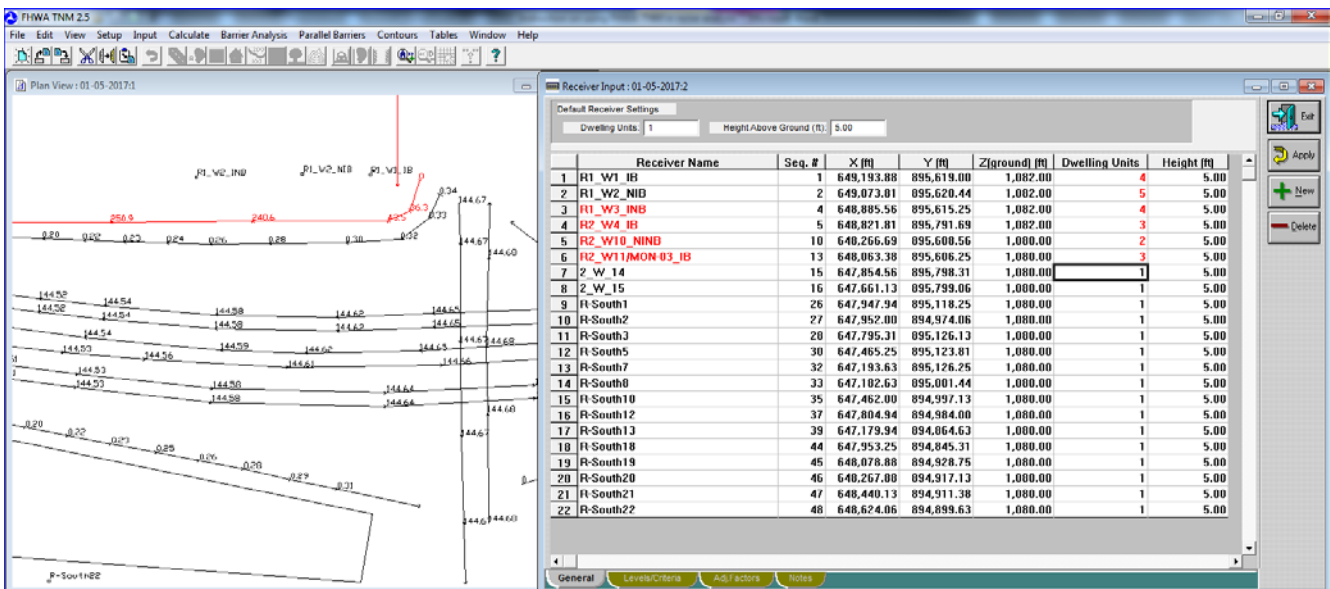
Please see Figure 11 as an example.

Figure 11 - Example of Default Noise levels in Model



3. Please insert the number of receptors represented by respective receiver, as shown on Figure 12.

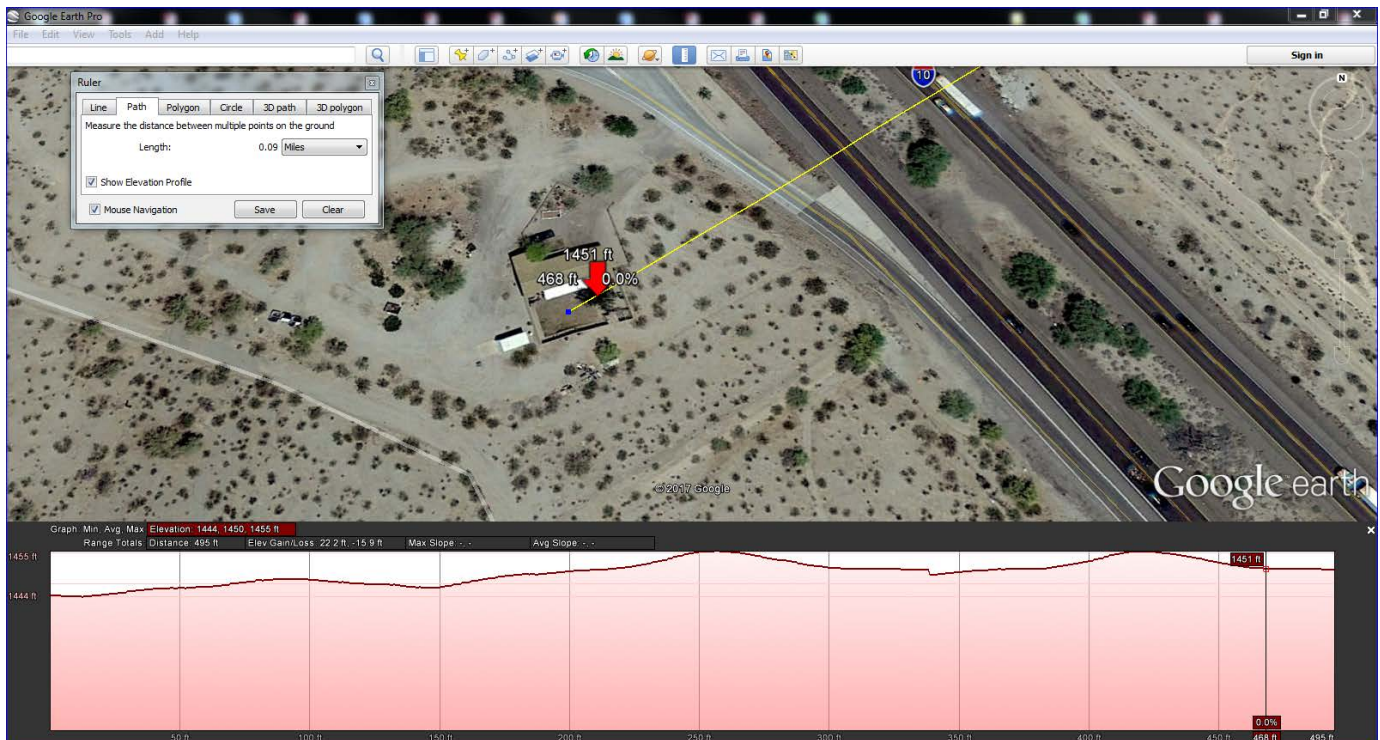
Figure 12 - Number of receptors represented by receiver - example



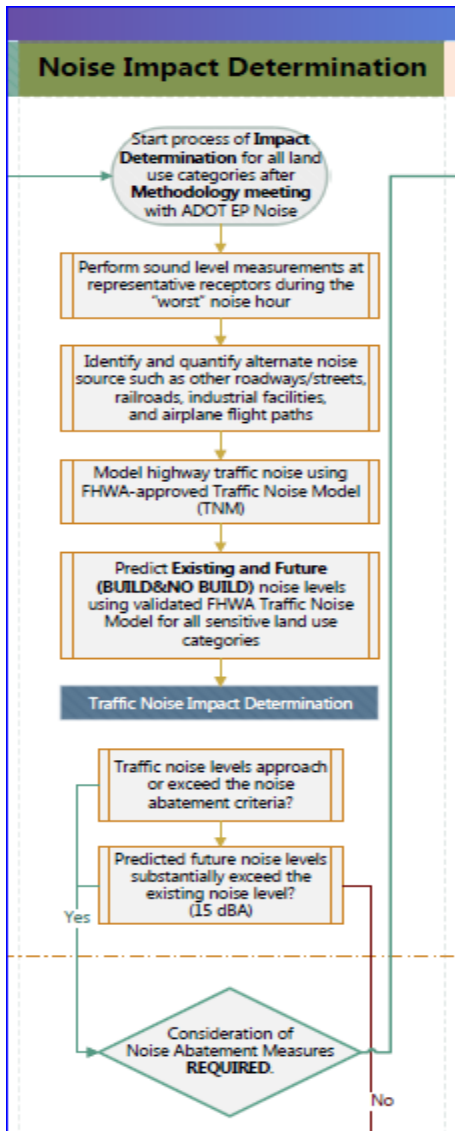
If all three steps are honored, impact determination and noise barrier feasibility and reasonableness can be done by using *Feasibility-Reasonableness tool*, thus streamlining model review.

4. Vertical coordinates of modeled receivers are extremely important, and every effort is to be made to properly determine the vertical coordinates, particularly in relation to the dominant noise source.
 - a. On smaller projects, if the data is not available elsewhere one may consult Google Earth Pro, using commands Ruler, Path, Show Elevation Profile, as shown in Figure 13.
 - b. Using altimeter in combination with design drawings is recommended; taking the altitude of the nearest Station (which would have Z coordinate and GPS coordinate) from the design drawings, then at the receiver location to determine the difference between roadway Station and receiver vertical coordinates.

Figure 13 Vertical coordinates of receivers - example



10. NOISE IMPACT ANALYSIS



Impact determination is a third phase of the *Noise Analysis Flowchart*, and determination of existing noise level is a precondition for determination of noise impacts.

Please use the following resources:

- [ADOT NAR, Chapter 2.8 Measurement of Existing Noise Levels](#),
- [ADOT NAR, Chapter 3 Noise Abatement Criteria and Impact Determination](#)
- *Instructions on Determination of Existing Noise Levels*
- *Instructions on Land Use Category determination*
- *Methodology meeting instructions*

It is important to remind that TNM model is to be validated, and before using the TNM model for determination of impacts it is to be submitted to EP Noise for acceptance, in line with [Methodology meeting and streamlining instructions](#).

As per [Table 2](#), page 11, one may observe that acceptable difference between predicted and measured noise levels at ± 3 dBA may require further considerations. For example, a difference in noise levels at 50 ft from roadway may be within 3 dBA, but same model at 800 ft may have difference over 10 dBA, which may be difference of noise levels perceived twice as loud at that distance. Some states require ± 2 dBA, but even that level of accuracy at distances close to the roadway may not necessarily entail desired accuracy.

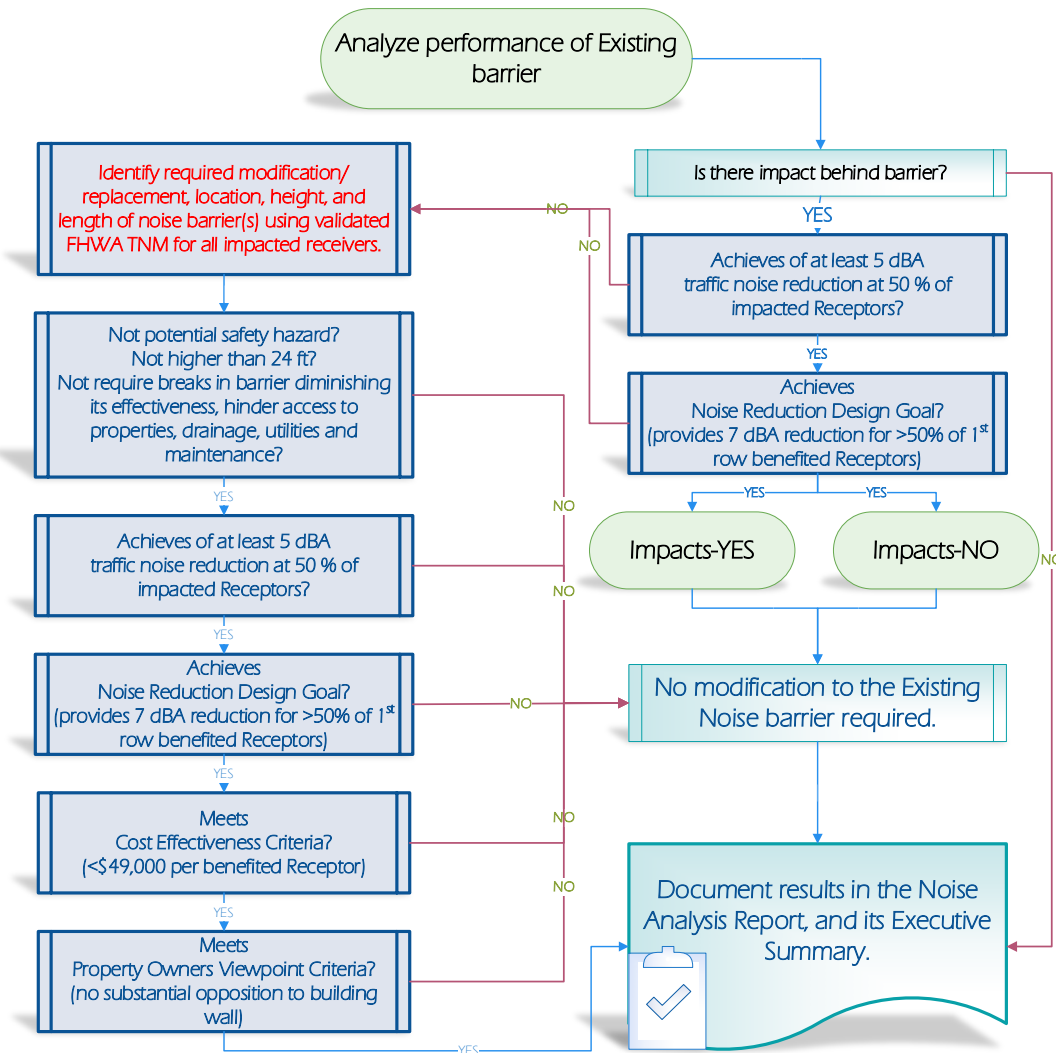
As per FHWA [TNM FAQ, Q-32](#) “Whatever the calibration process, it is important to apply good engineering judgment to the modeling and field measurements. Among other items, the placement of the microphone(s), site geometry, surrounding objects, extraneous noise, and highway traffic noise fluctuations must all be considered. Referring specifically to the sound level measurements, it is important to capture multiple samples of an appropriate length when measuring highway traffic sound levels.” Therefore, it is desired to achieve ± 3 dBA accuracy in throughout the area of the noise analysis, and it may be achieved by applying [ADOT NAR 2.8.2](#), where it says “When and where possible, it is recommended to take two noise measurements simultaneously, with sound level meters placed on the same line perpendicular to the highway, the farther being approximately within 400 ft from the highway, while the other placed half the distance.” The FHWA TNM run used to predict existing noise levels must be validated as per [23 CFR 772.11\(d\)\(2\)](#). Observed discrepancies at receivers may be included in TNM model by respective Adjustment factors, preferred method, or by using spreadsheets.

Once the model is validated and accepted, impact determination may proceed.

11. NOISE ABATEMENT MEASURES - BARRIERS

Determination of the noise abatement measures is the fourth step in [Noise Analysis Flowchart](#), and is contingent upon positive impact determination. [ADOT NAR](#) Chapters 4, 5 and 6 provide detailed explanation on noise abatement measures, requirements and consideration of feasibility and reasonableness.

Consideration of Existing Barriers ([FHWA-HEP-12-051](#))



Most CE Type I projects would coincide with the existing highway alignment and infrastructure; it is highly likely that there is a noise barrier already in place from previous Federal-aid projects.

Existing barrier is to be included in the noise analysis, and it should be assessed for all feasibility and reasonableness criteria, treated in the same way as any other newly proposed barrier.

If there are no noise impacts behind the barrier, the process is complete. If impacts are predicted with the project, further consideration is necessary.

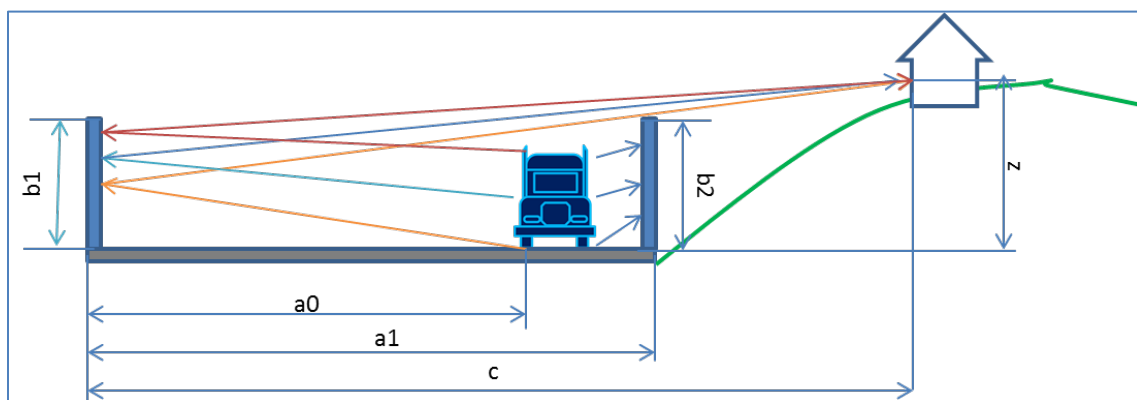
The next step in the assessment is to determine noise levels for impacted receivers with existing noise barriers in a "no barrier" scenario. Next, compare the "no barrier" case to the "with barrier" case to determine whether the existing noise barrier satisfies ADOT NAR. If the barrier meet these requirements, no further action is necessary, as per previous process flow. Even if there are still impacts, this approach is acceptable, as the goal of noise abatement is to achieve a substantial reduction in noise levels; not to reduce noise levels below the Noise Abatement Criteria (NAC).

If the existing barrier does not meet the current requirements modification or replacement of the existing barrier is to be considered to satisfy ADOT NAR. If it is determined that, either modification or replacing an existing barrier is not feasible or reasonable, the existing barrier should remain in place.

Parallel Barriers

Before there is any discussion on feasibility and reasonableness, one of the mostly overlooked features when it comes to the barriers analysis is the importance of the performance degradation of parallel barriers. [FHWA TNM FAQ](#) explains that the magnitude of the performance degradation associated with parallel reflective noise barriers is linked to the ratio of the separation (width) between the barriers and the average height of the barriers. Definitely analyze parallel barriers when the cross-section's width-to-height ratio ($a1:b1$) is less than 10:1. When the ratio is between 10:1 and 20:1, you may still want to analyze the cross-section with TNM, example below, for yourself and see if such a calculation will yield negligible sound-level increases. Such determination has to be included in the Report.

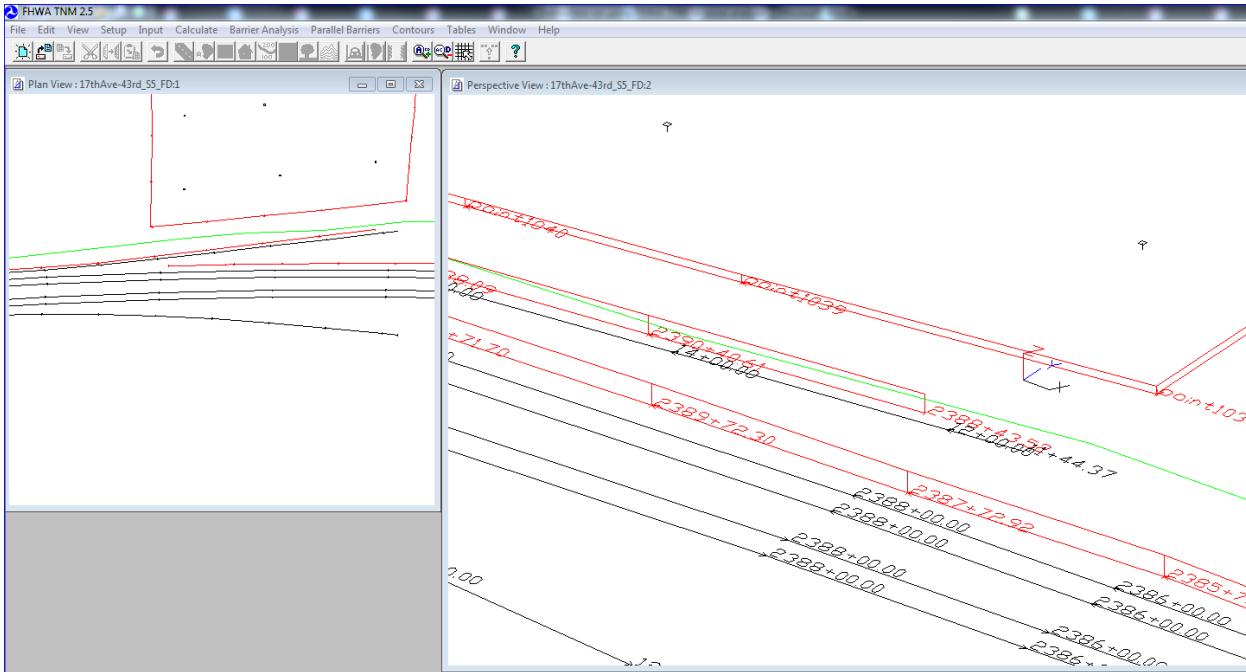
Figure 14 - Parallel barrier - example



In vast majority cases there will be no need for parallel barrier analysis; however, at TIs, ramps and frontage roads there are in most cases two overlapping barriers, Figure 15. In TNM 2.5 reflections would not be considered except through Parallel Barrier tool. Additionally, ADOT NAR now has a provision for the application of sound absorbing materials.

When analyzing barriers that are both in front of shielded receivers, please consider both as they work together for noise abatement, and any change to either one of them affects the other's effectiveness too.

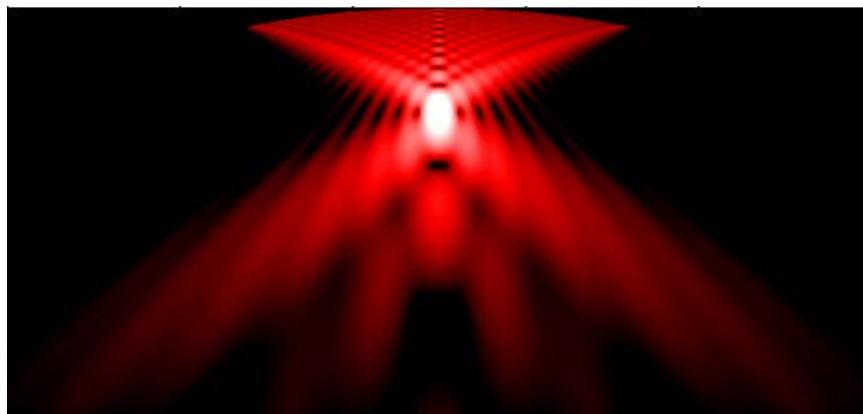
Figure 15 - System of two barriers



A barrier system exhibited in this particular case is commonly referred to as Foss system of barriers.

Reflection phenomenon becomes even more important when there are curvatures on both walls; that is, reflections off of barriers and particularly reflections off of barriers that have a curvature in X-Y coordinates. Any curvature in noise wall may result in focusing noise wave to a single point thus increasing noise levels at that point. However, TNM cannot capture this.

Figure 16 - Curvature focusing reflections - example



When it comes to the process, major requirements are:

1. Check the engineering documents depicting utilities and drainage infrastructure at the possible location of the barrier(s); any relocation cost is to be accounted for in the cost-per-benefited-receptor consideration at later stage

2. Name the Barrier to reflect Route (EN, NB) or logical Direction (N/S/E/W), and Purpose (existing, privacy, or new).
Examples: Barrier_I-10_WB_1,
3. Point name of the barrier should correspond to shielded roadway Stationing used in DCR /other engineering documents.
4. Vertical coordinate (Z), ensure it is appropriate for that Point-Stationing, as used in engineering documents and files, for that particular roadway, Figure 18
 - a. Ensure that height precision is within 2 ft for existing barriers and privacy walls
5. Barrier analysis should use Name of the Barrier and eventually height determined in the analysis; Figure 17. When doing Barrier Analysis, select all receivers shielded by that barrier.
6. When inputting barrier information in Barrier Input Table, Figure 18, make sure that the maximum height is 24 ft
7. When checking shielded receivers and barriers, it is important to cross reference vertical coordinates perpendicularly to the roadway(s) to ensure that noise abatement measure is properly georeferenced, by using View, New View, Skew Section, as shown on Figure 19.

Figure 17 Naming Barrier Analysis

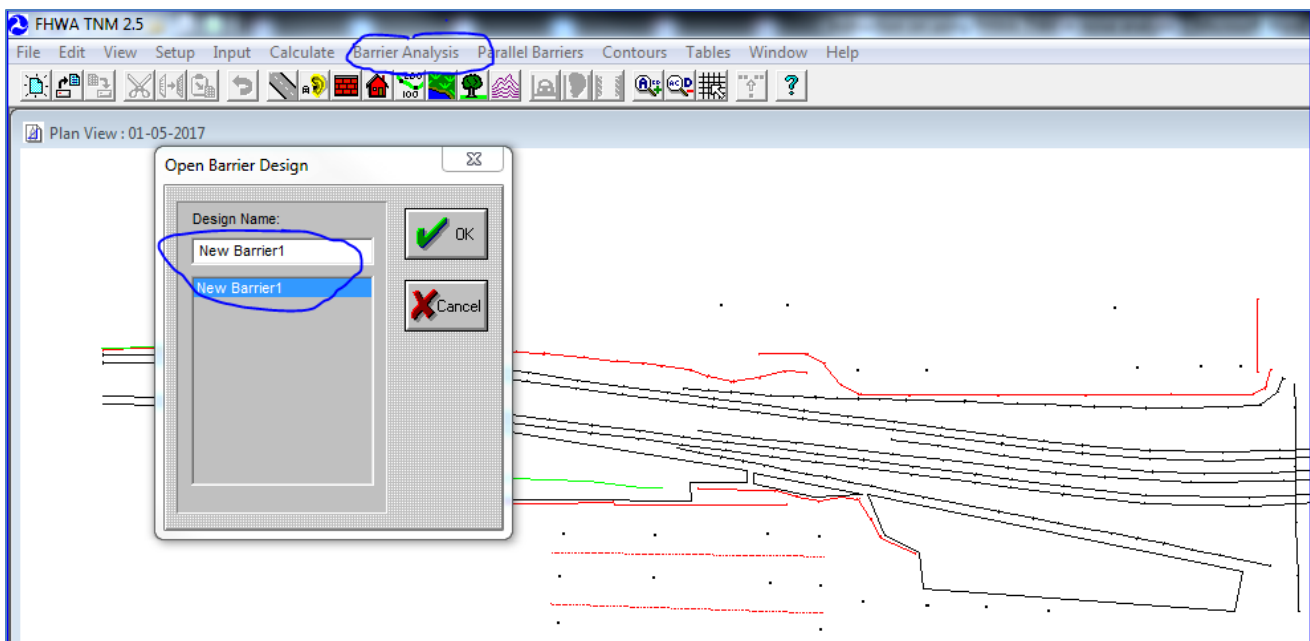


Figure 18 - Barrier Input Table - example

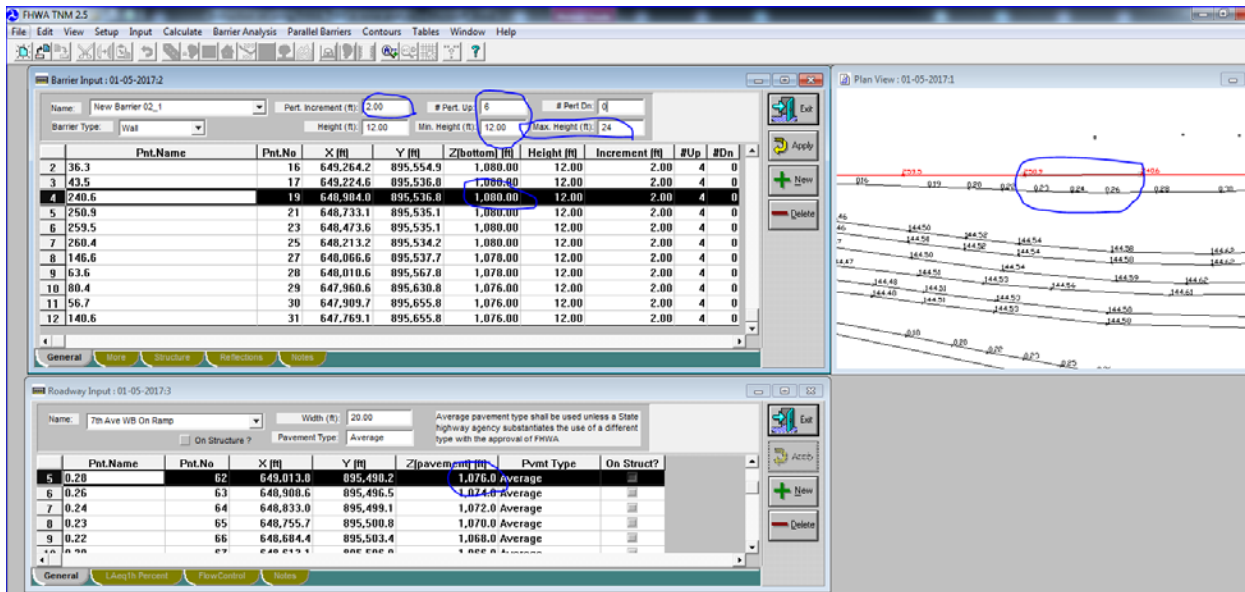
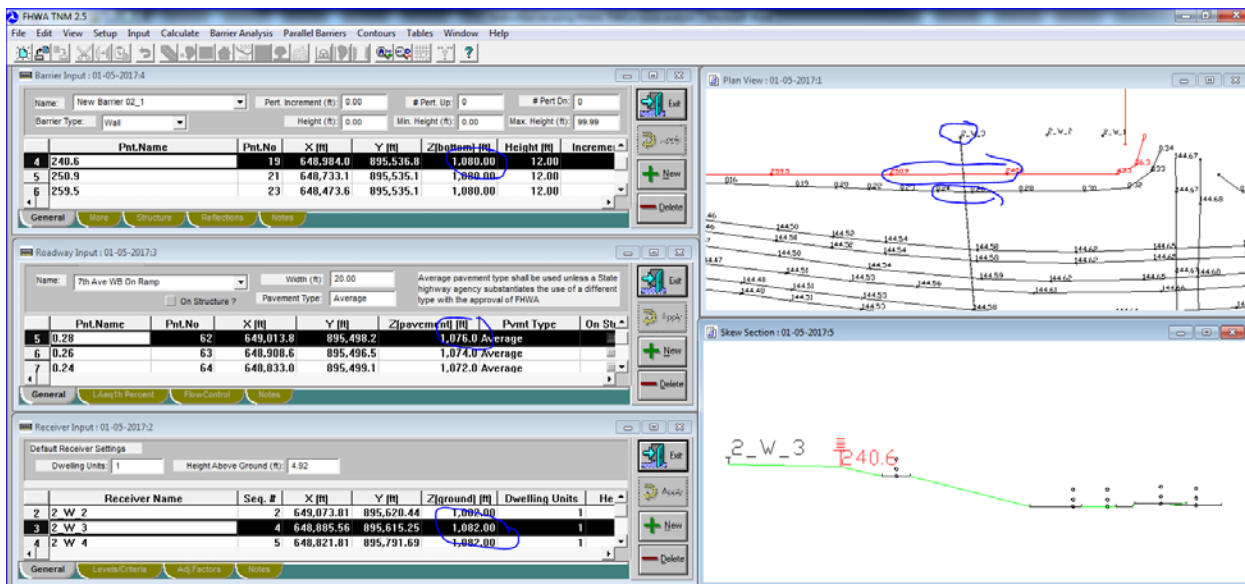


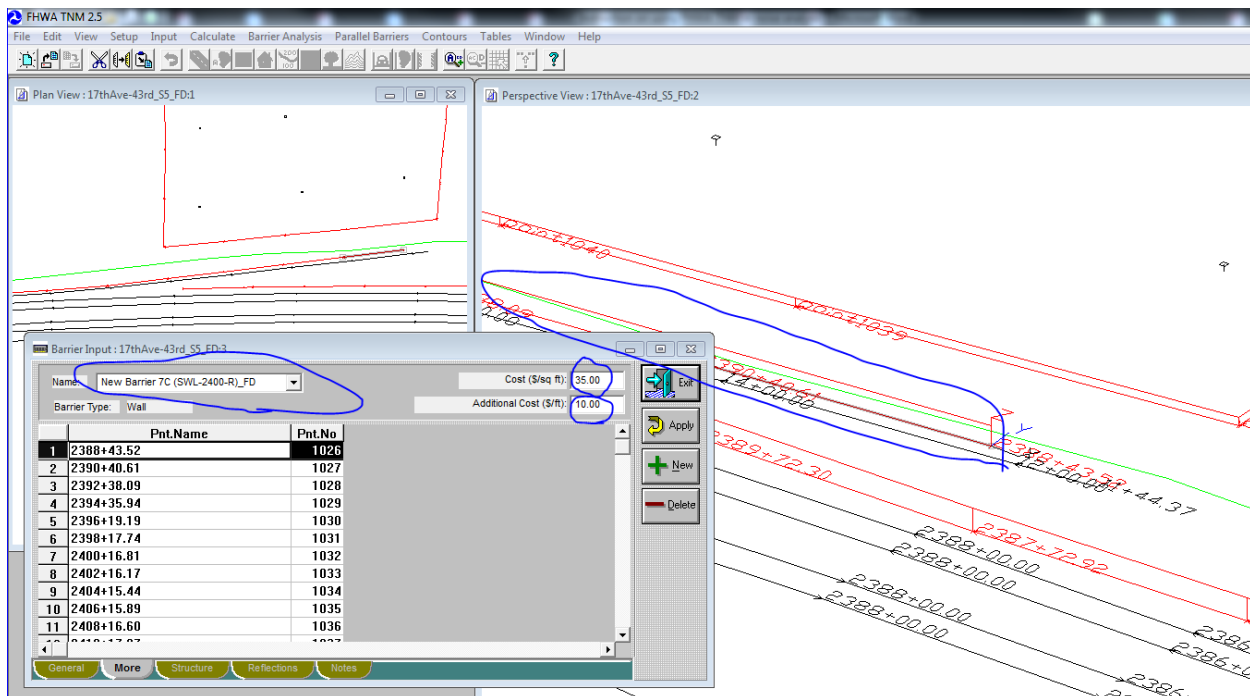
Figure 19 - Cross reference check of barrier, receiver and roadway



8. ADOT NAR Chapter 5 says that “the initial consideration for each potential abatement measure should be both the engineering and acoustic factors that determine whether it is possible to design and construct the measure.”
9. For a noise abatement measure to be acoustically feasible ADOT requires achievement of at least a five dB(A) highway traffic noise reduction at 50 % of impacted Receptors.
 - a. In some instances, the noise level at a particular location may be affected by an alternate noise source such as other roadways/streets, railroads, industrial facilities, and airplane flight paths. Use the same approach as in *Instruction on Determination on Existing Noise levels and Noise Measurement Data Form*

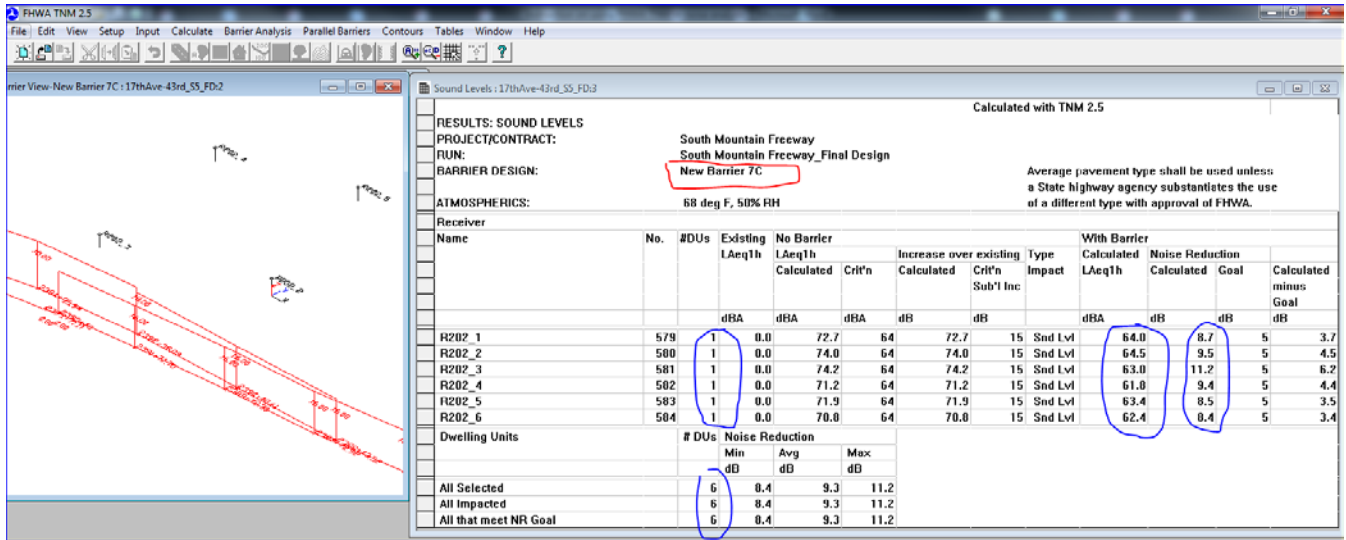
10. Noise barriers should be designed to reduce projected unmitigated noise levels by at least seven dB(A) for benefited Receptors closest to the transportation facility.
11. Make sure the cost is included in the Input Barrier table, as shown on Figure 20
 - a. Cost at \$35, and for on structure \$85. For on structure consider application of light-weight material in consultation with ADOT EP noise.
 - b. Note that additional cost is included because it is expected to have additional construction related cost on resolving drainage issues. All costs are to be considered in cost-per-benefited-receptor analysis.

Figure 20 - Barrier name and cost - example



12. Check if the barrier(s) meet noise reduction design goal.
 - a. Even if the predicted noise levels are at or above FHWA NAC, say 66 dBA, the noise barrier meets the design goal if it provides 7 dBA at 50% of the benefited receptors closest to the transportation facility. That is particularly important for Existing Noise barriers in Type I; if it still meets noise reduction design goal, it remains unchanged irrespective of the noise levels in future.
 - b. Make sure Noise Barrier analysis is open, and then open under Tables, Sound_levels Results.
 - c. Consider breaking line of sight, provided it still meets cost effectiveness.
 - d. Note that Figure 20 shows DU (dwelling units) which is incorrect and therefore requires a lot more time for review which is not in line with LEAN methodology; please use correct figures for DU represented by respective receivers and consider naming them as suggested in this document under *Receivers*.

Figure 21 - Noise reduction design goal - example



13. Consideration of Viewpoints or Preferences of Property Owners and Residents
 - a. Please use *Instructions on Solicitation of Viewpoints*
 - b. This process is normally done after TNM model and noise analysis is completed but is mentioned here as a reminder.
14. Submit the TNM run with the barrier-noise analysis to ADOT EP Noise for review and acceptance.
15. Once accepted it is the time for drafting Noise Technical Analysis Report using *Noise Report Template and Content Guide*.

12. TNM Low VOLUMES TOOL

Another tool that may be helpful in determining whether a detailed analysis is required is [TNM Low volume tool](#). As rule of thumb, if the noise levels are within 5 dBA of the NAC for the respective Activity Category, which is in most cases B or C (NAC 67 dBA), a detailed analysis is required using FHWA TNM 2.5 and instructions provided herein.

The screenshot shows the TNM Low Volume Tool interface. At the top, there is a diagram of a road with a microphone positioned between the Primary Lane and the Opposing Lane. The distance from the roadway to the microphone is indicated. Below the diagram are input fields for Characteristics (Pavement Type, Grade (%)), Traffic (Lane Average Speed (mph), Average Traffic (# Vehicles), Cars (% of Total Volume), Medium Trucks (% of Total Volume), Heavy Trucks (% of Total Volume)), and Receiver Distance from Roadway (ft). The Noise Abatement Criteria Activity Category is set to Activity Level B | 67 dB(A). A green button labeled "Calculate Noise (LAeq, 1 hour)" is present. The Results section shows the Primary Lane Noise (LAeq, 1 hour) as 62.5 dBA, the Opposing Lane Noise (LAeq, 1 hour) as 62.5 dBA, and the Total Noise (LAeq, 1 hour) as 65.5 dBA. A red box highlights the Total Noise result, and a message states: "Calculated noise level is within 5 dB of the noise abatement criterion. A detailed study is required."

13. FHWA TNM 3.0

As per information on [FHWA website](#), a draft version of TNM 3.0 was released on March 14, 2017 and will be available until September 14, 2017. Application of TNM 3.0 shall follow applicable guidance from FHWA,

ADOT encourages consultants to consider introduction for eventual future application to the new version of TNM, and as a first step view the introductory [webinars](#).

One may use [TNM 2.5 to TNM 3.0 Conversion Tool](#), please install it in a separate folder from TNM 2.5.

Please do not hesitate to contact ADOT EP Noise should you have any additional queries.