University of Central Florida

FDOT Rail Model

User Guide

July 2006
(modified Sept. 27 2007)

BD548-13

Contents

Problem Statement

Transportation noise is usually the dominant noise source throughout an urban area. Detailed procedures have been developed to predict the noise levels that occur for these sources. For highways and airports very defined models have been developed and promulgated by Federal agencies for use by State DOTs during environmental analysis required for project planning. The same cannot be said about noise from railroads or rail sources.

Although there is a spreadsheet promulgated by FTA for rail noise, it is difficult to use, requires a lot of user lookup, and can only predict for very simple cases. This is not acceptable for project analysis. This has recently become very crucial for FDOT since part of the CSX railroad line in now owned by FDOT. It is also very important during highway improvements to determine the impact from the railroad as compared to the traffic noise. Finally, FDOT is charged with the task of overseeing the development of high-speed rail in Florida. At present FDOT has no way to analyze the large impacts caused by high-speed rail. Even maglev is like an aircraft on final approach.

Additionally, because of the different noise spectra associated with rail events, barriers cannot be designed using models such as the Traffic Noise Model. This work will include the proper frequency components to allow abatement such as barriers to be evaluated.

This research will result in a user-friendly model that could be applied to evaluate rail noise from freight, light passenger, AMTRAC, and high-speed rail operations. It will allow agencies such as FDOT, FRA, and FTA to more accurately model the impacts from rail operations than ever before. The very simple scenarios that can be modeled now will be replaced with a much more robust model. This will lead to more accurate predictions rather than the large overestimation that often occurs now. In turn, projects will not be affected by overly conservative estimations.

Modeling Concept

The Florida DOT Rail Model (FDOT RM) is a simulation based noise prediction model that can predict the community noise environment from many types of sources including:

- Railways

- Point Sources such as:

  -front end loaders

  -back up sirens

  -warning horns

  -custom sources

The user creates a model of a community using the toolbar or the *Object Editors* from the menu. The model can include railways, rail crossing semaphores, point sources areas, receivers (homes), barriers, terrain lines, building rows and others.

Once the required data is input by the user, the user can run a simulation using the *Calculate* menu option or by pressing the F5 hot key.

The FDOTRM simulation is a two part process. The FDOTRM uses a time step based simulation where all source positions, speeds and modes are

updated at incremental time steps. All moving sources are first moved to new positions and their attributes are updated, then the *acoustic algorithms* begin their computations. The acoustic algorithms include the following:

- geometric spreading

- ground effects

- diffraction effects (single and double diffraction)

- atmospheric effects (absorption)

Acoustic Model
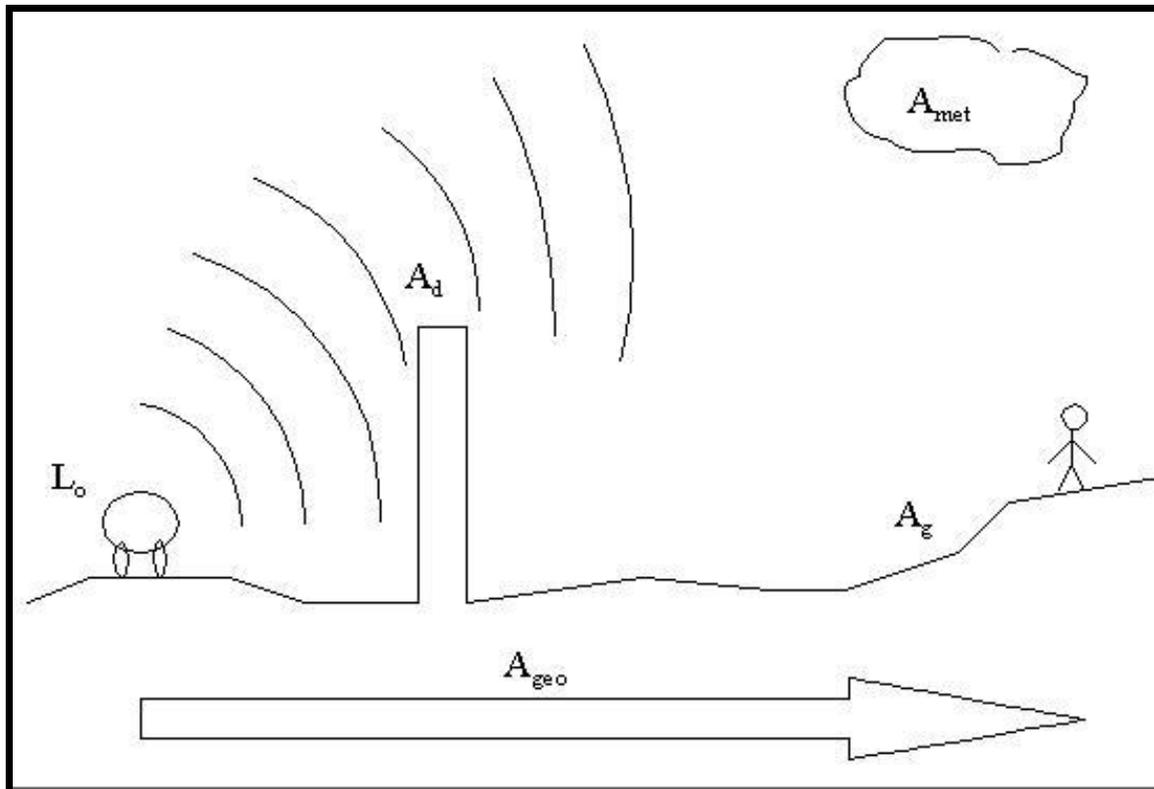
Simplified depiction of acoustic model and attenuation terms.

The general acoustic model assumes that each source has a reference sound pressure level (L_o) that is adjusted by independent attenuation terms (A_x) as shown in the equation below.

$$L_{receiver} = \sum_{allsources} [L_o + A_d + A_{geo} + A_g + A_{atm}]$$

L_o = reference level of source, REMEL or L_{max}

A_d = diffraction effect

A_{geo} = geometric spreading effect

A_g = ground effect

A_{met} = meteorological effects

The individual attenuation terms are as follows:

Term	Equation	Reference
A_d	$[10 \log_{10}(3+20*N)]$ where: N = Fresnel number = $(2*\ddot{A}r)/\ddot{e}$	1
A_{geo}	point source correction = $20*\log(R_1/R_2)$	2
A_g	$[4.8 - (2*H_m/r) *(17+300/r)]$ where: H_m = mean height of propagation path above ground (m) r = source to receiver distance (m)	3
A_{met}	based on ISO 9613:1	4

Each source-receiver combination is evaluated at each time step in a ray trace fashion. The reference sound pressure level of the source is computed followed by the attenuation terms. The reference sound pressure level may be dependent on the speed and operational mode of the source or may be essentially constant for stationary point sources. The attenuation terms are all dependent on the current position of the source. The diffraction term is dependent on intervening obstacles such as berms, barriers, building rows and terrain lines. The ground effect term is dependent on the type of ground at each receiver as specified by the user. This process is repeated for all sources present in the simulation at the current time step.

Building a model

A noise model consists of defining 1) sources of noise, 2) receiver locations that are sensitive to these sources and 3) describing the path between the source and receiver. Acoustic phenomena occur in the sound wave path and can include diffraction due to large objects such as buildings or berms or barriers, refraction due to the atmosphere, absorption and reflection off the ground surface and a spreading of the sound waves over distance.

Common sources found in a community environment can include railways and point sources. These objects can be explicitly defined in several "*editors*" that are found in the *Model Objects* menu. Receivers can also be placed with the FDOTRM toolbar or with the receiver editor.

Toolbar note: The toolbar is useful for estimating the location of some objects but most of the coordinate information for railways and receivers should be known before the actual modeling begins. The toolbar is useful for placement of objects but the complete definition of object characteristics is not possible with the toolbar and this is where the editors must be used.

In addition to sources and receivers, there can be objects that lie in the path of the sound waves from the sources to the receivers. These objects can include barriers, buildings and terrain lines. These objects can also be placed

with the toolbar and also have their own editors located in the Model Objects menu.

Other features of the path include the *atmosphere* which can cause bending and scattering of sound, and the *ground type* which can dissipate some of the sound energy similar to a resistor in an electrical circuit. These features are also taken into account in a noise model and the FDOTRM uses descriptions of the atmosphere and ground surface to predict the attenuative effects caused by them.

Once the sources, receivers and path characteristics have been defined a *simulation* of the model can be conducted. The length of simulation may be dependent on the purpose of the analysis, noise standards and regulations are usually described in terms of an equivalent sound level for a given period of time which could be one hour or a 24 hour period. The *results of the simulation* can be used to determine if abatement of sources is necessary and the model can then be used predict abatement benefits.

Using Toolbars to create objects

The toolbar on the left side of the working area can be used to drag and drop railways, crossings, barriers, receivers and to define point source areas. Select the appropriate button from the toolbar, down-click the mouse where the object/element is to begin, then drag the mouse to stretch the object, upclick the mouse to define the end location of the element. Once objects have been
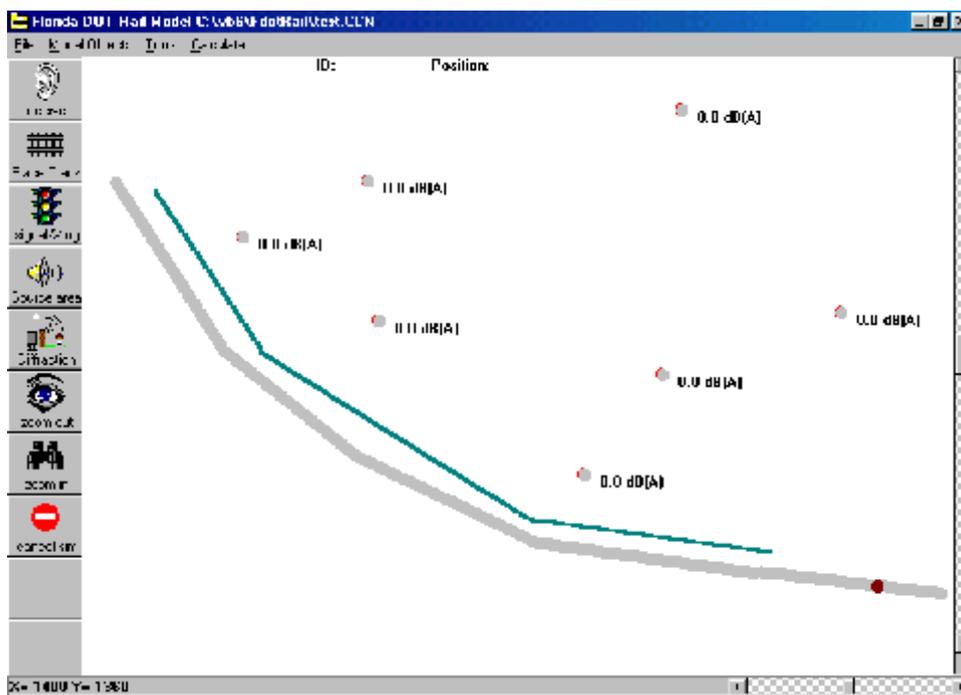
Working area of FDOTRM with toolbar displayed.

created using the toolbar, the user can access object properties using the *Object Editors* found in the *Model Objects* menu. An object can be deleted by right-clicking over the object and selecting the "delete" option or by using the

appropriate Editor.

Model Objects Menu

The model objects menu contains the editors used to add model objects

or modify existing objects that comprise a simulated community noise

environment. The figure below shows the various sub-menus found in the

Model Objects menu. Object editors include:

> *Railways*
> *Barriers/terrain lines/building rows*
> *Point source areas*
> *Train warning horns*
> *Receivers*
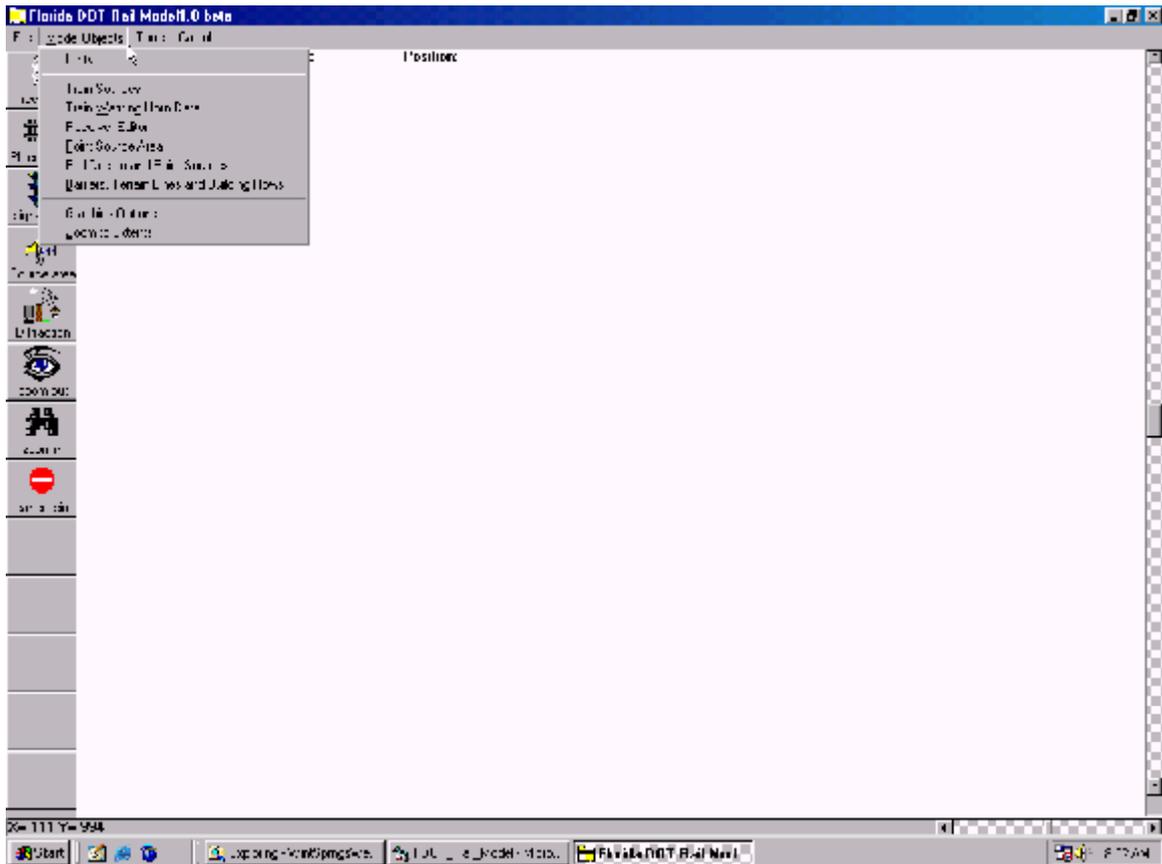
Model Objects menu item..

Rail Design and Point Sources

The railway editor has spreadsheet input that is used to specify the beginning and end points (x,y,z) of the railways. It contains an input for the speed of rail sources on the railway and it includes input for hourly operations (L_{eq} hour) or daytime and night time operations information for the computation of L_{dn}.

The "next track" column is used to notify the FDOTRM of a new track to send trains that reach the end of the current track. The FDOTRM track number

is required for this column, the number is the row number found in the left most

column of the spreadsheet. The "next track" feature is used to create a "curve"
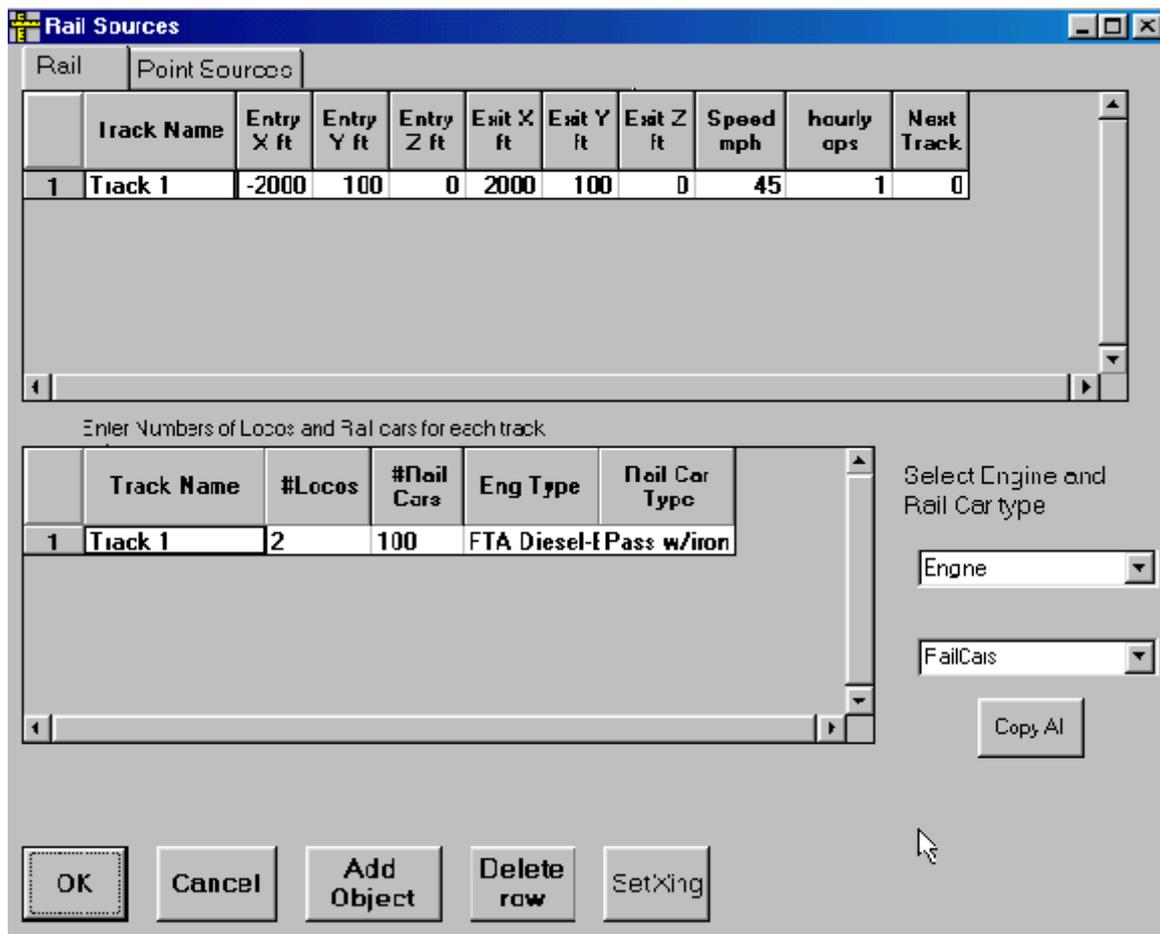
Railway Editor of FDOT Rail Model.

that is composed of several track links and each link specifies the destination of

the train after it clears the current link. For example, a series of 5 rail links could

be used to emulate a curved section of track and the "next track" input for track

#1 would be "2", the "next track" for track #2 would be "3" and so on.

The composition of a train (consist) on a railway is determined using the

smaller spreadsheet. The user specifies the number of locomotives and rail cars in a train consist and then chooses the locomotive and rail car types from the drop-down lists found to the right of the second spreadsheet input.   These sources are based on L_{max} data from the literature. The second spreadsheet input is used to specify the number of locomotives and rail cars.

The railway editor also includes the "Set Xing" button which opens the rail crossing editor. This feature places a railway crossing at a certain "distance" from the beginning of the railway. This distance is the location from the beginning of the track to the desired crossing location. For example, a 2000 ft. track segment with a crossing near the end of the track may have a *Xing position* of 1800. Setting this position can also be accomplished using the *toolbar*.

Warning horns are activated when a train approaches a railway crossing and the Model Objects menu includes a "*Train warning horn*" editor as shown below. The warning horn editor includes inputs that determine the maximum sound pressure level of the horn at a specified distance, the height of the horn above the track, and some information about the horn "*blast zone*." The "distance from crossing" input defines the region that the horn may be activated by the FDOTRM.   The horn is activated based on the distance from a crossing
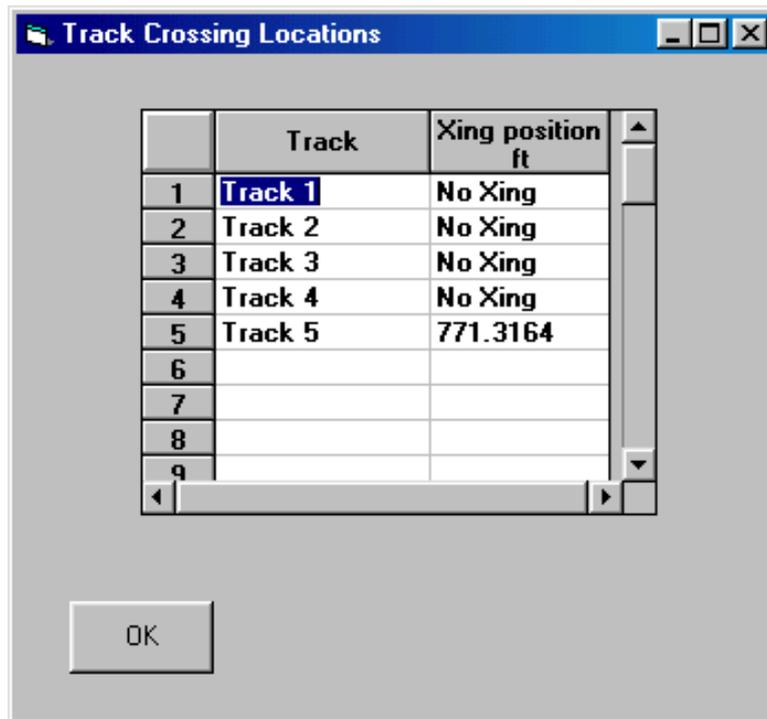
Rail Crossing Interface.

that the horn is first activated and the desired *number of horn blasts* while in the

blast zone. Once a train enters the blast zone, the FDOTRM determines whether

the horn should be activated by comparing a computer generated uniform

random variable to the inverse of the desired number of blasts while in the

zone. If the result is positive the horn is activated for the time step. This

technique is used to determine when the horn should be activated spatially.

Temporally, the horn is in use for one half of the time that the lead locomotive is

in the blast zone, unless a single horn blast is specified. In this case, the horn is

activated the entire time the train is in the blast zone. This provides a degree of

randomness for the horn activation rather than a pre-determined pattern of horn

activation.
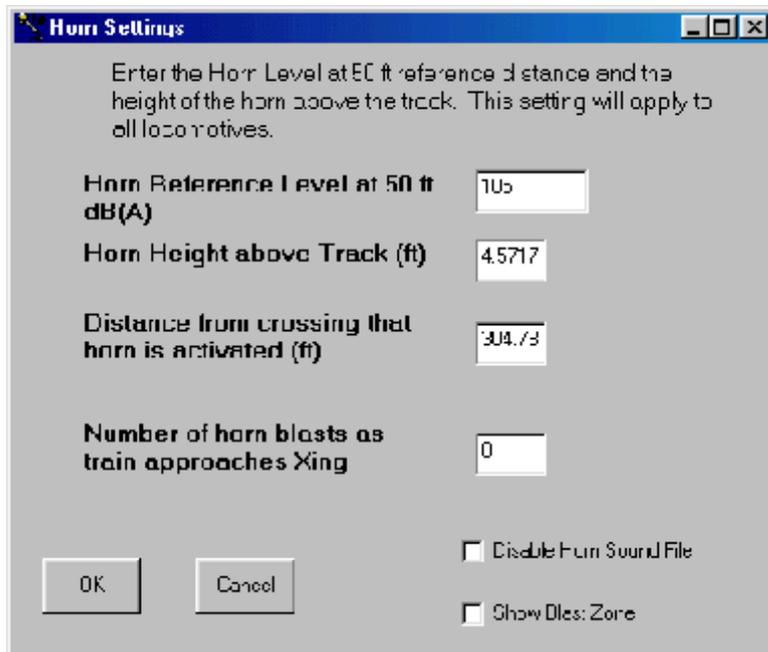
Train Horn Interface.

Receiver Editor

The receiver editor includes the coordinates of the receiver, the type of ground at the receiver, the background sound level at the receiver location and any additional shielding effects not included in the FDOTRM, such as vegetation. The *elevation* of the receiver is the ground plane elevation and the height is the height off the ground that the receiver is located.

Receivers can be "*included*" or not included to speed the simulation run times when only a certain number of receivers are of interest but the user does not want to remove them from the model.

Receiver Editor.

Diffraction Object Editor

The diffraction object editor contains input for three different diffraction objects including, barriers, terrain lines and building rows. The snapshot below shows a model that includes several partial barriers and no terrain lines or building rows. This editor is straightforward, the user specifies the beginning and end points of each object and the height of a barrier segment. Terrain lines have no height, they are completely described by their x,y,z coordinates.
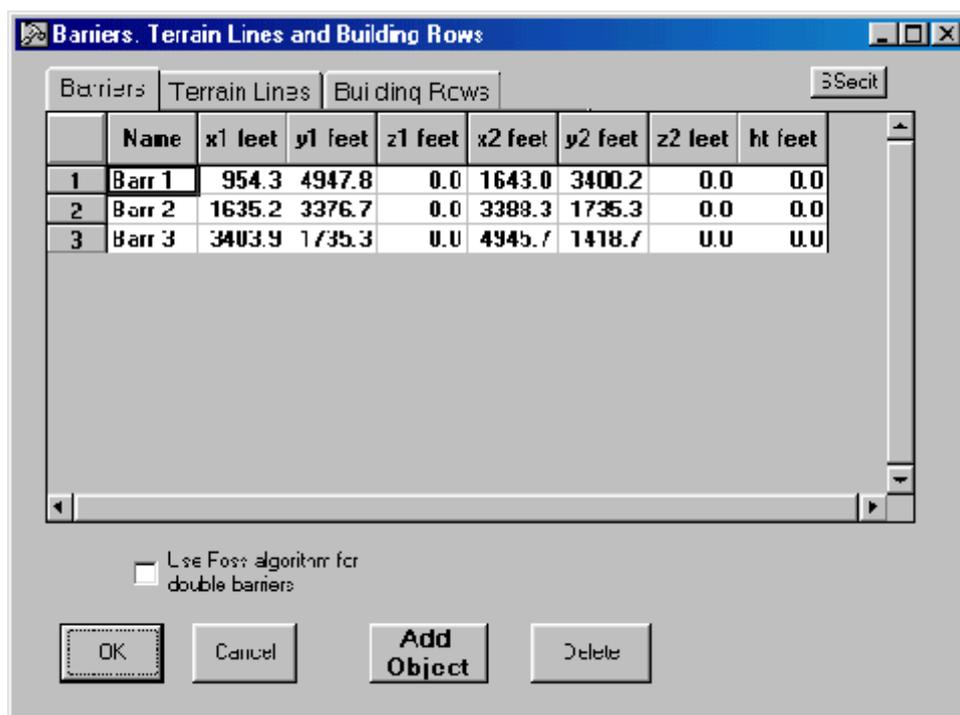
Diffraction Object Editor.

One additional input is the "gap fraction" for building rows. This specifies the total amount of gap between buildings for this building row. For example, a building row that has no gaps between buildings would have a gap fraction of zero (example: a solid apartment building several hundred feet long) and a building row with no building has a gap fraction of unity (1.0, this would not really happen, this would be a building row that has no buildings, in reality the fraction would be more like 0.1 to 0.2).

Point Source Area Editor

The Point Source Area feature of the FDOTRM is a powerful and flexible tool for modeling either moving or stationary point sources within a confined area. The area can be defined using the mouse and the tool bar or it can be specified in the editor itself.
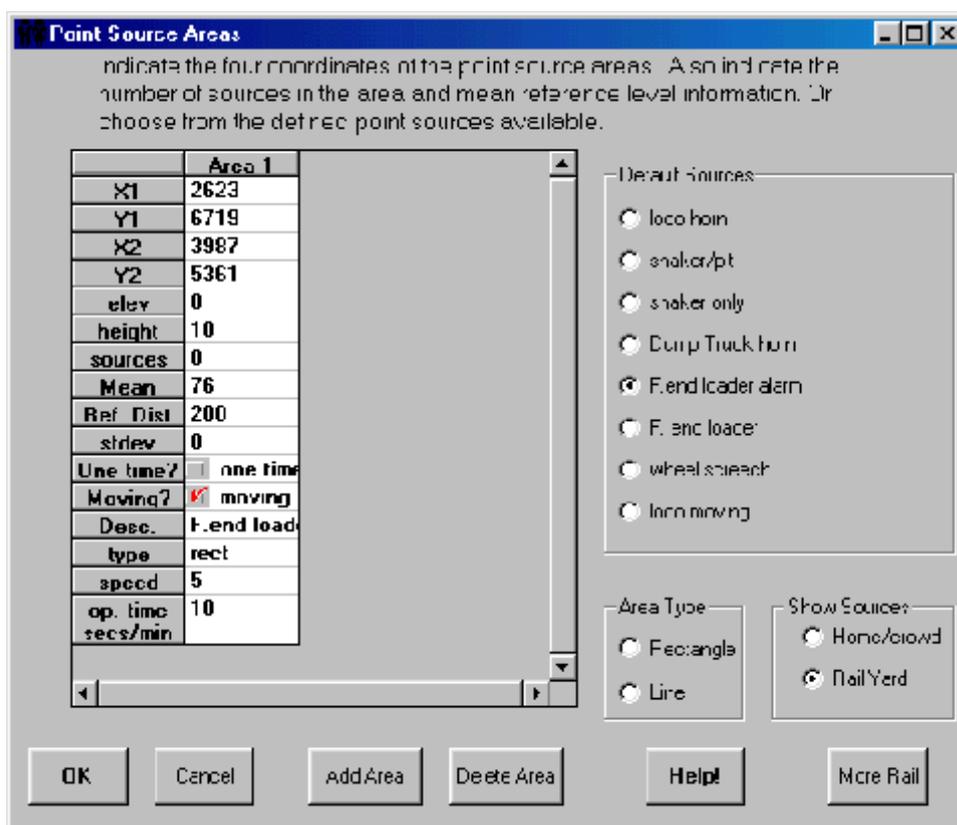
Point Source Area Editor.

Once the area is defined, the user specifies the elevation of the point source area, the height of the sources within the area, the number of sources

contained in the area and the reference sound pressure level and distance for the sources. The editor also asks for the *standard deviation* of the reference sound pressure level because the FDOTRM constructs a *Gaussian probability density function* of the reference sound pressure level and assigns each source a unique reference level based on the Gaussian distribution. If these levels and standard deviations are unknown, the user can choose from several *default point sources* located in the frame box. Clicking on one of these sources will automatically input the reference level, distance and standard deviation into the proper location on the spreadsheet. These default sources are some of the common sources found in a community.

If the sources located in the source area are moving sources, the user can select the "*moving*" check box, otherwise the sources will be distributed evenly within the area and remain stationary during simulation. The "*one time*" check box indicates if the source is continuous or if it is an impulsive event. If the one time box is checked the source will be active for only one time step and then will be removed from the simulation. This can be observed while the FDOTRM is running a simulation.

Passby Calculations and Insertion Loss

The Calculate menu contains two options that include running a simulation and performing "passby" calculations. The "passby" option moves sources on the rail objects to their closet location for each receiver and
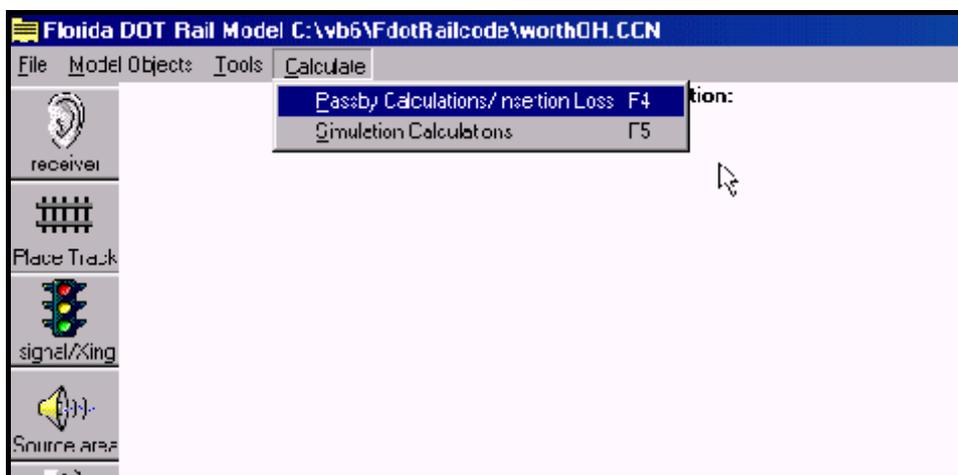
Calculate Menu: Passby Calculations and Insertion Loss

summarizes the maximum sound pressure levels at these locations and the distance to from the source to the receiver. This is useful for determining Lmax levels at receivers.

Another feature of this option is an "insertion loss" calculation that is computed by first ignoring any barrier objects in the model and then running the

Text Viewer

Dec. Results | Rail Results | Ground effects | Diff. Effects | Input Data | Time History

	A	B	C	D	E	F	G	H	I	J
1	C:\vb6\FdotRail									
2										
3	Passby Levels I									
4										
5	Track	Receiver	Distance,	No Barrie	Lmax, dB	Horn acti	locomotiv rail car		IL, dB	
6	Track 1	160ft	163	81.25	71.92	No	FTA Dies Pass w/in		9.33	
7	Track 1	260ft	262	79.47	72.66	No	FTA Dies Pass w/in		6.81	
8	Track 1	240ft	242	79.78	72.73	No	FTA Dies Pass w/in		7.04	
9										
10										
11										
12										
13										
14										
15										
16										
17										

OK

Passby Calculations Results and Insertion Loss results.

routine with the barrier objects in place.

Performing a simulation

A *simulation* can begin after a user has entered sources, objects/obstacles

and receivers for a desired scenario. A simulation is started by choosing the

Calculate menu item and then the *Simulation Calculation*. The Calculate

Sound Levels screen will appear. This screen defines the length of the desired

simulation, the simulation *time step* and the results update rate. A time step of

0.5 seconds is recommended for most simulation lengths of one hour or less or

for high speed railway sources (greater than 60-65 mph).
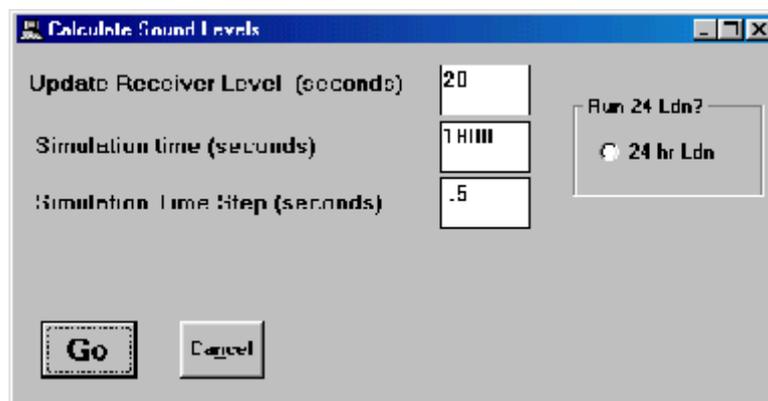
Initiate Simulation Interface.

A simulation of any time length can be specified. A one hour simulation is

a common choice for those interested in 1 hour Leq results. A 24 hour *Ldn*

simulation can also be selected. Pressing the Calculate button begins the simulation. The simulation can be canceled at any moment by clicking the Cancel button on the *Toolbar*. Detailed results are displayed upon completion of the simulation.

Simulation Results

The FDOTRM computes and tabulates a variety of results from each simulation and these are displayed at the conclusion of the simulation or can be recalled using the File/Print Results menu item. Overall *Leq* sound level, Lmax and *standard deviation* results are tabulated for all receivers. These are followed by a chronological histogram of sound levels for each receiver and then statistical results for each receiver.   Distribution data is also available for the *ground effects* and *diffraction effects* calculated at each receiver for the total simulation period.

Simulation Results.

Stochastic Features of the FDOTRM

FDOTRM includes a *stochastic* module that computes Gaussian distributed random variables based on user input of mean value and standard deviation information from the user. The FDOTRM generates a Gaussian cumulative distribution function for parameters such as point source reference levels and uses the computer generated uniform random variable to select parameter levels from the cumulative *distribution* function.

In the case of a point source area, the user is asked for the mean and

27

standard deviation for the reference sound levels of these point sources. The FDOTRM computes the cumulative distribution function prior to simulation and assigns a reference level to each point source in the area. Each point source keeps this reference level as one of its object properties throughout the simulation. The FDOTRM also allows a check at the end of simulation to plot the actual distribution of these reference levels.

Ldn Calculation Methodology

In L_{dn} mode, the FDOTRM computes a 20 minute sound energy contribution from railway and point sources and stores this result. Performing only a 20 minute simulation greatly reduces run time. A one hour L_{eq} provides an adequate measure of the sound energy contribution which can then be weighted for a full 24 hour period. Also, the FDOTRM adjusts the hourly Leq values so that it can impose the 10 dB penalty from 10:00 pm to 7:00 am which is specified by the L_{dn} metric.

REFERENCES

[1] Kurze, U. J., Anderson, G. S., "Sound attenuation by barriers," *Applied Acoustics*, vol. 4, pp.35-53, 1971.

[2] Cowan, James P., Handbook of Environmental Acoustics, p. 274, 1994.

[3] International Organization for Standardization, *Acoustics-Attenuation of Sound During Propagation Outdoors*, ISO 9613:2,1996(E), 1996.

[4] International Organization for Standardization, *Acoustics-Attenuation of Sound During Propagation Outdoors*, ISO 9613:1,1996(E), 1996.