ISY.CAD.Noise
User Manual

This User Manual is a part of a master thesis in Engineering and ICT, Structural Engineering and describes the main functions and assumptions of the ISY.CAD.Noise plug-in for MicroStation and the DLL NoiseComputation. It is written for users of the plug-in and developers of NoiseComputation and ISY.CAD.Noise.

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NTNU and Norconsult Informasjonssystemer

Contents

1 Introduction

1.1 Overview

ISY.CAD.Noise is a plug-in created for MicroStation v8i. It has the possibility to add noise sources and obtain noise maps and specific values. The base computational model behind ISY.CAD.Noise, SoundKernel, is a software application developed by SINTEF ICT, Acoustics. The link between ISY.CAD.Noise and SoundKernel is a DLL (Dynamic Link-Library) named NoiseComputation. These are connected in this way to provide possibilities for code reuse and to be able to properly run the application. The elements and connections are shown in the image below.

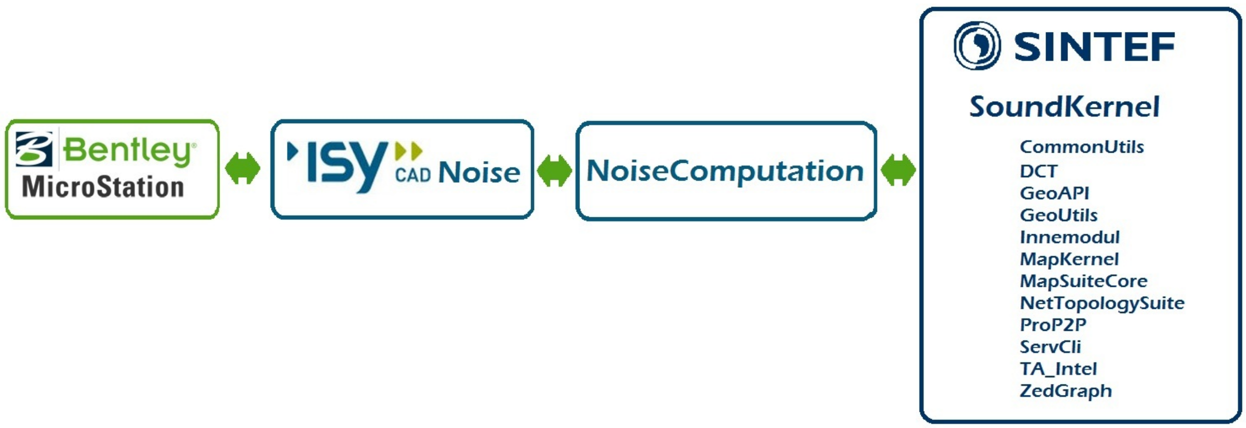


Figure 1: Overview over interactions between MicroStation, ISY.CAD.Noise, NoiseComputation and SoundKernel

This user manual will give an overview of the functions available in ISY.CAD.Noise and how to use them. In addition, the sub sections "Defaults" and "Possible further functionality" have been added to some sections to explain default values and assumptions in the code and what may be implemented later on. These are mainly for developers of the plug-in and advanced users.

Disclaimer: ISY.CAD.Noise is a plug-in under development, and have not been thoroughly tested and verified. Some errors may therefore occur.

1.2 Prerequisites

A PC with with Microsoft Windows and MicroStation v8i installed, basic MicroStation skills and access to ISY.CAD.Noise. Some knowledge of noise and noise sources is preferable.

1.3 Installation

An installation file has not yet been created. To run the plug-in, ISY.CAD.Noise.dll, NoiseComputation.dll and the SoundKernel DLLs have to be in the "C:\Bentley\v8i\MicroStation"-folder. (Maybe in C:\isycad_v8i\mdlapps\addin\bin too)

1.4 Loading ISY.CAD.Noise

The command line interface in MicroStation, called Key-in, is probably known for many users of MicroStation, however a brief introduction to it will be provided here. As of now, the new functions created in the ISY.CAD.Noise plug-in may only be accessed using the Key-in.

Accessing
The command line interface may be accessed either by choosing Utilities - Key-in in op menu, or by pressing the Enter-key on the keyboard.

Window explanation
The Key-in window is shown below, the most recent command are shown at the bottom part of the form, and available commands are shown in the scrollable window above.

Executing command
The selected command: "mdl load isycadnoise" is the command to load ISY.CAD.Noise. When this is executed the plug-in may be used. All the commands in the following sections should be executed in this Key-in form.

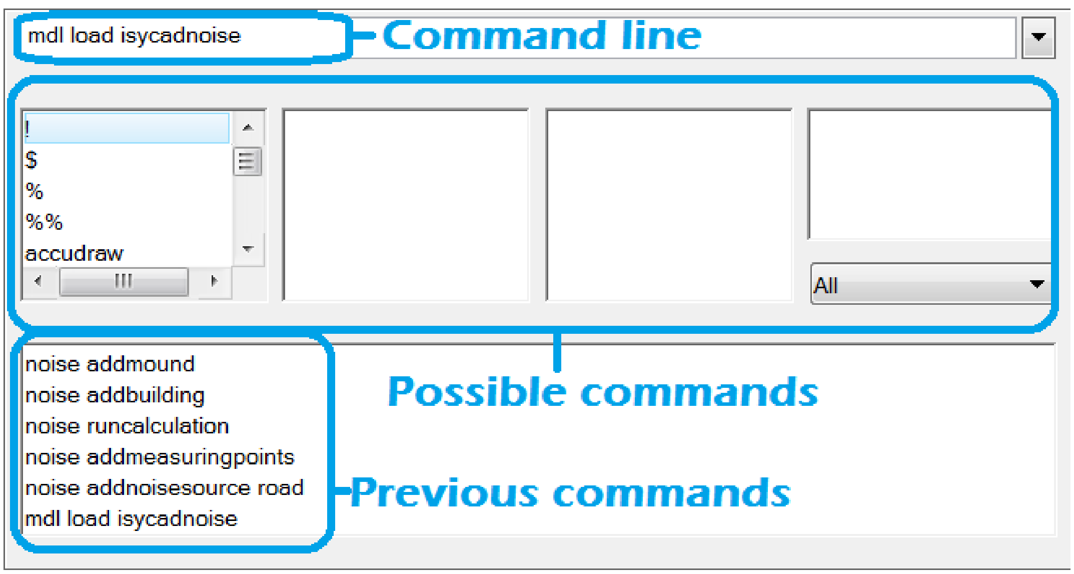


Figure 2: MicroStation Command Line Interface

1.5 Getting Started

Start MicroStation and establish terrain and mesh:

Terrain model
First establish a terrain model. The easiest way of doing this is to import a terrain model, preferably from SOSI data[1]. This model should be modified if there are any large differences between the model and the actual terrain.

Mesh
Then a mesh needs to be established. A mesh connects all the points of the selected elements and creates a surface based on these. This is done by selecting "create mesh from contours" in MicroStation and choosing the lines in the terrain model that are to be the base of the mesh. It is recommended to choose elevation lines (called "Høydekurver" in Norwegian SOSI data). These are displayed by selecting that level using MicroStation Level Display. This will create a nice and even mesh as shown below. The gray surface is the actual mesh while the white lines are the elevation lines.

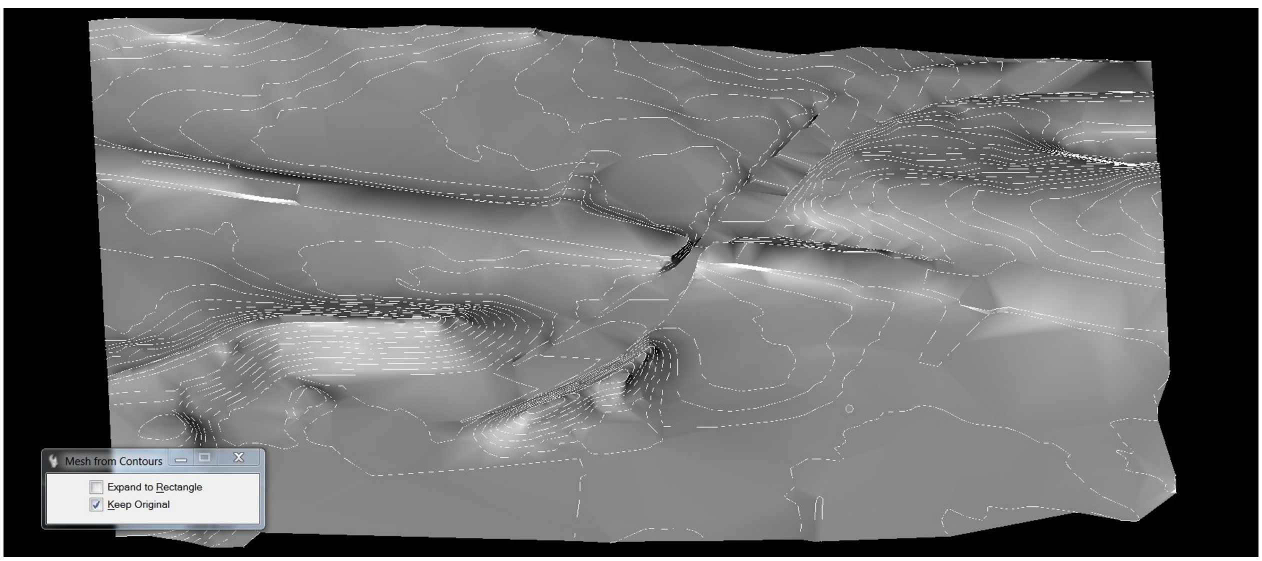


Figure 3: A mesh of a part of Visnes Kalk AS

2 Setting up a noise environment

2.1 Creation of grid

A grid has to be defined for SoundKernel to develop a topography model for the computation. Activate the function "Noise Mesh2Grid" in the Key-in to create grid lines based on the mesh in section 1.5. These are straight lines going north to south (Primary grid lines), and east to west (Secondary lines), creating a grid. The result complete with grid lines are shown below. These lines are saved in the MicroStation model, and this command only have to run once for each model. The intersection points of these lines are used as the base of the topography model created in SoundKernel.

Defaults

Grid Space - there are 5 m between each grid line, this may be changed if a finer or coarser grid is wanted.

Ground Type - may be set to unknown, hard, soft, A, B, C, D, E, F, G, H, Index6, these are defined in Ground Types. The default is soft.

Forest height - default value is 0 m.

Roughness - default value is 0.

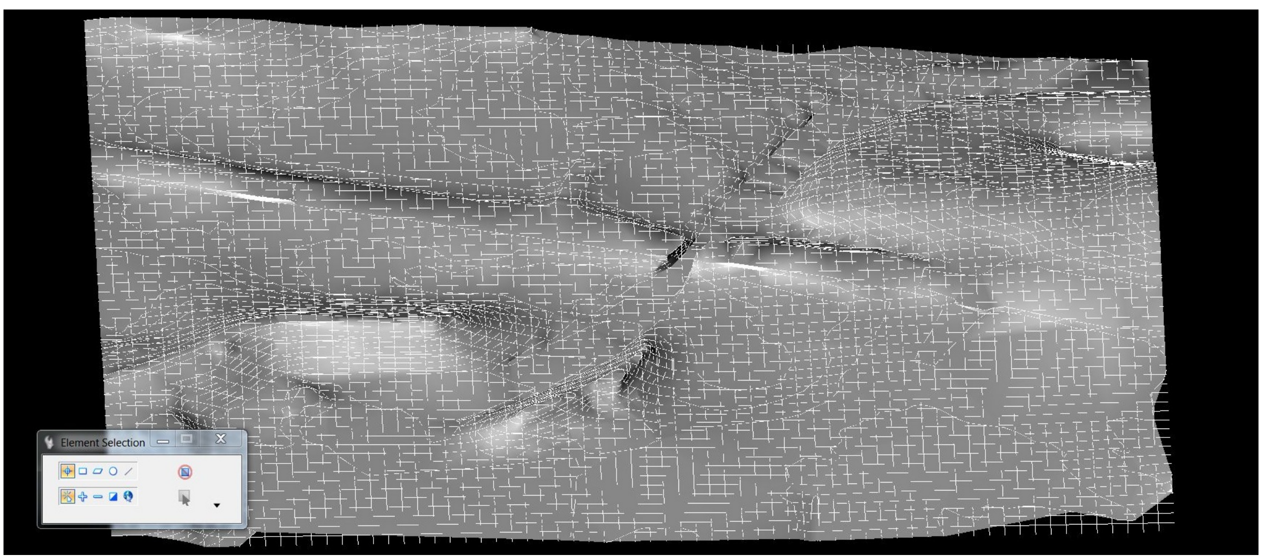


Figure 4: Mesh with Primary and Secondary Grid Lines.

The computation will run without errors as soon as a grid is established. However, the results will be zero unless one or more noise sources are added. There are two types of noise sources that may be added: Road and Industry noise source. These are detailed in the next sections.

2.2 Road noise sources

A road noise source may be added by activating the "Noise AddNoiseSource" -> "Road" function in the command line interface.

The road options form is shown to the right.

To add the road, the center line of the road is selected in the MicroStation model.

The level of the line will be changed to "StøyVeg" - Noise Road in Norwegian. The possible options for a road are explained below:

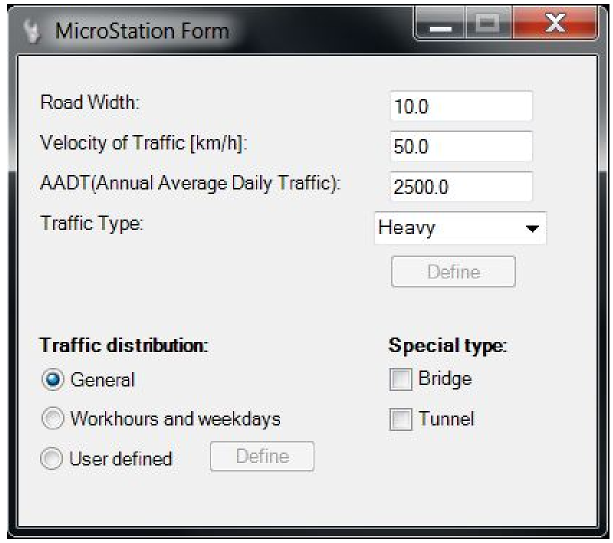


Figure 5: Form for adding a Road Noise Source

Table 1: Road Options

Option	***Description***
Road width	is defined in meters and as the entire width of the road. For some roads width may be found on the Norwegian Public Roads Administration (NPRA) website[2].
Velocity	is defined in km/h. Values may be found on the NPRA website[2].
AADT	Annual Average Daily Traffic is the number of vehicles passing the road on an average day. Values may be found on NPRA[2] or Norwegian Directorate for Civil Protection (DSB)[3] websites.
Traffic Type	defines the vehicles driving on the road. There are currently four possible traffic types: Heavy, Normal, Dumper or User Defined. These are defined in Table 2.
Traffic Distribution	defines a distribution of AADT over time. The distribution is created for every hour of every day in a week and is the same for all weeks in a year. This is a simplification as traffic may vary throughout a year. There are three possible options: General, Work hours and weekdays and User Defined. These are defined in Table 3.
Special type	may be used if the road is a bridge or a tunnel. These elements will have different parameters, these are detailed in the *Defaults* section.

Table 2: Traffic Types

Option	***Description***
Normal	this traffic type indicates a common road, for instance a highway, with continuous traffic throughout both day and night. There is a distribution of light, medium and heavy vehicles on the road.
Heavy	this traffic type consist of only heavy vehicles(buses, trucks, etc.).
Dumper	is a traffic type created from noise measurements of a Euclid dumper[4]. These are shown in Table 9 in Appendix B. A dumper is a large and heavy vehicle common in many industry and construction areas.
User Defined	if there is a specific traffic type on the road, the User Defined traffic type may be used, and the "Define" button opens the form shown below. Decibel values for each frequency may be input here and a user defined traffic type is created. The values are adapted to fit the input in SoundKernel. This process is shown in Appendix C.

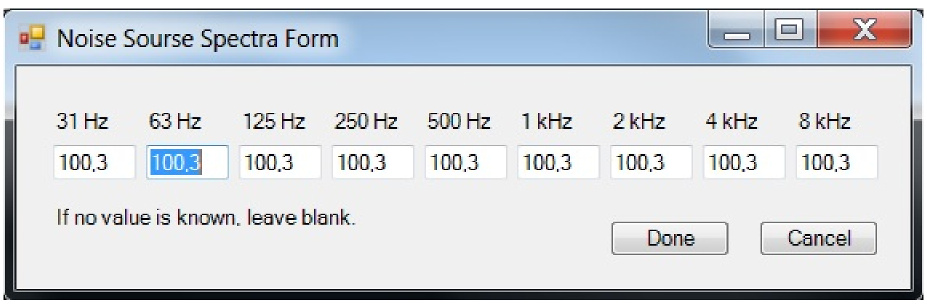


Figure 6: User Defined Noise Spectrum

Table 3: Traffic Distribution

Option	***Description***
General	defines the distribution on most common roads, such as highways.
Work hours and weekdays	all traffic is distributed between 08 and 16, Monday - Friday.
User Defined	if the traffic distribution is known for the road and does not fit any of the two options above, the user defined option may be used. When the "Define" button is pressed, the form below is shown. Specific values for daytime, evening and night time on Monday-Friday, Saturday and Sunday may be input. It is important to make sure that the AADT-value is the same as the number of vehicles for a day.

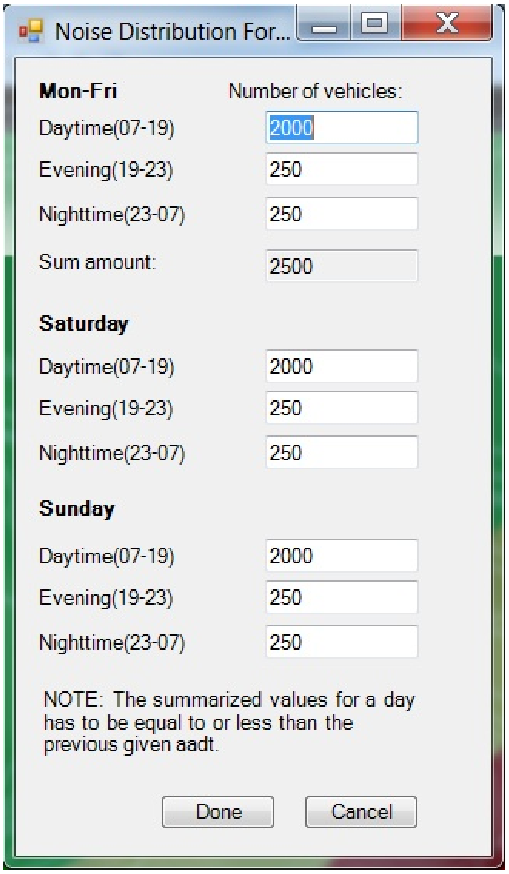


Figure 7: User Defined Noise Distribution

Defaults

Ground Type - may be unknown, hard, soft, A, B, C, D, E, F, G, H or Index6. This parameter defines the ground close to the road. These are defined in Appendix A. Default value is set to be hard.

Road Surface - road surface may be unknown, SKA8, SKA11, SKA16, SKA22, AB8, AB11, AB16, AB22 or POR. Default value is AB16. These are defined in Appendix D, Table 23 and 24, in Norwegian only.

Vehicle types
There are three main vehicle classes in SoundKernel: Light, Medium and Heavy. These are defined in Appendix E in Table 25. The number of heavy, medium and light vehicles may be difficult to estimate. There are generally between 0 and 15 % heavy vehicles, less in inhabited areas and more on highways[6]. NoiseComputation assumes 7.5 % heavy vehicles, 7.5 % medium vehicles and 85 % light vehicles in the Normal traffic type.

Vehicle Distribution
A distribution would of course vary, however some averaged values may be assumed. Generally two types of road may be the most relevant[6]:

- Typical road - average traffic in the summer compared to the rest of the year, average difference between day and night, and average difference between weekday and weekend.
- City road - less traffic in the summer, large difference between day and night and large difference between weekday and weekend.

The first type, the typical road is assumed in NoiseComputation. Annual Average Daily Traffic is divided as below:

Period	***Percentage***
Day (07-19)	75 %
Evening (19-23)	15 %
Night (23-07)	10 %

Figure 8: AADT percentage over 24 hours[6]

The distributions for Heavy/Normal traffic type and Work hours and weekdays/General used may be viewed in Appendix F in Tables 10, 11, 12 and 13.

Parameters for bridge and tunnel:

Tunnel Height - the height of the tunnel is set to be 4 m.
Tunnel Shape - the tunnel may have an unknown, semicircular or rectangular shape, semicircular is the default.
Tunnel Surface - possible surfaces are unknown, smooth, rough or absorbing, smooth is the default (and worst case).
Tunnel Opening - may be specified as having a opening at both sides, at the start or end of the line or no openings. Default is opening at both ends of the line.
Bridge Thickness - default value is 1 m.
Bridge End - specifies if there are bridge abutments at both ends of the line, at the start, the end, or no abutments. Default is both ends.

The image below shows the form with the options for the road, and a selected road. The terrain model is the same as before, however the levels have been changed to fit this demonstration.

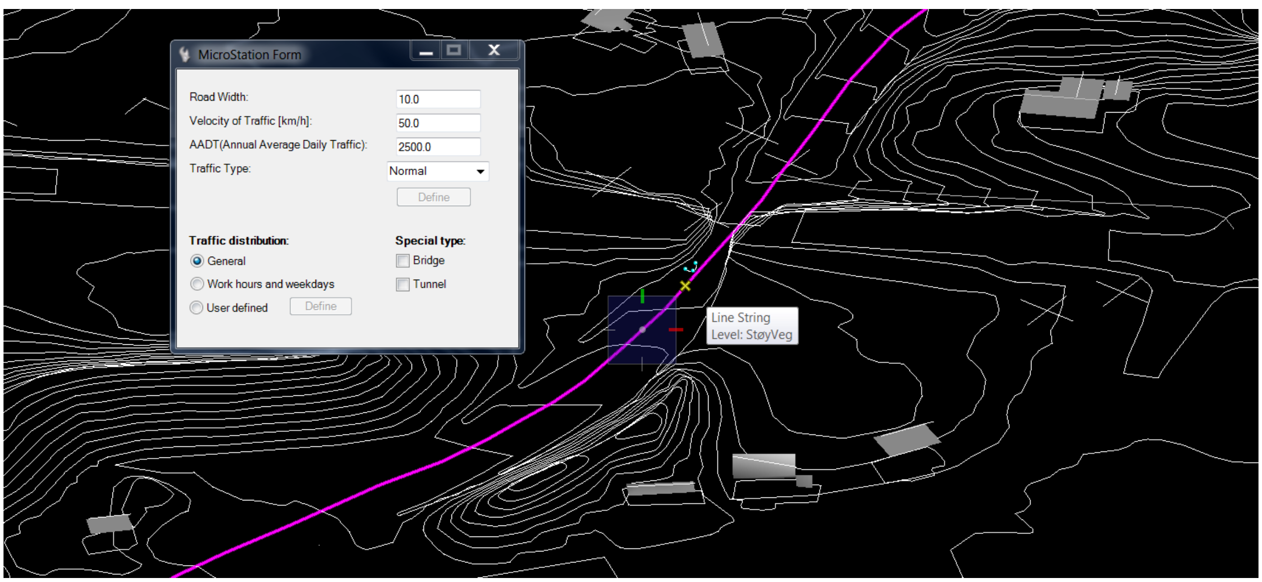


Figure 9: Adding a Road Noise Source

2.3 Industry noise sources

There are many different types of industry noise sources: machinery, heavy work, construction etc. The currently available noise types in ISY.CAD.Noise are more suited for mining than other industries. However, many other noise types may be added. User defined noise sources enable the use of all types of noise, provided the noise source may be specified or measured.

An industry noise source is created by first entering "Noise AddNoiseSource" -> "Industry" in the Key-in. This invokes the form shown to the right. The options available is described below.

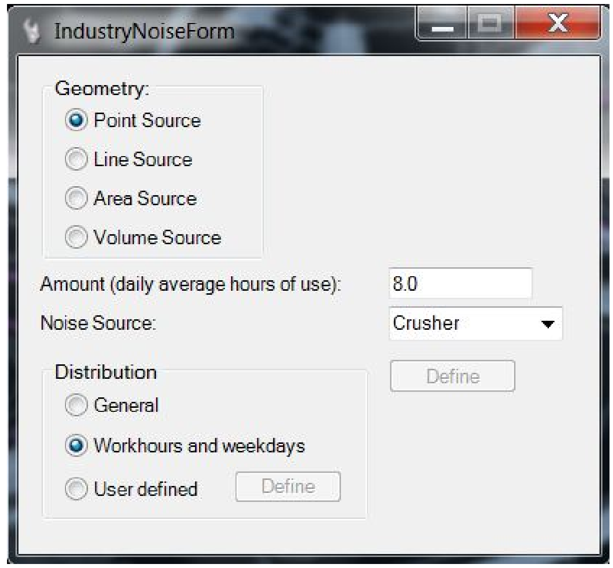


Figure 10: Adding an Industry Noise Source

After the options for the noise source have been entered a point, line or shape is selected in MicroStation and the industry noise source is created.

Table 4: Industry Options

Option	***Description***
Geometry	defines what the noise source will look like. There are four choices: Point, Line, Area and Volume Source. A point source is defined by a single point and a line source is a line with two or more points. For the area source, a line or shape should be chosen and the height of the line or shape will be the height of the noise source. A volume source should be created in the same way, here the noise will be distributed over the volume below the chosen line or shape.
Amount	daily average hours of use defines how long for instance a machine runs throughout a day. This number has to be between 0 and 24. The number of hours is distributed according to the distribution described below.
Noise Source	defines a few types of industry noise. There are as of now four possible types: Crusher, Drilling, Dumper or User Defined. These are defined in Table 5.
Distribution	this option defines how the hours are distributed over time. The distribution is created for every hour of all the days in a week and is the same for all weeks in a year. This is a simplification. There are three possible options: General, Work hours and weekdays and User Defined. These are defined in Table 6.

Table 5: Noise Source Types

Option	***Description***
Crusher	this is a large machine used for crushing larger rocks into smaller ones. The frequency spectra for this noise source and the ones below may be found in Appendix B, Table 9.
Drilling	when a drilling rig is creating a hole in rock, a lot of noise is created. The frequency spectra for this noise source originates from measurements performed in a Norwegian mine called Visnes Kalk AS.[5]
Dumper	is a large and heavy vehicle common in many industry and construction areas.
User Defined	industry noise sources may have a great variation in noise level and frequency range and the user defined option enables an advanced user to enter specific values for the different frequencies. The form is the same as in figure 6.

Table 6: Time Distribution

Option	***Description***
General	this distributes the noise over day, evening and night, and all days in a week are the same.
Work hours and weekdays	the hours are distributed between 08 and 16 and Monday - Friday.
User Defined	if none of the two options above are suited for the specified noise source a user defined distribution may be created. The time distribution form looks like the one in figure 7. It is important that the number of hours input to the form matches the daily amount.

Defaults

Time distribution
The time distribution in SoundKernel is based on three (vehicle) classes, hours in a day, days in a week and months in a year. For a road the classes are defined as light, medium and heavy vehicles. This term is not suitable for an industry noise source, so only the heavy class is used. Other than that, the time distribution is created quite similar to the vehicle distribution in *Defaults* in section 2.2.

The distributions for Crusher/Drilling/Dumper and Work hours and weekdays/General may be viewed in Appendix F, Tables 10 and 11.

NOTE: SoundKernel currently gives an error if an industry noise source is a line with an odd amount of points. To get past this error, the last point of the line is duplicated so that the line has an even amount of points.

2.4 Noise Mitigation

A mound, screen or wall may be added by selecting the "Noise AddMound" function and choosing a line to be the base of the mound. The options form for a mound are shown to the right.

It is very important that the line chosen for the new element is based on elevation lines or other elements that are based on the terrain, to make sure no errors occur. This function is quite sensitive to intersecting elements, etc. The options for the noise mitigation elements are described below. The radio buttons decide which of the values below may be input.

The level of the base line is changed to "Voll" - Mound in Norwegian and a line indicating the height of the element is added with the level "VollHøyde" - Mound Height.

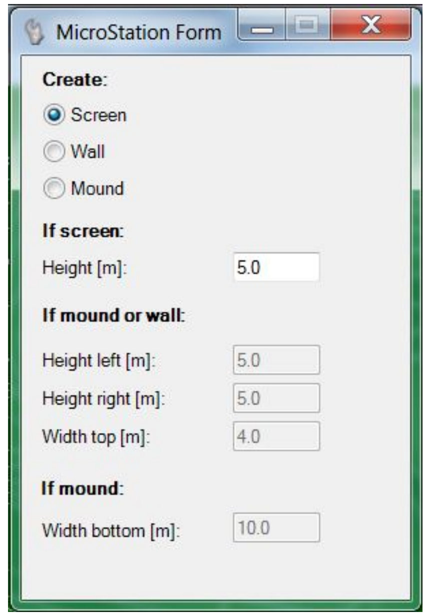


Figure 11: Noise Mitigation Form

Table 7: Noise Mitigation Form

Option	*Description*
Screen	only the height output needs to be set, the others are zero by default.
Wall	height at the left and right side of the wall and the width at the top is input. Left and right side of the wall is defined based on how the base line for the wall is drawn. A wall is actually a mound with the base being 20 cm wider than the top.
Mound	width at the top and bottom of the mound will be an input in addition to the height at the left and right side of the mound.

Defaults

Material - the material of the screen, mound or wall may be unknown, earth, stone or concrete and is set to be earth as a default.

Absorbing material - a noise mitigation element may be set to be absorbing on its right or left side, these are set as not absorbing as a default.

Possible Options

User defined heights for each point in the mound may be set. This is fairly advanced and not implemented in this version of ISY.CAD.Noise.

The images below show how to create a mound, and how a screen, wall and mound will look like in the topography model (see *Topography Model* in section 3.2 for more information).

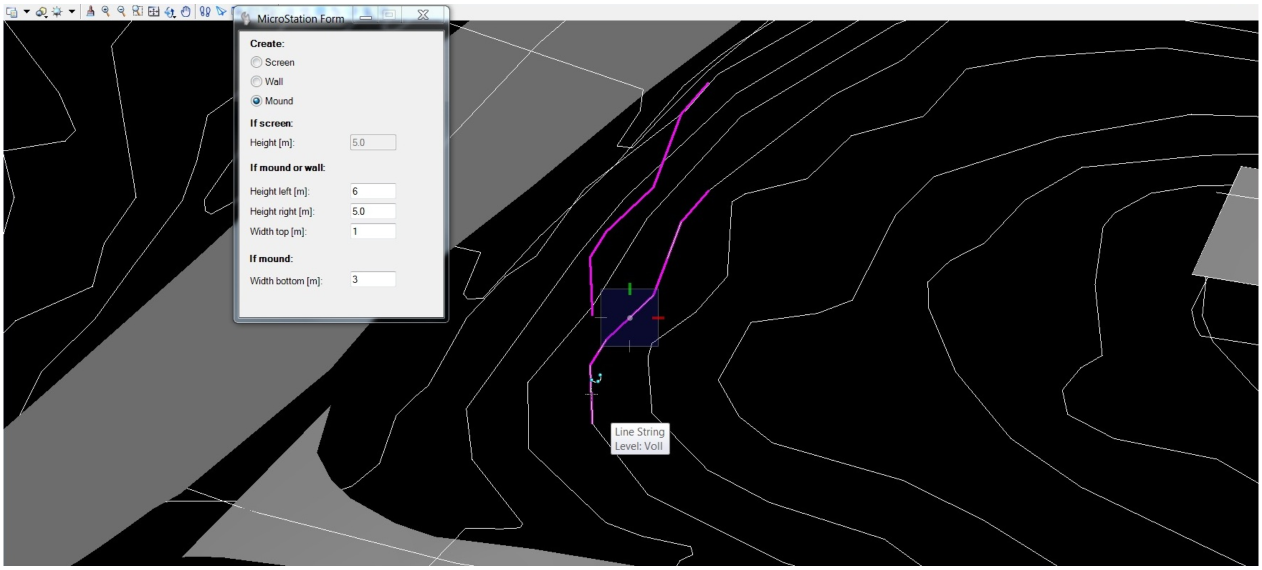


Figure 12: Adding a Mound

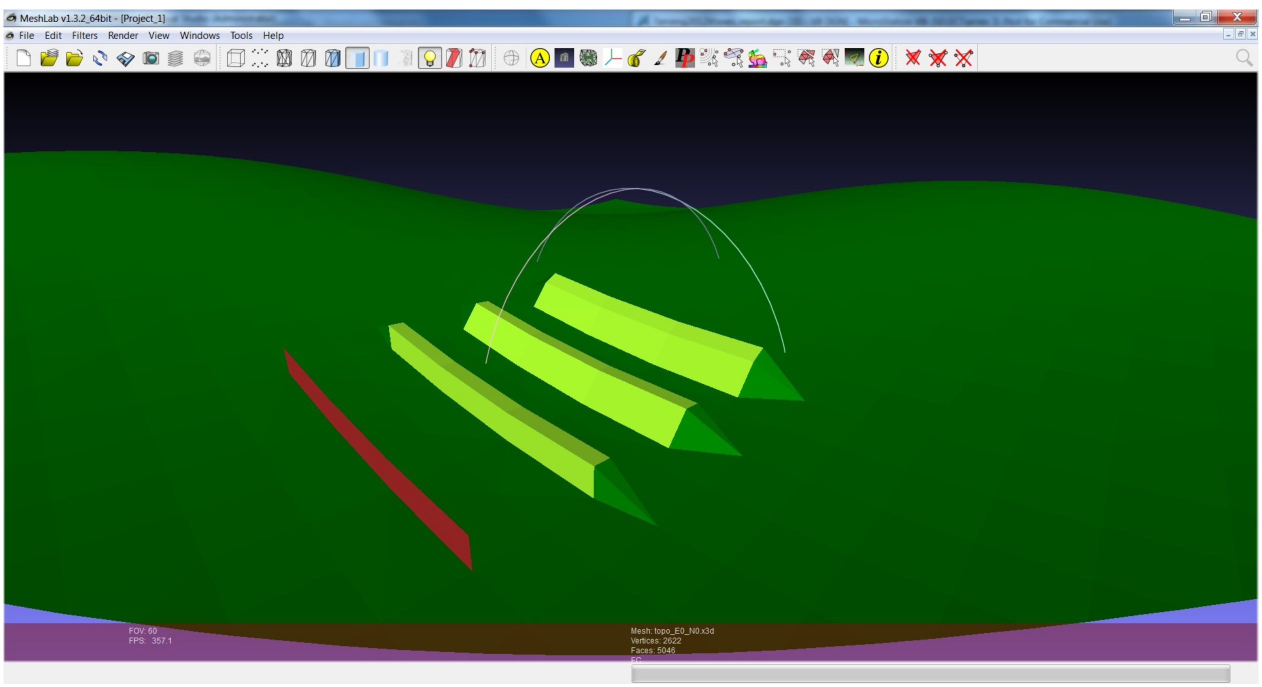


Figure 13: Resulting screen, wall, mound and mound with different left/right height

2.5 Buildings

To add a building the "Noise AddBuilding" function in the Key-in is selected. Then a cell or a line string in MicroStation is chosen as the outline of the building. An outline of the building should be a closed line or a shape at the height of the start of the roof of the building. Any top lines of the building will be automatically searched for and added. These have to have "Mønelinje" as Level.

Noise at facade points around the building is computed if the check box is checked. Many facade points will be added for each building, the house below will for instance have 52 facade points computed. These are only output if any of the values have a decibel value of 50 or larger.

The data provided by SOSI (Samordnet Opplegg for Stedfestet Informasjon[1]) is compatible with this function. Below is an image showing the process of adding a building.

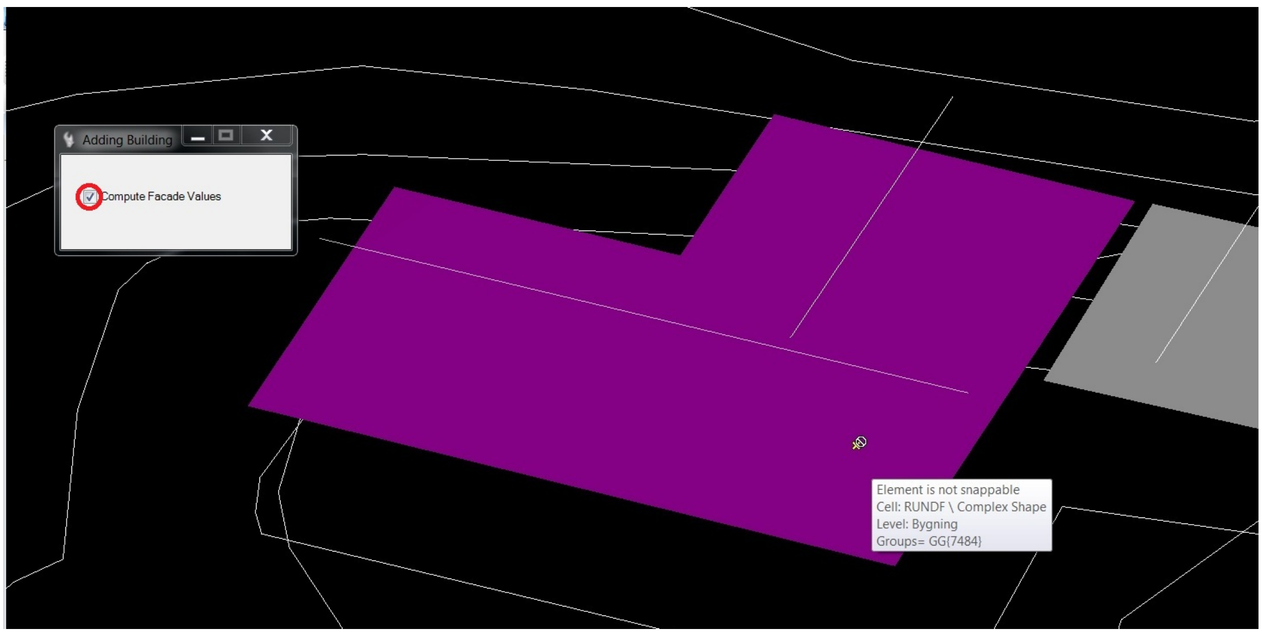


Figure 14: Adding a Building

Defaults

The outline of a building have to be a closed polygon. In SoundKernel a square building have to be defined by 5 points. This is default and set by SINTEF ICT, Acoustics. For the facade computation to work, the points of the outline have to be defined clockwise. NoiseComputation checks this and converts the points of the outline if they are defined counter-clockwise. For buildings without top lines, the outline will be added as the top line, giving a flat roof.

Possible Options

Some details about the computation of facade points may be changed. SK.Task.bldDetailedFP may be 0, 1, 2 or 3, indicating level of detail for output, 3 is the highest and the default value. SK.Task.lowthreshold and SK.Task.highthreshold may be set to specify the limits for a simplified computation.

2.6 Calculation points

If exact noise values are wanted for a house, the building could be added as shown above, and facade points computation selected. However, if exact values are desired for any other type of line, shape or solid, the "AddCalculationPoints" function may be used. The function is selected the same way as the others, and the specific line, shape or solid is chosen. The noise at the points will then be calculated and the results output to a file.

The main difference between these two ways of computing noise levels is that facade points takes reflections form its building wall into account.

Possible Options

Calculation points may be set to be facade points. This is useful if the user want to know the exact values of an exact point or of the outline of a building. The ID of the building for point 0 is set using SubTask.pntID[0] = buildingID, when SubTask.facade[0] = true; This has not yet been implemented in ISY.CAD.Noise.

3 Computation and Results

3.1 Running the computation

By activating "Noise RunCalculation" in the Key-in the form on the right is shown. The unit(s) to be computed may be chosen here. These units should be known for a user with some noise experience. When the units are chosen, the "Run Computation" button starts the computation process, which may take from seconds to several hours depending on how large the model is, how many noise sources there are and computer performance.

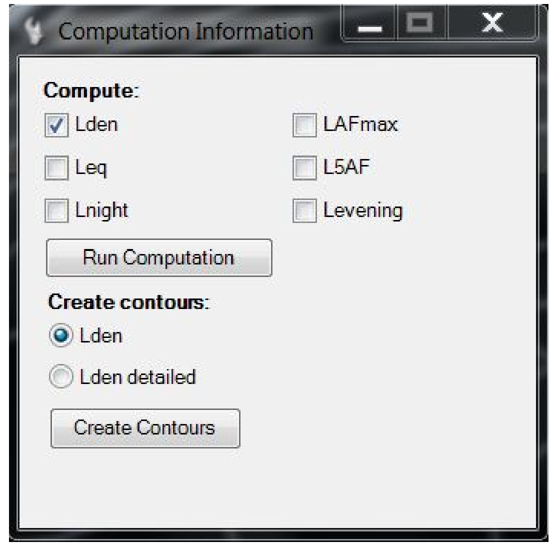


Figure 15: Run Computation Form

Defaults

Weather - a default weather is added, this is the only weather option implemented in SoundKernel.

konfig.dat - a file called konfig.dat is read to create configuration values for computing facade points. This file is created by SINTEF ICT, Acoustics. Amongst others, it creates some default situations for the facade points.

Possible Options

The possibility to draw contours for the other computation units, such as L_{night}, could be implemented. This would not be very difficult to implement.

The konfig.dat file could be investigated further, and the values it adds could possibly be added in code so that the konfig.dat file is no longer needed. Different situations for facade points could be tested and investigated.

3.2 Results

Topography Model

SoundKernel creates its own topography model based on the grid points created in section 2.1 and the buildings, noise mitigation elements and roads added. This model is output as an X3D file and may be viewed using MeshLab[7], a free open source software. The file will look similar to the image below, depending on which elements has been added and the terrain.

It is recommended to check this model to see if all elements are where they should be and look like they should. A common error for a building or a mound is that there are some intersecting elements causing it to look different from the MicroStation. If the mound is not established on the terrain properly (as mentioned in section 2.4), it might have a height lower than the terrain model and look like a ditch.

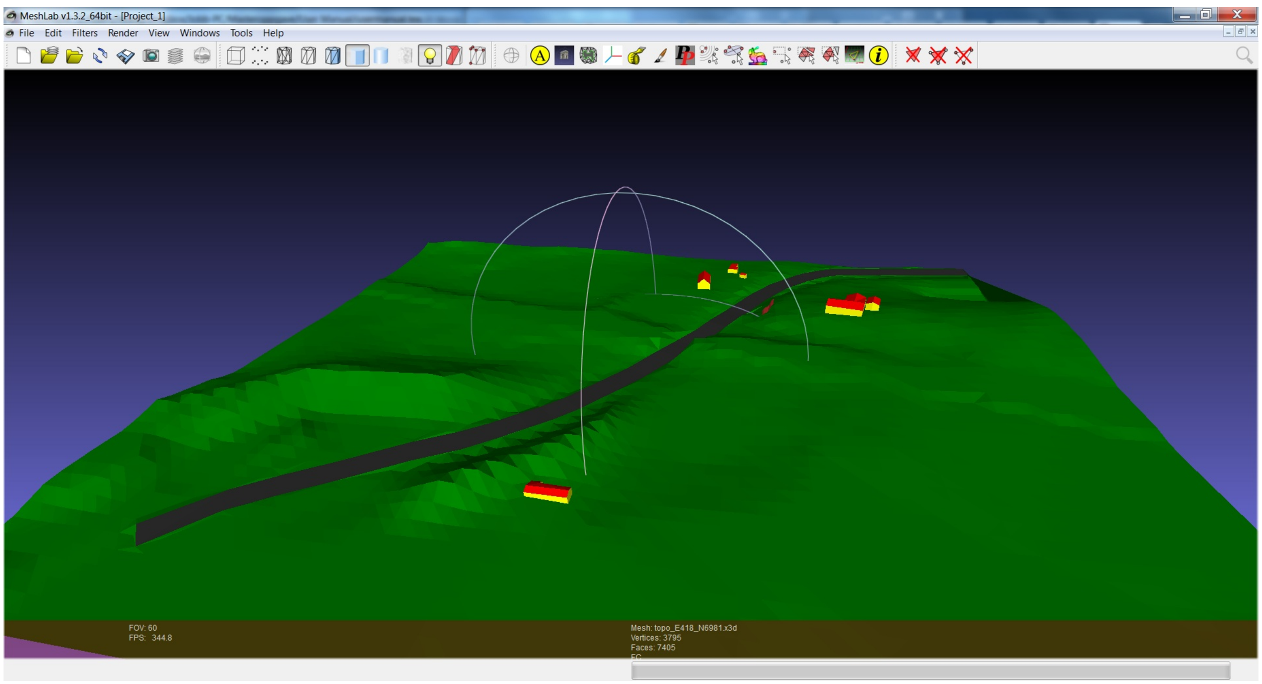


Figure 16: Finished Topography Model

Result File

When the computation is finished a form will pop up, showing how long time the computation took. The results and details of the computation, such as point coordinates for the grid, noise sources, buildings, mounds, computation points, etc have been written to a file called Summary.txt, in the folder "C:\TEMP". More information about what is output in that file may be found below:

Table 8: Information in Summary.txt

Element	***Information written to Summary.txt***
Noise sources	the points of the noise sources in addition to if it is a road or industry noise source. Amount/AADT, distribution, noise type, frequency spectra and other important parameters are written as well.
Building	the inline and outline points of a building.
Noise Mitigation Element	the points of the base line, left/right heights and top and bottom width are output if relevant for the element.
Facade Point results	the points, the resulting values and computation unit.
Grid	the start and end points of the grid, in addition to number of grid lines in each direction and total number of points.
Computation points	the exact computation points, resulting values and computation unit.

Contour Lines

If the computation has been run for the computation value L_{den}, the contour lines may be drawn. Either simple or detailed contours may be chosen and upon pressing the "Create Contours" button the contours will be drawn. The contours are color coded and look like the images in figure 17 and 18 on the following page.

Figure 17 shows the simple contour lines, with noise at 65 dB or higher inside the red area, and 55 dB or higher inside the yellow limit. Figure 18 shows detailed contour lines, where there are 3 dB between each color.

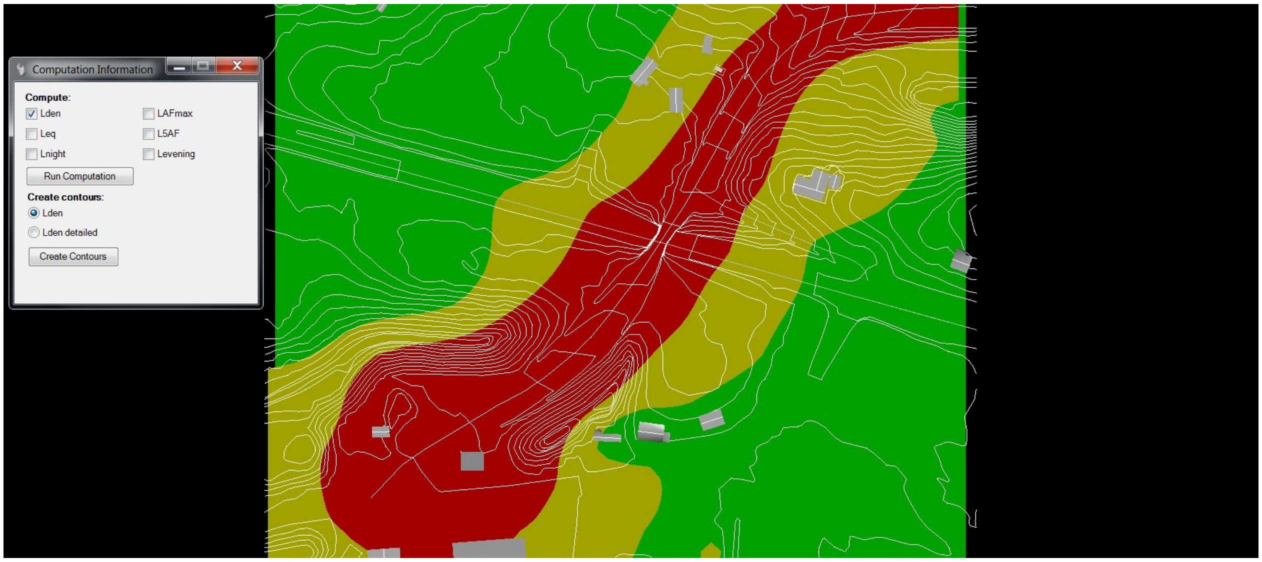


Figure 17: Drawn Contour Lines

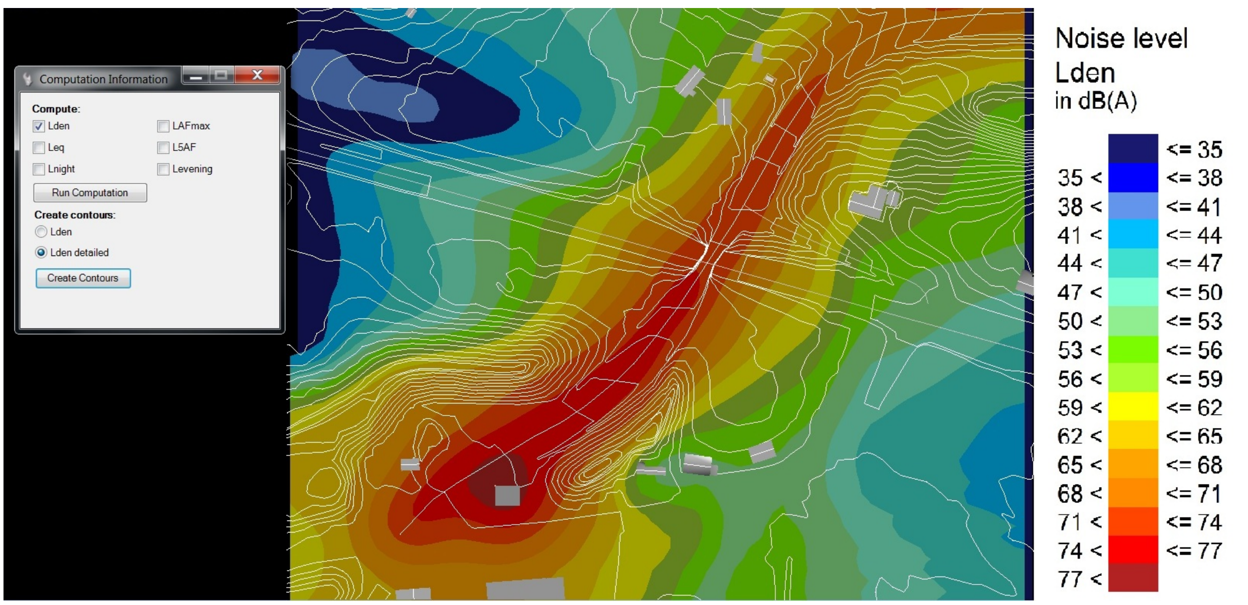
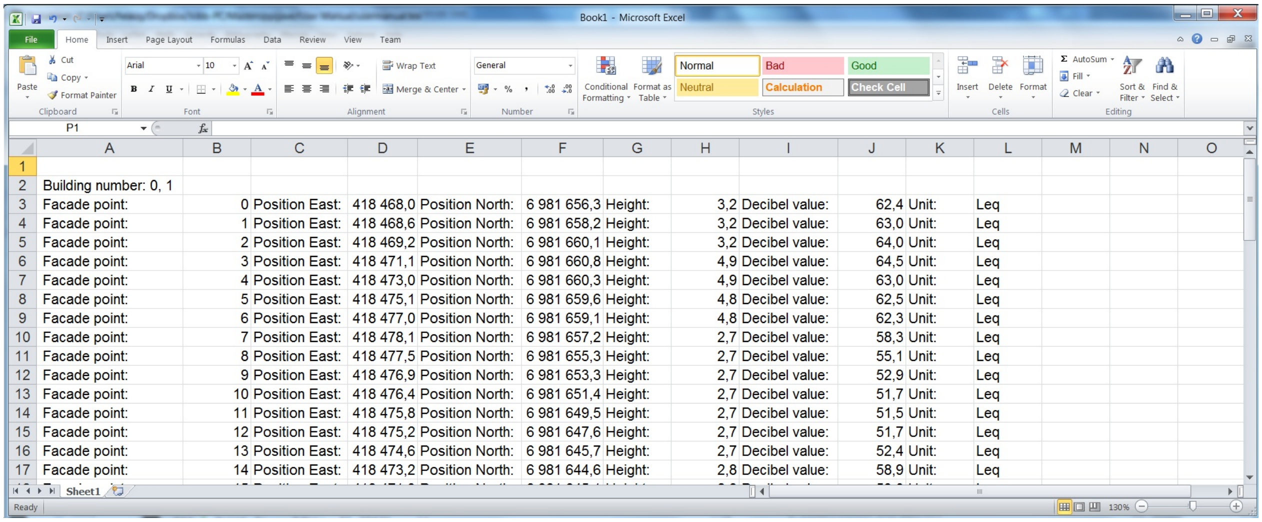


Figure 18: Drawn Detailed Contour Lines

Facade Points

The values for facade points are written to the summary file mentioned in *Result File*, and may easily be used in for instance an Excel document. The points are listed with building number, facade point number, position east and north, decibel value(s) and unit(s). Copy-pasted into Excel the values will look something like figure 19.



	A	B	C	D	E	F	G	H	I	J	K	L
1												
2	Building number: 0, 1											
3	Facade point:	0	Position East:	418 468,0	Position North:	6 981 656,3	Height:	3,2	Decibel value:	62,4	Unit:	Leq
4	Facade point:	1	Position East:	418 468,6	Position North:	6 981 658,2	Height:	3,2	Decibel value:	63,0	Unit:	Leq
5	Facade point:	2	Position East:	418 469,2	Position North:	6 981 660,1	Height:	3,2	Decibel value:	64,0	Unit:	Leq
6	Facade point:	3	Position East:	418 471,1	Position North:	6 981 660,8	Height:	4,9	Decibel value:	64,5	Unit:	Leq
7	Facade point:	4	Position East:	418 473,0	Position North:	6 981 660,3	Height:	4,9	Decibel value:	63,0	Unit:	Leq
8	Facade point:	5	Position East:	418 475,1	Position North:	6 981 659,6	Height:	4,8	Decibel value:	62,5	Unit:	Leq
9	Facade point:	6	Position East:	418 477,0	Position North:	6 981 659,1	Height:	4,8	Decibel value:	62,3	Unit:	Leq
10	Facade point:	7	Position East:	418 478,1	Position North:	6 981 657,2	Height:	2,7	Decibel value:	58,3	Unit:	Leq
11	Facade point:	8	Position East:	418 477,5	Position North:	6 981 655,3	Height:	2,7	Decibel value:	55,1	Unit:	Leq
12	Facade point:	9	Position East:	418 476,9	Position North:	6 981 653,3	Height:	2,7	Decibel value:	52,9	Unit:	Leq
13	Facade point:	10	Position East:	418 476,4	Position North:	6 981 651,4	Height:	2,7	Decibel value:	51,7	Unit:	Leq
14	Facade point:	11	Position East:	418 475,8	Position North:	6 981 649,5	Height:	2,7	Decibel value:	51,5	Unit:	Leq
15	Facade point:	12	Position East:	418 475,2	Position North:	6 981 647,6	Height:	2,7	Decibel value:	51,7	Unit:	Leq
16	Facade point:	13	Position East:	418 474,6	Position North:	6 981 645,7	Height:	2,7	Decibel value:	52,4	Unit:	Leq
17	Facade point:	14	Position East:	418 473,2	Position North:	6 981 644,6	Height:	2,8	Decibel value:	58,9	Unit:	Leq

Figure 19: Facade Points Results

Calculation Points

The calculation points are written to the same text file as the facade point results. The x, y and z-value of the points are given in addition to the point number, the units computed and the decibel values for the units. The text file may look something like below:

Point 0:	x: 418 495,9	y: 6 981 606,7	z: 50,4	Lden: 57,0	Lequ: 53,6
Point 1:	x: 418 494,9	y: 6 981 610,9	z: 50,3	Lden: 57,3	Lequ: 53,8
Point 2:	x: 418 493,9	y: 6 981 612,1	z: 50,3	Lden: 57,4	Lequ: 53,9
Point 3:	x: 418 492,7	y: 6 981 613,4	z: 50,1	Lden: 57,5	Lequ: 54,1
Point 4:	x: 418 491,6	y: 6 981 614,5	z: 50,1	Lden: 57,6	Lequ: 54,1

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A Ground Types

Below are a table explaining the ground types used in SoundKernel. The table is from a user manual for the Nord2000 method.[10].

Tabell 10
Klassifisering av marktyper

Dempnings-klasse	Representativ strømningsmotstand σ [kPas/m²]	Beskrivelse
A	12,5	Svært myk (snø eller moseaktig)
B	31,5	Myk skogbunn (kort, tett lyng eller tykk mose)
C	80	Ikke sammenpresset, løs grunn (torv, gressmark, løs jord)
D	200	Normal, ikke sammenpresset grunn (skogbunn, engmark)
E	500	Sammenpresset grunn og grus (valsede plener, parkområde)
F	2.000	Sammenpresset, tett grunn (grusveg, parkeringsplass, ISO 10844-asfalt)
G	20.000	Hard overflate (vanlig asfalt)
H	200.000	Svært hard og tett overflate (tett asfalt, betong, vann)

Figure 20: List of vehicle categories

B Frequency Spectra

Table 9: Frequency spectra for Noise Sources

Noise Source:	***31***	***63***	***125***	***250***	***500***	***1000***	***2000***	***4000***	***8000 Hz***
Crusher [dB]	-	52.1	76.4	93.1	104	107.6	106.7	99.8	88
Drilling [dB]	-	106.55	115.65	106.92	112.92	112.25	115.18	115.32	115.98
Dumper [dB]	-	75.6	92.8	99.4	100.8	101.6	100.3	94.1	83.3

C From Frequency Octave values to SoundKernel input

An Excel-sheet may be used to calculate the SoundKernel input from the Frequency Spectra from MicroStation. The sheet with equations are shown below:

Octaves	Frequency [Hz]	Input from MicroStation [dB]	1/3 octave	Distributed	Octave to 1/3 octave	dB value	Square pressure - Input to SoundKernel
			0	=D7	=10*LOG10(1/3)	=F6+G6	=10^(H6/10)
0	31,5	103,205450102066	1	=D7	=10*LOG10(1/3)	=F7+G7	=10^(H7/10)
			2	=D7	=10*LOG10(1/3)	=F8+G8	=10^(H8/10)
			3	=D10	=10*LOG10(1/3)	=F9+G9	=10^(H9/10)
1	63	108,105450102066	4	=D10	=10*LOG10(1/3)	=F10+G10	=10^(H10/10)
			5	=D10	=10*LOG10(1/3)	=F11+G11	=10^(H11/10)
			6	=D13	=10*LOG10(1/3)	=F12+G12	=10^(H12/10)
2	125	116,505450102066	7	=D13	=10*LOG10(1/3)	=F13+G13	=10^(H13/10)
			8	=D13	=10*LOG10(1/3)	=F14+G14	=10^(H14/10)
			9	=D16	=10*LOG10(1/3)	=F15+G15	=10^(H15/10)
3	250	116,005450102066	10	=D16	=10*LOG10(1/3)	=F16+G16	=10^(H16/10)
			11	=D16	=10*LOG10(1/3)	=F17+G17	=10^(H17/10)
			12	=D19	=10*LOG10(1/3)	=F18+G18	=10^(H18/10)
4	500	110,305450102066	13	=D19	=10*LOG10(1/3)	=F19+G19	=10^(H19/10)
			14	=D19	=10*LOG10(1/3)	=F20+G20	=10^(H20/10)
			15	=D22	=10*LOG10(1/3)	=F21+G21	=10^(H21/10)
5	1000	108,005450102066	16	=D22	=10*LOG10(1/3)	=F22+G22	=10^(H22/10)
			17	=D22	=10*LOG10(1/3)	=F23+G23	=10^(H23/10)
			18	=D25	=10*LOG10(1/3)	=F24+G24	=10^(H24/10)
6	2000	103,705450102066	19	=D25	=10*LOG10(1/3)	=F25+G25	=10^(H25/10)
			20	=D25	=10*LOG10(1/3)	=F26+G26	=10^(H26/10)
			21	=D28	=10*LOG10(1/3)	=F27+G27	=10^(H27/10)
7	4000	98,7054501020661	22	=D28	=10*LOG10(1/3)	=F28+G28	=10^(H28/10)
			23	=D28	=10*LOG10(1/3)	=F29+G29	=10^(H29/10)
			24	=D31	=10*LOG10(1/3)	=F30+G30	=10^(H30/10)
8	8000	91,1054501020661	25	=D31	=10*LOG10(1/3)	=F31+G31	=10^(H31/10)
			26	=D31	=10*LOG10(1/3)	=F32+G32	=10^(H32/10)

Figure 21: Equations for Frequency Spectra calculation

Some example values are used to demonstrate the calculation:

Octaves	Frequency [Hz]	Input from MicroStation [dB]	1/3 octave	Distributed	Octave to 1/3 octave	dB value	Square pressure - Input to SoundKernel
			0	103,21	-4,77	98,43	6 973 065 674
0	31,5	103,21	1	103,21	-4,77	98,43	6 973 065 674
			2	103,21	-4,77	98,43	6 973 065 674
			3	108,11	-4,77	103,33	21 548 833 002
1	63	108,11	4	108,11	-4,77	103,33	21 548 833 002
			5	108,11	-4,77	103,33	21 548 833 002
			6	116,51	-4,77	111,73	149 081 500 577
2	125	116,51	7	116,51	-4,77	111,73	149 081 500 577
			8	116,51	-4,77	111,73	149 081 500 577
			9	116,01	-4,77	111,23	132 869 027 248
3	250	116,01	10	116,01	-4,77	111,23	132 869 027 248
			11	116,01	-4,77	111,23	132 869 027 248
			12	110,31	-4,77	105,53	35 762 161 120
4	500	110,31	13	110,31	-4,77	105,53	35 762 161 120
			14	110,31	-4,77	105,53	35 762 161 120
			15	108,01	-4,77	103,23	21 058 321 677
5	1000	108,01	16	108,01	-4,77	103,23	21 058 321 677
			17	108,01	-4,77	103,23	21 058 321 677
			18	103,71	-4,77	98,93	7 823 908 369
6	2000	103,71	19	103,71	-4,77	98,93	7 823 908 369
			20	103,71	-4,77	98,93	7 823 908 369
			21	98,71	-4,77	93,93	2 474 137 065
7	4000	98,71	22	98,71	-4,77	93,93	2 474 137 065
			23	98,71	-4,77	93,93	2 474 137 065
			24	91,11	-4,77	86,33	429 955 744
8	8000	91,11	25	91,11	-4,77	86,33	429 955 744
			26	91,11	-4,77	86,33	429 955 744

Figure 22: Example values for Frequency Spectra calculation

D Road Surfaces

The Norwegian Public Roads Administration(Statens Vegvesen) uses certain mass types with specific rock sizes. These may be found for a particular road by using their mapping service[2]. The mass types are grouped into the road surface types in SoundKernel by how much noise they generate. The first table below summarizes the SoundKernel surface types. The next list the mass types and the suitable SoundKernel surface type. These tables are from a User Manual for NorStøy[8].

SKA = skjelettasfalt,
AB = asfaltbetong og
POR = porøs asfalt.

Vegdekkeklasser i Nord 2000 Road

1	SKA8	Generell SKA. Kornstørrelse mindre enn 10 mm.
2	SKA11	Generell SKA. Kornstørrelse lik eller over 10 mm men mindre enn 14 mm.
3	SKA16	Generell SKA. Kornstørrelse lik eller over 14 mm men mindre enn 19 mm.
4	SKA22	Generell SKA. Kornstørrelse lik eller over 19 mm.
5	AB8	Generell AB. Kornstørrelse mindre enn 10 mm.
6	AB11	Generell AB. Kornstørrelse lik eller over 10 mm men mindre enn 14 mm.
7	AB16	Generell AB. Kornstørrelse lik eller over 14 mm men mindre enn 19 mm.
8	AB22	Generell AB. Kornstørrelse lik eller over 19 mm.
9	POR	Generell porøs asfalt

Figure 23: Summarized Road Surface Types

Massetype	"Støyklasse"
A	AB16
Ab	AB16
Ab11	AB11
Ab11t	AB11
Ab12	AB11
Ab12t	AB11
Ab16	AB16
Ab16t	AB16
Ab19t	AB22
Ab22	AB22
Ab22t	AB22
Ab8	AB8
Ab8t	AB8
Aeg	AB16
Aeg11	AB11
Aeg11}	AB11
Aeg16}	AB16
Aeg18}	AB16
Ag	AB16
Ag11	AB11
Ag12	AB11
Ag16	AB16
Ag22	AB22
Ag8	AB8
Agb	AB16
Agb11	AB11
Agb12	AB11
Agb16	AB16
Agb16t	AB16
Agb22	AB22
Agb8	AB8
Agb9	AB8
Agbl11	AB11
Agbl16	AB16
Agbll	AB16
Agbll11	AB11
Agbll16	AB16
Alg	AB16
Alg16	AB16
Alg18	AB16

Massetype	"Støyklasse"
Ap	AB16
Ap16	AB16
Ap26m	AB22
Ap32	AB22
Arg	AB16
Asg	AB16
B	AB16
Bg	AB16
Br	AB16
Cg	AB16
Da	POR
Da11	POR
Da16	POR
Do	AB16
Do16	AB16
Dog	AB16
Dog12	AB11
Dog16	AB16
Eg	AB11
Eg11d	AB11
Eg16	AB16
Eg16d	AB16
Eg16t	AB16
Eg18	AB16
Eg18d	AB16
Eg18t	AB16
Eg32	AB22
Egd	POR
Egd16	POR
Egt16	AB16
Eo	AB16
Eo11	AB11
Eo16	AB16
Eo18	AB16
Eo4	AB8
Eo8	AB8
Eog	AB16
Eog16	AB16
Eog18	AB16
Fra	AB16

Massetype	"Støyklasse"
Frd	AB16
Frp	AB16
Gja	AB16
Gja11	AB11
Gja16	AB16
Grus	AB16
H	AB16
Ma	AB16
Ma11	AB11
Ma16	AB16
Ma18	AB16
Ma22	AB22
Ma8	AB8
Mda	AB16
Mda16	AB16
Mda22	AB22
Mda32	AB22
Og	AB16
Og11	AB11
Og16	AB16
Og18	AB16
Pp	AB16
Pp63	AB16
Sg	AB16
Ska	SKA16
Ska11	SKA11
Ska16	SKA16
Ska22	SKA22
Ska8	SKA8
Sla	AB16
Sta	AB16
Sta11	AB11
Sta16	AB16
Sta8	AB8
St}l	AB16
Top	AB16
Top16	AB16
Top22	AB22
Top4	AB8
Vb	AB16

Figure 24: List of NPRA road surfaces and SoundKernel surfaces

E Vehicle categories

Below are the European and Norwegian definitions for vehicle classes. The light, medium and heavy categories are used in SoundKernel. The table is from a guide for noise mapping and traffic data[9].

Main category	no	Sub-categories	Notes	Tilsv norsk (NorTraf lengdereg.)
Light vehicles	1a	Cars (incl MPVs ut to 7 seats)	2 axles, max 4 wheels	0 – 5,5 m (bil + henger/ campingvogn ikke inkludert)
	1b	Vans, SUV, pickup trucks, RV, car+trailer or car+caravan, MPVs with 8-9 seats	2-4 axles[19], max 2 wheels per axle	
	1c	Electric vehicles, hybrid vehicles driven in electric mode[20]	Driven in combustion mode	
Medium heavy vehicles	2a	Buses	2 axles (6 wheels)	7,7 – 12,5 m
	2b	Light trucks and heavy vans	2 axles (6 wheels)[21]	5,6 – 7,6 m
	2c	Medium heavy trucks	2 axles (6 wheels)[3]	7,7 – 12,5 m
	2d	Trolley buses	2 axles	7,7 – 12,5 m
	2e	Vehicles designed for extra low noise driving	2 axles	
Heavy Vehicles[22]	3a	Buses	3-4 axles	12,5 – 15,9 m
	3b	Heavy trucks	3 axles	12,5 – 15,9 m
	3c	Heavy trucks	4-5 axles	> 16 m
	3d	Heavy trucks	≥ 6 axles	> 16 m
	3e	Trolley buses	3-4 axles	12,5 – 15,9 m
	3f	Vehicles designed for extra low noise driving	3-4 axles	
Other heavy vehicles	4a	Construction trucks (partly off-road use)		
	4b	Agr tractors, machines, dumper trucks, tanks		(vil oftest være 7,7 – 12, 5 m)
Two-wheelers	5a	Mopeds, scooters	Incude also 3-wheel motorcycles	
	5b	Motorcycles		

19 3-4 axles on car+trailer or car+caravan
20 Hybrid vehicles driven in combustion engine mode: classify as either 1a or 1b
21 Also 4-wheel trucks, if it is evident that they are > 3,5 tons
22 Norske tunge kjøretøy kan ofte ha en aksel mer enn vanlig ellers i Europa pga fremkommelighet vinterstid

Figure 25: List of vehicle categories

F Distribution of vehicles

The Annual Average Daily Traffic is divided over three periods: Day, Evening, Night, three vehicle types: Light, Medium, Heavy, the days of the week and the months of the year. The values are the same for each month. Below are the tables for the distribution for two different traffic types and traffic distributions:

Table 10: Distribution for Heavy traffic type and Work hours and weekdays, percentage values

		Days of the week						
Period:	Vehicle:	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
	Light	0	0	0	0	0	0	0
Day	Medium	0	0	0	0	0	0	0
	Heavy	1.67	1.67	1.67	1.67	1.67	0	0
	Light	0	0	0	0	0	0	0
Evening	Medium	0	0	0	0	0	0	0
	Heavy	0	0	0	0	0	0	0
	Light	0	0	0	0	0	0	0
Night	Medium	0	0	0	0	0	0	0
	Heavy	0	0	0	0	0	0	0

Table 11: Distribution for Heavy traffic type and General traffic distribution, percentage values

		Days of the week						
Period:	Vehicle:	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
	Light	0	0	0	0	0	0	0
Day	Medium	0	0	0	0	0	0	0
	Heavy	0.89	0.89	0.89	0.89	0.89	0.89	0.89
	Light	0	0	0	0	0	0	0
Evening	Medium	0	0	0	0	0	0	0
	Heavy	0.18	0.18	0.18	0.18	0.18	0.18	0.18
	Light	0	0	0	0	0	0	0
Night	Medium	0	0	0	0	0	0	0
	Heavy	0.12	0.12	0.12	0.12	0.12	0.12	0.12

Table 12: Distribution for Normal traffic type and Work hours and weekdays, percentage values

		Days of the week						
Period:	*Vehicle:*	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
	Light	1.42	1.42	1.42	1.42	1.42	0	0
Day	Medium	0.13	0.13	0.13	0.13	0.13	0	0
	Heavy	0.13	0.13	0.13	0.13	0.13	0	0
	Light	0	0	0	0	0	0	0
Evening	Medium	0	0	0	0	0	0	0
	Heavy	0	0	0	0	0	0	0
	Light	0	0	0	0	0	0	0
Night	Medium	0	0	0	0	0	0	0
	Heavy	0	0	0	0	0	0	0

Table 13: Distribution for Normal traffic type and General traffic distribution, percentage values

		Days of the week						
Period:	Vehicle:	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
	Light	0.76	0.76	0.76	0.76	0.76	0.76	0.76
Day	Medium	0.07	0.07	0.07	0.07	0.07	0.07	0.07
	Heavy	0.07	0.07	0.07	0.07	0.07	0.07	0.07
	Light	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Evening	Medium	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	Heavy	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	Light	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Night	Medium	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	Heavy	0.01	0.01	0.01	0.01	0.01	0.01	0.01

The sum of these values multiplied with 12 months is 100 %.