



Noise Mapping From Above

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ABSTRACT

In the case of noise modelling preparation of industrial plants, if the client does not have the required quantity and quality of information and data for the proper outcome, we have to produce them for ourselves. In such instances, field survey is essential to obtain the desired data. In this paper, it is shown how to create the necessary digital terrain (DTM) and surface (DSM) models for the noise modelling in case they are not available. The implementation of the task was solved by photogrammetric survey obtained as the result of a drone (UAV) flight operation and its data processing. The aim is to produce a file that can be imported into the noise mapping software used in the project. On the generated orthographic photo of the study area the exact position of the noise sources can be marked in the horizontal plane. In vertical plane terms, the surface model will help us to determine the height of the noise sources and the relevant objects. Then, using an appropriate software, a shape file can be generated and imported into the noise mapping software and as the goal, the noise modelling can be performed.

1. PROBLEM STATEMENT, DESCRIPTION OF THE TASK

In the vast majority of cases, noise mapping also requires field-based survey work in order to perform the task in a complex way. Of course, the noise modelling itself takes place in the office, and it is also true that the parameters and noise data of the sources can be obtained from the manufacturer and thus incorporated into the noise model, but the data of noise measurements and the field-based survey provide us more accurate and credible results. To carry out the fieldwork, we need a floor plan, a site map or a machine layout drawing provided by the client, which we are able to identify the noise sources and important objects on. It may come as a surprise in 2022, but it is often happens that some industrial facilities can only provide us incomplete or inaccurate data, so the best way to carry out the needed survey is to rely on our telemetry and sketching skills.

In defining the topic of this thesis, I was guided by the question whether remote sensing methods could be suitable to assist and clarify the field survey process in everyday noise experts' tasks. My specific aim is to find a usable method that can be applied in noise mapping to overcome possible shortcomings in the data provided by the client in order to produce a better final product.

In performing this task, I used photogrammetric data processing to create a dataset that can be imported into a chosen noise mapping software. On the orthographic photograph of the site the contours of the plant buildings, the mechanical equipment and the data obtained from the on-site survey of noise sources can be marked, i.e. we get the exact position of noise sources and objects in the horizontal plane. In the vertical plane, the generated surface model (DSM) will help us to determine the height of the equipment and objects to be surveyed. The resulting shape file, which already contains

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the spatial position of the objects, is imported into the noise mapping software. The final step of the task will be the construction of the noise model of the industrial building, which will be carried out after processing the noise survey data and the noise sources location, as briefly described above, using the appropriate software IMMI.

2. A FEW WORDS ON ENVIRONMENTAL NOISE MAPPING

Computer modelling can be used to determine the noise exposure for a given area or entire noise source systems with a high degree of accuracy, knowing the exact input data. The noise exposure values calculated for the noise calculation points can be examined not only in two dimensions (as a function of distance), but also as a function of height, which is usually not possible with noise measurement methods. This way, the measurement or calculation results of industrial, service and other facilities, as well as traffic noise sources can be represented by graphical tools directly on a site plan or on a three-dimensional digital base map. Furthermore, by adjusting the input parameters, the environmental noise impact of a planned future investment can be assessed as well.

The noise map shows the current (or future) noise situation on a noise immission or conflict map, which represents the noise exposure caused by different noise sources in the area of interest in terms of isophonic curves over the time periods of the assessment. The colour-coded graphical representation allows an overview and analysis of the noise situation in a chosen municipality, linear infrastructure or industrial installation, as compliance with the exposure limits laid down in the legislation in force can be clearly determined. The noise exposure levels can be visualized over the entire area of influence of the noise source in issue with an accuracy of 1 - 2 dB depending on the type of the noise source and the investigated area, the outdoor noise propagation rules, and the topographical conditions.

3. IMPLEMENTATION OF THE IN FIELD-BASED TASKS

3.1. Environmental Noise Measurement

The environmental noise measurement for this task was carried out in April 2019. The results reflect the conditions of that time, which may no longer exist, but perfectly suitable for demonstrating the developed methodology. The environmental noise exposure of the investigated noise sources was determined by noise calculation and noise modelling. The noise measurements carried out are intended to provide the input data needed for noise modelling. Noise data from noise sources considered dominant during the on-site visit were stored with near-field measurements, and these values can be used to calibrate the noise model. The following parameters need to be recorded in order to process the data effectively:

- Name and designation of the noise sources.
- Determine the exact location of the noise sources.
- The measured equivalent sound pressure level of the noise sources [L_{Aeq}]
- The distance between the noise source and the measurement microphone.
- Directivity of the noise sources ($D = 1, 2, 4, 8$)
- The type of the noise sources (point, area or line sources)
- The spectrum of the emitted noise (optional)

The noise measurement procedure and a typical noise source group installed on the industrial building's roof are illustrated in Photo 1. and Photo 2.



Photo 1: the noise measurement procedure



Photo 2: typical noise source group on the field

The noise measurement has been carried out with a Brüel & Kjaer 2250 type class I sound level meter and hand-held analyzer. During modelling work, the sound pressure level values obtained from noise level measurements will be used to determine the sound power level of the noise sources.

3.2. Photogrammetric Survey

The photogrammetric survey was carried out in October 2018 at the site, which basically included the drone flight and the identification and measurement of the ground control points (GCPs). It was a specific request from the management of the facility that all survey operations should be properly notified and carried out in accordance with the legislation and regulations in force, so the necessary permits had to be obtained before the flight could commence. The airspace usage request was submitted to the Ministry of Defence in August 2018. A safety assessment had to be carried out as well in connection with the requested airspace usage, and since the chosen area overlapped the airspace of the Budapest CTR (Civil Airport Control Region), the flight also required an expert opinion of HungaroControl Zrt. Once all the permits have been obtained, the flight with the unmanned aircraft had to be notified to the Ministry of Innovation and Technology as the date of the flight approached.

The photogrammetric survey therefore consisted of two parts. First, the GCPs were placed on the rooftop of the investigated industrial building. The GCPs are points on the surface with known coordinates. By identifying these points with known spatial positions in the drone images, the processing software is able to generate the orthophoto and the DSM according to their real geographic position.

GCPs should be placed along the border of the investigated site as well as inside and even outside the area, so that the drone can detect freely a sufficient amount of them from all directions during flight. The go-to rule is to use high-contrast colors and be sure that they are large enough to be identified from the particular flight altitude.



Photo 3: ground control point called as *handrail1*

The general view is that 5 -10 GCPs should be placed in the study area, any more than this will not increase accuracy enough to be worth it. During this work the positions of the GCPs was measured with a Leica GS14 GNSS receiver and CS10 controller. This device receives continuous positioning corrections from the Lechner Knowledge Center (as the legal successor to the Institute of Surveying and Remote Sensing) via a GSM connection thus an accuracy of 1-2 cm can be achieved in both the horizontal and vertical planes. The GCPs defined in this work are shown in Table 1.

Table 1: The defined GCPs names and positions

Name of GCPs	EOV Y coordinates	EOV X coordinates	Altitude above sea level [m]
<i>handrail1</i>	658273,156	239392,049	140,226
<i>floor1</i>	658235,709	239426,865	136,916
<i>ventilation1</i>	658221,839	239429,790	140,014
<i>ventilation2</i>	658221,843	239429,794	140,013
<i>floor2</i>	658226,110	239415,224	136,918
<i>ventilation3</i>	658256,767	239385,608	137,023
<i>rooftop1</i>	658241,237	239409,585	140,023

The flight was carried out with a DJI Phantom 4 Pro drone. 297 piece of 9 MB jpg aerial photographs of the investigated building were taken for the creation of the orthomosaic and the digital surface model. When planning the flight, it should be taken into account that a lateral overlap of 60-80% and a forward direction overlap of 70-80% are required to achieve the necessary accuracy.



Photo 4: tracking the GCPs



Photo 5: DJI Phantom 4 Pro drone

4. IMPLEMENTATION OF THE OFFICE-BASED TASKS

4.1. Processing of the Noise Measurement Data

As a first approach, the sound power levels of the noise sources on the roof were calculated using the outdoor propagation calculation formula and the parameters shown in Table 2. The calculated sound pressure level values were used as an input data into the noise model. Where it was necessary, the reference measurements were used to calibrate the certain noise sources to obtain more accurate values. At the time of the noise measurement not all of the sources were operating, but as we usually planning for the worst-case scenario, estimated values for the non-operating sources have been included into the noise model.

Table 2: the noise sources data to be imported into the noise model

Measure- ment data	Noise source, location	Mic. height [m]	Sound pressure level [dB(A)]	Mic. - source distance [m]	Directiv- ity (D)	Type of source	Sound power level [dB(A)]
190416 003	between engine3 and engine4	1,0	76,2	1,0	1	Point	87,2
190416 001	between engine7 and engine8	1,0	74,9	1,0	1	Point	85,9
190416 002	between engine5 and engine6	1,0	76,9	1,0	1	Point	87,9
190416 007	chimney6	4,0	76,9	1,0	1	Point	87,9
190416 004	between engine1 and engine2	1,0	74,1	1,0	1	Point	85,1

Measure- ment data	Noise source, location	Mic. height [m]	Sound pressure level [dB(A)]	Mic. - source distance [m]	Directiv- ity (D)	Type of source	Sound power level [dB(A)]
190416 005	chimney2	4,0	75,0	1,0	1	Point	86,0
190416 006	chimney1	4,0	81,2	1,0	1	Point	92,2
190416 012	engine10	1,5	71,6	1,0	1	Point	82,6
190416 016	chimney10	4,0	81,3	1,0	1	Point	92,3
190416 013	engine11	1,5	72,2	1,0	1	Point	83,2
190416 015	chimney11	4,0	78,1	1,0	1	Point	89,1
190416 011	3 radial vent. units	1,0	70,3	1,0	1	Point	81,3
190416 014	reference meas.	1,5	70,9	1,0	1	Point	81,9
190416 008	reference meas.	1,5	70,7	1,0	1	Point	81,7
190416 009	reference meas.	1,5	66,5	2,0	1	Point	83,6
190416 010	reference meas.	1,5	66,9	1,0	1	Point	77,9

4.2. 3D Model Creation

The 3D model data was generated using QGIS software. As a first step, I used the created orthomosaic image as a basis and drawn the contours of the necessary buildings and objects onto it.

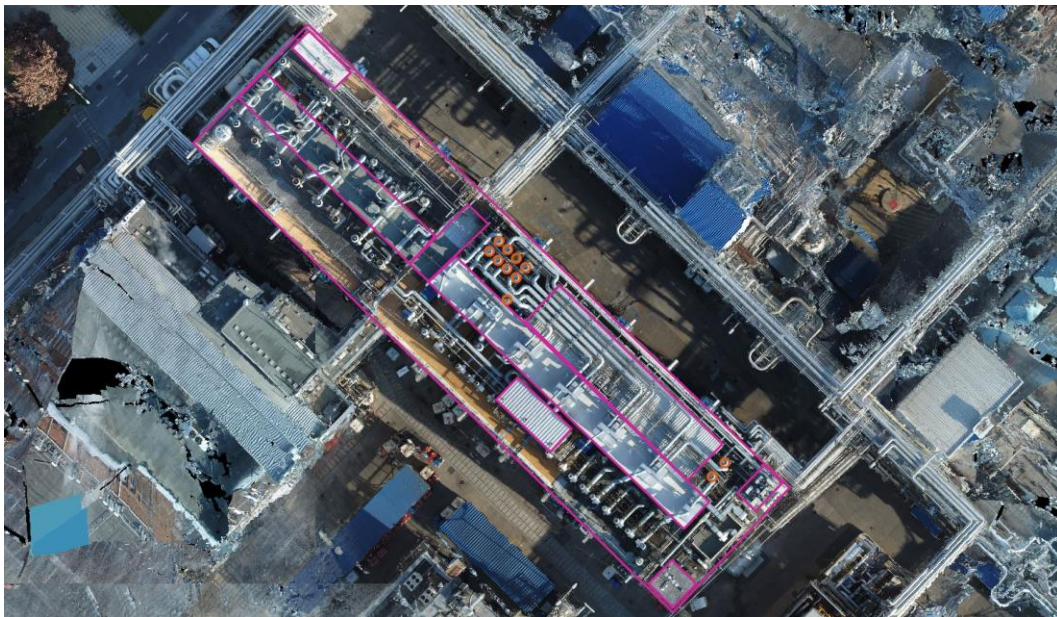


Figure 1: 3D model creation, defining the building and object contours (on the orthographic image)

As a second step, I coloured the DSM with discrete interpolation per meters and displayed the elevation lines with allocation per meters as well. At this stage, if necessary, the resolution of the model

could be fine-tuned, but I have found that this level of details are sufficient for this project work, and we would not get much more accurate results with further detailing.

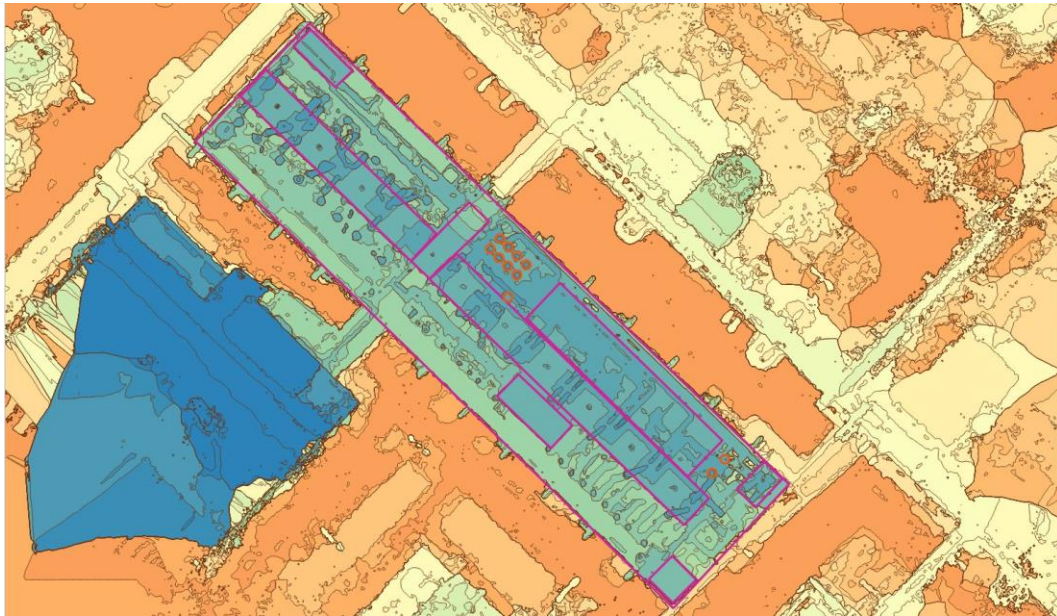


Figure 2: 3D model creation, defining height of the buildings and objects (on the DSM)

I included the height data into the attribute table of the objects and the buildings, which can be read from the coloured DSM and this, exported from QGIS as a shape file can be used to prepare the noise model in the chosen noise mapping software.

5. RESULTS OF THE METHODOLOGY

The noise model in this case was created using IMMI noise mapping software. In IMMI, we are able to import dxf or shp files, and then we can work with these files in the noise mapping software environment. Since the imported objects are already georeferenced - which means that, the internal coordinate system of them can be related to the geographic coordinate system of our project (namely Hungarian EOVS) -, in IMMI, we no longer have to deal with this issue. So according to the type of objects created in QGIS, be it lines, or areas, they are at their correct geographical position. Now the next step is to convert them to building objects in the noise mapping software, and since the input data has been provided with altitude data, our newly emerging buildings will also have their real height (see Figure 4). As next step, we have to work with the investigated noise sources in the model area. First we need to determine their spatial position, which can be achieved by matching their location to the objects imported into IMMI. If it feels more secure that way, the positions of the noise sources can directly marked on the orthographic image in QGIS at the earlier stage of the process. At this stage of the work, the files have been already created that we need to choose the best possible way to do the job properly. The noise source objects have to be fed with the formerly calculated noise data, if necessary, the calibration should be performed as well, and all that remains is to run the noise propagation calculation with the desired parameters.

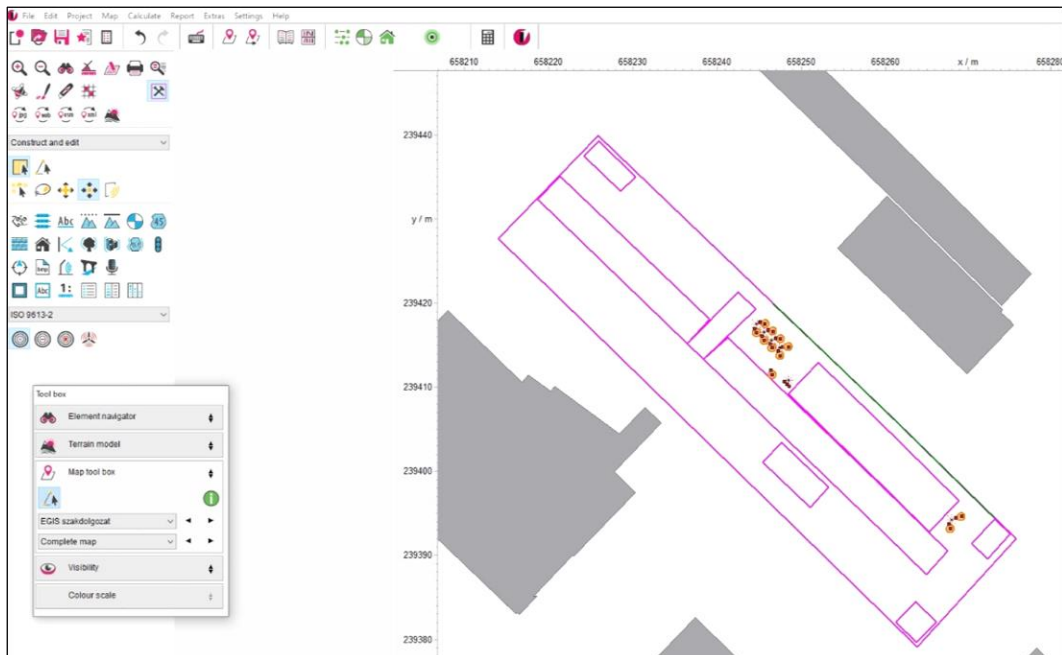


Figure 3: noise model creation, 2D view of the investigated building in IMMI

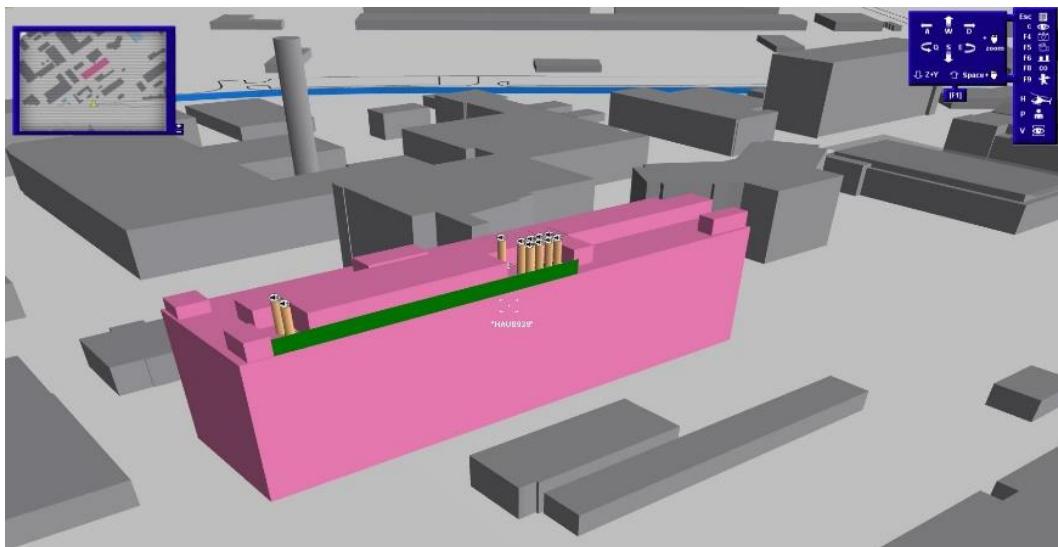


Figure 4: noise model creation, 3D view of the investigated building in IMMI

6. CONCLUSION

During the course of this pilot project, it became clear to me that we can use photogrammetric methods to produce the necessary data for noise modelling, in that case if the client cannot provide us them, or if they are not detailed and accurate enough for us to use them in our work. The accuracy of the data produced this way will then be up to us, depending on how much time and effort we want to put into it and what the target task requires of us. Of course, for each project, it is necessary considering whether the extra work and cost of using this method is worth the extra investment, but I believe that the promise of a more accurate and higher quality result in the noise modelling of a larger facility may be worth this extra input.