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Sound fields in narrow street canyons with noise from trams

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The existing prediction methods for noise in narrow street canyons are mainly focused on noise from small vehicles like cars and motorcycles. There are no prediction methods that yield reliable results for larger vehicles like trams. A complicated sound field is excited when a tram passes through a narrow street with buildings on both sides. The tram acts as both a sound source and a reflecting sound barrier, creating sound fields on both sides of the tram between the tram and the facades of near buildings.

An example of such a situation is in Storgata in Oslo where up to 36 trams pass per hour, with buildings standing as close as 1,5 m from the tram rails. In the present work measurements were made with 5 microphones to measure this complex situation. The microphones were mounted between the façade and the tram in different heights to see how the sound levels vary.

The street canyon with surrounding buildings and trams have been described in a 3D-model using Sketchup. This 3D-model has been imported to Odeon, a room acoustics simulation software. The main question of this study is whether or not it is possible to simulate the sound fields created by the trams.

1 Introduction

Noise from traffic in general is an increasing problem in several densely populated cities around the world. This paper is based on a master thesis written on the subject [1]. The study is focused on the measurement and simulation of noise from trams. The study is a continuation of a long series of studies of tram noise in Oslo [2,3,4]. There are no prediction methods that yield reliable results for larger vehicles like trams and buses [5,6]. When a tram is passing close to a façade, a complicated sound field is exited. The tram acts as both a sound source and a reflecting sound barrier. The question of this study is whether or not it is possible to simulate the sound fields created by the trams. Two different methods have been used to measure the noise, and the better method was chosen for further analysis. A 3D model of the street has been used to try to simulate the noise situation in Odeon.

2 Measurements and results

This paper will present noise measurements on trams in Storgata in Oslo, with a simulation and analysis in Odeon, in an attempt to simulate the real situation where trams pass through narrow street canyons. There are two different tram types in Oslo, SL 79 and SL 95. Measurements and simulations were made for both tram types and for both directions in the street.

2.1 Measurements

The measurements were performed using a multi-channel unit called OROS 36/16. A setup consisting of 5 microphones were connected to the OROS, and placed in different heights from 1,75 - 5 m on a large stand. The situation in Storgata is presented in Figure 1.

Figure 1: Measurement equipment and set-up in Storgata

The measurements were made by analysis of the noise through the entire passing of a tram, starting when the front of the tram was at the measurement setup, and ending when it had passed. Due to a lot of background noise from other sources in the traffic, this was considered the best solution.

Another measurement setup was tested, but proved more inaccurate and was therefore rejected. The setup had the microphones placed on individual stands along the façade. This caused difficulties measuring at the same passing.

The trams are measured in two directions in Storgata. The direction “out” is closest to the microphone and denotes the direction out of Oslo city centre. The direction “in” denotes trams on the other side of the street heading towards Oslo city centre.

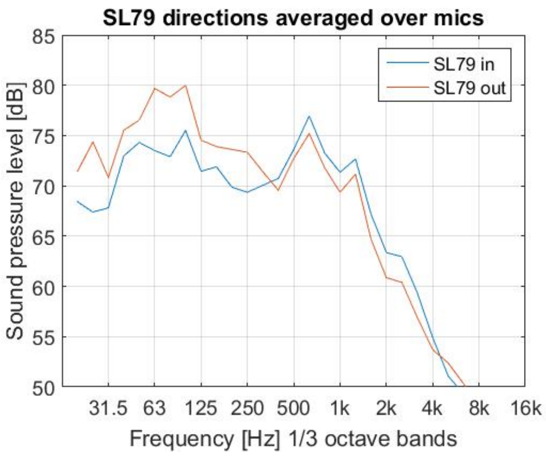
Measurements from a total of 40 trams passing were conducted in the same measurement position.

2.2 Data handling

The noise measurement from 5 microphones, maximum and equivalent level in 1/3-octave band in the frequency range from 20 to 20 kHz resulted in large amounts of numbers to be handled. With 31 different frequency bands, 5 microphones, 4 combinations of tram type and direction and 2 noise levels, this resulted in over 1200 different values to be handpicked for analysis of result. To be able to consider the details of the measurements, a script in Matlab was written. This script sorted and made calculations for the different data types.

2.3 Measurement results

Measurements from the two different directions for both trams have been averaged for all measurements and microphones to see how the directions of the tram affects the noise levels. Measurements from SL 95 and SL 79 are presented in Figure 2 and Figure 3, respectively.



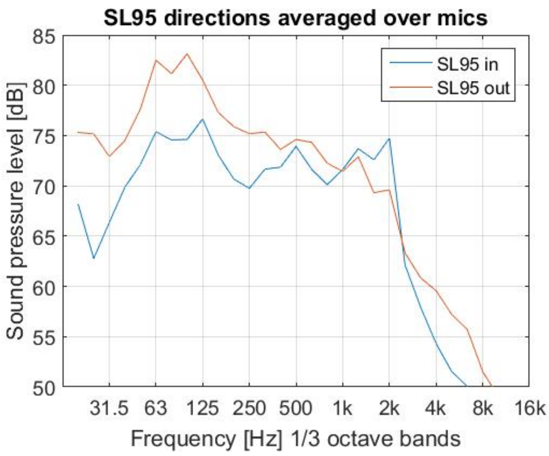


Figure 2: SL 79 noise levels in and out

Figure 3: SL 95 noise levels in and out

The low frequency noise is produced by the connection between tram and rail, the rolling noise. This noise is noticeable for both trams in both directions. A peak in 500-630 Hz was interpreted to be produced by the motor, while the noise in 2k Hz was likely made from squeal between the rails and the wheels.

The measurements show that low frequencies are more dominant when the trams are closest to the microphone setup (out). Interestingly, the measurements on trams passing further away (in) has higher noise levels in frequencies above 500 Hz. Due to a narrower 95 % confidence interval, further analysis is mainly focused on the measurements from SL 95.

2.4 Individual microphone values – SL 95

Measurements presented in Figure 4 shows the averaged noise levels from each of the microphone positions when a tram of type SL 95 is passing. If the main noise source is from the wheels connection to the rail, it is expected that the microphone closest to the ground has the highest noise level. What is interesting about this graph, is that the microphone at 3,6 m above ground, which is above the height of the tram, has an equal or even higher noise level than of the measurement at 2,4 m. This result is equal for trams passing both in- and out of Storgata.

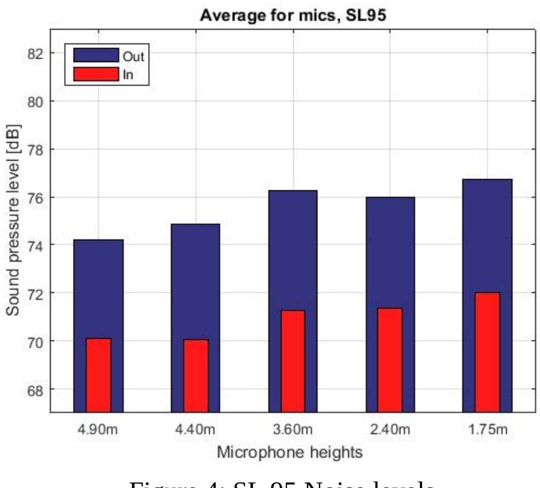


Figure 4: SL 95 Noise levels

Figure 5 presents a possible explanation for the measured values at 3,6 m height. As the tram acts as both a noise source and a sound barrier, the reflected sound from a façade on the other side of the rails will only contribute towards the measured sound pressure levels above the tram.

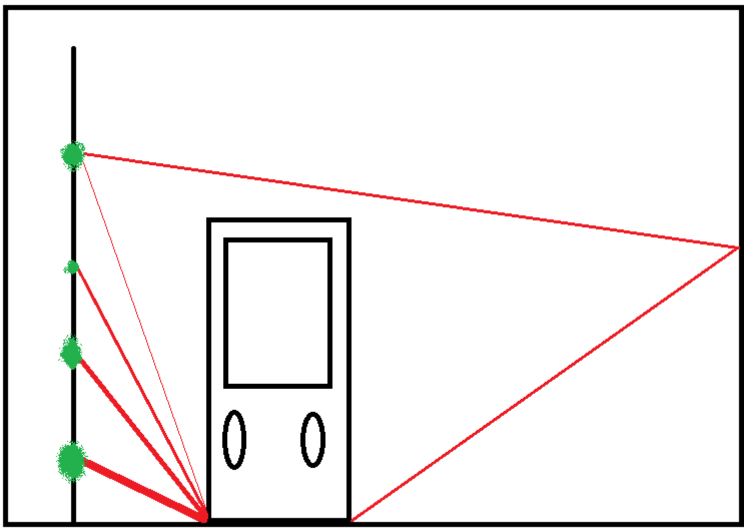


Figure 5: Reflection from façade

By calculating the distance from the source (assuming all sound is excited by the wheels/rails) to the different microphone positions, the sound level relative to distance is presented in Figure 6.

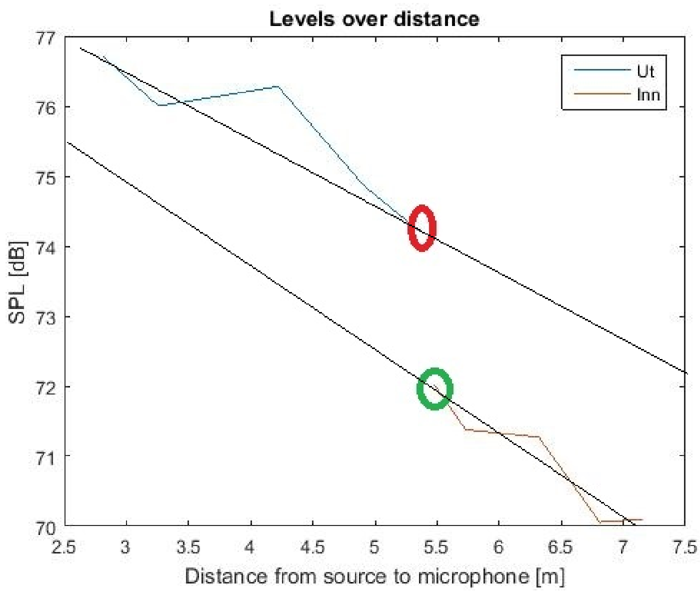


Figure 6: Sound levels relative to distance

The measurements on trams going out of Storgata are shown at the top of the figure, while the bottom graphs are from inwards passing. From the graphs it is possible to interpret that the sound pressure level is higher at the same relative distance, for the trams going out as compared to trams going in to Storgata. This shows that a sound field is present between the trams and the façade. If there was no sound field present between the tram and the façade, the sound pressure levels marked in figure 6 should have been equal. The graphs show that the sound pressure level over distance decreases at a higher rate when the tram is further away from the receivers. This supports the same interpretation.

3 Simulation

3.1 Sketchup model

To be able to simulate the situation in Storgata, a very simplified model of the street canyon was built in Sketchup. Measurements of the dimensions of the street, as well as positions of receiver positions and tram rails were made on site. Dimensions of the tram was taken from *Norske lok og motorvogner [7]*. Figure 7 shows the model of the street, with the tram built as a rectangular box. The entire model is closed in to work as a “room” for further simulations in Odeon.

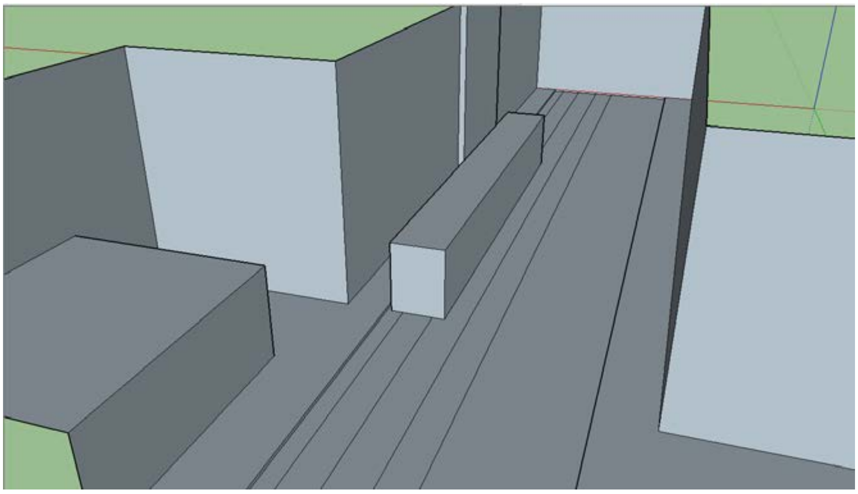


Figure 7: Sketchup model of Storgata

3.2 Odeon

For the simulations in Odeon, a lot of assumptions were made with regards to absorption and scattering of the different surfaces in the model. The “roof” is modelled as a surface with 100 % absorption to simulate the effect of the sky, while the end of the street was modelled with 50 % absorption and scattering to simulate a longer street canyon than modelled. The model is presented in figure 8. The sources in the model are two line sources on each side of the tram, placed on the ground. Microphones are positioned as they were placed in the measurements.

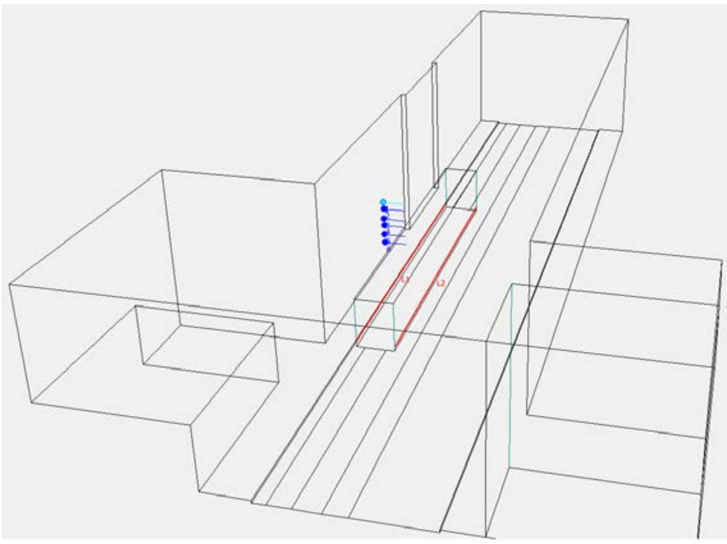


Figure 8: Odeon model of Storgata

The simulation results which showed the best match with the measured results are presented in figure 9. This result is based on a simulation of SL 95 going out. Even though the scale of the sound pressure level is quite limited, we see the simulated results act in a similar way as of the measurements shown in Figure 4. The simulated value above the height of the tram is higher than of the receiver placed further down on the façade. The simulations were made with simplified assumptions of scattering, absorption and source levels.

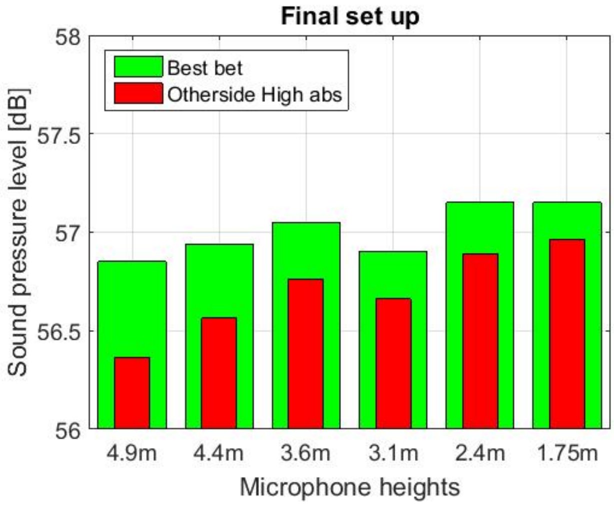


Figure 9: Simulated results SL 95 out

4 Summary

Measurements on noise from trams in narrow street canyons have shown that a sound field is excited between the tram and façade. Measurements compared with regards to the distance from the source, assumed to mainly be at the connection between rails and wheels, to the receivers show that sound attenuation decreases when the tram is closer to the façade.

A simplified model from Sketchup imported to Odeon has shown that it is possible to simulate the situation from Storgata. Even with a large amount of assumptions made towards the modelling and the source, a simulated result has the same behaviour as the measured result.

References

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