A comparison between predicted and measured noise levels at the Rijeka - Zagreb motorway

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The current calculations used for predicting the levels of road traffic noise can and usually do give results that can differ significantly from the results of measurements of noise levels performed in the field. In order to examine these discrepancies, levels of road traffic noise have been measured on two locations on the Rijeka – Zagreb Motorway. After that, the geographical layout of these locations has been prepared and then input into a computer simulation program with the goal of obtaining simulated road traffic noise levels. Following the assumption that these results will be different, the goal is to determine which of the simulation models used today will provide results that are in the best agreement with the results obtained from the actual field measurements, with the emphasis on this particular geographic region, namely, the Republic of Croatia.

1 Introduction

In the last few years extensive effort has been made on addressing the problem of noise pollution on the territory of the Republic of Croatia. This effort extends over all levels of noise protection, ranging from reduction of noise levels of a single noise source up to producing noise maps of entire cities.

This paper deals with the problem of road traffic noise. To be more specific, the goal is to determine how much do the results of the simulations based on existing models agree with actual on-site measurements. Up to this date, extensive work has been made on improving the existing calculation models in order to improve this agreement. However, the discrepancies between the simulations and measurements still exist and are directly related to the degree of uncertainty introduced in every step of the models available today. Specifically, four distinctive types of uncertainties can be defined: the uncertainty in model inputs and parameters, the uncertainty in model outputs resulting from the uncertainty in model inputs and model parameters, the uncertainty associated with different model structures and model formulations and the uncertainty in model predictions resulting from uncertainty in the evaluation data.

An obvious example is the daily number of vehicles utilizing a certain road, averaged over the whole year. The vehicle type is characterized only as passenger or heavy and the number of heavy vehicles is expressed as a percentage of the total number of vehicles. It is clear that further division of vehicle types into subcategories is required. The reason for this is that these two categories are too general and contain different vehicle sub-types that emit noise of very different levels and spectral content. Furthermore, the daily number of vehicles taken as an average over a one year period cannot be used as valid when it comes to roads with highly variable traffic intensity. In order to achieve the set goal, the comparison between the simulations and actual measurements has been made for two locations on the Rijeka – Zagreb Motorway. The traffic intensity on this particular motorway changes drastically depending on the time of the year, reaching its minimum values in wintertime and maximum values in the summertime.

2 Measurement locations

As stated in the introduction, two measurement locations have been chosen along the Rijeka – Zagreb Motorway. The residents who live on these locations have made numerous complaints on noise emitted from the motorway by passing vehicles. Responding to their complaints, the Rijeka – Zagreb Motorway Company ordered a series of measurements and a study that would solve this problem.

The first location is positioned deep in the mountain part of Croatia known as Gorski kotar, in the village called Rožman Brdo. This section of the motorway is of dual carriageway type having two lanes in each direction; the speed limit is set to 110 km/h, while the slope of the motorway is kept under 1°. The residents living at this location breed horses, which require peace and quiet as they are sensitive to noise, especially to sudden changes in noise level. The stable itself is positioned at the distance of approximately 100 meters from the motorway. Unfortunately, this particular section of the motorway is elevated with respect to the ground level of surrounding terrain. Furthermore, the horse stable is located on the slope of the nearby hill facing the motorway, so the noise emitted by passing vehicles propagates from the motorway to the receiving point (the stable) with no obstructions whatsoever. The layout of the location is shown in Fig.1. The photograph of the location, taken from the position in front of the stable, is shown in Fig.2.

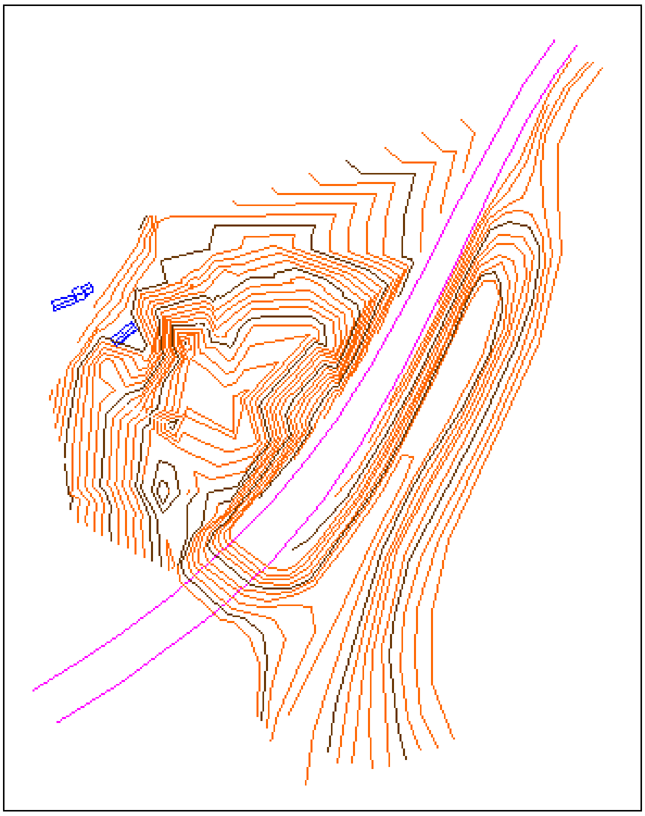

Fig.1 The layout of location 1.

Fig.2 The photograph of location 1.

The second location is positioned at the very entrance to the city of Rijeka. This section of the motorway is of dual carriageway type having three lanes in each direction; the speed limit is set to 80 km/h, while the motorway has a slope of approximately 3 percent. The residential object is positioned at the distance of only 5 meters from the edge of the motorway. Fortunately, the object is closer to the carriageway heading downhill towards the city, allowing the vehicles to drive at high gear at lower engine RPM, thereby emitting lower noise levels. On the other hand, the vehicles traveling in the opposite direction usually drive in lower gear at higher engine RPM in order to overcome the slope of the motorway, thereby emitting relatively high noise levels. Furthermore, the residential object is trapped between the motorway and a local road and is, therefore, affected by noise emitted by vehicles using both roads. However, the contribution of this local road to overall noise level is very small. The overall layout of this location is shown in Fig.3. The photograph of the location, taken from the edge of the property, is shown in Fig.4.

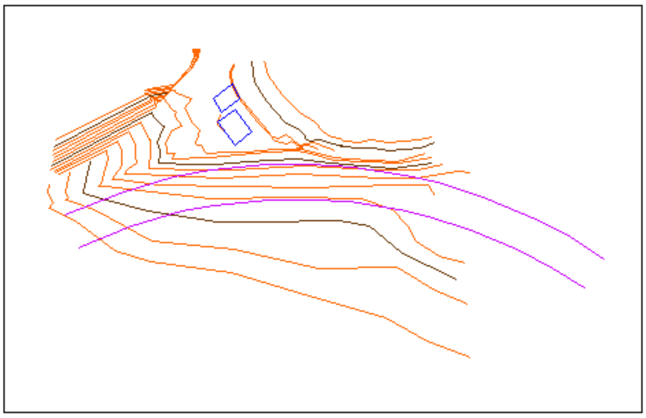

Fig.3 The layout of location 2.

Fig.4 The photograph of location 2.

3 The measurements

As stated before, the daily number of passing vehicles on this particular motorway changes drastically depending on the season of the year. For example, during wintertime the user population is limited to people who use this motorway because their line of work demands it. The daily number of passing vehicles at this time of the year is approximately 8000 vehicles per day. In the summertime, on the other hand, this motorway becomes a major route to the northern region of the Adriatic Sea for tourists arriving from Central European region. As a consequence, the user population is increased by a large number of the fore mentioned tourists who use this route to get to their desired destinations. Therefore, the traffic intensity is significantly increased, reaching a daily number of passing vehicles of almost 30 000. Furthermore, significant changes in traffic intensity can also be observed depending on the day of the week, especially in the summertime. To be more precise, the traffic intensity is significantly increased on weekend, compared to the one observed on weekdays. Finally, traffic intensity changes abruptly during a single day period due to the fact that many people use this motorway to get to their workplace and back home. This phenomenon is particularly emphasized at the second location due to its proximity to the city of Rijeka as a regional center. The greatest traffic intensity at this particular location was observed from 3 to 7 PM.

In order to make a plausible comparison between the results of the simulations and the results of actual measurements, the decision has been made to disregard the statistical data on traffic intensity as an input parameter to the calculation model. Instead, the counting of actual traffic has been done simultaneously with the measurements of noise levels. The results of this counting procedure have been used as the input parameter to the models.

The measurements of noise levels and the counting of traffic on both locations have been performed over a 24-hour period on two particular weekdays in the autumn season, namely, one day per location. As expected, the traffic intensity did not reach its maximum values due to the time of the year and to the day of the week. Therefore, the noise levels did not reach their maximum values. Furthermore, on the very day of measurement at the second location the two lanes closest to the residential object were closed down for repair work, leaving open only the innermost lane of the carriageway heading towards the city. As a result, the noise levels measured at that location on that particular day were somewhat lower than they would be if all three lanes had been opened for traffic. This unfortunate situation has been taken into account in preparing the noise level calculations.

In order to accommodate the changes of traffic intensity during the 24-hour period, the measured noise levels expressed with L_{Aeq} were recorded on the hourly basis. As stated above, the counting of actual traffic has been done simultaneously and also recorded on the hourly basis. These results of traffic counting have been converted into a daily number of vehicles in order to accommodate the input requirements of the calculation model. The noise levels measured at both the first and the second location are given in Tables 1 and 2, respectively, along with the number of the vehicles counted on the hourly basis.

Location 1:	Rožman Brdo	Date:	2005/10/12
Time period	Traffic intensity (vehicles/hour)	Percentage of heavy vehicles (%)	Noise level L_{Aeq} (dBA)
7:00 - 8:00	291	17.2	54.3
8:00 - 9:00	514	12.8	54.4
9:00 - 10:00	579	11.2	54.5
10:00 - 11:00	409	17.6	55.1
11:00 - 12:00	479	22.3	56.0
12:00 - 13:00	415	19.0	55.3
13:00 - 14:00	434	22.4	53.5
14:00 - 15:00	495	20.0	55.5
15:00 - 16:00	549	18.4	53.7
16:00 - 17:00	563	14.4	53.5
17:00 - 18:00	579	16.1	54.2
18:00 - 19:00	560	19.1	53.5
19:00 - 20:00	492	14.8	54.9
20:00 - 21:00	309	19.4	53.1
21:00 - 22:00	267	21.7	52.3
22:00 - 23:00	160	19.4	49.1
23:00 - 0:00	91	19.8	48.7
0:00 - 1:00	39	20.5	48.1
1:00 - 2:00	31	22.6	47.8
2:00 - 3:00	30	20.0	47.2
3:00 - 4:00	40	17.5	48.0
4:00 - 5:00	49	20.4	47.9
5:00 - 6:00	119	21.8	51.0
6:00 - 7:00	220	20.4	52.1

Table 1 Noise levels and traffic intensity measured and counted at location 1

Location 2:	Svilno (Rijeka)	Date:	2005/10/26
Time period	Traffic intensity (vehicles/hour)	Percentage of heavy vehicles (%)	Noise level L_{Aeq} (dBA)
7:00 - 8:00	1190	20.2	69.4
8:00 - 9:00	1530	17.6	69.2
9:00 - 10:00	1542	16.3	69.5
10:00 - 11:00	1572	19.8	68.2
11:00 - 12:00	1520	20.4	69.2
12:00 - 13:00	1538	15.0	68.3
13:00 - 14:00	1930	16.1	68.0
14:00 - 15:00	2238	14.5	69.5
15:00 - 16:00	2046	6.4	69.7
16:00 - 17:00	2106	12.3	69.8
17:00 - 18:00	2098	14.3	69.6
18:00 - 19:00	1632	15.7	68.9
19:00 - 20:00	1504	19.7	69.0
20:00 - 21:00	1230	20.9	68.4
21:00 - 22:00	950	21.1	64.3
22:00 - 23:00	867	19.1	63.9
23:00 - 0:00	700	22.1	63.3
0:00 - 1:00	578	22.5	62.8
1:00 - 2:00	540	19.4	62.1
2:00 - 3:00	505	21.0	62.2
3:00 - 4:00	493	22.3	61.9
4:00 - 5:00	497	20.8	62.1
5:00 - 6:00	908	19.3	63.4
6:00 - 7:00	1006	20.9	64.0

Table 2 Noise levels and traffic intensity measured and counted at location 2

4 The comparison of results

Having acquired the real data on noise level and traffic intensity for two particular locations in 24-hour period of time, simulations have been made for the same locations using the layouts shown in Figs. 1 and 3. As stated before, the data on traffic intensity expressed as the daily number of passing vehicles averaged over a one year time period was disregarded. Instead, actual traffic intensity counted on the hourly basis along with the percentage of heavy vehicles served as the input parameter to the model. Three different calculation methods were examined in order to compare the results obtained from actual measurements to the results provided by simulations. Specifically, the RLS90 and the DIN18005 methods have been chosen as the most common ones used in European countries. Additionally, the Hungarian standard MSZ 15036 has been included in the examination, as Hungary is the only neighbouring country that has adopted its own standard for road traffic noise calculations. The results of the simulations made for both locations are shown in Tables 3 and 4, respectively, along with measured noise levels and counted traffic intensity.

Location 1:	Rožman Brdo			
Traffic intensity (vehicles/hour)/ Percentage of heavy vehicles (%)	Noise levels L_{Aeq} (dBA)			
	Measured	RLS90	DIN 18005	MSZ 15036
291 / 17.2	54.3	54.8	54.0	55.2
514 / 12.8	54.4	56.4	55.5	56.7
579 / 11.2	54.5	56.5	55.6	56.8
409 / 17.6	55.1	56.6	55.7	56.9
479 / 22.3	56.0	58.3	57.4	58.6
415 / 19.0	55.3	56.9	56.0	57.2
434 / 22.4	53.5	57.1	56.2	57.4
495 / 20.0	55.5	57.6	56.7	57.9
549 / 18.4	53.7	58.4	57.2	58.1
563 / 14.4	53.5	57.2	56.3	57.5
579 / 16.1	54.2	57.7	56.8	58.0

Table 3 Measured and simulated noise levels and traffic intensity counted at location 1

Location 2:	Svilno			
Traffic intensity (vehicles/hour)/ Percentage of heavy vehicles (%)	Noise levels L_{Aeq} (dBA)			
	Measured	RLS90	DIN 18005	MSZ 15036
1530 / 20.2	69.2	69.1	69.9	69.3
1542 / 17.6	69.5	69.5	70.3	69.7
1572 / 16.3	68.2	69.2	70.0	69.4
1520 / 19.8	69.2	70.1	70.9	70.3
1538 / 20.4	68.3	70.1	70.9	70.3
1930 / 15.0	68.0	68.8	69.6	69.0
2238 / 16.1	69.5	70.2	71.0	70.4
2046 / 14.5	69.7	70.3	71.1	70.5
2106 / 6.4	69.8	67.6	68.4	67.8
2098 / 12.3	69.6	69.4	70.2	69.6

Table 4 Measured and simulated noise levels and traffic intensity counted at location 2

5 Conclusion

The comparison of results obtained from simulations to the results of actual field measurements has lead to the following conclusions: the comparison shows much better agreement of results obtained for location 2 for all investigated calculation methods. The possible explanation for these findings is that the residential object at this location is located in close proximity to the noise source. As a consequence, the noise levels emitted by traffic are dominant and mask all other noise sources that might contribute to overall noise level. On the other hand, the object under test at location 1 is located relatively far away from the noise source. In addition, the traffic intensity at this location is much lower. As a result, the noise levels measured on this location are lower than the ones obtained at location 2. Therefore, a certain degree of uncertainty is expected for the results obtained from field measurements at this location due to possible influence of other noise sources, e.g. birds, horses, etc. Furthermore, the deviation between the simulated and measured results tends to grow depending on the time of the day. The reason for this phenomenon could be a significant change of meteorological conditions during the investigated time period, ranging from temperatures of +1 °C and high humidity caused by fog in the morning to the temperature of +11 °C and a much lower humidity in the afternoon caused by breaking the fog.

Due to the reasons stated above, the decision has been made that the results obtained for location 2 should be used for a valid examination. The direct comparison of measurement and simulation results reveals that the RLS90 method yields results that are in best agreement with the results obtained from field measurements at this particular location. However, it should be noted that all three investigated methods yield results that do not deviate from measured values at this location by more than 2.5 decibels, as shown in Table 4.

References

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