MODELIRANJE KARTE BUKE ZA POSLOVNU ZONU "BUKVA-VILA" U TEŠNJU

NOISE MAP MODELING FOR THE BUKVA-VILA BUSINESS ZONE IN TEŠANJ

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REZIME

Poslovna zona „Bukva-Vila" predstavlja prostor za odvijanje različitih poslovnih aktivnosti i nastala je kao rezultat preliminarnog prostornog planiranja i organizovanog razvojnog koncepta privređivanja poduzetnog lokalnog stanovništva, na jedinstvenom području sa razvijenom infrastrukturom i blizinom užeg centra grada Tešnja. Sa razvojem Zone dolazi i do povećanja nivoa buke na ovom području. Ovaj rad predstavlja izradu karte industrijske buke korištenjem podataka dosadašnjeg nadgledanja preduzeća u cilju određivanja utjecaja industrijske buke na ukupnu buku u okolišu, kao i izradu konfliktne karte buke korištenjem rezultata vlastitih mjerenja.

Professional paper

SUMMARY

The Bukva-Vila Business Zone is a place for various business activities and it was created as a result of preliminary spatial planning and organized development concept of the enterprising local population, in a unique area with developed infrastructure and proximity to the center of Tešanj. The development of the Zone caused the increase of the noise levels in this area. This paper presents the development of industrial noise map using data from previous monitoring of companies to determine the impact of an industrial noise on total environmental noise, and as well as, the development of a conflict noise map using results of own measurements.

1. INTRODUCTION

Noise is a big problem in today's urban environment and everyday life. Although it is an indispensable part of life, if it is not moderate in its intensity. It significantly impairs human health, what reflects in increased stress levels, blood pressure, hypertension, sleep disorders, etc. According to the Directive on the identification and management of environmental noise 2002/49/EC, environmental noise is considered to be unwanted or harmful to human health and environment sound outside caused by human activity, including noise emitted by: road, rail and air traffic and noise from areas with industrial activities [1]. Inadequate spatial planning can lead to increased noise levels in residential areas. Spatial planning in this case should be based on the calculations, projection, measurement and modelling of noise parameters in the environment. For this reason, noise maps are made as a graphical representation of existing or projected noise levels in the observed area. The most common data that a noise map can contain are values exceeding the allowed limits, the estimated number of inhabitants and buildings, exposed to certain noise levels in the observed area [2]. The problem of environmental noise and the development of noise maps in the Federation of Bosnia and Herzegovina (FBiH) is not given due attention, since the only noise map was made for a part of the City of Sarajevo (by DvokutPro). When it comes to noise measurements, some companies within the framework of their environmental monitoring, according to the environmental permission, perform measurements. Without noise mapping, it is not possible to solve the negative impact of noise, nor to reduce the risk to the health of the population. Bearing in mind all the complexity and a scarce level of noise map modelling, the desire emerged to invest its own contribution to make a noise map of one of

developed business zones in FBIH, i.e., Bukva-Vila. Therefore, the priority goals of this paper are to develop industrial noise maps, using existing data from companies' noise monitoring, to develop conflict noise maps, i.e., maps showing values that exceed the legal permissible ones, and to propose noise protection measures for future action plans.

2. SPATIAL CHARACTERISTICS OF THE BUSINESS ZONE

Like many municipalities, the Municipality of Tešanj has organized its economic life through business zones. The business zone is a space for various business activities that emerged as a result of an organized and well-designed development concept, characterized by a common infrastructure and proximity to economic entities [3].

Three business zones have been established in the Municipality of Tešanj [3]. They are:

- Bukva - Vila,
- Ciglana-Glinište and
- Ekonomija.

Due to its economic importance, Bukva-Vila seems very important and interesting to study the noise levels in it and to make its noise map. Bukva-Vila is one of the three business zones in the Municipality of Tešanj and it consists of Bukva, Logobare and Novo Selo, along the local road Tešanj - Tešanjka, with the starting point at Toplana and the endpoint located in the Dubalj road, as shown in Figure 1. This business zone covers a total area of 59,5 ha. Considering the residential areas that make up this business zone, the total population in Bukva, Logobare and Novo Selo is approximately 2300. The construction of small and medium enterprises is planned in a comprehensive area, so the entire Plan would be homogenized. Although, according to the Plan, the Business Zone does not include residential areas of Bukva, Logobare and Novo Selo, households are in its immediate vicinity. The only inhabited area in this location is the refugees' settlement Vila, which is preparing to be removed to some other place [3]. In the area of Bukva-Vila, 38 business entities have been established, out of which 17 (45%) produce various types of goods. Given the impact of industry on noise levels, it is considered important to address it in the paper.

Figure 1. *Location of the* Bukva-Vila *Business Zone* [3]

3. NOISE MAPPING FRAMEWORK

3.1 Legislation

In the Federation of Bosnia and Herzegovina and Zenica-Doboj Canton (ZDC), to which the area of this Business Zone belongs, the issue of noise is regulated by the Law on Noise Protection (Official Gazette of the Federation of B&H No. 110/12) and the Law on Protection from Noise (Official Gazette of ZDC No. 1/14). Also, there is the Law on Environmental Protection that regulates the limit values of noise depending on the purpose of the location, surrounding area, time of day, noise protection measures, method of measuring and recording noise in order to protect human health, protection of working and living space and the environment in general [4].

According to this Law, the day lasts from 06:00 a.m. to 10:00 p.m., and the night from 10:00 p.m. to 06:00 a.m. [4]. Table 1 shows the permissible noise levels of the parameters Leq and L_1 for the selected purpose of this area. Also, according to the Law, federal, cantonal, city and municipal bodies, responsible for spatial planning, are obliged to produce noise maps, and an initial noise map should have been made within 3 years from the entry into force of this Law, but it was not done.

Table 1 Allowed noise levels in the zone VI [4]

Area (zone)	AREA PURPOSE	Equivalent noise level (Leq)		Peak level
		day	night	L_1
VI	Industrial, cargo, service and traffic area without residential area	70	70	85

3.2 Selection of measuring points and measuring noise

Noise measurement is an activity without which noise protection cannot be planned, as well as the formation of a base in relation to which noise will be judged. Also, the goal of the measurement is to collect data that will be used in making spatial planning. In order to see the impact of industrial noise on the total environmental noise, and to make a conflict map of noise, it was necessary to perform our own measurements. Noise measurement was performed in accordance with BAS ISO 17025:2005, using a Bruel & Kjaer type 2250 sound level meter, shown in Figure 2, with its basic components. A sound level meter is an instrument designed to measure noise levels in a standardized way [5]. Since the observed business zone is a large area, 28 measuring points were selected near industrial plants and on the border between the business zone and residential areas, and the measurement was performed for a period of day and night. Graphical representation of measuring points is shown in Figure 3 (MM1-MM14) and Figure 4 (MM15-MM28).

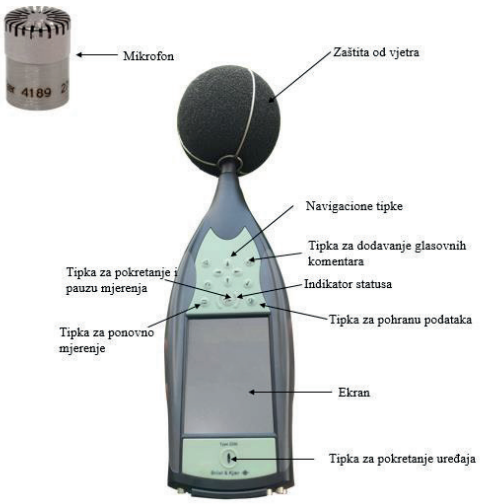

Figure 2 *Sound level meter Bruel & Kjaer*

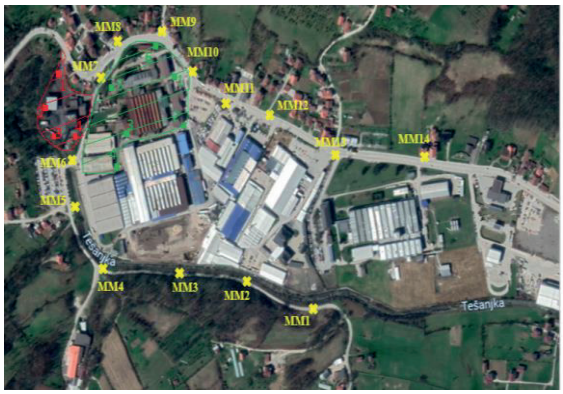

Figure 3 *Locations of measuring points MM1 - MM14*

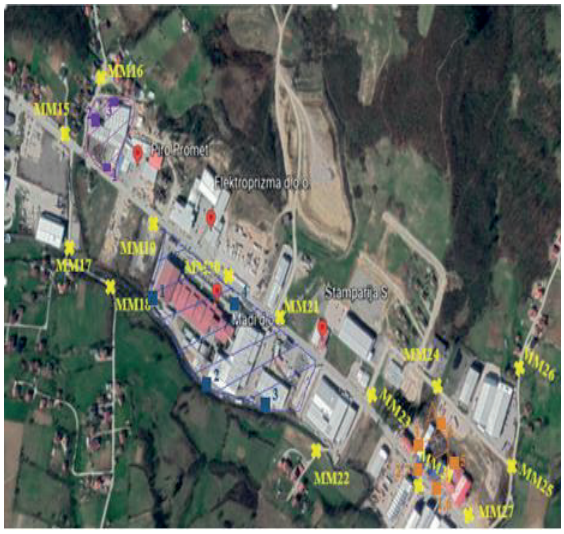

Figure 4 *Locations of measuring points MM15 - MM28*

During the measurement, the frequency of traffic (number of passengers and cargo vehicles) in the measuring interval of 15 minutes was recorded to gain a better insight into the character and dynamics of some measurements, i.e., results.

3.3 Creating industrial noise maps using iNoise

Business entities in the area of Bukva-Vila, in accordance with the Monitoring Plan, were

issued in environmental permits to perform noise monitoring as an integral part of environmental monitoring. For the need of this paper, data on previous monitoring were collected for five (5) industrial plants: JP[1] Toplana d.d.[2], JP Pobjeda d.d., Saračević d.o.o.[3], MADI d.o.o. and Eko-servis d.o.o. Modeling of the industrial noise map was performed using the iNoise program. The iNoise software version V2021.1 Free is free software for acoustic modeling of industrial noise in the environment, according to the ISO 9614 method and the recommendations of the ISO 17534 quality standard [6]. The reason for choosing this software is the ability to create a map, if the sound power of the noise source is not known, but measured at a known distance from the source.

3.3.1 Georeferencing

In iNoise software, an image from Google Earth can easily be georeferenced to a model, using the option *View* → *Background Map* → *Calibrate*. To calibrate the map, as shown in Figure 5, the *Scale only* option was used, which requires knowing the distance between two selected points that have already been measured in Google Earth Pro.

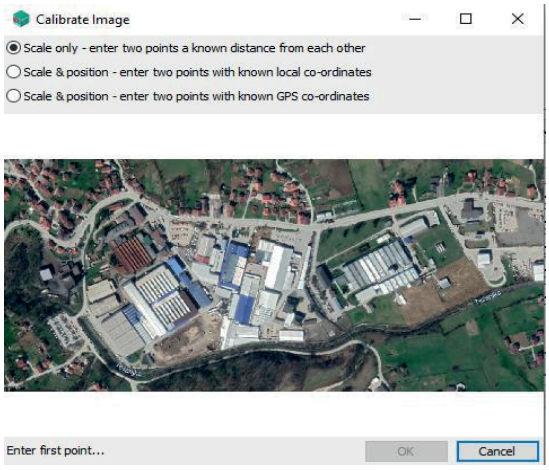

Figure 5 *Georeferencing of map into model*

3.3.2 Defining the network, buildings, vegetation and residential buildings

After georeferencing the map, it is necessary to set up a grid to calculate the model itself. The grid is drawn to cover the entire surface of the map with a distance between the grid points of 10 m along the x and y axes, as seen in Figure 6.

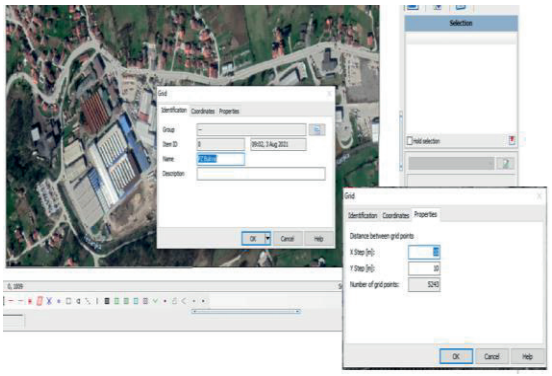

Figure 6 *Setting up the model grid*

In addition to the model network, it is necessary to set other layers of the model, such as buildings, vegetation layer and residential areas. Each of the layers in order to be complete and to be able to perform the calculation of the model needs to have a height and not to intersect with each other. The appearance of the map model after this step can be seen in Figure 7.

Figure 7 *Map view with layers*

3.3.3 Data entry of previous monitoring in industrial plants

Data from previous monitoring in industrial plants were entered using the *Source Explorer* option, which was a demo for the unlicensed free version of this software. Using this option, it is not necessary to know the data on the noise source, but the noise level with a known distance from the source. When entering data, the *Sound power calculation* option, using ISO 8297, was selected, because the number of noise sources within one plant is not known. According to this standard for determining the sound power, as can be seen in Figure 8, it is necessary to enter the basic parameters of noise level measurement such as temperature, wind speed, wind direction, relative humidity,

[1] JP stands for *public enterprise (PE)*
[2] d.d. stands for *joint stock company (JSCo)*
[3] d.o.o. stands for *limited liability company (LLC)*

measurement height, noise source height, measuring area and distance from the source. Because most noise measurements, according to previous monitoring of business entities, are said to be measured near the noise source, it was adopted that the distance is 3 m, due to the rule that a measuring point must be 3 m away from reflective surfaces, the area of the nearby object must be considered, because it is assumed that noise is coming from that object, and also, it is assumed that all noise sources are point sources. To compare the results of modeling the map in iNoise and own measurements near the plant, receivers were put at the places where noise measurements were performed.

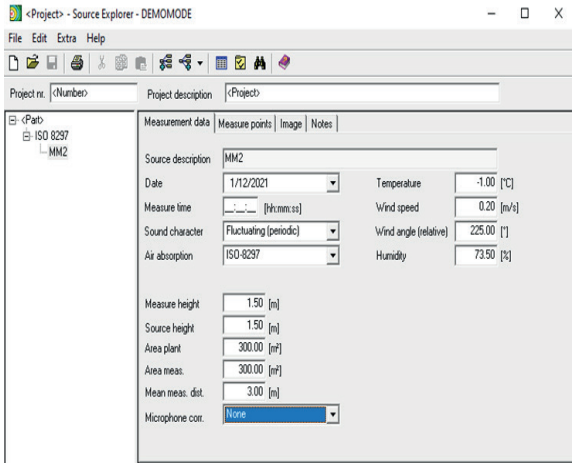

***Figure** 7 Display of measurement data entry for MM2 - JP Toplana in the Source Explorer option*

4. RESULTS AND ANALYSIS OF RESULTS

4.1 Measurement results

Measurement of noise levels in the area of the business zone was performed in the period from July 26, 2021 to July 28, 2021. Table 2 shows the meteorological conditions read from the AccuWeather application and all the data provided are consistent with the values that make the measurement credible [7]. The differences between the measurement results of the obtained noise level values for the stated locations measured using the Bruel & Kjaer noise meter and the limit values are shown in Table 2 for day measurements and in Table 3 for night measurements. The tables show the equivalent noise values, maximum and minimum values, as well as the values of L1, L10 and L90 noise. As can be seen from the Table 3 at five measuring points, namely MM10, MM11, MM14, MM15 and MM27, the equivalent noise level (Leq) exceeds the legally allowed values for the business zone of 70 dB in the interval of exceeding 0,7 dB up to 2,2 dB. The reason exceeding the allowed values for these places is the higher frequency of traffic, as well as the business activities of the companies located near the specified measuring points. Table 4 shows that only at one measuring point the measured value of Leq exceeds the limit value, since most companies do not perform business activity during the night. The measured value of Leq at measuring point MM27 exceeds the allowed value by 0,7 dB due to the speed of vehicles on this road, as well as the higher frequency of cargo vehicles. The value of parameter L_1 does not exceed the limit value for the selected area purpose.

Table 2 Meteorological conditions during noise measurements

Parameter	26.7.2021.		27.7.2021.		28.7. 2021
	Day	Night	Day	Night	Night
Temperature ^{0}C	32	29	30	25	20
Wind direction	SSE	SSE	SSE	S	S
Wind speed, m/s	3	3	1	1	2
Precipitation	Ne	Ne	Ne	Ne	Ne
Relative humidity, %	52	71	38	65	71
Atmospheric pressure	1015	1015	1018	1016	1016

Table 3 Noise measurement results by sound level meter - day period

Label	Measurement interval	Traffic frequency		Measured values [dB]					
		Pass. veh.	Cargo veh.	LA_{eq}	L_1	LA_{max}	LA_{min}	LA_{90}	LA_{10}
MM1	7:41-7:56	4	0	49,9	62,8	70,9	42,3	50,2	55,2
MM2	8:01-8:16	6	0	55,4	68,1	74,9	48,7	57,6	61,2
MM3	8:18-8:33	2	0	67,5	69,9	89,6	66,3	66,9	67,7
MM4	8:38-8:53	11	0	54,5	67,9	72,9	45,3	47,8	54,2
MM5	8:57-9:12	7	1	59,2	65,7	76,1	56,4	57,7	59,5
MM6	9:15-9:30	8	5	59,2	68,7	78,7	52,4	55,1	60,5
MM7	9:36-9:51	94	7	60,2	70,8	75,6	55,4	57,2	60,4
MM8	9:54-10:10	161	10	67,1	76,3	82,6	51,3	54,7	71,1
MM9	10:13-10:28	168	4	66,2	74,3	81,6	45,0	52,4	70,2
MM10	10:30-10:45	201	12	**71,9**	82,2	88,4	44,1	50,1	75,9
MM11	12:50-13:05	183	7	**71,1**	80,7	87,7	46,4	55,8	75,0
MM12	10:50-11:05	172	5	62,5	71,2	78,4	49,2	52,7	66,4
MM13	11:09-11:24	188	8	62,5	71,4	79,9	51,6	54,9	65,3
MM14	11:34-11:49	239	16	**71,8**	81,4	92,9	52,3	59,6	75,2
MM15	11:15-12:11	177	8	**72,2**	82,0	88,2	53,2	59,5	76,2
MM16	17:53-18:08	9	0	62,0	70,2	75,1	59,1	60,2	62,4
MM17	18:12-18:27	6	1	53,6	66,0	75,6	38,8	41,6	52,7
MM18	18:31-18:47	2	0	51,1	60,9	78,1	42,7	45,8	51,3
MM19	18:54-19:09	138	4	69,8	79,7	86,8	40,3	51,9	74,2
MM20	19:13-19:28	131	0	67,8	76,9	81	47,8	53,8	72,2
MM21	19:31-19:46	99	0	69,7	80,3	84,2	46,5	51,5	74,1
MM22	19:52-20:07	5	0	53,8	66,4	76,1	41,0	43,9	55,4
MM23	12:13-12:28	118	8	67,0	76,1	86,2	46,0	52,9	71,2
MM24	20:10-20:25	2	0	49,2	60,4	74,7	31,4	35,6	49,4
MM25	20:29-20:44	1	0	45,4	53,2	68,6	38,3	41,4	45,8
MM26	20:46-21:01	0	0	66,0	69,3	72,1	54,1	64.7	67,1
MM27	21:06-21:21	82	2	**70,7**	79,8	96,2	44,2	51,7	72,6
MM28	11:53-12:08	121	12	66,2	75,3	81,6	44,4	52,6	69,1

Table 4 Noise measurement results by sound level meter - night period

Label	Measurement interval	Traffic frequency		Measured values [dB]					
		Pass. veh.	Cargo veh.	LA_{eq}	L_1	LA_{max}	LA_{min}	LA_{90}	LA_{10}
MM1	5:26-5:41	0	0	44,1	51,5	71,6	40,3	41,3	44,1
MM2	5:07-5:22	1	0	64,3	66,7	74,5	62,8	63,8	64,7
MM3	4:51-5:06	0	0	59,5	61,1	64,7	57,4	58,6	60,4
MM4	4:33-4:48	0	0	45,7	51,0	60,4	41,7	43,8	46,9
MM5	4:16-4:31	3	0	60,8	64,1	76,7	56,5	59,6	61,5
MM6	3:59-4:14	2	0	52,5	61,8	73,3	46,8	48,4	51,9
MM7	3:40-3:55	11	1	50,1	56,5	70,5	46	47,2	50,7
MM8	3:23-3:38	8	0	59,8	72,1	86,1	42,5	46,8	53,2
MM9	3:06-3:21	12	0	54,2	66,2	73,1	38,5	40,4	57,0
MM10	4:15-4:30	21	1	64,1	77,6	84,6	46,0	47,5	63,8
MM11	4:32-4:47	15	0	60,9	73,8	86,2	43,8	45,0	58,7
MM12	4:49-5:04	12	1	57,1	68,7	76,5	48,0	51,9	56,4
MM13	5:06-5:21	10	1	56,7	70,0	75,7	44,9	46,0	56,0
MM14	5:24-5:39	24	2	65,0	77,9	84,6	50,3	51,4	66,9
MM15	23:28-23:43	31	1	64,0	77,6	81,4	42,1	44,7	66,1
MM16	23:12-23:26	72	3	62,4	75,1	82,3	47,5	48,7	64,3
MM17	22:52-23:07	10	0	60,0	70,8	89,6	45,8	50,2	56,8
MM18	3:44-3:59	2	0	51,1	60,9	78,1	42,7	45,8	51,3
MM19	22:32-22:47	76	3	68,7	79,9	84,2	44,2	52,1	72,6
MM20	22:16-22:31	70	5	67,7	78,3	85,4	50,9	71,5	53,6
MM21	22:00-22:15	55	2	68,3	80,3	86,7	49,2	51,6	71,9
MM22	22:00-22:15	5	0	53,8	66,4	76,1	41,0	43,9	55,4
MM23	22:18-22:33	70	1	68.7	79,7	86,5	47,0	53,4	72,7
MM24	22:35-22:50	2	0	49,2	72,3	74,7	31,3	35,6	49,4
MM25	22:54-23:09	1	0	45,4	65,1	68,4	38,3	41,4	45,8
MM26	23:10-23:25	0	0	66,0	71,6	72,1	54,1	64.7	67,1
MM27	23:31-23:46	74	2	**70,7**	83,0	96,2	44,2	51.7	72,6
MM28	23:50-00:05	56	1	64,2	74,8	83,7	35,7	42.9	68,4

4.2. Results of industrial noise maps

As can be seen from the industrial noise maps of the Bukva-Vila Business Zone, shown in Figures 8 and 9, noise levels higher than the legal limit levels are near the noise source, i.e., the plant (marked in purple), while at the measurement sites of the previous monitoring data, the noise level does not exceed the limit values. Also, by comparing the results of own measurements, using a noise meter, and the results of noise levels, using the software at measuring points MM6, MM7, MM8, MM9, MM10, MM11, MM15, MM16, MM18, MM19, MM20, MM21, MM24 and MM28, it can be seen that the average part of industrial noise in the total environmental noise is approximately 67,7 %. The smallest difference between the results of own measurements and model results is at MM6 and MM24, as seen in Figure 10, because these places have the lowest traffic frequency and no other significant noise sources. The biggest deviation is at measuring point MM15, due to the increase in traffic frequency and higher driving speed on this part of the road.

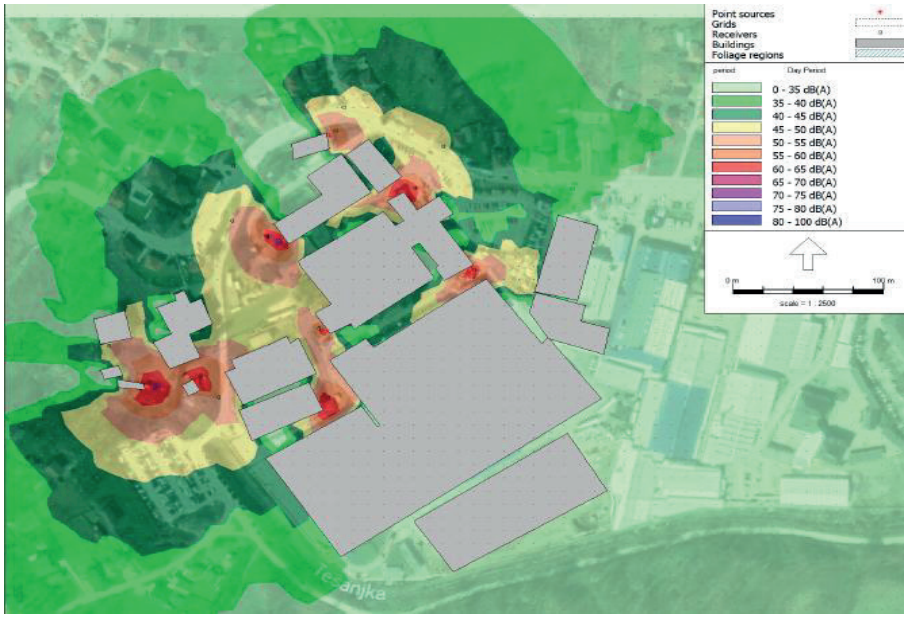

Figure 8 *Industrial noise maps for PE Toplana and PE Pobjeda, iNoise*

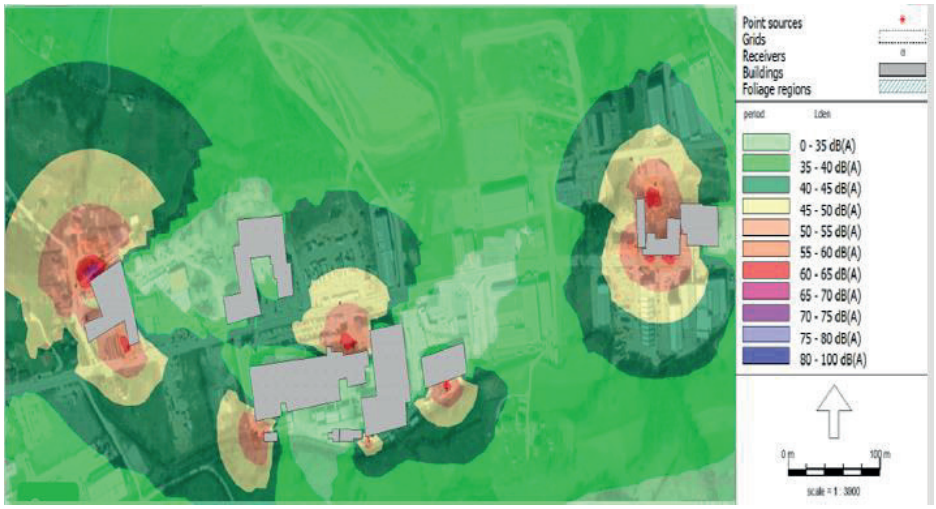

Figure 9 *Industrial noise maps for Saračević, MADI and Eko-servis, iNoise*

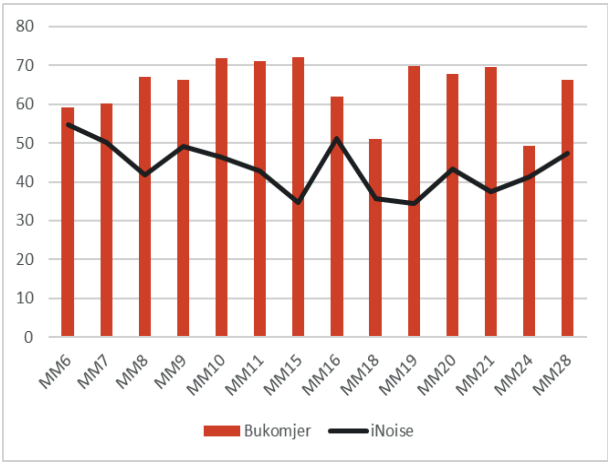

Figure 10 *The difference between the results of the measurement by sound level meter and the results obtained by calculation in iNoise*

5. CONFLICT NOISE MAPS

Although the area of the Bukva-Vila Business Zone is not intended for the existence of residential parts, it is in the immediate vicinity of populated areas, i.e., they are divided only by the road that passes through this Zone. If this statement were taken into consideration, then the area to which this Zone belongs, according to the Law on Noise Protection, is the combined industrial, storage, service and traffic area in a residential area with allowed value Leq during the day of 65 dB and during the night of 55 dB and the limit value L1 of 80 dB []. For this reason, it was necessary to make conflict noise maps (shown in Figures 11 and 12) in relation to the allowed values of Leq for the purpose of the area. For the period of the day (6 a.m. - 10 p.m.), it can be noticed that the noise is at the highest, more precisely, 6 measuring points above the allowed noise level, in the interval up to 3 dB on certain sections of the road, and at locations SM3 branch located in Bukva-Vila, while at three measuring points it exceeds the limit value in the interval of 6 to 9 dB. Places where the noise level has exceeded the allowed noise level in the interval 6-9 dB are places near the road and companies Pobjeda, MANN + HUMMEL BA, ENKER and Saračević.

Observing the conflict map of noise for the night period, much larger exceedances of the allowed values of Leq can be noticed. During this period, there are exceedances of more than 15 dB marked on the border of the Business Zone, i.e., at the beginning of the road of Dubalj. Although the conflict noise maps were made according to the Leq parameter, it is important to mention the second legal parameter L_1. The limit value of this parameter was exceeded during the day at few measuring points and the reason for exceeding the L_1 value was fast driving near the measuring points.

Figure 11 *Conflict noise map for the Bukva-Vila Business Zone - day*

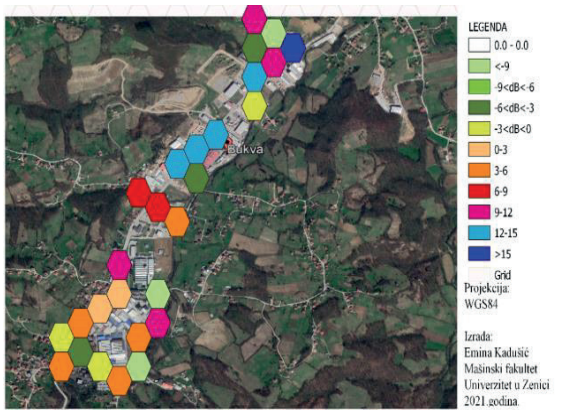

Figure 12 *Conflict noise map for the Bukva-Vila Business Zone - night*

During the day, the largest percentage of 51,6% of the population is exposed to the noise above the limit values, i.e., in the interval of 65 to 68 dB, while during the night, the largest number of the population of 30,6% is exposed to noise in the interval of 68 to 71 dB. Looking at the entire population in the settlements that make up the Zone, it can be concluded that 5% of the population is exposed to noise above 60 dB during the day, while at night 17% of the population is exposed to noise above 55 dB.

6. CONCLUSION

Business zones, as one of the important organizational and spatial segments of economic development, with their construction and expansion, mainly negatively impact all components of the environment. Certainly, one of such environmental impacts is noise, its emission, occurrence and accumulation in the zone itself and its immediate surroundings. In the specific case of this paper, Bukva-Vila and the impact of its noise sources on the Business Zone and the immediate environment were investigated through previous monitoring, own measurements and modeling of noise maps in real circumstances. Comparing the results of sound level meter measurements in the Business Zone with the allowed limit values for the Leq parameter, which for the purpose of this area is 70 dB and for the period of day and night, it can be seen that during the day (from 6 a.m. to 10 p.m.) at measuring points MM10, MM11, MM14, MM15, MM27 the statutory values are exceeded by an average of 1.5 dB. During the night, only at one measuring point the noise level exceeded the limit value, i.e., at MM27 by 0.7 dB. The noise values for parameter L_1 did not exceed the limit values at any measuring point, which are 85 dB for the purpose of this Zone.

Industrial noise maps created in the iNoise program show the spread of noise from industrial plants in this Zone and its impact on the overall noise in the environment. Comparing the results of own measurements, obtained by using noise meters, and the results of noise levels, obtained by using software, at the same measuring points, it was found that the average share of industrial noise in total environmental noise is approximately 67.7%, and that industrial noise had the greatest impact on MM6, MM7 and MM24, since no significant other noise sources were at these measuring points.

Based on the conflict noise maps, it was concluded that 5% of the population living in areas covered by the Business Zone is daily exposed to noise above 60 dB, while at night 13% of this population is exposed to noise above 55 dB.

The results of noise measurement and noise mapping in iNoise and QGIS can be an excellent starting point for developing a new or reprogramming the existing spatial plan of this area of the Municipality of Tešanj and possibly further research, to more advanced software development of road models, distribution of population, meteorological conditions during the year, development of mandatory and unique noise maps of this and all other areas of importance, which is ultimately a legal obligation and what is expected from the responsible community in the near future.

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