DETERMINATION OF AIRCRAFT MODEL USING A NOISE MEASURING SYSTEM

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ABSTRACT

The development of turbo-jet engines resulted in the construction of larger, safer and faster aircraft. High power of the turbo-jet engine contributes to the increase of noise level and, in general, to the increase in the number of aircraft which produce noise. Noise created by aircraft on the ground refers to take-off, landing and taxing on the ground. The maximum influence of noise is in the area close to airports and under the landing and take-off flight paths. Investigations of noise produced by aircraft began in the late fifties of the last century in order to explore the characteristics of noise sources, environmental impact on its spread and the subjective human perception of noise. Defining noise levels must be done by noise measuring systems, which is specified for that kind of aircraft noise. Noise measurements must include all the elements influencing on the formation and expansion in air traffic noise.

The measurement and research conducted at Zagreb Airport and area around it, except information about the negative impact of noise on the surrounding population, showed that by measuring noise, and visualizing the frequency spectrum of noise, it can be possible to determine the model of aircraft. Furthermore, it is shown that by using the frequency spectrum it is possible (with further research) to make an insight into the potential failure of an approaching aircraft. The result can be manifested in increasing of further air traffic safety, reducing maintenance costs and longer exploitation of an aircraft.

Keywords: aircraft noise, noise frequency, airport, “frequency signature”

1 INTRODUCTION

Today, when the great attention is directed to environmental protection and ecology, one of the most negative elements in the environment, as well as in traffic, is noise. With the increasing number of flights and in accordance with the expansion of airports, air traffic is becoming a serious problem of the present times. Air transport is the youngest branch of transport, which began to develop rapidly in the fifties of the last century, and the introduction of turbo-jet engines is responsible for its rapid growth. The implementation of such engines in aviation resulted in the construction of larger, safer and faster aircrafts. A negative side effect of the high efficiency and power of turbo-jet engines is noise. Sudden increase in air traffic contributed to frequency of noise, which made it unbearable. These engines generate vortex and larger quantities of exhaust gases at high speeds. On segmentation where a supersonic aircraft starts to operate the result is an additional noise known like sonic boom, which is created due to the impact waves produced during take-off and landing. Today, air traffic is constantly growing and the number of produced aircraft in the world is growing fast due to entrance of low-cost airlines into the market. In this rapid traffic increase the aircraft noise presents a serious problem, which does not affect only the comfort and efficiency of a relatively small number of people in the aircraft, but also the population living close to the airports.

Due to constant expansion of the cities and inhabiting areas around the airports, there are more complaints regarding the impossibility of living in these regions. These complaints refer to disturbances, insomnia, and impossibilities of communications. Negative impact of aircraft noise depends on a number of factors: sound magnitude and duration, direction of movement during take-off and landing, number and type of operations, operation procedures, usage of the runway systems, time of day and meteorological conditions.

The prevention methods due to negative aircraft noise impacts on the population are the construction of facilities equipped with high-quality noise isolation and the distance of the constructed facilities from the airport. With the development of technology, the new generation of aircraft is much quieter than the previous ones, and the noise at airports has been significantly reduced.

2 AIRCRAFT NOISE SOURCES

Noise from aircraft can be defined as an unwanted sound produced by aircraft. Noise at the vicinity of the airport comes from the various air operations and other modes of transport transport. At the airport there are two sources of “airport” noise: the noise created by flight operations and the noise resulting from operations on the land. The noise generated by aircraft is observed quite differently from other contaminants and can be divided it to three parts. The first part of aircraft noise is produced by the propulsion of aircraft, second is a mutual influence between the engine and aircraft structure, and the third is a structure (shape) of the aircraft.

Figure 1: Noise sources on aircraft

Depending on the type of operations, aircraft noise can be divided on the noise that occurs at the phase of take-off or landing, and the noise on the ground during maintenance and testing of engines. From the figure 2 it is evident that the main sources of aircraft noise at take-off are coming from the fan exhaust, and jet exhaust, while during approach most of the noise are generating by fan inlet, turbine and airframe. The second generator of noise in aircraft noise structure is produced by aircraft structure and is defined as an unwanted sound that occurs when air flows along the airfoil. The main parts of the airfoil that generate noise are landing gear, elevators, flaps, moveable surfaces on the wing and the vertical stabilizer. Noise caused by the aircraft structure is the result of pulsing aerodynamic forces on the wing, the existence of turbulent boundary layers and vortexes that appears in the flow area of wings, fuselage and tail surfaces and landing due to the currents around stopping surfaces, flaps and various protrusions on the fuselage. The noise produced by the flap comes from the external edges of the flaps and their lateral edges. Furthermore, the new generator of noise is appearance of vortexes, which is the result of airflow between open and closed flaps. A strong vortex is formed by sharp transitions in the take-off between the raised and lowered flaps which becomes the main cause of noise that occurs at the ends of the wings. Near-edge flaps split air creating turbulence and resistance to flow of air creates additional noise. At take-off, the noise level from power plants is the main source while during approach or landing phases the main noise generator is aircraft structure (airframe).

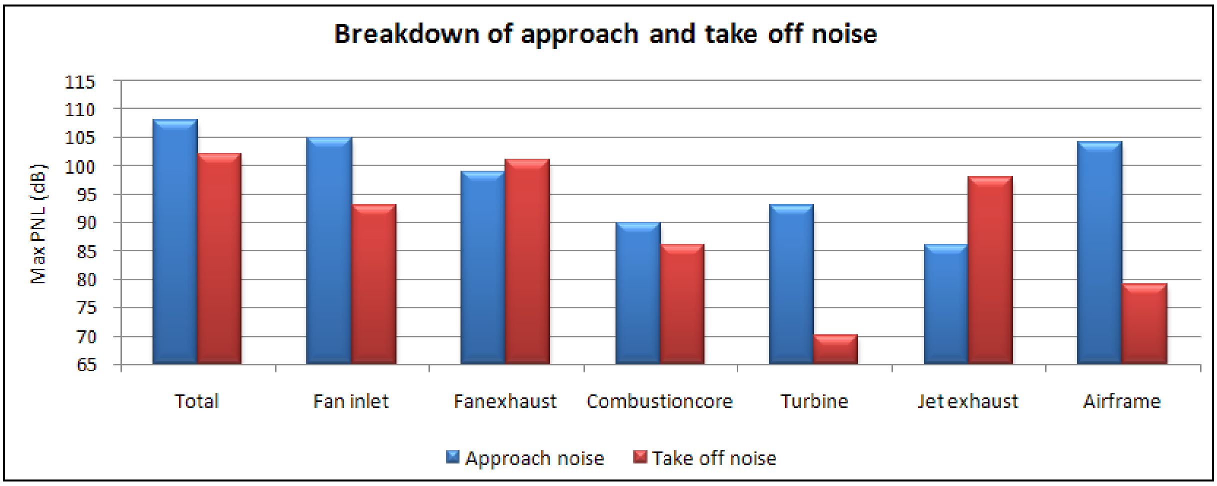


Figure 2: A breakdown of the noise components of a typical engine with 1992 level technology during takeoff and approach [9]

3 NOISE MEASUREMENT AT ZAGREB AIRPORT

Zagreb Airport started with planning of implementation of a system for measuring aircraft noise. There are two main objectives of setting a system for monitoring aircraft noise at the Zagreb Airport. The first objective is to determine the actual noise levels around the airport and to see how it affects to the population living close to the airport. The second goal is related to the candidacy of Croatia in the European Union, where it is required that all main airports adapt EU regulations associated with monitoring noise from aircraft. Yearly noise mapping and continuous monitoring of noise are parts of those regulations. In response to these conditions, the equipment for aircraft noise monitoring from Brüel & Kjaer has been placed at Zagreb Airport.

The system installed at the Zagreb Airport consists of three fixed noise monitoring terminals (NMT) and one mobile terminal, which are optimized to work outdoor in all weather conditions. The location that was chosen for fixed noise monitoring terminals at Zagreb Airport is in the area of the airport because of all necessary infrastructure which is needed for their work. Another reason, which is very important, is that this area is most exposed to aircraft noise because of its closeness to the runway threshold. On that position noise can be measured without any obstruction for the microphone. According to this, two noise monitoring terminals (NMT1 and NMT2) were placed near the runway threshold 05 - 23 as it is shown in Figure 3. Monitoring terminal NMT1 (Noise Monitoring Terminal 1) is located 366 meters laterally from the threshold 05, while NMT2 is placed 330 meters laterally from the runway threshold 23.

The third noise monitoring terminal NMT3 is also fixed terminal and is located on the side wall of the ATC tower, while the microphone is physically transferred to the edge of the building and is connected to the database via a cable. The fourth NMT4 terminal is a mobile terminal and has no fixed position, but its location is determined depending on the need to collect data from multiple positions. The terminal is currently located in the village Donja Lomnica with the role of continuous monitoring of noise levels in the village (Figure 3).

Figure 3: Positioning of Noise Monitoring Terminal at Zagreb Airport

4 DETERMINING THE AIRCRAFT TYPE AND ITS FLIGHT LEVEL USING GENERATING NOISE

At this point, regarding the implementation stage, the system for noise monitoring is not connected directly to the radar system. According to that, for determining the aircraft type and time of landing a combination of information system is used from Zagreb Airport FAIS (Flight and Airport Information System) with the synergy of the model developed at Environmental Noise Model software (ENM). With this correlation, the level of noise and frequency can be determined accurately giving as the result a model of an aircraft and time of over-flight over measurement terminals in approaching the airport. The reason for the application of this model is the detection of possible human error in defining the exact time of landing and take-off and to make corrections with written data. The problem appeared in detecting an aircraft and their pairing to the noise level at peak hours. Specifically, with regard to the "hand-entered" time of landing and take-off is not an automated system, there may be mistakes that delay the entry time of landing and take-off due to the amount of activities performed at that time on the apron. Such a mistake in typing down the wrong time at peak loads could cause a wrong association of noise and aircraft in landing, which is the real source of noise. An example for this is if the time of landing of larger aircraft Tupolev 154 randomly entered 2-3 minutes later than real time, and landing a small aircraft like Cessna Citation easily could be attributed to the higher noise levels produced by larger aircraft. The system for measuring noise is automated and works on the principle of starting the recording of events as soon as the noise level at the measuring terminals exceeds 45 dB. For this purpose, one could hardly correlate noise during recording and the actual time of landing aircraft. The only solution was to do manual correlation and correction of data with FAIS and ENM software. It can be seen in Figure 4.

For the solution to this problem, a model was developed to determine the type of aircraft, which was based on monitoring the noise model of an aircraft, which for this study followed the most common model of aircraft at Zagreb Airport, the Airbus A320.

S	Flt/No	Des	Via	STD	Ofb	ATD/E	PTD	Slot	Std	Type	Regist.	Rotation	TT	Remk	Dy	T	Gate	CI/Cntr	Li	LT
S	OU 416	FRA		0905	0908	0920			08	EA322	9ACTM	OU 381	11				16			
S	LH 3491	MUC		0910	0925	0933			07	DH83	DBACH	LH 3490	11				18			
S	TP 7989	MUC		0910	0925	0933			07	DH83	DBACH		80				18			
S	GDK01CB	OMO		0930	0928	0936			16	C560	OEGCB	GDK01CB	60		I	1				
S	8P 172	SJJ		0930	0943	0959			20	0410	9ABTC	8P 172	12		I					
S	OU 490	LHR		0935	0928	0937			04	EA322	9ACTJ	OU 631	11				13			
S	GAV 003	LCK		1005	1005	1013			G11	C210	N50DD	GAV 002	51		I					
S	GAV 002	RJK		1005	1005	1015			G46	PA18	9ADKH	GAV 005	54	SCH	I					
S	MA 471	BUD		1025	1023	1028			05	E120	HAFAI	MA 470	11			1	15	2,3		

Noise-Events-Standard

Time Start	Location Index	Location Description	Time Max	Time End	Grph Lev..	Level Leq [dB]	Level Max	Level SEL	Duration
1.4.2008 4:54:47	1	Trafo Station 3	1.4.2008 4:55:05	1.4.2008 4:55:57	System.Byte[]	50,8	53,2	69,2	
1.4.2008 4:56:33	2	Trafo Station 4	1.4.2008 4:56:55	1.4.2008 4:58:41	System.Byte[]	54,6	61,5	75,7	
1.4.2008 4:56:42	1	Trafo Station 3	1.4.2008 9:55:59	1.4.2008 10:38:25	System.Byte[]	83,4	117,4	126,6	
1.4.2008 4:59:51	2	Trafo Station 4	1.4.2008 5:10:40	1.4.2008 5:12:25	System.Byte[]	53,7	59,6	82,5	
1.4.2008 5:13:06	2	Trafo Station 4	1.4.2008 9:22:31	1.4.2008 9:29:56	System.Byte[]	66,8	91,5	108,7	
1.4.2008 9:31:45	2	Trafo Station 4	1.4.2008 9:31:50	1.4.2008 9:32:42	System.Byte[]	67,8	74,1	85,3	
1.4.2008 9:33:48	2	Trafo Station 4	1.4.2008 9:34:04	1.4.2008 9:34:12	System.Byte[]	72,4	76,3	86,0	
1.4.2008 9:36:12	2	Trafo Station 4	1.4.2008 9:36:27	1.4.2008 9:37:05	System.Byte[]	79,6	88,3	96,4	
1.4.2008 9:38:00	2	Trafo Station 4	1.4.2008 9:38:19	1.4.2008 9:38:41	System.Byte[]	82,6	90,6	98,3	
1.4.2008 9:46:04	2	Trafo Station 4	1.4.2008 9:46:17	1.4.2008 9:46:19	System.Byte[]	66,7	69,7	78,5	
1.4.2008 9:49:35	2	Trafo Station 4	1.4.2008 9:50:07	1.4.2008 9:50:48	System.Byte[]	69,0	77,7	87,3	
1.4.2008 9:56:13	2	Trafo Station 4	1.4.2008 9:56:33	1.4.2008 9:57:33	System.Byte[]	100,3	113,6	119,0	
1.4.2008 9:58:32	2	Trafo Station 4	1.4.2008 9:58:44	1.4.2008 9:58:57	System.Byte[]	68,8	74,5	82,7	

Figure 4: Correlation of data between FAIS and ENM software

The first step in creating this model was setting up the noise monitoring terminal in the village of Donja Lomnica, because 90% of the landing operations is conducted over that area. Given that the noise level charts were different, depending on the duration of the noise measuring over NMT, the aircraft speed and altitude, followed by an insight into the frequency level where the results obtained from the frequency observed for each aircraft landing, were almost identical. In order to make control models, there were created frequency charts on other types of aircraft. After making the measurement for aircraft Boeing 737 and Dash 8-400 it was concluded that each aircraft type has a specific frequency range ("signature"). From the 30 aircraft it was concluded that each aircraft generates a characteristic frequency and can be said that this frequency is his „signature“ in approach. Further research goes to the direction of following the amount of aircraft flying over noise monitoring terminal and try to determine level of their flight in relation to its ideal approach.

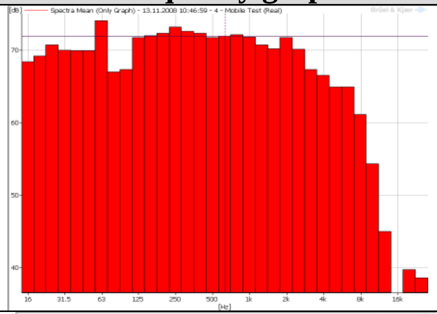
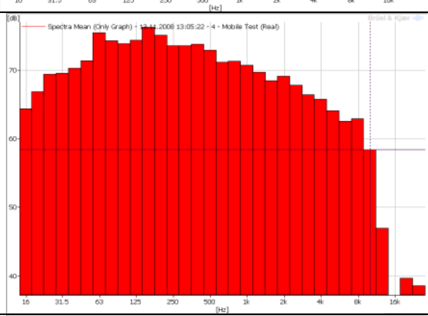
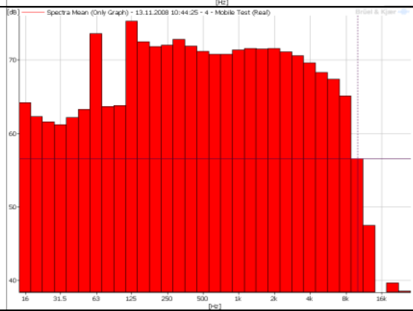
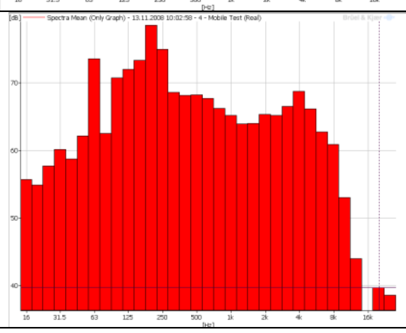
Type of aircraft	Visualization	Frequency graph
Airbus A320		
Boeing 737		
Dash 8-400		
EMB-120		

Figure 5: Frequency of airplanes Boeing 737, Dash8-400, ATR-42 andEMB-120 over the noise monitoring terminal NMT 4

Furthermore, what followed was checking of the level of flight in the approach procedure and to determine whether the approaching aircraft was flying lower than the ideal line of approach and whether there were differences in approach. For this purpose NMT 4 mobile terminal was used, which was situated in the village of Donja Lomnica. In order to determine the aircraft position accurately, it was necessary to measure the maximum noise level above the noise monitoring terminal in a position below the flight corridor over Donja Lomnica.

Aircraft land at Zagreb Airport using the angle of landing under 3° (ILS). Measurements for determining the position of an aircraft were carried out by observing one of the most frequent aircraft landings at Zagreb Airport, Airbus A320. The measuring sample was 22 aircraft in the approach to the airport. According to the information from the air traffic control and navigation charts, aircraft should be over NMT4 measuring terminal in Donja Lomnica at a height of approximately 670 ft (+/- 50). In order to establish the noise levels at the point of flight, the maximum noise level (L_{max}) from 22 aircraft flying above the measuring terminal 4 (Table 1) must be considered. The average value of the maximum noise level of 22 aircraft flying over noise monitoring terminal NMT4 at altitude 205 m (+ / - 15 m), i.e. 670 (+ / - 50) ft was L_{max} = 80.4 dB.

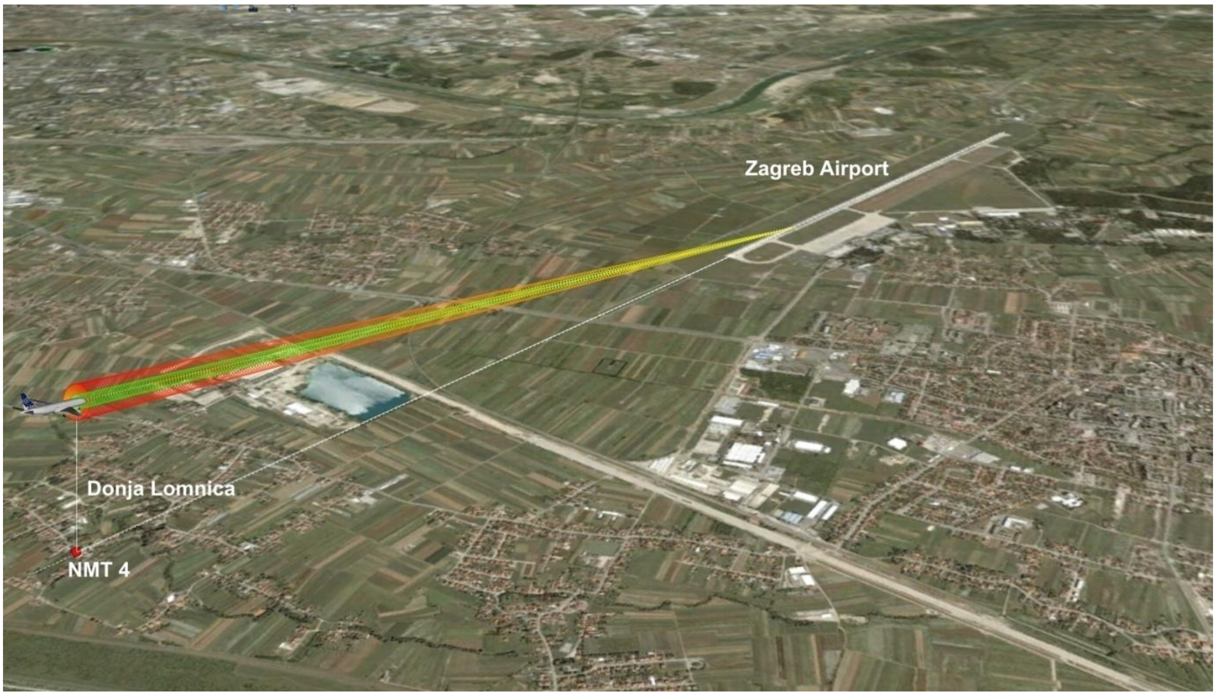


Figure 6: Location of aircraft in approach due to Noise monitoring terminal NMT 4

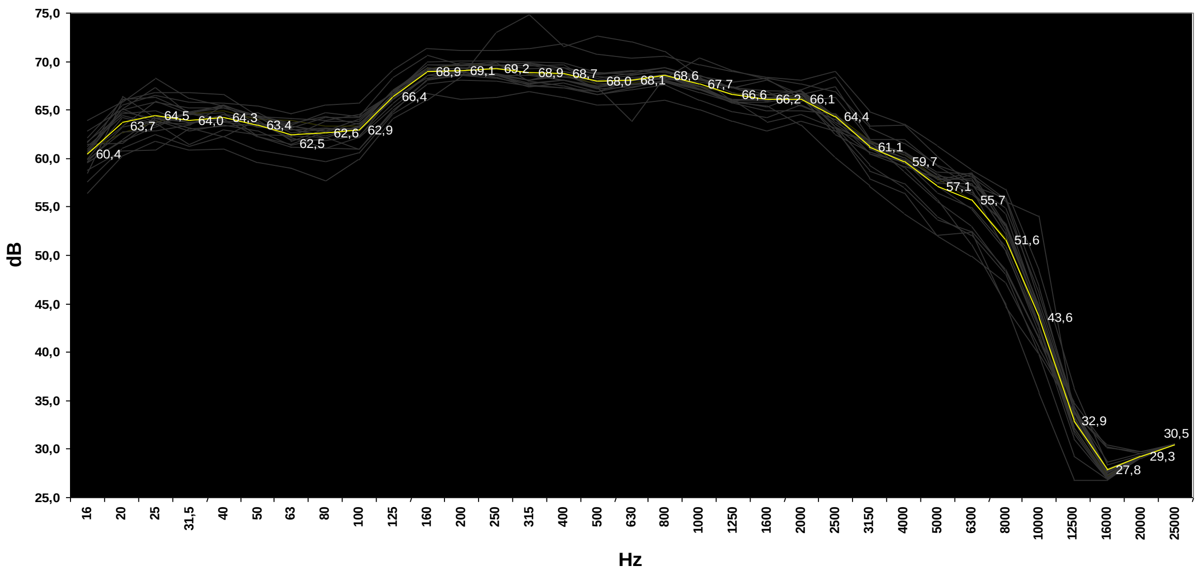


Figure 7: Average frequencies from 22 Airbus A320 at landing

According to this model, the position (the altitude) can be determined for each type of aircraft in relation to the maximum noise level at the time of over-flight above the noise monitoring terminal.

Table 1: Location of an aircraft in the air relative to its noise on the ground

		Aircraft altitude in relation of noise measured at NMT 4			
No.	**L_{max}**	**Altitude (m)**	**Feet (ft)**	**Position**	**Comments**
1	83,2	149,96	491,87	↓	VFR – confirmation from CroControl
2	79,9	219,27	719,21	○	Ideal approach
3	80,9	195,42	640,98	○	Ideal approach
4	79,9	219,27	719,21	○	Ideal approach
5	80,9	195,42	640,98	○	Ideal approach
6	79,7	224,37	735,93	↑	Aircraft is over the ideal approach line
7	80,1	214,27	702,81	○	Ideal approach
8	79,6	226,97	744,46	↑	Aircraft is over the ideal approach line
9	79,3	234,95	770,64	↑	Aircraft is over the ideal approach line
10	79,5	229,60	753,09	↑	Aircraft is over the ideal approach line
11	80,4	207,00	678,96	○	Ideal approach
12	80,5	204,63	671,19	○	Ideal approach
13	82,3	166,33	545,56	↓	VFR – confirmation from CroControl
14	79,5	229,60	753,09	↑	Aircraft is over the ideal approach line
15	81,1	190,97	626,38	○	Ideal approach
16	81,0	193,18	633,63	○	Ideal approach
17	81,0	193,18	633,63	○	Ideal approach
18	80,6	202,29	663,51	○	Ideal approach
19	80,7	199,97	655,90	○	Ideal approach
20	78,9	246,02	806,95	↑	Aircraft is over the ideal approach line
21	79,1	240,42	788,58	↑	Aircraft is over the ideal approach line
22	80,0	216,76	710,97	○	Ideal approach

Based on the measured data on a sample of 22 aircraft and the calculation of the maximum noise level on the ideal trajectory of 3° for aircraft Airbus A320 flying above the noise monitoring terminal NMT 4, it can be concluded that within the ideal approach, there were 13 aircrafts, 2 aircrafts were under the ideal approach which can cause greater noise on the ground, while above the ideal approach with creating less noise were 7 aircrafts.

5 CONCLUSION

Ecology has become a significant parameter for funding and approval of projects in all sectors of transport, as well as in air traffic. At the Zagreb Airport for monitoring the trend of environmental awareness it is implemented the system for measurement and analysis of aircraft noise.

The problem of accessing to air traffic control radar data set and exact time of landing is in the direct dependence of the traffic centre for incoming information from the control tower where the time of landing and take- off is entered manually into the system and thereby may end up by a mistake. The problem of detecting the type of aircraft, and connection with the level of generated noise is solved by the development of the detection model of aircraft types using frequency and noise. In this way, it is possible to determine accurately which aircraft is in over-flight and to join the corresponding noise level to each aircraft.

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