IMPLEMENTATION OF CONTINUOUS DESCENT APPROACH AT ZAGREB AIRPORT

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ABSTRACT

With the increase in the number of flights and in accordance with the expansion of airports, air traffic is becoming a serious problem of the present times. In spite of the tendency to integrate maximally air traffic into all the ecological aspects, one of the main problems today is the noise generated by aircraft engines. These engines generate vortex, exhaust gases at high speeds, whereas in supersonic aircraft there is the additional thunder due to the impact waves produced during take-off and landing of the aircraft. The aircraft noise-related problems will have to be solved by certain alternatives, such as the replacement of the existing aircraft fleet by new generations of aircraft or by fitting the aircraft with hush-kits and other special parts or by using new, alternative procedures in landing and taking off.

This paper will deal with procedure model of Continuous Descent Approach (CDA) on Zagreb Airport. Due to the expansion of the city and nearby villages, implementation of such a system on Zagreb Airport could be cost efficient for the airport itself as well as for the airlines that use the airport. It would reduce the bad influence of noise on human health in those, ecologically critical surroundings. Apart from noise reduction, the usage of this system would decrease fuel consumption of aircrafts which would directly reduce exploitation costs of an aircraft.

Key words: noise reduction, ecology, Zagreb airport, airlines, fuel consuption

1 INTRODUCTION

Airport noise is generated by various operations of air and combined traffic. Apart from aircraft that are the main sources of noise, it is generated also by vehicles moving along the airport platform. The vehicle engine power is lower but, due to high concentration it may be considered continuous. Therefore, the expansion of cities and populated areas around the airports result in complaints about the noise in these regions. The complaints are mainly directed to aircraft noise which causes disturbances, sleeping problems and problems in communication. According to various studies, aircraft noise raises the level of stress, anxiety and generally has adverse impact on health. With the introduction of jet engines on commercial aircraft in 1960, noise has become one of the major problems.

According to FAA (Federal Aviation Authorities) data [1], aircraft noise has risen seven times in the period since 1970. International noise level standards for certification of subsonic aircraft were first introduced by ICAO in 1969 and published in Volume I Annex 16 of Chicago Convention (International Civil Aviation Organization, ICAO) [2]. Chapter 2 standard was completed in 1976 when Chapter 3 was announced. Chapter 4 of the standard has been applied since 2001 to all types of aircraft manufactured after 2006. ICAO enabled adaptation to the standard for country depending on when it decides to start applying the Chapters on protection against noise, provided Chapter 2 is the initial one.

Since 1970 aircraft noise has been reduced by 75% but this process is still continuing with new projects dealing with further noise reduction, both from aircraft and other sources at airports. Noise around airports depends on several various factors and must be objectively measured, and defined. The measured data need to be put into a model which should be used to reduce noise. Airports, that still accept aircraft with the same level of noise, may charge penalties for exceeding the allowed levels. The charges need to be based on aircraft noise certification issued according to the ICAO standards.

The development of technology has brought the design of new aircraft that are much quieter and the airport noise was significantly reduced. In order to avoid conflicts with the people living around the airport, some of airports have adapted their master construction plans of and have directed the new runways outside the populated areas. Apart from substantial costs for the construction and maintenance of infrastructure, incident situations and high social price, there is significant responsibility for the psychological and medical condition of the population as the result of pollution of air, underground water and soil, consumption of energy and natural resources. The effect if aircraft noise may be classified into two categories. The first category is the impact of noise on the behaviour of people, and the other is the impact of noise on the medical and psychological condition of people. The effect which refers to the behaviour of people can be observed in their mental activity, relaxation and communication. The medical effect can be reflected in the damaged or total loss of hearing, increased blood pressure or increased stress hormone secretion.

ICAO made a methodology which would reduce the aircraft noise at single airports, at the same time satisfying the forms of environmental protection and economic forms. This methodology consists of four parts:

1. reduction of noise at the very source,
2. proper physical planning and land use,
3. operational procedures in noise reduction,
4. operational flight bans for certain aircraft.

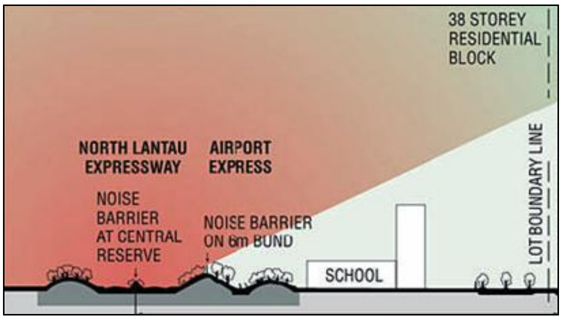


Figure 1: Sound direction by setting barriers in the form of embankments

Currently there are several noise reduction programs:

- take-off and landing should be performed more on the runways set towards less populated areas;
- construction of noise barriers and insulation of buildings;
- ban on landing of aircraft that are not in compliance with noise standards;
- different charging depending on the level of aircraft noise.

2 NOISE REDUCTION AT AIRPORTS

Apart from physical insulation and barriers, noise reduction at airports can be achieved also by operative measures in landing, i.e. by avoiding populated areas during these operations.

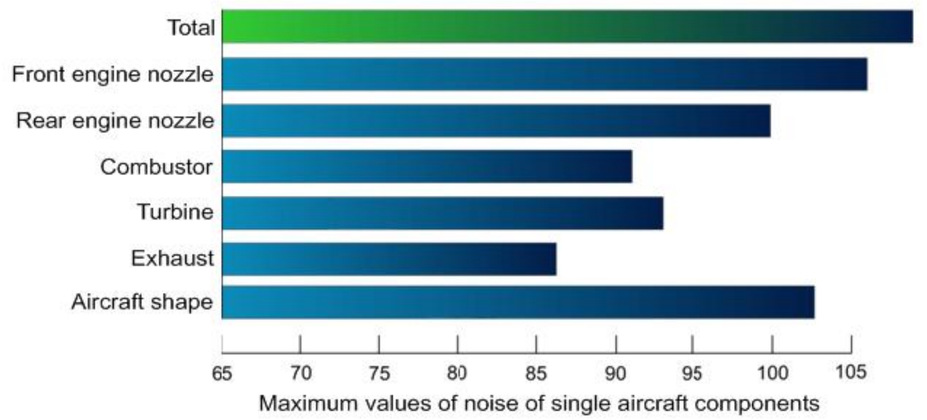


Figure 2: Level of noise of certain aircraft components in landing

2.1 Standard landing procedure

Standard landing procedure represents aircraft landing from the altitude of 1500 – 2000ft above the airport of landing. In this flight the pilot receives first the marker signal bringing the aircraft to the runway axis, i.e. the line that matches the runway axis. Flying in that plane, the pilot accepts the dive angle signal (which is at the angle of 3 degrees in relation to the horizontal plane), and then starts to dive. Flying at the dive angle the pilot brings the aircraft to the runway threshold to the altitude of 15 metres, and then starts landing. During the entire flight from the moment the pilot receives the marker signal, the aircraft is in the landing procedure (extended landing gear, flaps extended, flaps fully extended). For the normal flight performance (first in level flight, and then in diving), the engine thrust must be increased in order to be equal to the total aircraft drag, and the increased thrust generates a secondary phenomenon – greater noise generated by the engine itself.

Figure 3: Standard landing procedure

3 MODELS OF IMPLEMENTING OPERATIVE MEASURES TO REDUCE NOISE AT ZAGREB AIRPORT

Apart from standard procedures, there are several models of operative measures which might reduce the noise at Zagreb Airport [3].

3.1 Increasing the altitude at which the diving starts

This is the most widely used procedure and does not require installation of any special equipment onboard the aircraft or on the ground. Instead of flying the aircraft at level flight at the altitude of 450 to 600 metres (1500-2000ft), in order to receive the dive angle signal, the level flight is performed at the altitude of 900 metres, until receiving the dive angle signal, and then the aircraft dives towards the runway. Since the flight proceeds at a higher altitude than the flight in standard procedure, the noise level on the ground below the flight path will be lower. It should be emphasised that in both cases the flight is performed in the same configuration. According to this procedure the noise is reduced until arrival to the point of starting the dive, after which the flight proceeds identical to the definitions of the standard procedure, so that the noise in further flight is the same as in the standard procedure.

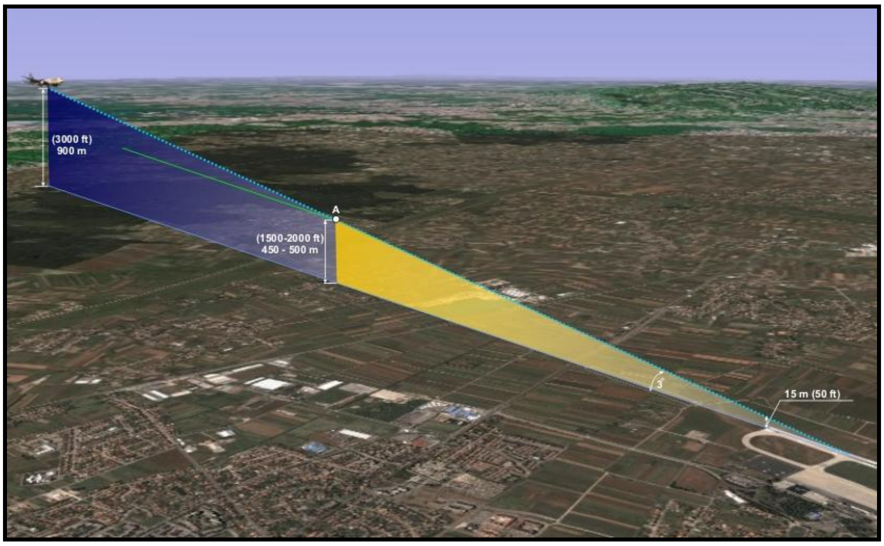


Figure 4: Increasing the altitude at which the diving starts

3.2 Lufthansa procedure

The Lufthansa procedure does not require additional equipment neither onboard aircraft nor on the ground. The approach until detecting the dive angle signal is performed at the altitude of 900m (3000 ft) as in the standard procedure, but the flaps are gradually extended. In this way the noise is lower since the aircraft drag in flying with less extended flaps is lower. This requires lower thrust in approach flight which means less noise. In this case the aircraft stays longer in the configuration with lower drag and therefore this procedure is called the low drag – low pressure procedure. At 450m (1500ft) of altitude, the landing gear is extended, and at 220m (700ft) full flaps are extended. This brings the aircraft into final configuration for landing, and the noise is equal to the noise of standard procedure. From that moment there is enough time for the pilot to balance the flight according to the dive angle path and to finally touch the ground. Apart from noise reduction this procedure brings also certain saving of the fuel.

3.3 Approach in two stages

For its implementation the aircraft needs to be fitted with the electronic equipment and additional devices need to be installed at the airport. The aircraft flies horizontally at the altitude of 900 metres (3000ft) up to a point where the pilot receives the special dive angle signal which is set at an angle of 6 degrees and then the aircraft dives at this angle all the way to approximately 300 metres (1000ft) of altitude, where the pilot detects the signal at the standard dive angle of 3 degrees, at which the final part of approach is performed and finally landing. Whereas in previous practice the pilots landed so that they approached the runway at an angle of 3 degrees, in this procedure they have to perform the first part of the approach at a double angle. This method of landing requires additional pilot training, but due to longer stay of the aircraft at a higher altitude, the noise directly below the aircraft remains at the same level. Noise begins to increase in close vicinity of the airport at a distance of about 11.6km when the aircraft starts diving, and becomes equal to the noise of the standard procedure at about 300m of altitude, i.e. at about 6.5km from the runway threshold.

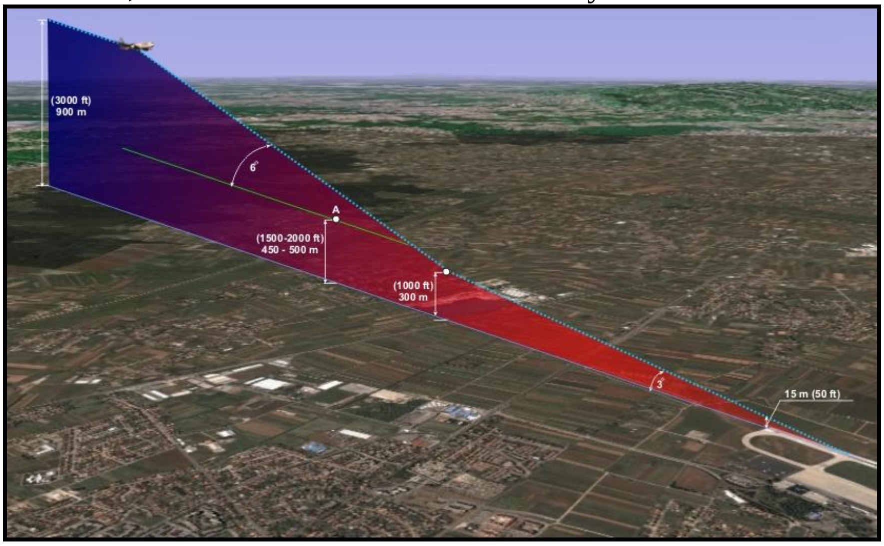


Figure 5: Approach in two stages

3.4 Approach / take-off on curved path

The use of the Microwave Landing System (MLS) makes it possible to use in approach a curved path, and only finish the approach by flying at the level of the runway axis. If there is a settlement in line with the runway axis, it is possible to avoid flying over it and thus reduce the noise in that place. This procedure needs special electronic equipment onboard the aircraft and on the ground. The situation is similar if in take-off, instead of straight flight the turn is taken so that the settlement is avoided. This method reduces the noise in that place.

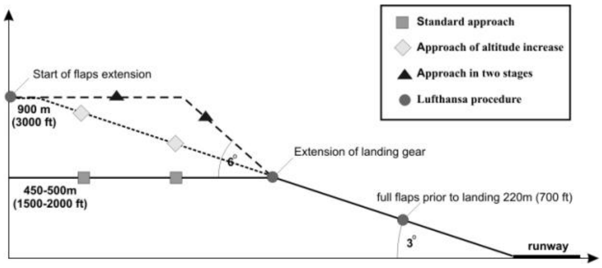


Figure 6: Models of landing procedures applicable at Zagreb Airport

4 CONTINUOUS DESCENT APPROACH (CDA)

The system which helps reduce the negative impact of noise and exhaust gases in the near vicinity of airports is CDA (Continuous Descent Approach) procedure. CDA procedure allows maintaining of aircraft at higher flight levels, i.e. delays the very start of the landing operation resulting in substantially reduced noise level, fuel consumption and harmful emissions towards the populated areas that are located in the near vicinity of airports (Figure

1). Aircraft that use conventional approaches descend earlier than necessary whereas those that use CDA procedure fly linearly and fly at higher levels longer. Additional altitude is important since the level of noise is significantly reduces when the distance between the source of the noise and the receiver is greater and for shorter distances.

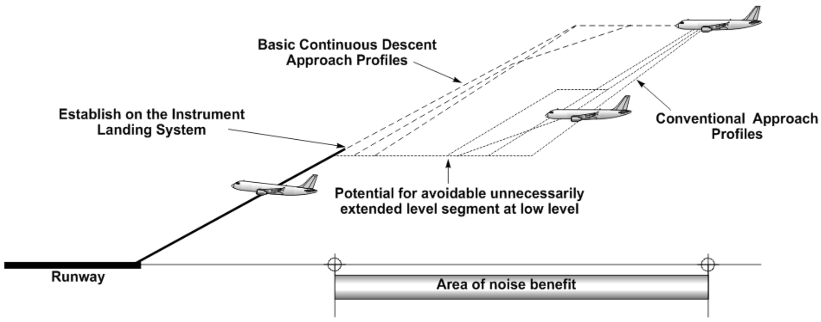


Figure 7: Conceptual diagram of the CDA procedure [4]

For the CDA procedure to be applied, the air traffic control should determine the specific or minimal speed of the approaching aircraft and inform the pilot on the distance of the runway touchdown point so that the pilot could insure vertical aircraft profile. This speed control maximizes the runway capacity. The approach control guides the aircraft by applying the radar vectoring procedures and approves continuous descent to the level of inter-approach, so that the level is reached in the direction of the localizer at a distance of about 8NM from the touchdown point. Continuous descent to the approved level is performed at a descending speed of 300ft/NM (descending angle of about 3°).

4.1 Comparative analysis of CDA and conventional approach

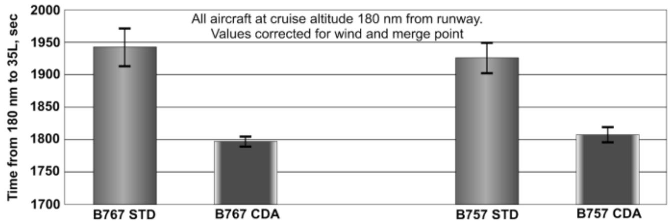
One of the first testing of the CDA procedure was performed during night at one of the runways of Amsterdam airport Schiphol. The citizens living in the surrounding area were surveyed and they said that after the introduction of the CDA procedure the level of noise was significantly reduced in comparison to aircraft that applied the conventional approach. Fuel consumption was also controlled at aircraft Boeing 747-400 and 737-300/400 on 10 flights for the last 45km of approach flight by means of CDA procedure, and approach at altitudes of 2,000ft and 3,000ft. The studies showed that fuel consumption for the last 45km of flight in CDA procedure was reduced by 25-40%, which e.g. amounts to about 400kg of fuel for Boeing 747-400 and 55kg of fuel for Boeing 737 -300/400. [5]

Table 1: Aircraft fuel consumption during approach phase

Aircraft/procedure		Fuel consumption (kg)
B747	2,000 ft	799
	3,000 ft	1,045
	CDA	638
B737	2,000 ft	213
	3,000 ft	225
	CDA	170

4.2 Analysis of flight time

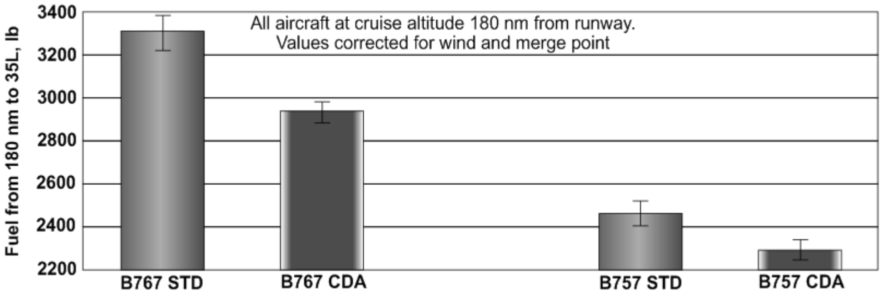
Graph 1 shows the flight time of the last 180NM to the airport. The average flying time for aircraft B757-200 that flies using CDA procedure amounts to 1,808 seconds whereas for the same distance, the same type of aircraft that applies conventional approach takes 1,926 seconds which makes the flight using CDA procedure by 118 seconds shorter. The same testing was carried out for aircraft B767-300 and the time for CDA procedure amounted to 1,797 seconds whereas in conventional approach it took 1,944 seconds making the flight with conventional approach longer by 147 seconds. The majority of differences in the flying time were realized in the area of the terminal.



Graph 1: Time necessary to fly 180NM in the landing phase for CDA and conventional approach [6]

4.3 Fuel consumption analysis

Graph 2 shows the fuel consumption for the last 180NM in the descent phase. Average fuel consumption for aircraft B757-200 that flies using CDA procedure amounted to 2,308lb whereas for the same distance, for the same type of aircraft flying in conventional approach, the fuel consumption amounted to 2,426lb which results in 118lb lower fuel consumption in case of CDA approach. The same testing was carried out for aircraft B767-300 and the average fuel consumption for CDA procedure amounted to 2,937lb whereas for conventional approach 3,301lb of fuel were needed resulting in 364lb greater fuel consumption in case of conventional approach. The research results lead to the conclusion that fuel consumption, especially for larger aircraft is significantly higher in case of using conventional approach. [6]



Graph 2: Average fuel consumption for a flight of 180NM in the landing phase for CDA and conventional approach [6]

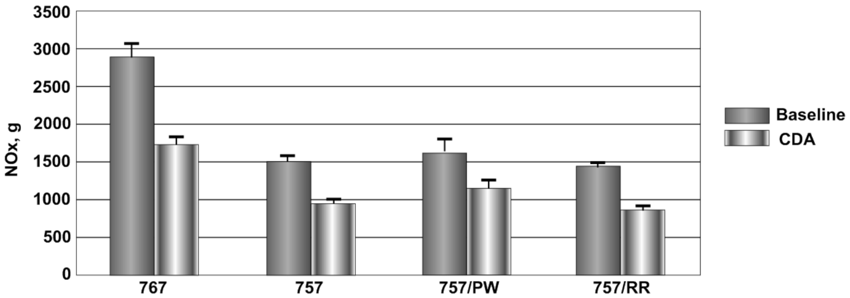
4.4 Exhaust emissions analysis

Exhaust emissions at airport are usually the result of combustion of gases generated by jet engines propelled by kerosene and road vehicles powered by gasoline or oil. The major polluters are carbon monoxide, carbon dioxide, nitrogen oxide, lead and hydrocarbons. Since airports cover large areas, air pollution is lower than air pollution on urban streets. Exhaust gases at airports are consequence of aircraft engine operation (45%), road vehicles used for passenger transfer from and to the airport (45%) and vehicles used for passenger, baggage and post handling (10%). [7]

The development of new technologies, especially jet engines of the new generation have significantly reduced the share of single polluters. Thus, over the last decade the share of carbon monoxide decreased by 70%, hydrocarbons by 85%, but there was increase in the emissions of nitrogen oxide by 12%. On the average the decrease in the share of polluters amounts to 58%. The volume of exhaust gases at airports can also be reduced by introducing road vehicles that use environmentally-friendlier types of propulsion (e.g. electrical power), by shortening the aircraft operation time, by construction of air bridges thus eliminating the need for buses transporting passengers from aircraft to the terminals, by better organization of public urban transport (primarily rail transport) thus certainly reducing the number of passengers who arrive to the airport by passenger cars.

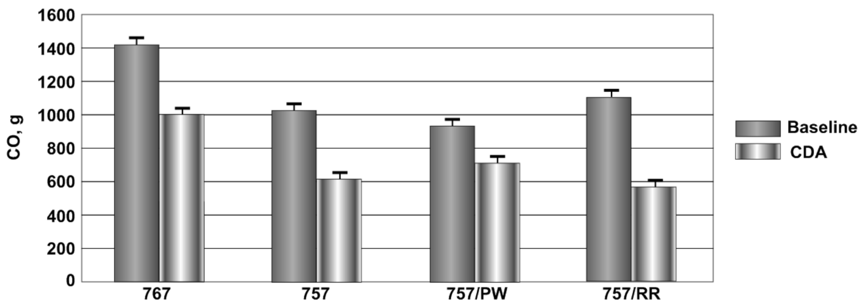
The main part of studying the exhaust gases was carried out in the transition phase between approach / landing (altitude of up to 3,000ft from the airport altitude). The emission of gases at altitudes of up to 3,000ft from the ground level influence to the greatest extent the local air quality. Testing was done on aircraft B757-200 and B767-300 in CDA approach and conventional approach. The emitted volumes of nitrogen oxide (NO_X), carbon monoxide (CO) and hydrocarbons (HC) were measured.

Graph 3 gives the average emissions of NO_X for aircraft B757-200 and B767-300 in CDA and conventional approach. Testing on aircraft B757-200 were carried out on engines of type Pratt and Whitney (PW) and Rolls Royce (RR), and graph gives also the average harmful emissions for this type of aircraft. Aircraft that applied CDA approach flew shorter and consumed less fuel which resulted in lower emissions of NO_X, CO and HC. The average quantity of emitted NO_X for aircraft B757-200 in CDA approach was reduced by 37% (from 1,510g to 951g), whereas the same measurement for aircraft B767-300 showed reduction of 39.9% (from 2,882g to 1,732g).



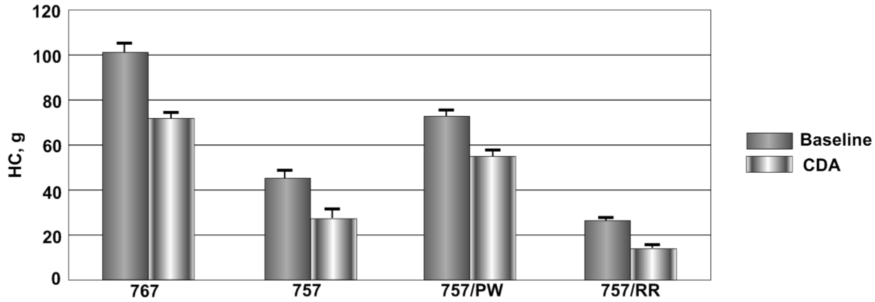
Graph 3: Average emission of nitrogen oxide (NO_X) for aircraft B757-200 and B767-300 for CDA and conventional approach [6]

Graph 4 gives the average emissions of CO for aircraft B757-200 and B767-300 u CDA and conventional approach. The average quantity of emitted CO for aircraft B757-200 u CDA approach was reduced by 39.9% (from 1,030g to 620g), whereas the same measurement for aircraft B767-300 showed reduction of 28.5% (from 1,408g to 1,007g).



Graph 4: Average emission of carbon monoxide (CO) for aircraft B757-200 and B767-300 for CDA and conventional approach [6]

Graph 5 gives average emissions of HC for aircraft B757-200 and B767-300 in CDA and conventional approach. Average quantity of emitted HC for aircraft B757-200 in CDA approach is reduced by 29% (from 45g to 27g), whereas the same measurement for aircraft B767-300 showed a reduction of 39.2% (from 101g to 72g).



Graph 5: Average emission of hydrocarbons (HC) for aircraft B757-200 and B767-300 for CDA and conventional approach [6]

5 CONCLUSION

Aircraft is the main source of noise that influences people within a certain radius around this source, as well as the crew and passengers onboard. Aircraft noise can be solved by replacing the existing fleet of 2nd category and installing hush kits, the model of which has been already used in the United States, while most of European countries have been introducing a new generation of aircrafts. The Zagreb Airport traffic is mostly based on the new generation of aircrafts, i.e. aircrafts of 3rd category with relatively silent engines. From the infrastructural point of view, one of long-term solutions for noise reduction is the positioning of runway whose take-off and landing corridors do not overflow populated areas. Also there are areas nearby the Zagreb Airport which can be affected by negative impact of aircraft noise due to the increased traffic. If safety standards have been met and there is a need for noise reduction, operational methods can be introduced by approaching/taking off on curved path or by increasing the altitude at which the diving starts. Recently the introduction of Continuous Descent Approach (CDA) has been shown as the best soultion which can also be implemented at the Zagreb Airport, thus reducing noise as well as pollution. With the development of airports and expansion of urban areas, which result in big problems related to noise and air pollution, human factor will have to find a way how to harmonise development and modernisation of air traffic and the "potential enemies" that occur as the consequence of technological development of airports. In air traffic, as in other branches of traffic, the priority lies in the safety of passengers, crew and the transport means, the aircraft. The latter refers to the technical characteristics of aircraft and people who are exposed to constant impact of aircraft noise. There are certain limits when noise could be prevented but the safety standards do not allow it. In such situations noise reduction is neglected and everything is focused on the flying safety. Safety requirements during take-off procedure mostly refer to the reduction of engine power. Noise reduction can be achieved also by operative measures in landing both by purchasing additional equipment onboard aircraft and at airports, and by higher investments. The introduction of CDA at world's airports, including the Zagreb Airport, could affect the reduction of environmentally harmful elements such as noise, fumes as well as aircraft fuel consumption. CDA can also result in the reduction of expenses in air traffic, such as: [4]

- **Noise** – harmful influence of exceeding noise of all sources is estimated at about 13 – 38 billion euro in EU countries only, out of which 5% is accounted for by air traffic.

- **Fuel** – the basic environmental problem, not only due to exhaust gases but also because of the limited resources. If only 10 litres fuel were saved per flight in the European airspace, the result would be about 80,000 tonnes of saved fuel a year.
- **Exhaust emissions** – emissions of aircraft flying below 3,000ft have harmful effect on the local quality of air. It is estimated that apart from contributing to the climatic changes, one tonne of exhaust emission particles can cause damage of over 150,000 euro if the emission occurs above the city. Every tonne of carbon dioxide (CO_2) costs the society about 32 euro (1 tonne of fuel = approximately 3.14 tonnes of CO_2).

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