Air Traffic Assignment As A Noise Abatement Measure Case Study: Zurich Airport, Switzerland

Fedja T. Netjasov

***Abstract*— One of the biggest problems of modern airports is the noise generated by air traffic, and the impact of this noise on those living near the airport. Noise is an unavoidable consequence of air traffic but it can be decreased by numerous measures: technical innovations in aircraft design, legislation, etc. This paper presents a suggested measure which has been developed for the needs of Zurich Airport (one of busiest airports in Europe). The proposed measure is based on the air traffic assignment model and takes into account Zurich Airport's basic goals: airport capacity increase with reductions in noise level in the airport surroundings. Although, these abovementioned goals are in apparent conflict, it is shown that the proposed model allows for decreases in noise level of, on average, 1dB(A) with a traffic volume increase of 20%. The model is based on categorization of aircraft according to engine type (jet and turbo prop) and wake turbulence category (heavy, middle, small and light) and the assignment of specific runways for take-off and landing for each of the mentioned categories.**

***Index Terms*—Airport, Noise Abatement Measures, Air Traffic Management, Air Traffic Control**

I. Introduction

ONE of the biggest problems of modern airports is the noise generated by air traffic, and the impact of this noise on those living near the airport. Noise is an unavoidable consequence of air traffic but it can be decreased by numerous measures: technical innovations in aircraft design, legislation, etc. These measures, however, often amount to discrimination against some airlines. In the judgment of numerous authors, the noise will probably remain the top concern in airport operation, planning and design in the future, primarily because of greater public sensitivity to noise and other environmental problems [1]. This justifies the level of attention given to finding solutions to this problem by numerous air transport system stakeholders (aircraft manufacturers, airports, airlines, air navigation service providers, etc). This paper presents a measure developed for the needs of Zurich Airport (one of busiest airports in Europe) which does not discriminate against certain airlines and which allows for noise level reduction in the airport surroundings.

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The proposed measure is based on the air traffic assignment model and takes into account the Zurich Airport basic goals: airport capacity increase with reductions in noise level in the airport surroundings. Although, these goals conflict, it can be shown that the proposed air traffic assignment model allows for decreases in noise level of, on average, 1dB(A) with a traffic volume increase of 20%. The proposed air traffic assignment model is based on categorization of aircraft according to engine type (jet and turbo prop) and wake turbulence category (heavy, middle, small and light) and the assignment of specific runways for take-off and landing for each of the mentioned categories.

II. Existing Ways of Addressing the Noise Exposure Problem

The noise exposure problem, generated by air traffic, can be addressed at different levels.

At the first level the problem is addressed during the aircraft design and production process – decreasing the noise at source (quieter engines, aerodynamic construction generating low drag, etc). Since 1960, in this way, the noise level has been decreased by around 10 dB(A) (on average 3 dB(A) per decade) [1] (Figure 1).

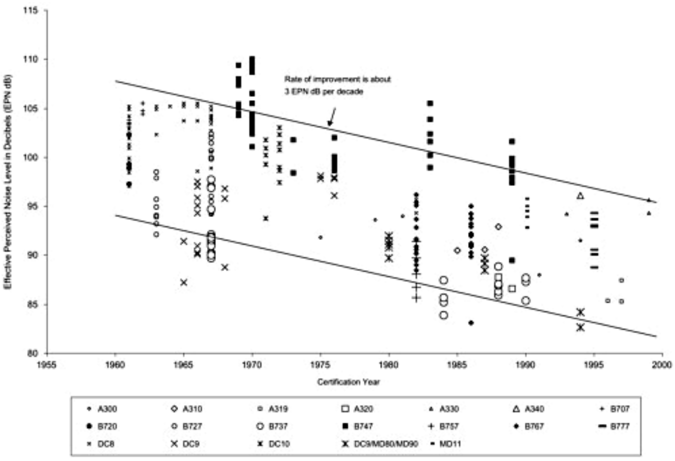

Figure 1. Trends in aircraft noise levels reduction during take-off for aircraft at the maximum take-off weight as a function of certification date [1]

The basic document for dealing with the noise problem at this level is ICAO Annex 16, Volume 1 – Aircraft Noise [2]. This document contains recommendations and guidelines for certification of aircraft intended for use in international air traffic, from a noise point of view. Modernization of the Aircraft Certification Scheme is the topic of the ICAO Committee on Aviation Environmental Protection (CAEP) Working Group WG1 – "Noise" [3].

The second level is related to changes in arrival and departure procedures, i.e. in flying techniques during the mentioned operations. Numerous departure procedures are known: Cutback, IATA, Climb-Cleanup-Cutback…, as well as arrival procedures: Low Drag - Low Power, Continuous Descent Approach,… [4]) and fundamentally all are based on two requirements [5]: to keep the aircraft further from the zones which they contaminate (higher climb and descent rates) and to generate lower noise at source (flying under lower engine power). The tendency in recent decades has been increased work on new arrival and departure procedures as well as on international harmonization and standardization of their development [6]. The European Union, through the Projects SOURDINE I and II is focusing on the development and assessment of new Noise Abatement Procedures (NAP) [7].

The third level is related to legislative measures of restriction introduced by airports and aviation authorities (restrictions related to airport usage and/or prohibition of airport usage at night for some or all aircraft types). Such measures penalize airlines whose aircraft exceed the permitted noise levels during arrivals or departures, and in some cases completely prohibit their operation. Figure 2 presents the number of airports during the past 30 years, which have introduced some kind of restriction. The number of restrictions as well as their type has become even higher, especially after 1996, because of the greater awareness about the air traffic noise among local communities [1] (Figure 2, values in brackets are for year 2001.).

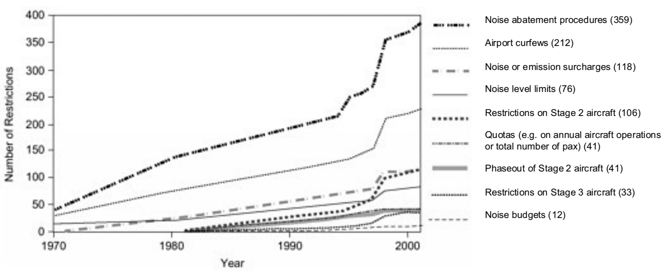

Figure 2. Number of airports worlwide imposing various constraints and charges as a function of time [1]

Recently the ICAO presented an Assembly Resolution A33-7 (September 2001), the Balanced Approach [8] to aircraft noise management around airports. The Balanced Approach is defined as a program for addressing aircraft noise at the individual airport level and considers four elements:

1) Reduction of noise at source;
2) Land-use planning and management;
3) Noise abatement operational procedures;
4) Operating restrictions on aircraft.

This Approach recommends that noise policy should not target single solutions but use any combination of solutions as the most appropriate option to solve the causes of problems [9]. The goal of implementing the above mentioned approach is to achieve the maximum environmental benefit in the most cost effective way. [8].

III. FACTORS INFLUENCING AIR TRAFFIC NOISE

The extent to which the airport surroundings will be exposed to air traffic noise depends on numerous factors, starting with the location of the airport, i.e. local topography, then with the traffic characteristics (number of take-offs and landings, as well as their distribution during the day), the structure of the fleet which uses the airport (aircraft types) and departure and arrival trajectories [5]. Other factors, contributing to the noise exposure, are: atmospheric characteristics (e.g. air temperature), noise from aircraft and handling vehicles on the airport maneuvering areas as well as other activities at the airport – aircraft maintenance, engine testing, etc [10].

IV. AIR TRAFFIC NOISE MEASUREMENT

Noise generated by air traffic can be considered using numerous measures (more then 20 [11]) starting with those, which estimate the noise generated by one event (arrival or departure) to the cumulative measures taking into account all operations during the day. All estimation methods are characterized by weighting of the measured noise level, which can be by: frequency, duration or level [11]. Today, the most frequently used measure for a single event is SL (Sound Level) and for cumulative measures - Leq (Equivalent Sound Level), CNEL (Community Noise Equivalent Level), DNL (Day – Night Average Sound Level), NEF (Noise Exposure Forecast), etc [10]. The unit used for measuring the noise generated by air traffic is most commonly the dB(A).

Noise measurement is today an activity performed by specialized services (divisions) at the airports, which collect (at measuring points, with sound level meters), analyze and archive the data about the noise levels around the airport. This data is often used as evidence for penalizing airlines whose aircraft exceed the permitted noise level. Data collected in this way are used for the validation of new arrival and departure procedures, i.e. validation of noise abatement effects, for appropriate land usage (zoning) around the airport, for the acoustic insulation of buildings in airport vicinity, etc [6].

V. AIR TRAFFIC ASSIGNMENT AS A MEASURE OF NOISE EXPOSURE REDUCTION

It is the aim of modern airports to reduce noise in the airport's surroundings by applying various measures. From another perspective, it is in the airport's interest to serve increasing traffic and not to lose potential clients by applying some of the discriminatory measures for noise reduction. Taking all the mentioned facts into account, the idea has emerged that, for airports, which have already implemented some noise abatement measures, further, additional decreases of noise level could be achieved through various air traffic management measures. This paper presents an air traffic assignment model as well as the results of its application in the case of Zurich Airport [12].

The model, proposed in this paper was developed with the goal of decreasing noise levels while at the same time improving the usability of available airport resources (capacity is presented as an hourly number of operations). The presented model is designed for planning purposes.

The model consists of several steps and, for a given airport, contains the following assumptions:

1. Traffic volume for a given day (number of departures and arrivals and their daily distribution) is known;
2. A noise monitoring system (measuring points) is implemented at the airport;
3. Average noise over measuring points, generated by specific aircraft type is known;
4. Sets of departure and arrival routes are known, as well as their characteristics,
5. The ratio of specific aircraft types share in the total daily traffic is a constant (day, evening, night);
6. Sequencing of the arrival traffic as well as the location of parking position are not taken into account, and
7. Transition from en-route sectors to TMA and vice versa, is not taken into account.

Structure of the model:

STEP 1: Analysis of daily traffic characteristics (real or forecasted) with the aim of determining the aircraft fleet structure (aircraft mix) using the airport (aircraft types as well as number of aircraft of specific type (N) during the day); as well as classification of aircraft depending on engine type (turboprop or jet engine) and wake turbulence category (Heavy, Medium, Large and Small) [13];

STEP 2: Analysis of average (measured) noise values generated by different aircraft types, over M specific measuring points separately for departures and arrivals (average noise value is used because the noise value for the particular aircraft type over the particular measuring point is a random variable);

STEP 3: Distribution of aircraft of different classes on runways in use (heuristic model) based on the following criteria (by importance):

1. Average noise level for each aircraft type (departures and arrivals);
2. Available runway length;
3. Over-flying of densely populated areas.

This distribution is based on the air traffic controller's expertise and current practice in use. For example, instead of landing on a runway where, over a particular measuring point, a given aircraft generates a higher noise level, it is instructed to land on another runway (if its length is sufficient for landing of that aircraft type) where it will generate lower noise level over a given measuring point and it will over-fly a less populated area. For every aircraft type it was decided, based on a given criteria, on which runway they should land. Aircraft distribution on runways also depends on the current and forecasted meteorological situation (the runway condition as well as the runway configuration in use).

STEP 4: Calculation of the noise level using the proposed model, for each measuring point in the airport's surroundings separately (based on all departures and arrivals):

$$NL_i^{arr} = \frac{1}{m_i^{arr}} \sum_j (a_{ij}^{arr} \cdot n_{ij}^{arr}) \tag{1}$$

$$NL_i^{dep} = \frac{1}{m_i^{dep}} \sum_j (a_{ij}^{dep} \cdot n_{ij}^{dep}) \tag{2}$$

$$NL_i = \mathbf{max}\left\{NL_i^{arr}, NL_i^{dep}\right\} \tag{3}$$

$$m_i^{arr} = \sum_j a_{ij}^{arr}, \; m_i^{dep} = \sum_j a_{ij}^{dep} \tag{4}$$

where:

i – measuring point, i=1 to M;
j – aircraft type, j=1 to N;
NL_i^{arr} – noise level at measuring point i during arrival [dB(A)];
NL_i^{dep} – noise level at measuring point i during departure [dB(A)];
NL_i – maximal noise level at measuring point i [dB(A)] ;
n_{ij}^{arr} – average noise level which aircraft of type j generate at measuring point i during arrival [dB(A)];
n_{ij}^{dep} – average noise level which aircraft of type j generate at measuring point i during departure [dB(A)];
m_i^{arr} – total daily number of aircraft which over-fly measuring point i during arrival;
m_i^{dep} – total daily number of aircraft which over-fly measuring point i during departure;
a_{ij}^{arr} – daily number of aircraft of type j which over-fly measuring point i during arrival;
a_{ij}^{dep} – daily number of aircraft of type j which over-fly measuring point i during departure.

Equation (1) and (2) calculate noise level over a particular measuring point during arrivals and departures respectively. Equation (3) compares noise values calculated by equations (1) and (2) and takes the higher value as a critical one from the environmental perspective. Equations (4) present the additional condition that the total daily number of aircraft over-flying a particular measuring point during arrival/departure presents the sum of the daily number of aircraft of all types over-flying the same measuring point during arrival/departure respectively.

STEP 5: Comparison of the obtained noise level values NL_i (STEP 4) for each of the M measuring points, between various runway configurations as well as various time horizons.

VI. CASE STUDY: ZURICH AIRPORT, SWITZERLAND

The proposed air traffic assignment model is illustrated with reference to Zurich Airport. This airport is one of the major European hubs and is a pioneer in controlling the impact of aviation on the environment (aircraft noise and engine emission). It is characterized by rather complex infrastructure (three runways), by major spatial operational constraints (9 km from the city center, 15 km from the German border) and by high traffic volume (approximately 1000 operations per day).

In the year 2000, Zurich Airport defined a strategic goal related to the increase of traffic volume by 20% by year 2005 (from 297.000 operations in year 2000, to 358.000 operations in year 2005, Figure 3 [12]).

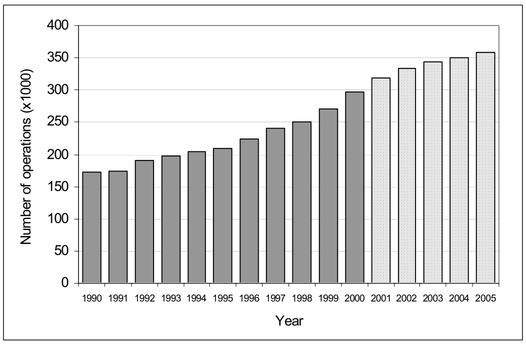

Figure 3. Forecasted traffic volume until 2005, at Zurich airport

Zurich Airport Authority determines the acceptable runway configurations, which will allow capacity to increase and thus service the planned traffic volume (Figure 4). The second goal, equally important, is related to the reduction of noise levels in the airport's surroundings.

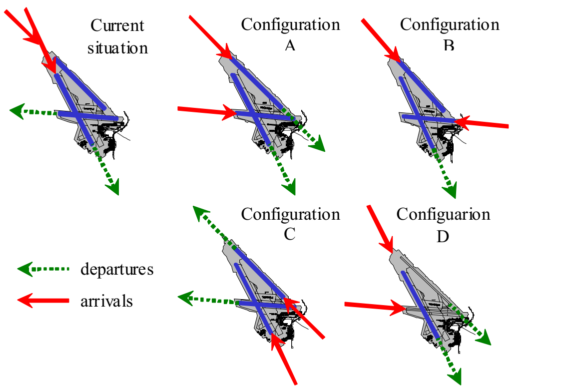

Figure 4. Current situation (year 2000) and available runway configurations

The "Average November 2000 day" was predicted based on Traffic data for November 2000 .(Figure 5). It was identified by traffic analysis that 34 aircraft types used the airport during that day (general aviation aircraft ware not taken into account) [12].

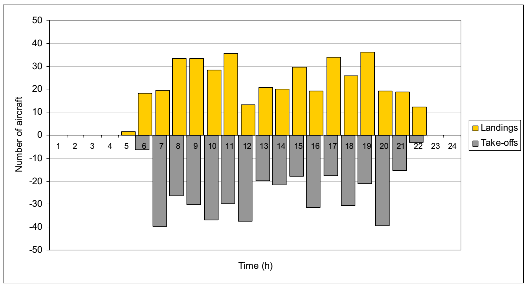

Figure 5. "Average November 2000 day" traffic volume

Based on this data, as well as data about the planned number of operations for 2005 (see Figure 3), the "Average November 2005 day" was predicted. This forecast took into account the planned technological development of aircraft as well as the plans of certain airlines, which are committed to introduce new aircraft.

There is a Division which monitors noise at Zurich Airport, and which collects data on measured noise levels for each aircraft type (separately for departures and arrivals) using a monitoring system containing 9 measuring points (sound level meters) in the airport vicinity (Figure 6, [14]). After statistical analysis, the Division makes this data available to the public.

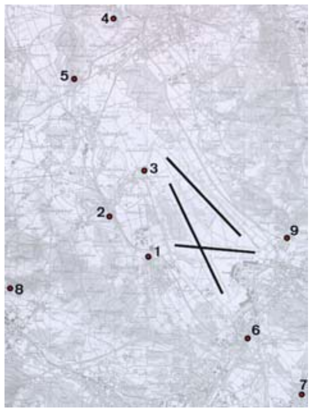

Figure 6. Locations of measuring points [14]

Analyzing the traffic from an "Average November 2000 day" (816 operations), the peak traffic period was identified as being between 08:00 and 11:00 hours with 194 operations in total (Figure 7). In this peak period 16% of operations were made by Medium Turbo Prop (MTP) aircraft, 71% Medium Jet (MJ) and 13% Heavy Jet (HJ) [12].

The noise level analysis for all 34 aircraft types shows that noise during aircraft take-off and departure is higher than noise during arrival and landing, for each aircraft type (Figure 8, e.g. measuring point No. 3, comparison of Medium Turbo Prop and Heavy Jet aircraft [12, 14]), as well as that Medium Turbo Prop aircraft generate lower noise than Medium Jet and Heavy

Jet aircraft (Figure 9, comparison by measuring points for both departures and arrivals, data for measuring point No. 8 were not available).

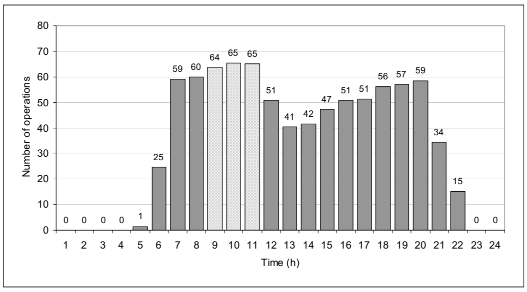

Figure 7. "Average November 2000 day" peak period (total operation)

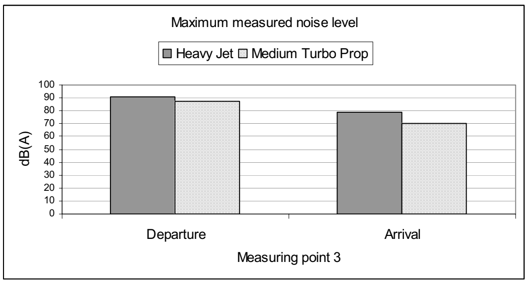

Figure 8. Comparison of noise levels during departure and arrival (measuring point 3)

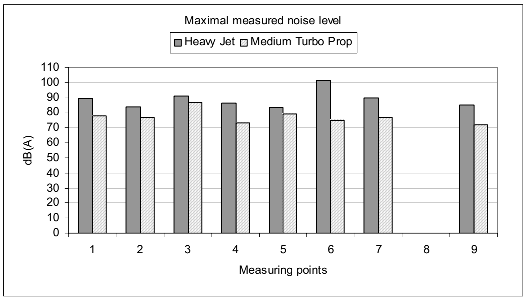

Figure 9. Comparison of noise levels by measuring points

The proposed model is firstly applied to the runway configuration currently in use (in year 2000) and traffic sample containing 816 operations, i.e. "Average November 2000 day", and after that, on each of four runway configurations accepted by the airport authority (see Figure 4). The average noise levels, calculated by the model, are shown in Table 1. The results unequivocally show that the application of new runway configurations, in certain cases, influence noise reduction (relative to the current situation). Noise level values vary depending on the runway configuration in use as well as the measuring point location [12]. For some measuring points, either in current and other runway configurations, it was not possible to calculate noise levels or it was not necessary because of the measuring point location. E.g. in the current situation, measuring point 4 was written "<M.p.3" (see Table 1) which means that the value for measuring point 4 is less then value for measuring point 3 due to the fact that the point 4 is much further from the runway then point 3, see Figure 6. (The two decimal places for noise level values shown in the tables are used only for computational reasons).

TABLE 1. AVERAGE NOISE LEVELS IN dB(A) BY RUNWAY CONFIGURATIONS (YEAR 2000)

Measuring point (M.p.)	Runway configuration				
	Current situation	A	B	C	D
1	79.81	67.16	67.16	74.72	-
2	75.71	< M.p. 1	< M.p. 1	73.08	-
3	71.18	72.89	72.89	81.19	72.91
4	< M.p. 3	< M.p. 3	< M.p. 3	74.94	< M.p. 3
5	< M.p. 3	< M.p. 3	< M.p. 3	71.32	< M.p. 3
6	92.21	74.86	74.86	67.17	80.36
7	80.26	73.19	73.19	< M.p. 6	73.69
8	-	-	-	-	-
9	-	84.43	84.43	72.80	67.16

For the purpose of checking the effects of the proposed assignment model, noise level is also calculated for forecasted traffic (as it was mentioned before), i.e. for an "Average November 2005 day's" traffic (984 operations, Figure 10, Table 2.) [12].

"Average November 2005 day" traffic sample, uses the same percentage ratio in the total traffic amount, between the three above mentioned aircraft classes, as in the year 2000 sample. Although there is a traffic increase of 20%, it was shown that the proposed model influenced noise level reduction. So, comparing the noise level values for two years (year 2000 and 2005), for the same runway configuration in use and for the same measuring point, the obtained values are, on the whole, lower (Table 3) [12].

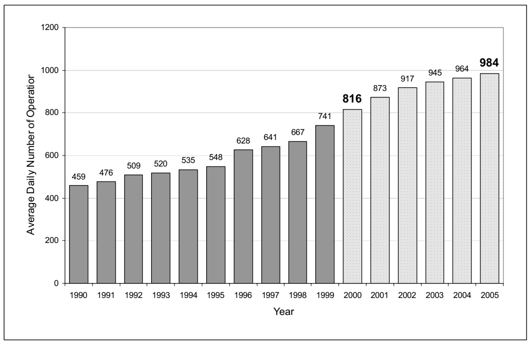

Figure 10. Predicted "Average November day" traffic volume until 2005, at Zurich airport

TABLE 2. AVERAGE NOISE LEVELS IN dB(A) BY RUNWAY CONFIGURATIONS (YEAR 2005)

Measuring point (M.p.)	Runway configuration			
	A	B	C	D
1	66.57	66.57	74.17	-
2	< M.p. 1	< M.p. 1	71.79	-
3	72.89	72.89	81.19	72.91
4	< M.p. 3	< M.p. 3	74.94	< M.p. 3
5	< M.p. 3	< M.p. 3	71.32	< M.p. 3
6	73.94	73.94	66.56	80.02
7	72.18	72.18	< M.p. 6	73.32
8	-	-	-	-
9	84.43	84.43	72.80	66.57

TABLE 3. NOISE LEVELS REDUCTIONS IN dB(A) BY RUNWAY CONFIGURATIONS (YEAR 2005. VS YEAR 2000.)

Measuring point (M.p.)	Runway configuration			
	A	B	C	D
1	0.59	0.59	0.55	-
2	0*	0*	1.29	-
3	0	0	0	0
4	0*	0*	0	0*
5	0*	0*	0	0*
6	0.92	0.92	0.61	0.34
7	1.01	1.01	0*	0.37
8	-	-	-	-
9	0	0	0	0.59

NOTE: reduction for measuring points for which noise level values are not calculated are depicted as 0*.

VII. DISCUSSION AND FURTHER RESEARCH

Comparing the average values for two years can show that at certain measuring points the resulting noise reduction is (roughly) between 0.5 and 1 dB(A), for a given aircraft fleet mix (16% MTP, 71% MJ, 13% HJ, Table 3). The percentage ratio of aircraft in the fleet mix fluctuate during the day, mostly increasing the share of quieter aircraft (MTP or MJ, Figure 11), so it can be expected that values of reduction could be increased to 2 dB(A) during the day for some measuring points.

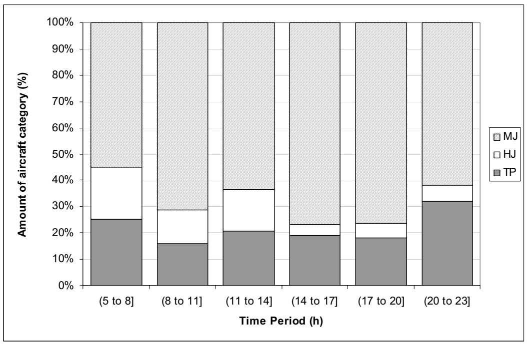

Figure 11. Fluctuation of Percentage ratio of aircraft in the fleet mix during the Zurich Airport working hours (from 5 to 23 o'clock)

According to obtained results, it could be concluded that promising potential for noise level decrease exist. But one question appears: how much the noise level decreases due to change of the percentage ratio of aircraft in the fleet mix and how much because of different runway configuration in use? Also, it would be very interesting to compare the obtained noise levels with the long-term noise levels recommended by the European Commission (2003/613/EC) [15]. It is expected that noise level values determined in such a way, will produce similar reductions to those presented in Table 3. Those are further research steps, together with comparison with results of some noise simulation models (such as FAA's Integrated Noise Model - INM).

VIII. CONCLUSION

The problem of air traffic noise exposure is solved with the application of various practical measures, often discriminating against certain airlines. This paper presents a model for noise level reduction, based on air traffic assignment, which is not discriminatory. The model is based on aircraft classification on two criteria: engine type and wake turbulence category. Distribution of aircraft classes (defined in such a way) on runways, is made using a heuristic algorithm with the aim of decreasing noise exposure. For illustration purposes, the model is tested on Zurich Airport, for different runway configurations as well as time horizons. It was shown that, in the case of a traffic volume increase of 20%, a significant noise level reduction (up to 1 dB(A)) would be possible to achieve.

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