ENVIRONMENTAL PROTECTION

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ENVIRONMENTAL CAPACITY AND SUSTAINABLE DEVELOPMENT OF AIRPORTS IN UKRAINE

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Abstract. *Forecasting of development of the major airports of Ukraine indicates that further increasing of air traffic and approaching of residential areas close to airports will cause constraints of airport operational capacity according to ensuring environmental requirements. At present, aircraft noise is the most significant factor among other factors of airport environmental impact. For ensuring sustainable development of civil airports the model of airport environmental capacity is proposed. The model in long-term consideration allows determination of optimal (according to reduction of noise levels) fleet, choosing the most profitable aircraft operational regimes in the frames of ICAO Balanced Approach to aircraft noise control. The model is based on entropy optimization method. Using proposed approach needs taking into account additional constraints: operational, environmental (emissions of aircraft engines). Meteorological and flight characteristics of aircraft type also should be taken into account.*

Keywords: aircraft noise, acoustical capacity, environmental capacity, operational restrictions.

Introduction

Investigations carried out by experts of the Center of Environmental Problems of Airports (CEPA) at the National Aviation University confirmed that nowadays most of the Ukrainian airports (Borispil', Kyiv (Zhuliany), Odesa, Simferopol, Dnipropetrovs'k, Kharkiv, Ivano-Frankivs'k, Cherkasy, Rivne, Dzhankoj and Gostomel) have zones with high noise levels and air pollutant emissions, which partially overlay the residential areas. Those airports consider potential constraints of air traffic according to environmental requirements. Nowadays, aircraft noise is one of the most negative environmental factors in airport operation.

Aircraft noise not only impacts on aviation personnel, but mainly on people living on the airport vicinity.

In 2001, the ICAO Assembly endorsed the concept of a "balanced approach" to aircraft noise management [1]. It consists of four principal elements, namely noise reduction at source (quieter aircraft), land-use planning and management, noise abatement operational procedures and operating restrictions, with the goal of addressing the noise problem in the most cost-effective manner.

For the land use management around civil airports there are legit State Sanitary Norms [2] and the Regulations for determination of restrictions zones around airports according to aircraft noise impact [3] (below – the Regulations) are developed. In accordance with the Regulations, airport vicinity is divided into three zones of construction restrictions (tab. 1).

The normative criteria of noise contamination are equivalent noise levels L_{Aeq} (dBA) and maximum noise levels L_{Amax} (dBA) during daytime (from 7:00 till 23:00) and nighttime (from 23:00 till 7:00).

Table 1. **Regulation of construction restrictions around civil airports, dBA**

Type of restriction in a zone	Daytime		Nighttime	
	L_{AeqD},	L_{AmaxD},	L_{AeqN},	L_{AmaxN},
Unsuitable for construction	≥75	≥90	≥65	≥80
Protection against noise	<75 ≥65	<90 ≥80	<65 ≥55	<80 ≥70
Limitations for residential construction	<65 ≥55	<80 ≥70	<55 ≥45	<70 ≥60

For acoustical assessment in the specified airport the schedule of air traffic during a week is used which represents the maximum intensity of aircraft movements. Zones of construction restrictions are estimated for current and perspective (5-10 years forecasting) operational conditions and also the scenario of airport operation at the level of maximum operational runway capacity is under consideration.

Experts of the CEPA have made the complex of investigations and as a result of it the zones of aircraft noise impact for the most of civil airports in Ukraine. Thus, for the Borispol international airport three operational scenarios were evaluated:

– For the first calculated scenario (fleet and intensity of aircraft movements for the year of 2006) the noise level equals to L_{AeqD}=75 dBA, (that according to the Regulations [3] determines a zone unsuitable for construction) doesn't cover any residential area for both flight directions.

– For the second scenario (redouble intensity of aircraft movements for the year of 2006) the fleet is changed in accordance with Chapter 3 of ICAO Annex 16 Volume 1 and Directive 20002/49/EC [4; 5]. Because of fleet change contours of the noise levels 55, 65 and 75 dBA are very close by their characteristics to the respective contours of the first calculation variant.

– For the third calculation scenario (intensity of aircraft movements equal to the maximum runway capacity, and fleet corresponds with the demands of the Chapters 3 and 4 of ICAO Annex 16 Volume 1) [4], noise levels don't exceed normative levels on the residential areas.

Hence, for the short and mid-term prediction of airport operational conditions (f. e., for the period of 5-10 years, when intensity of aircraft movements doubles in comparison to the years 2005-2006) it is recommended to implement operational measures for noise control, such as optimization of routes for landing and take-off, architectural and constructional methods, specific flight techniques, operational restrictions during nighttime.

In accordance with ICAO and EU requirements [4; 5] for sustainable developments of civil airports it is necessary to, step-by-step, replace noisy aircraft types with the modern aircrafts with better noise characteristics which correspond to the Chapter 3 [4].

The problem of noise contamination around civil airports in Europe and also in Ukraine becomes more acute because most of airports are located close by inhabited localities and thus, as a result causes high environmental pressure on the residential areas. For Ukraine this problem becomes of current importance in a perspective of EURO-2012 because of sharp increase in aircraft movements intensive when acoustical capacity can be a limiting factor for airport development.

This is why the aim of the current investigation is the development of the assessment method of environmental civil airports capacity taking into account operational characteristics and flight safety requirements.

Estimation of runway capacity

Runway capacity is one of the determinative airport capacities. For the capacity's assessment in case of single runway or their combinations it is necessary to use statistical data of number of departure and arrival aircraft.

Arrival and departure intervals between aircraft are calculated as normal random variables. Total time between landings and /or departures, average value and dispersion of time distribution between operations are calculated for a leader and the next aircraft. For the time period (as usual – for one hour) such calculations include the sum of several time intervals. It is also possible to calculate the maximum runway capacity in the same manner.

For assessment of airport capacity with two parallel runways which are located at a distance more than 210 m it is necessary to take into account that the distances between two aircraft operated on different runways are the same as for aircraft operated single runway.

In modeling the inter-departure times on the target runway, we assume that a departure has just occurred on the other runway. To capture the separation times required between two aircraft on the target runway (aircraft of type *i*, following an aircraft of type *j*, which is next to depart), we need to consider also the aircraft of type *l*, which has just departed on the other runway, and the aircraft of type *k*, which is due to depart the other runway after the aircraft of type *j* departs the runway under consideration. The departure sequence is *l*, *j*, *k*, *I* (fig. 1).

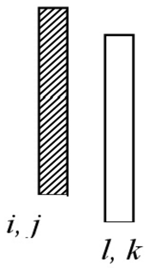


Fig. 1. The order of aircraft take-offs for the two parallel runways:
– target runway;
– non target runway

The results of investigations have shown that for two close runways the total capacity depend not only from average interval between operations, but also from the probability of aircraft operating on the target or the other runway.

Thus, according to the proposed model the runway capacity depends on the two principal parameters – aircraft fleet and time intervals between departures and arrivals.

Impact of aircraft fleet on environmental airport capacity

Let us evaluate operational situation in an airport, for prototype of which operational, geographic and environmental characteristics of Borispol airport that has been chosen, as the most loaded airport in Ukraine. Aircraft types operated are mainly A319, A320, B 737 series, MD-82, EMB-145, also Yak-40, Yak-42, Tu-134 and Tu-154 are still in operation. Borispol airport, just as most of civil airports in Ukraine which are located close by inhabited localities, has perspective constraints of its development in mid- and long-term forecasting by means of acoustical normative requirements.

Noise levels generated in an airport vicinity highly depend on the noise characteristics of aircraft type under operation. For evaluation of effects of aircraft types characteristics on noise levels around the airport two target zones were chosen: under arrival and departure tracks respectively, as it is shown on fig. 2 (contours of noise levels for one landing and take-off (LTO) cycle of Yak-42 aircraft).

Aircraft noise during arrivals and departures was estimated using L_{Amax} criteria (tab. 2). For evaluation of differences in noise characteristics of aircraft types relative index is proposed, which consider relation of noise levels generated at specific point from particular aircraft type against noise levels generated at the same point by the noisiest aircraft type operated in the airport: $L_{Amax}/L_{AmaxMAX}$.

Such kind of relation shows how noisier is one aircraft type in the given operational conditions in comparison with the other aircraft type (for different stages of LTO cycle).

F.e., noise index generated by one take-off of B-734 corresponds to 0,69 compared to Yak-42. Using of such relation allows evaluation of noise characteristics of different aircraft types relative to

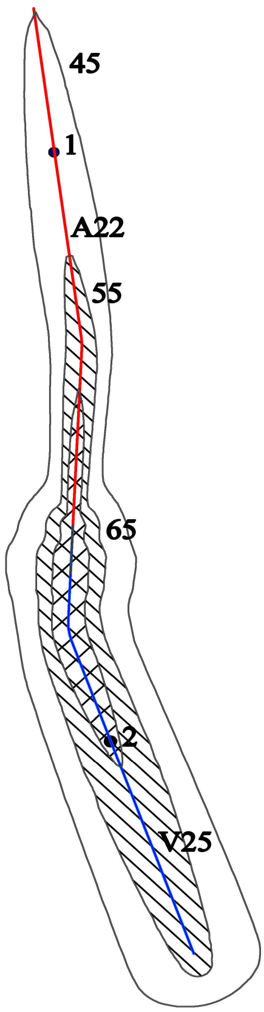


Fig. 2. Contours of the maximum noise level for single landing and take-off cycle of Yak-42:
– 45 dBA;
– 55 dBA;
– 65 dBA;
1–2 target points;
A22 and V25 – arrival and departure routes

Table 2. **Maximum noise levels L_{Amax}, for take-off and landing, dBA**

Aircraft type	Take-off (point 2)		Landing (point 1)	
	L_{Amax}	$\frac{L_{Amax}}{L_{AmaxMAX}}$	L_{Amax}	$\frac{L_{Amax}}{L_{AmaxMAX}}$
B733	47.8	0.72	48.7	0.91
B734	45.8	0.69	48.9	0.91
B735	50	0.75	48.7	0.91
A319	52.2	0.78	52.6	0.98
A320	54.8	0.82	53.8	1.00
Yak-40	62.2	0.94	52.8	0.98
Yak-42	66.5	1.00	50.5	0.94
E-145	47.9	0.72	47.2	0.88
MD-82	60.2	0.91	46.6	0.87

each other by means of using only one criterion. Nevertheless, it should be mentioned that noise characteristic of a single event can not be used for managing of airport acoustical capacity, which is based on analysis of all events during day and night.

Number of LTO cycles significantly influences on sizes of zones at which residential construction is limited. The correlation between size of zones of limiting residential construction for the equivalent noise level L_{AeqD}=55 dBA (daytime normative value) and number of aircraft operated were made. Such graphs allow to define what kind of aircraft generates the worst effect on environment in case of air traffic growth and to evaluate perspectives of airport development. The results of this investigation indicate that for the given operational conditions the equal areas of noise contours L_{AeqD} = 55 dBA for take-off are generated from single operation of aircraft Yak-40 or Yak-42; 15 operations of aircraft types such as B733, B735 or A319; and about 55 operations of aircraft type EMB-145, that allows increasing of capacity respectively. For landing those correlations are different. F.e., the largest areas of noise contours for landing are generated by aircraft types A320 and Yak-42.

In general, derived conclusions corresponds to ICAO recommendations concerning withdrawal of aircraft types which doesn't meet requirements of Chapter 3 [4] and recommendations of EU Directive [5], such as Yak-40, Yak-42, MD-82. Choosing aircraft type for operation at particular conditions it is necessary to take into account such parameters as number of passengers, operational directions, economical and environmental concerns etc.

Assessment of acoustical airport capacity

For predicting of optimal fleet according to demands for increasing of environmental airport capacity it is necessary to take into account series of restrictions such as economical, operational and environmental (such as aircraft noise requirements).

The optimization task is under consideration with ensuring operational restrictions such as a total number of aircraft type and acoustical requirements such as meeting normative noise levels at target zones in the airport vicinity. Problem solving is found by means of linear programming methods.

As an example operational situation at international airport is chosen. As scenario 1 two aircraft type B737300 and A320 are operated during an hour. Each aircraft type perform 20 landing and take-off operations ($Q=20$). Landing is performed using one route ($j=1$).

Solving of this problem of linear programming lies in decreasing number of landings and is equal to $Q=10$ (scenario 2) for each aircraft type. Normative noise levels in critical areas are fulfilled, but the output value of landing operations is halved.

On the other hand, increasing of time interval between arrivals (for scenario 2) allows possibility of performing take-off operations using the same runway. Ensuring flight safety requirements the maximum number of take-off operations is about 55 (scenario 3). Noise contours for this case demonstrate that increasing of take-off operations up to 55 doesn't cause significant extension of noise contour 65 dBA (tab. 3).

Table 3. **Comparison of noise contour areas for different operational scenarios (1–3)**

Scenario	Area of noise contours, km^2	
	65 dBA	75 dBA
1	242,2	43,5
2	222,9	41,2
3	230,4	43,5

The disadvantage of the represented approach is the limitation of optimal problem solving by predetermined conditions.

For determination of the optimal fleet and distribution of aircraft types between routes entropy methods are used [5].

Effects of maximum take-off weight changes on an airport acoustical capacity

Another parameter which can be used for optimization of a runway capacity is a quota for particular aircraft type in total air traffic. This is related to changes of the minimal intervals of safety between aircraft types depending on their Maximum Take-Off Weight (MTOW). Investigations of effects of MTOW (category of aircraft type – light or heavy) on an airport acoustical capacity have shown the following results.

As an example, operation of three aircraft types B737-300, A320 and DCH6 at an airport is considered. Three routes are used for take-off (*j=3*): V21, V25, V23 (tab. 4).

Table 4. **Initial data for scenario 4**

Aircraft type, *i*	Route number, *j*			Total sum
	1 (V21)	2 (V25)	3 (V23)	
1. B737-300	5	5	5	15
2. A320	5	5	5	15
3. DCH 6	5	5	5	15
Total sum	15	15	15	45

The optimization goal is to decrease noise level at the target zone $l=1$ to 65 dBA. At the same time the number of aircraft operations for each route is invariable $D_j=15$, number of aircraft of each type is $Q_i=15$, total number of aircraft operations is $N=45$.

The probable distribution of aircraft types is defined by means of non-modified entropy method [6]. The results of optimization are presented in tab. 5 (scenario 5).

Table 5. **Optimization results for scenario 5**

Aircraft type, *i*	Route number, *j*			Total sum
	1 (V21)	2 (V25)	3 (V23)	
1. B737-300	3	9	3	15
2. A320	3	3	9	15
3. DCH 6	9	3	3	15
Total sum	15	15	15	45

Noise contours for scenario 5 ensure meeting normative noise levels at the target zone. But the largest decrease of noise (to 62 dBA) at the target zone can be achieved by performing scenario 6 (tab. 6).

Table 6. **Optimization results for scenario 6**

Aircraft type, *i*	Route number, *j*			Total sum
	1 (V21)	2 (V25)	3 (V23)	
1. B737-300	0	15	0	15
2. A320	8	0	7	15
3. DCH 6	7	0	8	15
Total sum	15	15	15	45

Hence, operating light aircraft types on the routes which are located close to target zones allows decreasing of noise levels to normative values. This strategy also allows at particular operational conditions increasing of airport capacity by means of minimizing safety time intervals after take-off of the heavy aircraft for the take-off of light aircraft.

It should be mentioned that there could be more than one target zone in airport vicinity [7]. At this case it is necessary to take into account additional restrictions for climb.

By means of modified entropy method (for more than one points) [6] the most probable fleet can be selected. Optimized fleet is presented in tab. 7 (scenario 7).

Table 7. **Optimization results for scenario 7**

Aircraft type, *i*	Route number, *j*			Total sum
	1 (V21)	2 (V25)	3 (V23)	
1. B737-300	4	3	5	12
2. A320	6	4	6	16
3. DCH	5	8	4	17
Total sum	15	15	15	45

Hence, fleet changes allow decreasing of noise levels till normative value equal to 65 dBA in all target zones.

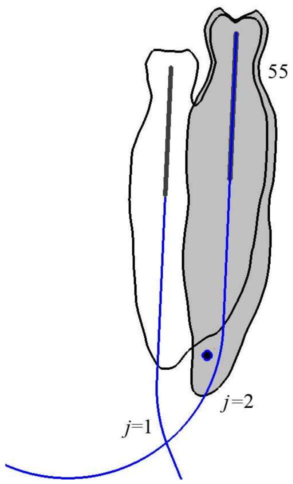
Consequently, by changing of percentage of particular aircraft type in total operation at an airport it is possible to optimize airport operational capacity in accordance with environmental parameters, including requirements for noise levels.

Peculiarities of capacity evaluation for closely spaced runways

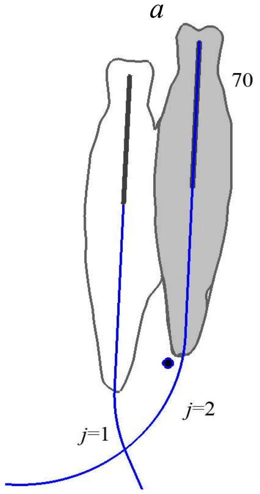
Let us consider the case, when the probability of aircraft operation from untargeted runway tents to zero. At that, 300 aircraft performs take-off from 7:00 till 23:00. Noise contours for the scenario 8 are shown on fig. 3, *a*, fill area.

There is one critical zone covered by contour of noise level which determines zone limited for residential construction (L_{AeqD}=55 dBA). The maximum operational capacities for one hour's duration also as the daily capacity are not yet reached. Though, there are restrictions for equivalent noise levels at the target zone (since, maximum noise levels do not exceed normative values at the target zone, as shown on fig. 3, *b*).

To define optimal proportion of operations from each of two runways can be found by means of entropy method [6] taking into account operational and acoustical constraints.



a



b

Fig. 3. Using of target and untargeted runways:
a – equivalent noise levels for daytime L_{AeqD} =55 dBA;
b – maximum noise levels for daytime $L_{A\max D}$ =70 dBA;
– scenario 8;
– scenario 9;
$j=1$, $j=2$ – flight routes

Scenario 8 assume operation of 300 aircraft of the same type using two routes and performing take-offs from two parallel runways (*N=300, i=1, j=2*). It is necessary to decrease noise levels at the target zone up to normative values L_{AedD}=55 dBA (fig. 3)

Entropy optimization gives the most probable distribution of aircraft between two runways: T_{ij}=150, so the probability of an aircraft operation from each of two runways is equal to 0,5. This case is described as scenario 9, noise contours do not exceed normative values at the target zone (fig. 3, *a*, not filled area).

Evidently from the fig. 3, the area of zone limited for residential construction at the case of two runways under operation is doubled, though the normative values at the target zone are not exceeded. Moreover, the maximum noise levels are not exceeded in both scenarios.

Consequently, selection of the target runway and probability of aircraft operation have an influence not only on airport operational capacity, but also on area and shape of noise contours. In turn, it is possible that such effects can lead to limitation of airport capacity according to environmental parameters, in particular, because of exceeding normative noise levels.

Conclusions

Sustainable development of an airport is significantly effected by airport environmental capacity. Environmental capacity significantly depends on acoustic loading on environment in airport vicinity.

The proposed methodology allows estimation of environmental airport capacity taking into account operational and flight safety requirements.

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