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Development of a cognitive model for the analysis of relationships in the airport environmental management system

Inokentii Horobtsov*

Postgraduate Student, Assistant
National Aviation University
03058, 1 Liubomyr Huzar Ave., Kyiv, Ukraine
https://orcid.org/0000-0001-6890-4370

Larysa Cherniak

PhD in Technical Sciences, Associate Professor
National Aviation University
03058, 1 Liubomyr Huzar Ave., Kyiv, Ukraine
https://orcid.org/0000-0003-4192-3955

Margaryta Radomska

PhD in Technical Sciences, Associate Professor
National Aviation University
03058, 1 Liubomyr Huzar Ave., Kyiv, Ukraine
https://orcid.org/0000-0002-8096-0313

Oksana Tykhenko

Doctor of Technical Sciences, Professor
National Aviation University
03058, 1 Liubomyr Huzar Ave., Kyiv, Ukraine
https://orcid.org/0000-0001-6459-6497

Kateryna Synylo

PhD in Technical Sciences, Associate Professor
National Aviation University
03058, 1 Liubomyr Huzar Ave., Kyiv, Ukraine
https://orcid.org/0000-0003-1333-0351

Abstract. Aviation enterprises (airports) are massive facilities with a variety of effects on the environment, yet, those influences are significantly understudied and lack structuring, leaving the airports at low levels of sustainability and with impaired management. Thus, the aim of this research was to compile the mind map to describe a system of environmental impacts and problems associated with the airports. The model (map) was created by conducting complex multi-stage expert surveys with scoping of elements of airport management system, which identified 68 factors belonging to 8 groups. The factors are related to atmospheric air, soil and water, flora and fauna, physical impacts, organisational, environmental, administrative, logistical and spatial issues, construction and technical solutions as well as social, economic and human factors. With the help of ranking based on experts' judgements, 13 most relevant (key) factors of the impact on the environment were distinguished. To build an oriented graph of the airport management system and

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*Corresponding author

analyse it, the approach of drawing arcs (arrows) of impact was used. It is found that the most influential factors tend to be dynamic, related to the planning stages of airports and instead of purely environmental ones are interdisciplinary. The annual passenger traffic at the airport, compliance with the standards of sanitary protection zones, airport's capacity and types of aircraft received by the airport demonstrated the highest impact on the airport environmental management system. In combination with studies of the effects of individual factors and the impact of the airport on the environment, the results of the work can be applied practically in the management and decision-making processes regarding the environmental safety of the airport

Keywords: mind map; aviation industry; factors of influence; expert assessment; environmental protection; decision-making

Introduction

In ensuring the sustainable development of the aviation industry, an important role is attributed to the environmental vector and compliance with international standards regarding the impact on the environment of both aircraft and airport infrastructure. The impact of airports on the environment is manifested both locally (pollution of the atmosphere, hydrosphere, soil, acoustic pollution, etc.), and in global changes of landscapes and ecosystems, displacement of populations from their natural habitats. Solving a number of current problems in this area at the global level can significantly improve the general environmental situation in Ukraine and the world. However, the aviation industry as a whole, airports as its principal structural units and even individual aircrafts are extremely complex systems with many elements and influencing factors, threats and relationships. It is essential to identify, consider, and analyse the internal connections within those entities and the effects of altering individual elements within them on all other components and the system overall. Thus, the ranking of environmental issues of the aviation industry and its individual divisions, particularly airports, will allow to properly determine the priorities of their solution.

The study of environmental problems of the aviation industry is not a new topic for the scientific community. However, as R. Qiu *et al.* (2021) noted, this topic always remains relevant. For a long time, the main attention of research was given to environmental problems related to airplanes and the process of air transportation itself, and not to the ground infrastructure of airports. A lot of attention is paid only to certain causes and threats that lead to the negative impact of airport infrastructure on the environment. N. Bahman (2023) provided an environmental impact analysis and a life cycle assessment of auxiliary power plants and ground support equipment at the airport, but did not give recommendations for mitigation or management. In turn, V. Parkhomenko (2020) considered the causes and threats that lead to the appearance of birds and other wildlife at the field, but only brief recommendations were given to minimise such collisions.

A significant amount of research is focused on the problem of adverse impacts of an airport's infrastructure on the quality of atmospheric air on a local and regional scale. The problem of regional air pollution by civil aviation airports is discussed in the recent work by O. Zaporozhets *et al.* (2018). But the given strategy of environmental protection regulation involves the organisation of airport's monitoring system, oriented towards the established priorities in regulating the quality of atmospheric air only. Other factors of negative influence are not considered. In conducting this kind of research, it is quite difficult to investigate direct cause-and-effect relationships in this system and establish, in particular, the place of biota in the general objectives of airport environmental management, or to investigate the consequences of secondary effects arising from other impacts as highlighted by F. Greer *et al.* (2020). As a result, threats to the environment resulting from the activities of airports are studied in isolation from each other, either very specifically, that is, with reference to a separate airport, or more generally, analysing all possible environmental consequences.

As noted by R.C. Alberts *et al.* (2023), determining the extent of impact is one of the preliminary stages of environmental impact assessment in environmental quality management. This is important when summarising and assessing the significance of the potential impacts of a project (or activity such as airport construction or operation) and its alternatives (e.g. airport construction alternatives or operating modes). Furthermore, R.C. Alberts *et al.* (2020) emphasised that it also allows to narrow the range of issues that require further consideration and careful assessment, and guide subsequent decision-making processes. E. Zarghami & D. Fatourehchi (2020) argue that impact scoping is often considered very important (sometimes – of utmost importance) in the general practice of environmental impact assessment, but according to K. Emerson *et al.* (2022) it is still understudied.

The later research indicates insufficient attention to the environmental impact of airport operations. While various aspects have been examined individually, there's a lack of efforts to consolidate these factors into a cohesive framework. Such a system could reveal interconnections between environmental issues, offering insights into their mutual influence. To enhance aviation sustainability, creating such a model is a pertinent scientific endeavour. Therefore, developing a comprehensive model of significant airport-environment impacts and their interactions is crucial for a holistic environmental management system (EMS) at airports. The purpose of the study was to develop a cognitive

model of the complex impact of the airport on the environment. To achieve this goal, the following research tasks were defined: to determine the main factors of airport's impact on the environment and evaluate their significance; to develop a cognitive model for the analysis of relationships in the EMS of the airport.

Materials and Methods

The model for the analysis of interrelationships in the EMS of the airport was developed using the method of constructing cognitive maps. This method was proposed by R. Axelrod (1976). This study followed one of the most detailed examples in Axelrod's methodology (Chernyshev *et al.*, 2021). The core of the research was a series of surveys to assess the environmental impact of airports survey by the given methodology, involving experts in the field with special knowledge of certain aspects of the aviation industry. The surveys took place during the first half of 2021 via correspondence (*in absentia*). Overall, 7 experts were questioned. All experts were informed about the anonymity of the survey, the ways of information protection, purpose of the investigation and related risks. They also did not have the opportunity to participate in discussions or meetings regarding their expertise and conducted their evaluations independently. In the course of the surveys, the ethical norms of social work with people were adhered (The ethics of social work…, 1994). Due to the announcement of martial law in early 2022, Ukrainian airports have been closed, making it impossible to conduct the second qualitative expert survey after 2021.

The experts were asked to identify, in accordance with their expertise, the full scope of factors, which influence or form the system of environmental management in airports. Further, with the help of cross-examination, grouping and clustering, the main factors of airport's impact on the environment were determined. 68 influencing factors were identified, which were grouped into 8 categories. The next step was the ranking procedure, during which experts were asked to evaluate the importance of all factors by two independent scales:

- absolute, with values from 1 (the least important variable, the impact of the factor on the state of the environment is insignificant), to 4 (moderately important changes in the environment status and impact), to the highest score – 7 (the change is extremely important, the factor has a significant qualitative and quantitative impact);
- relative, with points from 1 to 100, by the procedure of factor's weight assessment. Given the division of variables into groups, it was recommended in each category to assign 100 points to the most significant impact factor with the greatest weight, and then evaluate other factors in the group relative to this variable.

After ranking, all scores were collected and ordered, rating each factor within a separate group. Based on this, the most significant factors were defined by selecting one to three variables from each category based on the sum of their average absolute and relative scores. In this way, 13 main variables were obtained. The subsequent task was to identify interdependencies between the selected variables and to build the table of interdependencies. For this, once more, experts were asked the following questions: "Is there a connection between these two factors?" and "If dependency exists, what is its nature/quality – is it direct or inverse?" Then, for the processing purposes, all data (answers) were placed in a table with the following symbols: "+" – positive connection, direct impact; "-" – negative connection, reverse effect; "0" – the impact is absent or negligent; "?" – the relationship is uncertain, the nature of the impact is unclear. The following rules were established during this procedure:

- if at least 85% of experts (6 out of 7) believe that an impact (with a certain sign) exists, then there is an impact curve; otherwise, the curve is not drawn;
- the sign of the impact curve is placed only if at least 85% (6 out of 7) of the experts agree on the nature of the influence;
- if there is uncertainty about the nature of an impact, but there is clear certainty (agreement) about its presence among experts – the impact curve is drawn, but marked as unclear ("?");
- if experts' opinions were split (three different opinions or more), the impact curve is not drawn at all.

At the end of the study, a cognitive map was built based on the table of interdependencies, which reflects the system of sources and ways of the airport's impact on the environment from the perspective of their significance.

Results and Discussion

68 factors of environmental impact of airports were initially identified, and were grouped into 8 groups. The 1st group of factors is related to the impact on atmospheric air. It includes the following variables: emissions of NO_x, CO, greenhouse gases, particulate matter, volatile hydrocarbons C_xH_y, other possible pollutants (e.g. SO_2, N_2, O_2, etc.), integral air quality index (AQI) by target pollutants, the nature and scale of interaction of pollutants (persistence, accumulation, magnification, etc.), availability and quality of work of the atmospheric air monitoring service.

The 2nd group of factors is related to the impact on soil and water bodies. It includes the following variables: the area of the territory with a solid cover, pollution of soils and water bodies by heavy metals, petroleum products, anti-icing and de-icing agents, the total quantity and quality of effluents/wastewater, secondary pollution (water pollution via soil or soil pollution via water), the type of affected soils and the class of adjacent water bodies, availability and quality of work of the soil and water monitoring service, the efficiency of the wastewater collection and treatment.

Impact on flora and fauna was the focus of the 3rd group of factors. It includes the following variables: the intersection of wildlife migration routes (especially birds) with airport (or its immediate vicinity), the number of Red

List species in the impact zone, the abundance and density of populations around the airport, the levels of habitat fragmentation and destruction, the types of surrounding ecosystems and ecotopes, the distance to the nearest protected areas (sites), availability of ornithological safety service, availability and quality of functioning of ornithological monitoring service, the overall risk (probability) of introducing invasive or pathogenic organisms into the zone/region due to airport activities.

Factors of the 4th group are related to the physical impacts caused by an airport. They include: levels of noise, light, electromagnetic fields and radiation, heat, vibration, visual pollution, protection from exposure to physical factors outside the airport, effectiveness of protective measures for the control of physical factors.

5th group of factors concentrated on organisational, environmental and administrative decisions. The following variables were included: the amount and composition of waste generated at the airport, the method of disposal of solid waste, the presence of solid waste sorting at the airport, the presence and size of payments for comprehensive impact on the environment, the regularity of inspections of technical equipment and airport facilities, approved environmental policy, the presence and nature of voluntary mitigation measures, the number and complexity of additional services on the territory (aircraft repair and maintenance, accommodation, etc.).

Factors related to logistical and spatial decisions are listed in the 6th group. They include the following variables: climate zone of airport, geological and geographical location of the airport (relief and geological-dynamic situation), social and political situation in the area (political tension in the region, proximity to areas of armed conflicts, etc.), compliance with the standards of the sanitary and protective zone for this type of industrial objects, location of airport relative to the nearest population centres and settlements, types of airport commuting, location of the airport relative to large water bodies (levels of sea/ocean etc.), location relative to important airways/hubs (international and domestic).

Construction and technical solutions made up the 7th group of factors. In this group the following variables are included: environmental friendliness of the airport design (degree of its integration into the environment), number and length of runways on the territory, total size of the airport, types of aircraft served by airport (by take-off weight or passenger capacity), airport capacity (average number of aircrafts received simultaneously, the number of terminals and/or boarding gates), the structure of fuel depot, the type of aircraft refuelling system, depreciation of the airport's ground and air equipment.

Finally, 8th group of factors is related to social, economic and human factors, and includes: average annual passenger traffic at the airport; level of qualification of service personnel; environmental training of the staff; frequency of emergency situations; availability, quantity and quality of environmental advocacy, general level of environmental performance and environmental awareness of the country hosting the airport, the image and popularity of the airport, the level of economic development of the country hosting the airport. The results of ranking, arrangement and selection of the most significant factors in each category are presented in Table 1 and Table 2.

Table 1. Expert assessment of the primary factors of the airport's impact on the environment

Group No.	Factors	Expert assessment													
		Absolute value (from 1 to 7)							Relative value (from 1 to 100)						
		1	2	3	4	5	6	7	1	2	3	4	5	6	7
1	Impact on atmospheric air	6	6	7	7	6	6	6	95	95	100	99	100	83	78
	Availability and quality of air monitoring system	5	7	6	7	5	6	6	85	100	80	100	75	85	76
2	Soil and water pollution by petroleum products	7	7	7	7	6	6	7	100	97	100	98	91	80	98
	Efficiency of wastewater collection and treatment	7	7	6	7	5	7	7	100	98	80	100	59	98	100
3	Intersection of wildlife (especially birds) migration routes with the airport	7	7	7	7	7	7	6	100	98	70	100	100	97	83
	Availability and quality of functioning of the ornithological monitoring service	6	7	6	4	7	7	6	90	100	100	75	99	92	85
4	Airport's noise pollution level	6	7	7	7	7	7	7	90	100	100	100	100	99	93
	Effectiveness of protection from exposure to physical factors	7	7	6	6	6	7	7	100	99	30	94	86	100	100
5	The amount and composition of waste generated at the airport	5	7	6	7	7	7	7	75	100	70	100	98	94	92
	Availability of solid waste disposal methods	7	6	6	6	7	6	7	90	85	60	88	97	76	93

Table 1. Continued

Group No.	Factors	Expert assessment													
		Absolute value (from 1 to 7)							Relative value (from 1 to 100)						
		1	2	3	4	5	6	7	1	2	3	4	5	6	7
6	Compliance with the standards of the sanitary protection zone	7	7	7	7	7	7	6	100	95	100	96	99	100	76
	Location of the airport relative to the nearest settlements	7	6	7	7	7	5	5	100	80	100	92	100	69	73
7	Types of aircraft accepted by the airport	7	7	7	7	7	5	6	100	97	100	95	99	62	76
	Airport capacity	6	6	7	6	7	7	7	90	85	90	87	98	99	95
8	Average annual passenger traffic	6	7	7	7	7	7	7	85	100	100	100	98	100	100
	The general level of environmental performance	7	5	6	6	6	7	6	100	85	70	85	80	96	82

Source: made by the authors

Table 2. The results of the assessment of significance of the primary variable (ordered ranking)

Group No.	Factors	Mean absolute significance according to expert evaluation	Median position (absolute significance)	Mean relative significance according to expert evaluation	Relative significance position (rank)
1	Impact on atmospheric air	6.29	5	92.86	5
	Availability and quality of air monitoring system	6.00	7	85.86	13
2	Soil and water pollution by petroleum products	6.71	2	94.86	4
	Efficiency of wastewater collection and treatment	6.57	3	90.71	9
3	Intersection of wildlife (especially birds) migration routes with the airport	6.86	1	92.57	6
	Availability and quality of functioning of the ornithological monitoring service	6.14	6	91.57	8
4	Airport's noise pollution level	6.86	1	97.43	2
	Effectiveness of protection from exposure to physical factors	6.57	3	87.00	12
5	The amount and composition of waste generated at the airport	6.57	3	89.86	10
	Availability of solid waste disposal methods	6.43	4	84.14	15
6	Compliance with the standards of the sanitary protection zone	6.86	1	95.14	3
	Location of the airport relative to the nearest settlements	6.29	5	87.71	11
7	Types of aircraft accepted by the airport	6.57	3	89.86	10
	Airport capacity	6.57	3	92.00	7
8	Average annual passenger traffic	6.86	1	97.57	1
	The general level of environmental performance	6.14	6	85.43	14

Source: made by the authors

Based on the data obtained in Table 1 and Table 2, the key factors of the impact of airports on the environment were determined – they are 20% (13 out of 68) of all the factors, and are listed in Table 3.

Table 3. Key factors of the airport's impact on the environment

No.	Factors
1	Average annual passenger traffic at the airport
2	Noise pollution level
3	Compliance with the standards of the sanitary protection zone
4	Soil and water pollution by petroleum products
5	Intersection of wildlife (especially birds) migration routes with the airport
6	Availability and quality of air monitoring system
7	Airport capacity (the average number of aircraft received at the same time, the number of terminals and/or departure locations)
8	Availability and quality of the ornithological monitoring service
9	Efficiency of wastewater collection and treatment system
10	The amount and composition of waste generated at the airport
11	Type of aircraft served by the airport (by take-off weight or passenger capacity)
12	Location of the airport relative to the nearest settlements
13	Effectiveness of protection from exposure to physical factors

Source: made by the authors

Having examined the identified interdependencies, a cognitive map (model) was drawn up in accordance with the construction method (Fig. 1). On this model the factors presented in Table 3 are marked with numbers, regular arrows show a positive interaction – a direct dependence, dotted arrows indicate a vague influence which requires additional consideration.

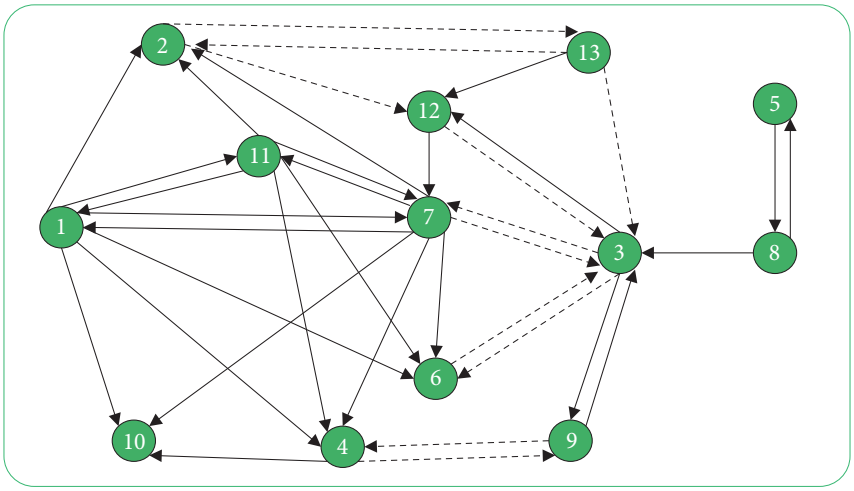

Figure 1. Cognitive model (oriented graph) for the analysis of the environmental situation in the airport impact area
Source: created by the authors

When considering the results of the first stage of expert evaluation (ranking factors by importance), it immediately becomes obvious that most experts consider the factors that are dynamic and/or related to the planning stages of airport facilities to be most important. That is, these are the factors that are not changeable at the existing object, but can be influenced at the stages of planning and construction. Even if the variable is a characteristic of an existing facility, experts also usually prefer those that can be affected in some way during airport operations (e.g. NO_x emissions or noise pollution levels). At the same time, a ratio of 8:5 is observed between purely environmental and interdisciplinary factors. This fact provides important insights into the dependence between the environmental situation in the airport impact area and airport management.

Analysis of relations between individual pairs of factors provides mostly obvious and expected conclusions regarding their interaction. However, for such key factors as 1, 3, 7 and 11 (Table 3) the number of connections and, in particular, the influence on other variables differ significantly. In addition, all these factors are not direct environmental indicators; rather, they are at the edge of environmental components with organisational, technical, logistical, administrative, etc. This means that 4 out of 5 interdisciplinary factors have the highest number of interconnections in the current system. It once again confirms the importance of interdisciplinary factors for the environmental situation in the airport impact area. In turn, most environmental factors are dependent rather than influential, that is, they play certain role in the environmental situation, but their

role is passive and/or indicative, so they must be controlled by influencing higher-order or wider-ranging components. As a result, it is possible to formulate the following conclusions, which are important for analysis, planning and decision-making regarding the management and control of the environmental situation in the airport impact area.

Factor number one is the average annual passenger traffic at the airport. It is related to many environmental factors (such as noise level, water and soil pollution around the airport, NO_x emissions, waste generation, etc.). It also has some direct interactions with other complex factors, such as airport's capacity or the types of aircrafts served. Thus, this variable has significant impact on the environmental situation and contributes to the overall instability of the system (since all the identified relationships of this variable are positive), as well as the complexity of its tangential management (especially the reduction of the value). This means that it needs to be controlled directly, for example by setting limits on its value, in order to achieve the desired environmental status at the airport area. This factor is also the least manageable, as airport traffic is of primary importance to the administration.

Third factor – the compliance with the standards of sanitary protection zones for these objects – has the opposite situation, since most experts recognize its importance for the environmental situation of the airport territory and the overall stability of the system. But this variable has a high level of uncertainty about the nature and quality of its interactions, which, on the one hand, indicates their complexity and dependence on other sub-factors, and on the other hand, provides potential opportunity for their regulation.

The situation is quite similar with factors that took the seventh and the eleventh positions according to relative importance – namely, airport capacity (average number of aircraft received at the same time, number of terminals and/or departure points) and types of aircraft received by the airport (by take-off mass or passenger capacity), which also occupy a prominent place in the overall system, but unlike the factor that took the third position, these factors also have strong destabilising effect on a number of other important environmental indicators, but they could be managed easier by controlling variables that affect them, which to some extent puts them in a somewhat intermediate position.

Significant number of works are dedicated to sustainable aviation and aircraft. However, the consideration of airport infrastructure has begun gaining momentum only recently. As suggested by A. Graham (2023), scientists working in this field are in agreement that such developments call for reconsideration of airport's EMS. Some instances of knowledge generalisation on airport's sustainability and its components were made by I. Karagiannis *et al.* (2019), F. Greer *et al.* (2020) and S. Sreenath *et al.* (2021). All those works provide valuable insights in the structure of environmental management of airports, however they still miss some important points on the environmental part, while concentrating on economic, social and technical-operational ones. Their studies identify and evaluate sustainable practices and dimensions in airport operations giving a thorough overview of environmental, social and economic elements and assessing how they are implemented. Yet, those researches also underline that while there are lots of works on aircraft emissions, greenhouse gases, noise, bird strikes – other environmental and especially interdisciplinary factors still remain unexamined and ill-included.

More practical approaches to comprehensive view on elements of the airport's EMS are suggested in works related to airport design and planning. Research by S.K. Kaya & N. Erginel (2020) suggest a way of assessment and integration of sustainability requirements into the airport planning, yet authors note that this is the sole application, meaning the approach is not really practical in terms of management. Investigation by S.L. Boca Santa *et al.* (2020) is the closest to the given research in terms of results, as they were working on indicators – elements of airport's sustainability, relevant for EMS. Still, instead of modelling they incorporated descriptive methods in order to establish the characteristics. Thus, this and previous works lack the understanding of interrelations between separate factors or their groups, and they do not consider how those connections may affect the whole system. Ukrainian examples by V. Isaienko *et al.* (2019) and D. Kalnytska (2020) suggest a more structured and mathematical approach to administration of the airport's technoecosystem, focusing on management and partially addressing the interactions between different components. Yet they consider only generalised environmental and technogenic parts without an in-depth detailed view on the actual multitudes of factors in those groups.

In contrast with all those previous studies, the given work combines comprehensive analysis of environmental management and sustainability factors, as well as both modelling and expert assessment offering a qualitatively new view on the investigated system. Additionally, the proposed model allows a certain degree of flexibility in depth of examination, which can be reached by increasing the number of relevant elements in the system. All those components were identified and presented in the paper, and more complex models may be built by expanding this research and increasing the number of experts involved.

Here, it is worth noting that application of the methodology of expert evaluations has certain limitations. As mentioned by S. Durst & M. Zieba (2019), the most important are their subjective character and human factor. Expert judgments depend on the qualifications of experts, and in case of expert groups, rely on the assumption that if the majority agrees, the results will be true. But in practice this is not always the case. Thus, the higher the qualification is, the higher the probability of reliable results will be. In order to solve this issue, experienced scientists and environmentalists from the aviation industry were involved in this research.

Another significant limitation is the attitude of experts, who can either take the research and its results very seriously or rather lightly. Additional negative point is the discrepancy of repeated assessments, i.e. same experts may

give different assessments of the same impact factor over time, in case of repeated assessments. O. Boiko *et al.* (2021) suggest that this problem can be managed by incentivizing experts (e.g. remuneration), which was not the case in this study. In this work, the basis for ensuring objectivity was the strict rules of evaluation, work ethics and the responsible nature of experts. If repeated discrepancies occurred, they were usually resolved by repeated assessments, averaging, or identification of discrepancies and their exclusion. While drawing up this study the usefulness of individual repeated assessments was emphasised, although this was not required.

It should also be noted that cognitive maps themselves have certain limitations in terms of application as stated by G. Felix *et al.* (2019). They are quite complex in their design and interpretation, and their complexity increases proportionally to the complexity of the system under consideration. Additionally, there is an increased likelihood of deviations from the original research topic, resulting in a final sign graph that may not accurately reflect the problem intended for research. Finally, cognitive maps are hardly a stand-alone scientific tool, that is, they should not be relied upon as a single comprehensive answer to all questions. These maps may reveal additional aspects of systems or events, structure well-known ones, assist in decision-making or drawing conclusions, but they are not exclusive in nature and should be used as an additional tool to increase reliability and efficiency.

Nevertheless, the developed model allows for new research and decision-making possibilities. Suggested cognitive map lays the foundation for further research of interdependencies between different groups of factors that create the environmental situation in the airport impact area. It also has a great potential to support administrative and managerial decisions. Thus, despite certain constraints the model still proves to be useful, relevant and applicable both from purely scientific and applied point of view.

Conclusions

The given study has focused on the system analysis of airport's environmental impacts, their management and links to sustainability. It also attempted to generalise elements and interrelations of the studied system and create its comprehensive model (cognitive map) for further use in science, decision-making and administrative work. In accordance with the first objective of the paper, 68 most significant and influential system elements, grouped into 8 categories, were established via expert survey and literature analysis, confirming that the airport's EMS is complex and multi-layered. Using the method of expert evaluation, the main elements and factors of airport's impact on the environment were analysed and evaluated by weight and significance and narrowed down to 13 main factors by means of ranking. On the basis of this analysis, a cognitive model of the relationships between the identified factors within the airport management system was created, pursuing the second objective of the research.

Expert evaluation reveals that factors which tend to be dynamic, related to the planning stages of airports and interdisciplinary (instead of purely environmental) have the highest impact on the overall system (with the ratio of 8:5 between environmental and interdisciplinary factors). Key factors – (1) annual passenger traffic at the airport, (3) compliance with the standards of sanitary protection zones, (7) airport's capacity and (11) types of aircraft received by the airport, – exhibit distinct connections and effects, therefore being central to the system. Most environmental factors are passive, necessitating control through higher-order components. Factor (1) significantly impacts various environmental aspects, demanding direct control and management to improve environmental performance. In contrast, factor (3) holds importance but has uncertain interactions, being both dependent and having potential for tangential regulation.

Further research is possible in directions of errors identification and correction, increase in model detail, consideration of individual factors as separate systems, deepening the understanding of their role in the system of environmental impacts of the airport; finding ways to apply the achievements of this research to regulate the environmental situation in the area of influence of the airport.

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Conflict of Interest

None.

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Розробка когнітивної моделі для аналізу взаємозв'язків у системі екологічного управління аеропортом

Інокентій Владиславович Горобцов

Аспірант, асистент
Національний авіаційний університет
03058, просп. Любомира Гузара, 1, м. Київ, Україна
https://orcid.org/0000-0001-6890-4370

Лариса Миколаївна Черняк

Кандидат технічних наук, доцент
Національний авіаційний університет
03058, просп. Любомира Гузара, 1, м. Київ, Україна
https://orcid.org/0000-0003-4192-3955

Маргарита Мирославівна Радомська

Кандидат технічних наук, доцент
Національний авіаційний університет
03058, просп. Любомира Гузара, 1, м. Київ, Україна
https://orcid.org/0000-0002-8096-0313

Оксана Миколаївна Тихенко

Доктор технічних наук, професор
Національний авіаційний університет
03058, просп. Любомира Гузара, 1, м. Київ, Україна
https://orcid.org/0000-0001-6459-6497

Катерина Вікторівна Синило

Кандидат технічних наук, доцент
Національний авіаційний університет
03058, просп. Любомира Гузара, 1, м. Київ, Україна
https://orcid.org/0000-0003-1333-0351

Анотація. Авіаційні підприємства (аеропорти) – це масивні об'єкти з різноманітними впливами на навколишнє середовище, проте, ці впливи досі є недостатньо вивченими, їх розгляду не вистачає структуризації, що спричиняє низьку стійкість аеропортів та погіршує управлінські можливості. Тому метою даного дослідження було скласти когнітивну мапу для опису системи впливів на навколишнє середовище та екологічних проблем, пов'язаних з аеропортами. Модель (мапу) створено шляхом проведення комплексних багатоетапних експертних опитувань зі скоупінгом елементів системи управління аеропортом, у результаті яких було визначено 68 факторів, що належать до 8 умовних груп. Фактори пов'язані з впливами на атмосферне повітря, ґрунти і воду, флору й фауну, фізичними впливами, організаційними, екологічними, адміністративними, логістичними, просторовими, будівельними та технічними рішеннями, а також враховано соціальні, економічні та людські фактори. Експертами виокремлено 13 найбільш релевантних (ключових) факторів впливу на довкілля за допомогою методу ранжування. Для побудови орієнтованого графа системи управління аеропортом та його аналізу використано підхід прокладання дуг (стрілок) впливу. Виявлено, що найбільше на загальну систему впливають фактори, які мають динамічний характер, пов'язані зі стадіями планування аеропортів, а замість суто екологічних є міждисциплінарними. Встановлено, що річний пасажиропотік в аеропорті, дотримання нормативів санітарно-захисних зон, пропускна спроможність аеропорту та типи повітряних суден, які приймає аеропорт, мають найзначніший вплив на систему екологічного менеджменту аеропорту. У поєднанні з дослідженнями впливу окремих факторів та впливів аеропорту на навколишнє середовище, результати роботи можуть застосовуватися практично в процесах управління та прийняття рішень щодо екологічної безпеки аеропорту

Ключові слова: когнітивна мапа; авіаційна промисловість; чинники впливу; експертна оцінка; захист довкілля; прийняття рішень