AIRPORTS AND THEIR INFRASTRUCTURE

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URBAN PLANNING ASPECTS OF AIRPORT RECONSTRUCTION: TECHNIQUES OF THE AIRPORT CLUSTER CONCEPTS EFFICIENCY EVALUATION

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Abstract

The purpose of this paper is to discuss the techniques of evaluating the efficiency of the airport cluster concepts. ***Methods:*** *methods of urban, territorial and transport planning and the fuzzy set theory.* ***Results:*** *the fuzzy system of airport selection for implementation of airport cluster concepts was modeled in uncertainty conditions using the Fuzzy Logic Toolbox. Rule Viewer and Surface Viewer graphic tools were used for developing a fuzzy conclusion system in the interactive mode. It was concluded that the combination of a few factors positive for the project with the expectation of change of the land purpose near the airport reduces the efficiency of decisions to create the airport-cluster with a conditional maximum score of "1" to "0.4".* ***Discussion:*** *airport-centered concepts are still insufficiently investigated in terms of the implementation effectiveness. The use of fuzzy set theory techniques requires a preliminary decomposition of the task within the framework of the airport-centered concept subject to involvement of experts from various fields knowledge. The basis for substantiated expert assessments to construct the membership functions should be a preliminary implementation of a few feasibility tasks.*

Keywords: airport-centered concept; airport cluster; fuzzy theory; urban planning.

1. Introduction

According to the 2013 study [1], the sum of direct and domestic indirect added value (GVA) generated by air transport and airports in the EU is € 249 billion. If indirect GVA from outside the EU is included, this adds the further €49 billion of indirect GVA generated by air transport and by airports. Approximately 1.9 million persons were employed in air transportation, aircraft manufacturing and at airports in the EU28 in 2013. 1.4 million persons are employed in the airport cluster, which includes all activities considered essential for flight operations (including air navigation). 0.9 million persons are employed in the airport-related activities cluster, which includes air transportation activities inside airports and other activities performed in airport campuses (e.g. retail activity).

The airport cluster can be defined as the stakeholders' interaction involving the following organizations: airports and airport associations; airlines and airline associations; aircraft manufacturing; civil aviation administrations; EUROCONTROL and the Civil Air Navigation Services Organization; freight associations; ground-handlers and ground-handling associations; maintenance representatives; temporary work agencies; worker associations; and the Computerized Reservations Systems organizations.

Commercial air transportation has traditionally been a well-regulated sector [2, 3]. Airports form a part of the public sector, being originally built by national, regional or local governments. Consistent with aforesaid, airport management has been a traditional responsibility of the state, either directly or through the civil aviation administration [4]. Over the past

four decades, since the 1980s, there has been progressive movement globally towards:

- progressive privatization of airports;
- commercialization and corporatization of airport management;
- private sector involvement;
- appearance of low cost carriers;
- emergence of hub and spoke networks;
- establishment of global airlines alliances.

The world industry has been changed by transnational alliances and mergers, as well as the bankruptcies of several carriers. While the progressive implementation of the uniform aviation market has been transforming the air transport market, the passenger traffic has grown rapidly, stimulated by new airline business models, a wider choice of air services, and lower airfares in Europe, the Ukrainian aviation market is still in its infancy.

Governments began privatization or restriction of governmental support of airports. Therefore, airports have diversified the sources of revenues, engaging in non-aeronautical business activities. Gradually, they entered in the real estate business in the airport's landside and surrounding lands, leading to the emergence of new *airport-centered concepts*. The most discussed concepts are *airport city*, *airport corridor, airport cluster and aerotropolis* [5].

The purpose of this paper is to discuss the techniques of the airport-centered concept efficiency evaluation for Ukrainian airports.

2. Analysis of Recent Research and Publications

The *airport city model* is based on the fact that in addition to their core aeronautical infrastructure and services, major airports have developed significant non-aeronautical facilities, services and revenue streams. Still, they are extending their commercial reach and economic impact well beyond airport boundaries [6, 7, 8]. At present, airports are important logistics centers, as well as major employers and sites for business contacts. The Hong Kong Airport City and the Amsterdam Schiphol Airport City are examples of the airport city model. The following four critical factors for airport city development were identified by the authors of [5]: connectivity; economic potential of the hinterland; commercial attitude of the airport operator; sustainable development context.

It should be emphasized that the airport taxes have a vital influence on construction aspects of airport expansion. For instance, to meet the future growth of the air traffic and maintain Hong Kong's competitiveness as an international aviation hub, the Airport Authority has decided to expand Hong Kong International Airport according to a three-runway system (3RS). In this regard, airlines started to collect the Airport Construction Fee (ACF) for the 3RS project from departing passengers, charging the same to air tickets issued on or after 1 August 2016. Airlines will charge the ACF to the departing passengers, including the origin-destination and transit/transfer travelers, at Hong Kong International Airport (HKIA). The ACF collection will be in effect until all borrowings related to the 3RS project are fully repaid.

The primary goal of the *airport corridor model* is to develop recommendations to improve safety, mobility, multi-modal accessibility, sustainability, and airport passenger service quality [9].

The *airport cluster* concept usually encompasses an urban complex or a territorial entity located within 20-30 km away from a city or inside the city boundaries. The cluster typically revolves around airport-related technical activity centers, land delimitations and air traffic zones. At the light of the worldwide *cluster* building experience, some historical domestic examples can be found, such as satellite towns, open industrial towns and remote military bases with allocated transport infrastructure.

The Airport Cluster Finland (ACF) is a *cluster* example and case study [10]. ACF is a network of Finnish companies operating in the airport industry. The findings of [10] showed, that one of the biggest challenges in cluster branding is involvement of stakeholders into the branding process. The lack of resources, especially timely investment by the participating companies, makes it difficult to include everyone into the branding process. The cluster manager and other cluster employees play a key role in the cluster branding process. The discussions with airport cluster members also revealed that cluster branding should be the focus, and it is not recommended to create sub-brands under the main brand in the cluster context.

There is still no example of a mature *aerotropolis,* and no relevant research has been conducted, but there are some discussions about planning strategies. This type of development implied a spontaneous, market-driven and entrepreneurial real estate development around airport cities, seeking to capitalize the land-use value added by the airports' proximity [5]. Nevertheless, Kasarda [6] points out the examples of aerotropolis in airports such as Dallas-Fort Worth, Chicago's

O'Hare and Washington Dulles International in the United States; Sao Paulo's Viracopos International Airport in Brazil; Amsterdam's Schiphol and Frankfurt Airport in Europe.

The typical airport cluster planning strategies and layouts are poorly codified and almost non-existent in academic work, thus hindering the technical and economical retrofit or development of airport-related buildings in Ukraine. There are, however, quite many examples of excessive investment into the airport-centered concepts. Since, for instance, there are about 160 airports in France, environmental experts are concerned about the lack of efficiency, poor organization and planning in the airports build before the 1960's. They claim that the outdated functioning system of the airport causes many of them to operate at a loss. There are 84 metropolitan airports engaged in commercial passenger traffic. 66 other airports only fulfill 4.3% of the French passenger transport load. 40 of those account only for 0.3%, i.e. 300 thousand passengers per year. In the 20th century, the urban planning in France as well as in Ukraine has been aligned with military requirements, leading to such an oversized air transportation network. Local communities generally insisted on having "their own airport". However, in the past years, the situation changed and the airports are becoming less profitable. Economic indicators show that those airports are underused and therefore become less profitable. Subsidized airplane tickets require the state to spend on average EUR 100 to 3,500 per passenger. The outlook of 20 French airports is bleak, so the experts agree on their closure. This issue is also reported in the other European countries. The Spanish airport Ciudad Real was initially build with a 4 million passenger capacity and is serving only 100 thousand passengers per year. The cost of this airport construction was EUR 35 billion and as of 2007 its sale price dropped down to EUR 10 billion.

The above examples stress the importance of a methodical approach to the feasibility aspects during planning and reconstruction of airports according to the airport-centered approach.

3. Urban Planning Requirements for Airport Clusters

During the past 20 years, a deep crisis of the air transportation in Ukraine led to a quasi-destruction of this field and closing of approximately 110 military and civilian airfields.

Ukrainian specialists in airfield construction were tasked by the government to create a scientifically proven consensus on reconstruction, renovation and retrofit of the airfield infrastructure in the context of the military operations in the East of the country.

As a result of analysis of the airport cluster's main transportation infrastructure planning strategies, the following results were obtained:

- curved railroad and road axes were observed to be twice shorter than straight ones in the 20th century use of civilian and military airports;
- airports located within 10-12 km away from a town and having two main railroads and a road parallel axis on opposite sides have the lowest amount of the commuting transport and pedestrian traffic. This planning is the most popular in domestic and international, civilian and military airport construction (fig. 1);
- the airports using a perimetrical road and a dead-end railroad structure are characterized by a clear separation between the transportation modes and allow for the most convenient and safest commuting of goods and pedestrians;
- the highest territorial use efficiency and density was observed for the "transportation corridor" airports using the parallel railroad/road infrastructure located at the minimal allowable distance;
- construction of a railroad near an airport proved to be not only unreasonable, but also created unpractical and dangerous conditions for goods and pedestrian traffic. Also, such a structure greatly limits the opportunities for further airport expansion.

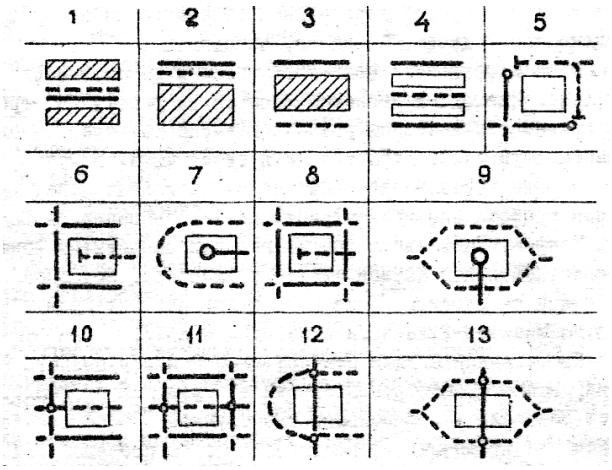

Fig.1. Transportation layout around airport clusters [11]:
1-5 Railroad/road in a parallel setup.
6-9 Railroad/road in a surrounded dead-end setup.
10-13 Railroad/road in intersecting setups.

4. The Technique of Decision-Making about Airport Cluster

Among the known decision-making methods, the most interesting are the ones considering several variables and their probability, and allowing to run different alternative scenarios depending on the chosen criteria. As regards the methods of decision-making in uncertainty, the fuzzy set theory methods best meeting the requirements of universality, consideration of a multicriteral choice in conditions of uncertainty with a discrete or a continuous set of alternatives, and simple presentation of expert information has become the most popular.

Thus, let's consider a universal set of the airport-centered concept strategies $U=\{u\}$. A fuzzy set Q on set U is called a totality of pairs

$$Q=\left\{\left\langle \mu_Q(u),u\right\rangle\right\}, \qquad (1)$$

where $\mu_Q : Q\to[0,1]$ is a reflection of set Q within a single section [0,1], which is used to be called a *Membership Function* (MF) [12, 13].

The value of the membership function $\mu_Q(u)$ for element $u\in U$ is called a *membership degree*. Together with the membership function and degree, the concepts of *linguistic* and *fuzzy variables* are traditionally used. Linguistic variables describe the concepts inherent in human thought. A fuzzy variable is described by set (N,U,Q), where N is the variable name. The values of the linguistic variable may be fuzzy variables, i.e. the linguistic variable is located at a higher level as compared to the fuzzy variable. A set of all possible linguistic variables is called a term set, and any element of a term-set is called a term.

The task of building a MF is set as follows: two sets are given: a set of terms $L=\{l_1,l_2,...l_F\}$ and a universal set $U=\{u_1,u_2,...,u_H\}$. A fuzzy set $\tilde{l}$ used to describe the linguistic term l_f on a universal set U is presented as [9]:

$$\tilde{l}_f=\left(\frac{\mu_{l_f}(u_1)}{u_1},\frac{\mu_{l_f}(u_2)}{u_2},...,\frac{\mu_{l_f}(u_H)}{u_H}\right),\ f=\overline{1,F}, \qquad (2)$$

It is required to determine the degrees of membership of the U set elements to the L set elements, i.e. to find $\mu_{l_f}(u_h)$ for all $f=\overline{1,F}$, $h=\overline{1,H}$.

The task of choosing an investment-attractive project for reconstruction of airports according to an airport-centered concept in terms of uncertainty implies the involvement of many experts, so one of the methods of constructing a MF can be the method based on statistical processing of the judgments of a group of experts.

Let's introduce the following designations: K means the number of experts; $b_{h,f}^k$ means the judgment of the k th expert on availability of properties of l_f, $k=\overline{1,K}$, $f=\overline{1,F}$, $h=\overline{1,H}$ a fuzzy set with u_h element. Let's consider that the expert judgments are binary, i.e. $b_{h,f}^k\in\{0;1\}$, where 1 indicates that u_h element has the properties of a l_f fuzzy set, and 0 that it has not. According to the expert polling results, the degrees of membership in a l_f fuzzy set shall be calculated as follows [14]:

$$\mu_{l_f}(u_h)=\frac{1}{K}\sum_{k=\overline{1,K}} b_{h,f}^k,\ h=\overline{1,H}. \qquad (3)$$

For example, it is required to build the functions of membership of the "fast", "expected", "more or less acceptable", "unacceptable" terms used for linguistic assessment of the variable "payback period of investment in the *Ukrainian airport cluster* project." The conventional results of polling of five experts are summarized in Table 1.

Table 1

Linguistic assessment of the "payback period of investment in the airport cluster" variable

Term		Number of years				
		[5-10)	[10-15)	[15-20)	[20-30)	[30-35]
MF	fast	1	0.4	0.4	0	0
	expected	0	0.6	0.4	0.2	0
	more or less acceptable	0	0	0.4	0.6	0.4
	unacceptable	0	0	0	0.2	0.6

The task of a multicriterial choice is to find a set of the chosen solutions $S(U)$, $S(U)\subset U$ taking into account its prevalence ratio $\succ u$ based on the set f vector criterion reflecting a set of the decision-maker's (DM) objectives .

For example, in the task of choosing an investment-attractive airport-cluster in terms of uncertainty, the following list of input conditions can be considered:
- the possibility of changing the intended use of the land near the airport;
- an investment payback period;
- the average airport profitability over the past three years;
- the projected terms to organize the production and development of service technologies;
- the suitability for development of transport and warehouse infrastructure.

Airport-centered projects are remarkable due to the fact that at the time of decision making there is no complete information on the development of external environment (legal, economic, political, etc.) or the information is vague. The evaluation of alternatives based on these criteria will be of an expert nature and is based on intuitive judgments.

To begin the analysis process, it is required to construct a mathematical model of the decision-making problem, which is reduced to the task of two structures: implementation structure and evaluative structure. The implementation structure reflects the relationship between the alternatives selected and resulting consequences (results). With the help of the evaluative structure, a subjective assessment of the emerging results is carried out according to DM opinion.

Let's suppose that as a result of the marketing analysis the investor chose an investment project involving the investment of free funds in creation of an airport cluster based on one of the Ukrainian airports. This project may evolve in several ways, depending on the airport geographical location. As a result of solution of a series of technical and economic tasks and subsequent discussions with DM, the investor's analysts suggested the following alternatives:

Alternative 1 - airport A;
Alternative 2 - airport B;
Alternative 3 - airport C;
Alternative 4 - airport D;
Alternative 5 - airport E.

The input conditions $(F_1,...,F_4)$ used to evaluate these alternatives were set as follows:

F_1 the possibility of change of a target purpose of lands near the airport: change of the land purpose is not required, then we assign "3" grade; it is required to change the purpose of a private land - "2", if the land is a state or communal property - "1";

F_2 means the investment payback period (see table 1);

F_3 means an average profitability of the airport business for the past three years (the range of 0 to 30 % a year);

F_4 means the projected terms to organize the production and development of service technologies (range from 1 to 5 years);

$n_1,...n_4$ variables will be measured against a basic set of U alternatives.

A fuzzy knowledge base $(d_1,...d_5)$ is formed of the following expressions:

1. When F_2 or F_4 are unacceptable and F_1, F_3 are low for the alternative, it is unsatisfactory (US).
2. When F_1, F_2, F_4 are acceptable and F_3 is low for the alternative, it is satisfactory (S).
3. When F_2 is expected, F_1 and F_4 are acceptable, but F_3 is low for the alternative, it is satisfactory (S).
4. When F_2 and F_4 are expected or rapid, F_1 is acceptable but F_3 is low for the alternative, it is more than satisfactory (MS).
5. When F_1, F_2 are expected, F_3 is acceptable and F_4 is rapid for the alternative, it is perfect (P).

For the further building of rules, the possible values of a set of $n_1,...n_4$ variables and a set of the possible evaluations to be used to evaluate the alternatives in rules $(d_1,...d_5)$ will be determined.

The options of solving the proposed model of the fuzzy airport selection system to create a cluster in terms of uncertainty can be obtained using MATLAB. To do this, enter the input values. For example, one of the options being evaluated has the following input parameters: it is proposed to change the intended use of some privately-owned lands; the estimated project payback period is 20 years; the average airport profitability for the past 3 years was 3%; the estimated time frame for technological improvement of the aircraft, passenger and cargo servicing is 2 years (Fig. 3). As a result of modeling in the created system, we obtain a conventional estimate of 0.47 on the efficiency of decision-making with the maximum possible value of "1". The DM should assess whether the obtained evaluation of the airport cluster establishment is

acceptable or whether it requires the search for other alternatives.

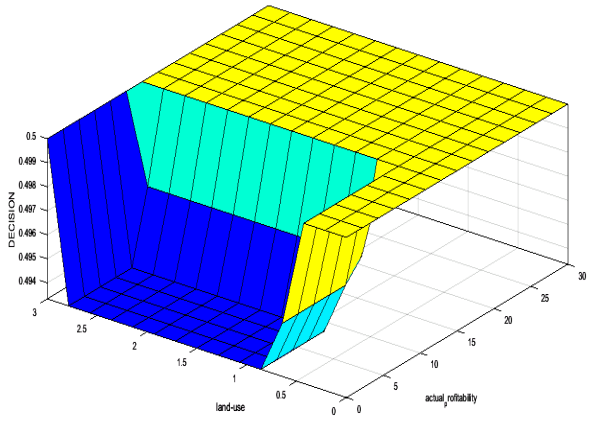

Fig. 3. Decision view example

8. Conclusions

Airport-centered concepts (airport city, airport corridor, airport cluster and aerotropolis) are still poorly investigated in terms of the effective implementation of all transport market participants and market-related transportation, logistic and other services and industries. Given the large size of the task of evaluating the effective implementation of these concepts, a large number of input parameters, a significant ambiguity of the environment, it is recommended to use the method of task decomposition subject to involvement of experts from various fields. A particular attention should be paid to the urban planning requirements with the provision of transport highways maintained by the city, which would link the functional areas of the city and had sufficiently developed relevant infrastructure. The application of the fuzzy set theory during the final processing of input data for a formal assessment of the "efficiency" or "probability" of the decision-making simplifies the process of merging and formalization of expert assessments for the DM.

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Аспекти міського планування реконструкції аеропортів: методи оцінки ефективності концепції аеропорту-кластера

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Метою цього дослідження є представлення методів оцінки ефективності концепції аеропорт-кластер. **Методи:** методи міського, територіального та транспортного планування та теорії нечітких множин. **Результати:** нечітка система вибору аеропорту для реалізації концепції кластеру була змодельована в умовах невизначеності, використовуючи Fuzzy Logic Toolbox. Для розробки нечіткої системи висновків в інтерактивному режимі були використані графічні інструменти Rule Viewer та Surface Viewer. Зроблено висновок, що поєднання ряду факторів, позитивних для проекту, з очікуванням зміни цільового призначення земельної ділянки поблизу аеропорту знижує ефективність рішень щодо створення аеропортового кластеру з умовно максимальної оцінки "1" до "0,4". **Дискусійні питання**: концепції орієнтації на створення аеропорту, як генератора бізнесових процесів міста все ще недостатньо вивчені з точки зору ефективності впровадження. Використання методів теорії нечітких множин вимагає попередньої декомпозиції вищезгаданого завдання та залучення фахівців з різних галузей знань. Підставою обґрунтованих експертних оцінок для побудови функцій приналежності має бути попереднє вирішення ряду техніко-економічних завдань.

Ключові слова: аеропорт-кластер; концепція аеропорту-генератора бізнесу; містобудування; теорія нечітких множин.

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Аспекты городского планирования реконструкции аэропортов: методы оценки эффективности концепции аэропорта-кластера

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Целью данного исследования является представление методов оценки эффективности концепции аэропорт-кластер. **Методы:** методы городского, территориального и транспортного планирования и теории нечетких множеств. **Результаты**: нечеткая система выбора аэропорта для реализации концепции кластера была смоделирована в условиях неопределенности, используя Fuzzy Logic Toolbox. Для разработки нечеткой системы выводов в интерактивном режиме были использованы графические инструменты Rule Viewer и Surface Viewer. Сделан вывод, что сочетание ряда позитивных для проекта факторов с ожиданием изменения целевого назначения земельного участка

вблизи аэропорта снижает эффективность решений по созданию аэропортового кластера с условно максимальной оценки "1" до "0,4". **Дискуссионные вопросы:** концепции ориентации на создание аэропорта, как генератора бизнес процессов города все еще недостаточно изучены с точки зрения эффективности внедрения. Использование методов теории нечетких множеств требует предварительной декомпозиции вышеупомянутой задачи и привлечения специалистов из разных областей знаний. Обоснованием экспертных оценок для построения функций принадлежности должно быть предварительное решение ряда технико-экономических задач.

Ключевые слова: аэропорт-кластер; градостроительство; концепция аэропорта-генератора бизнеса; теория нечетких множеств.

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