Innovative technologies of environmentally sound design exemplified by new airport complex in Western Yakutia

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Abstract. The article considers such a relevant problem as innovative technologies of environmentally sound design of Mirny Airport. Mirny Airport provides air communication with the largest cities of Russia. It is also a reserve airport for transcontinental routes from North America and Europe to Asia. The article develops a methodological approach to the environmentally sound design of Mirny Airport, taking into account low-waste and zero waste technologies. Unlike the existing ones, the design is based on the continuous monitoring of the corresponding technology parameters. A system of indicators for assessing the environmental efficiency of sound airport design, taking into account industrial waste treatment, is proposed. The authors imply the system shall include management efficiency indicators, performance indicators and environmental impact indicators of sound airport design. The theoretical basis of the article includes scientific methodological and theoretical developments of domestic and foreign scientists, theorists and practitioners in the area of environmentally sound design revealing issues related to the adoption of management technologies for minimizing the negative environmental impact by airlines. The following research methods were used in the article: analytical, economic-statistical, monographic, computational-constructive, graphical method, abstract-logical.

Keywords: environmental management, airport construction, environmental risks, environmentally sound design, “green” construction, sustainable development, innovative technologies, Mirny Airport.

1 Introduction

The aggravation of the environmental situation is quite a relevant problem today. Environmental issues are becoming especially urgent during the construction of new facilities. Currently, the existing approaches to the production of building materials as well as their quality are subject to a thorough and detailed analysis. Apparently, these
approaches are being improved and refined in accordance with the requirements of today's environmental standards [1]. Aviation is not an environmentally friendly transport mode while airports are commonly considered to be a poor ecology area. That is why the integral components for the construction of “new generation” airports should include environmental management, environmentally sound design, which will bring about the environmentally friendly manufacture of construction materials [2].

The problems of environmentally sound design are particularly acute in terms of industrial waste recycling considered by the aviation industry. The existing classifications of aviation industry waste do not allow us to qualitatively and efficiently consider the problems of the environmental state of waste from the airport construction industry [3].

Ranging the total aggregated mass of aviation industry waste into waste generation cycles will allow presenting a complete picture of the impressive composition of industry waste as well as the problems of environmentally sound airport design associated with them. Identifying the most promising areas for the use of industry waste will allow the industry to solve a huge list of environmental problems. It will also facilitate the transition to the sound principles of facilities' design in accordance with the standards of environmentally sound airport design which in turn will allow products to increase their competitiveness thus further entering the global market [4].

2 The study goal and objectives

The purpose of the research is to elaborate approaches to the development of methods and innovative technologies for the environmentally sound design of Mirny Airport.

The achievement of this purpose stipulates for the solution of the following objectives:
- analysis of international standards and environmental legislation of airport construction;
- consideration of the European experience in the “green airport” design;
- study of environmental risk management methods in the implementation of airport construction projects;
- analysis of Urban Blue Project as an innovative airport design solution [5];
- providing the classification of methods and innovative technologies of environmentally sound design;
- identification of environmental problems of Mirny.
- giving rationale for the selection of universal methods for the environmentally sound design of Mirny Airport.

The theoretical significance of the research work consists in the fact that the results obtained can facilitate solving the problems associated with negative environmental impacts and faced by airlines [6-8]. By means of proper processing and disposal of industry waste, it is possible not only to reduce environmental costs, but also to obtain additional benefits inherent in the sale of by-products from the industry waste processing. The practical significance of the research work is in the possibility of applying the basic scientific provisions for practical activities and operation, both in airports and regional and the appropriate controlling state supervisory authorities [9].

The developments proposed in the scientific work can be used for teaching such disciplines as: "Management", "Environmentally sound design", "Business economics", "Economics of Environmental Management".

3 Research results

Due to the constantly aggravating environmental situation, the concept of environmentally
sound design is assigned a special significance and importance and gradually becomes an integral part of a new generation company, the primary task of which is not only maximizing profits by any available means, but also taking care of the environment as well as minimizing the negative environmental impact [10]. The introduction of innovative technologies in the construction of architectural space is based on the eco-friendly principles of sustainable development and reduction of human impact on the environment. Building environmentally sustainable facilities is a key task of modern design. The tasks of environmentally sound design can include “the reduction of greenhouse gas emissions throughout the life cycle of the construction facility; adaptation of the territory to climate change; conservation of biodiversity” [11].

The approach to the design and construction of transport infrastructure is changing today. These processes stipulate for the adoption of digital twins (information models) of objects the use of which will not only speed up the design and construction, but also significantly reduce the cost of their construction and increase their operation efficiency. There is an opportunity to manage (from a technical and economic point of view) the life cycle of transport facilities (TF) from the early design stages to commissioning. Foreign researchers have considered methods for assessing the sustainability indicators of Bellagio STAMP and compared environmental certification systems developed for districts. When analyzing the standards (LEED-ND, BREEAMC, DGNB-UD, CASBEE-UD, Green Star Communities), R. Callway identified their similar sections: “management, ease of further use; accessibility of the construction object; reduction of the construction impact on health and nature; reduction of maintenance and construction costs; developed transport infrastructure; economic sustainability; reduction of water consumption” [12]. The adoption of the environmentally sound design in airport construction is due to the following problems and trends identified in the development of the “green” economy (Fig. 1).

In the authors' view, the main tasks of environmentally sound airport design are as follows:
- application of low-waste and zero waste technologies in their activities [13];
- environmental friendliness in the organization of production processes by means of environmentally sound airport design;
- minimization of the human impact on the environment at all stages of the life cycle by means of environmentally sound airport design;
- environmental compatibility of production;
- pursuance of increasing production capacity while minimizing the negative impact on the ecosystem [14];
- building up a reputation of the environmentally friendly production [15];
- using new growth opportunities through environmental constraints;
- support of activities aimed at environment protection;
- ongoing monitoring of the assessment of the ecological and economic condition of the
territories [16];
- optimal management of environmental objects in the market economy;
- assessing the economic impact on natural resources [17].

Environmentally sound design is to protect the environment, reduce the negative impact caused by the air transport infrastructure on the environment and the ecosystem as a whole, promote sustainable use of natural resources, etc. The scientific research defines the functions of environmentally sound design.

The authors believe that environmentally sound design is a purposeful activity of the airport aimed at preserving and improving the quality of the environment based upon the compliance with regulatory and legal environmental parameters operating within the framework of the existing environmental policy.

One of the areas of the environmentally sound design system in Russian airports should be the planning of production activities taking into account low-waste and zero waste technologies (Fig. 2). The recycling of aviation industry waste can not only bring about economic benefits to the air transport infrastructure, but also makes it possible to solve environmental problems through the development of such type of technologies.

![Fig. 2. Proposed principles for planning production activities of sound airport design taking into account low-waste and zero waste technologies.](image-url)

According to the authors, the basis of sound airport design, taking into account low-waste and zero waste technologies, should rely on the ongoing monitoring of parameters that provide low- and zero waste production of air transport infrastructure; this will allow for the timely detection of deviations from compliance with the principles of such production.

The rationale for the feasibility of adopting low- and zero waste technologies of air transport infrastructure is given in Figure 3.

When assessing the impact of the airport sound design activities on the environment, the hazard class group of the production is considered. This information is important and significant for studying environmental issues. In our opinion, this information is not exhaustive enough to judge the negative impact on the ecosystem. At the same time, the use of such information for assessing environmental performance is valuable and significant.

For the sound airport design with the account of the processing of industrial waste, it is necessary to use a system of indicators that will allow an assessment of their environmental efficiency. The indicators relating to economic benefits are supplemented by the authors with those indicators that allow considering cost efficiency as well as additional benefits resulting from the use of environmentally sound design systems by the company. In particular, this includes the effect of the measures discussed in the previous parts of the research work and concerning the use of industrial waste recycling, the application of zero
waste and low-waste technologies.

Fig. 3. Results of the adoption of low- and zero waste technologies of air transport infrastructure based on the principles of environmentally sound design.

The author's methodology (Fig. 4) makes it possible to assess the environmental efficiency of sound airport design, taking into account the specific features of the industry, including industrial waste management.

Fig. 4. The author's system of indicators for assessing the environmental efficiency of sound airport design.

“New airport terminals can be built in accordance with one or another standard depending on the country and the designer's discretion. In addition, there are international ISO standards in place for environmental management (14001), energy management (50001), greenhouse gases (14064), and others that determine the qualitative characteristics of materials and technologies” [18].

Mirny is located in the western part of the Republic of Sakha (Yakutia) and is the center
of the Mirinsky district. The environmental problems of Mirny include the following: land disturbance and insufficient reclamation volumes; incomplete provision of the population with high-quality potable water; low provision of certain town areas with sewerage and wastewater treatment systems.

The construction of an airport complex continues in Mirny. The arrangement of the thermal insulation embankment of the service and technical territory of 500 m³ has already been completed. The buildings and structures of the complex, which are already under construction, will be located here. The Capital Construction Department of JSC ALROSA (PJSC) provides drilling for ramps and front porches, equips a monolithic slab of the air terminal building. Now 105 people and 50 pieces of equipment operate at the facility. The construction is scheduled for completion by the end of 2023.

Mirny Airport is the base airport of ALROSA Airlines, a reserve airport for transcontinental routes and the only airport in Western Yakutia that provides a year-round accommodation of the midrange aircraft of all types.

The site for the construction of a new runway is located 6 km eastwards from the center of Mirny in the undeveloped area. The territory of the airfield complex designed, including the runway along the fence perimeter, the service and technical territory and separate sections of flight radio engineering support, is located outside the boundaries of diamond deposits. In terms of passenger traffic, the airport belongs to Class V, in terms of cargo traffic – to Class III. An airfield of the class “B”. The project framework includes the designed airport complex “Mirny”, including the airfield and elements of the airport structure, with transport and engineering infrastructure and other land plots adjacent to the airport complex lands intended for the airport production purpose.

The economic activity planned in accordance with the project for the construction of Mirny airport, taking into account the environmental measures stipulated, will not have a significant impact on the environmental components in the Mirny area.

Currently, the following types of work are being conducted at the facility:
- construction of the runway (installation of artificial pavements and reinforced roadsides);
- the apron arrangement (earthworks);
- the drainage network arrangement (the drainage ditch arrangement);
- the construction of a patrol road (the construction of an embankment, the layout of the roadbed top, etc.), as well as other types of works stipulated by the project.

While developing the list of environmental protection measures, the following stages were taken into account: an analysis of environmental parameters was conducted, including the assessment of the natural and urban conditions of the area where the object being designed is located; the character of the environmental impact of the object designed, both for the period of construction works and operation, is defined with the account of the data on the purpose and specifics of the object, pollutant emission types and intensity, the parameters of the alleged violation and harm done to the natural conditions in the area, etc.

We will monitor environmental risks in the area of Mirny. All hazardous production facilities (HPF), depending on the level of possible danger for the vital interests of the individual and society in case of accident at this facility, are divided into four hazard classes in accordance with the criteria specified in the Federal Law “On Industrial Safety of Hazardous Production Facilities” [19]:
- Class I – extremely hazardous objects;
- Class II – highly hazardous objects;
- Class III – medium hazard objects;
- Class IV – low hazard objects.

The calculation of the company's danger coefficient is based on determining the ratio of the mass of the pollutant gross emission by the average daily value of the maximum
allowable concentrations of this substance taking into account the hazard class. “According to the magnitude of the hazard category, the territories of the Mirny airport infrastructure are divided into 4 hazard categories in compliance with which the volume and content of the draft standards of maximum allowable emissions for the working territory of the Mirny airport infrastructure are established” [20].

The hazard category of the Mirny airport infrastructure is calculated according to the formula:

\[ \text{COP} = \sum_{i=1}^{n} \left( \frac{M_i}{\text{MAC}_i} \right)^{a_i} \] (1)

where \( M_i \) is the mass of the emission of the i-th substance, t/g; \( \text{MAC}_i \) is the average daily maximum allowable concentration of the i-th substance, mg/m\(^3\); \( n \) is the amount of pollutants emitted on the territory of the Mirny airport infrastructure; \( a_i \) is a dimensionless constant that allows correlating the degree of harmfulness of the i-th substance with sulfur dioxide harmfulness. The value \( a_i \) is a dimensionless value for the substances of different hazard classes is provided in Table 1.

Table 1. The values \( a_i \) values for the substances of different hazard classes.

<table>
<thead>
<tr>
<th>Constant</th>
<th>Hazard class</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>( a_i )</td>
<td>1.7</td>
</tr>
</tbody>
</table>

Table 1 shows the values of \( a_i \) for the substances of different hazard classes. The boundary conditions for dividing the territory of the Mirny Airport infrastructure into hazard categories are given in Table 2.

Table 2. Boundary conditions for dividing Mirny Airport into hazard categories.

<table>
<thead>
<tr>
<th>Hazard category of the territory of the Mirny airport infrastructure</th>
<th>The company's danger coefficient (CDC) values</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>CDC &gt; 10(^6)</td>
</tr>
<tr>
<td>II</td>
<td>10(^6) &gt; CDC &gt; 10(^4)</td>
</tr>
<tr>
<td>III</td>
<td>10(^4) &gt; CDC &gt; 10(^3)</td>
</tr>
<tr>
<td>IV</td>
<td>CDC &lt; 10(^2)</td>
</tr>
</tbody>
</table>

Table 2 shows that, having the CDC > 10\(^6\), the company belongs to the first hazard category, at 10\(^6\) > CDC > 10\(^4\) – to the second, at 10\(^4\) > CDC > 10\(^3\) – to the third one, and at CDC < 10\(^2\) the company belongs to the fourth hazard category. The CDC values are calculated under the condition that \( M_i/\text{MAC}_i > 1 \). “When \( M_i/\text{MAC}_i < 1 \), the CDC values are not calculated and assumed to be equal to zero. To calculate the CDC in the absence of average daily values of maximum allowable concentrations, the values of the maximum one-time MAC, approximate safe level of impact (ASLI) values or the MAC values within the working area reduced by 10 times are used” [21]. The substances with no information on MAC or ASLI provided, the CDC values equal the mass of these substances' emission. The results of the generated waste estimation at the company are provided in Table 3.

Table 3. Estimate waste generated in the area of Mirny.

<table>
<thead>
<tr>
<th>No.</th>
<th>Name of the substance</th>
<th>( a_i )</th>
<th>Hazard class</th>
<th>( M_i ), mg/year</th>
<th>MAC(_i), daily average mg/m(^3)</th>
<th>( M_i/\text{MAC}_i )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Iron oxide</td>
<td>1</td>
<td>3</td>
<td>0.6857061</td>
<td>0.04</td>
<td>17.1426525</td>
</tr>
<tr>
<td>2</td>
<td>Manganese and its compounds</td>
<td>1.3</td>
<td>2</td>
<td>0.0157273</td>
<td>0.001</td>
<td>35.94</td>
</tr>
</tbody>
</table>
Table 3 shows that the substances emitted into the air of the working zone in the area of Mirny exceed the MAC values. In this regard, a system for capturing these substances from the air, separating them from wastewater and processing them more efficiently should be provided at the production site.

\[
CDC = 17.1426525 + 35.94 + 64.108 + 22.66034 + 4.871944 + 0.158 + 6.710625 + 0.542 + 0.176 + 0.7194 + 6.0345588 + 14.068 + 0.00013824 + 0.50544 = 242 \ (10^4 > COP > 10^2)
\]

In accordance with the criteria specified in the abovementioned Federal Law, the company belongs to the III\textsuperscript{rd} hazard category. The category III includes objects that have a minor negative environmental impact. The territories of the Mirny airport infrastructure of the III\textsuperscript{rd} hazard category are the most numerous, however, they generally account for no more than 10% of all emissions. The substances emitted, in particular, belong to the III\textsuperscript{rd} and IV\textsuperscript{th} classes of “low-hazard” pollutants [22]. Based on the results of the values obtained, we suggest improving the air purification system emitted into the environment to retain the released harmful substances and reapply them in the industry and introduce a system for cleaning liquid waste containing harmful substances for their secondary use.

At the same time, the main tasks of the aviation industry for the infrastructure of Mirny Airport remain the following: safety improvement, efficiency of production processes and quality of service. The digitalization of various airport operation aspects is one of the great objectives the aviation industry needs to achieve. The main vector of development and the final goal is to combine a set of operating processes within a single system based on the artificial intelligence (AI).

The Russian experience already includes the solutions typical for the “smart airport”. In the most general form, these are IT systems using AI and machine learning capabilities that distribute the set and priority of tasks for the specialists of the ground services of the Mirny
airport infrastructure. They allow for smart monitoring of various components that affect the operation of a particular runway, the work of the airfield service and the airport as a whole. Everything is interconnected; the airport is a single organism. For example, the icing of the runway occurs and there is no possibility to accommodate flights, the chain of normal operation is disrupted, and every participant is affected, from baggage services and passport control to taxi drivers.

For the Mirny airport infrastructure, it seems relevant to maximize the use of land plots allocated for the airport construction, the execution of construction works, the storage and movement of materials, the placement of soil dumps within the plots whose boundaries are taken out and fixed on the ground. Also, when storing bulk construction materials, the work is accompanied by the implementation of measures to prevent their erosion because of rain and meltwater, reduce dust formation in the area of open storage of construction materials; each vehicle involved in construction is subject to frequent engine testing for exhaust gas toxicity.

To minimize the acoustic impact during the construction works, it is assumed construction shall be executed exclusively during the daytime; for the period of operation, the use of low-noise civil aviation aircraft is provided with the preservation of existing aircraft flight routes. When implementing design solutions and to avoid the formation of additional environmental impacts, the work will have to be conducted in strict compliance with the project documentation subject to state expert appraisal.

4 Conclusion

Thus, the authors specify the concept of “environmentally sound design” in the research work. A characteristic feature of this design is the assessment of the environmental impact of the economic activities taking into account their ecological and economic condition. They propose a methodological approach to the airport production activities' planning with the account of low-waste and zero waste technologies. A system of indicators for assessing the environmental efficiency of the airport is proposed, taking into account waste recycling on the territory of the Mirny airport infrastructure.

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