Maritime airports in Japan: location and construction features

M.I. Amosov, S.S. Safina, and E.M. Tolmacheva

1 St. Petersburg State University, Universitetskaya nab., 7/9, 199034, St. Petersburg, Russia
2 St. Petersburg State University of Economics, 191023, St. Petersburg, Russia

Abstract. The article deals with the experience of creating airports on artificial islands in Japan. On the basis of ministerial and departmental statistics, available on the Statistics Bureau of Japan portal and on the websites of regional services of individual prefectures, the role of these airports in solving the country's transport problems is considered. A definition of a maritime airport has been formulated and their share in the total number of airports, passenger and cargo turnover of all airports in the country has been determined. The peculiarities of seaports localization are revealed. The main phases of Kansai airport construction and the "three airport problem in the Kansai region" are considered.

1 Introduction

Japan has advanced experience in solving transportation problems due to the need to adapt the industry's modern infrastructure to the country's very challenging natural conditions (location on islands, predominantly mountainous rugged terrain, volcanism, earthquakes, frequent typhoons, etc.). Japanese engineers have been working for decades on technologies to overcome the complex natural obstacles that arise during the construction of cities and transport systems. One of the techniques used in Japan is the creation of reclamation areas (including artificial islands). Thanks to their creation, it became possible to create new industrial objects and residential areas, to realise complex infrastructure projects in the field of transport, including maritime airports.

The purpose of this paper is to identify the location patterns and characteristics of the construction of airports created in Japan in the place of sea areas transformed into land.

2 Materials and methods

The term "maritime airport" requires clarification. According to the "Air Code of the Russian Federation" from 19.03.1997 N 60-FZ (ed. from 19.12.2022), an airport is a complex of facilities including an airfield, air terminal, other facilities designed to receive and dispatch aircraft, service air traffic and having the necessary equipment for these purposes [1-21].

According to Japanese Law No. 80 of 1956, "Airport Law," Article 2, the term "airport" means any airfield for public use, except "joint airfields" with the Japan...
3 Results

Maritime airports are among the most important in Japan. In such a large country, and also located on several islands, the main task of air transport is to connect major urban agglomerations with each other as well as with distant and peripheral cities and islands. Equally important, Japan's air transport is the primary means of international passenger communication.

The prefectures in Japan's Pacific Industrial Belt (PIB), which includes the southern coast of Honshu, stretching from Tokyo to Shimonoseki, and the northern coasts of Shikoku and Kyushu, are particularly difficult. PIB is the most convenient part of Japan for settling and economic development, it is a low-lying coastal strip from 15 to 65 km wide, sandwiched between mountains and ocean. If average population density in Japan is 336 persons/km², then in some prefectures of PIB it is much higher: Kanagawa - 3,823 persons/km²; Aichi - 1,458 persons/km²; Osaka - 4,639 persons/km². The Tokyo metropolitan area is the leader in this indicator with a density of 15,510 persons/km² [1]. The PIB is characterized by a shortage of suitable and affordable land that can be used for residential and commercial purposes. According to [3], the leaders in terms of land cost per square meter are Tokyo metropolitan area (land cost 1,133 thousand yen/m²) as well as Osaka (317), Kyoto (262), Aichi Prefecture, where Nagoya city is located (208), Fukuoka (180). However, there is a wide variation in land values for residential and commercial purposes. Figure 1 shows the trend in the estimated value of land (“chika-koji” - literally, normative/basic land price) from 2013-2020. Since 2014, the value of commercial land has begun to significantly outpace the increase in the value of land intended for residential development. This has been a favourable factor for the creation of ‘expensive’ reclamation land for commercial purposes (transport, trade, tourism, etc.) [11].
Over the past decade, maritime airports have led the way in many respects. Analysis of 2018 statistics from the Ministry of Land, Infrastructure, Transport and Tourism shows that maritime airports rank 1, 3, 8, 13, 14 and 21 in terms of international and domestic passenger traffic; their total passenger turnover exceeded 135 million people per year (Table 1). The share of maritime airports in the total number of airports in Japan with a passenger turnover exceeding 1 million people per year (30 airports) is about 20% and 44.11% by passenger turnover volume. The undoubted leader in passenger traffic is Haneda Airport (Tokyo Prefecture) with passenger traffic volume exceeding 85 million people, which has 4 runways and 3 passenger terminals. It is also only 15 km from the city centre, making it easily accessible. Haneda Airport was built in August 1931 on an island off the west coast of Tokyo Bay. Previously, the land was a tidal strip that had been dried up as early as the 19th century [13]. Thus, Haneda became the first large seaport in the world. It now has the largest land area (15.22 km²) of any maritime airport in Japan.

Table 1. Passenger traffic (international + domestic), 2018

<table>
<thead>
<tr>
<th>Rank among airports in Japan</th>
<th>Airport</th>
<th>Prefecture</th>
<th>Number of passengers (persons) per year</th>
<th>Year of opening, year</th>
<th>Territory area, km²</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Tokyo International Airport (Haneda Airport)</td>
<td>Tokyo</td>
<td>85 487 929</td>
<td>1931</td>
<td>15.22</td>
</tr>
<tr>
<td>2</td>
<td>Kansai International Airport</td>
<td>Osaka</td>
<td>29 312 339</td>
<td>1994</td>
<td>10.5</td>
</tr>
<tr>
<td>3</td>
<td>Chubu International Airport</td>
<td>Aichi</td>
<td>12 344 628</td>
<td>2005</td>
<td>4.70</td>
</tr>
<tr>
<td>4</td>
<td>Nagasaki Airport</td>
<td>Nagasaki</td>
<td>3 269 487</td>
<td>1975</td>
<td>3.6</td>
</tr>
</tbody>
</table>

Fig. 1. Dynamics of land valuation "chika-koji" for the period 2013-2020 in Japan, national average.
For freight transport, which is an important export component of Japan's economy, maritime airports are also in the lead. According to Table 2, "sea" airports are ranked 2, 3, 5, 11, 14 and 25 for 2020. According to statistics from the Ministry of Land, Infrastructure, Transport and Tourism [8], maritime airports such as Haneda International Airport (Tokyo) - 31.9%, Chubu International Airport (serving Nagoya City and others) - 38.7%, Nagasaki and Kitakyushu airports - 149.6% and 75.7% showed the highest growth rates from 2018 to 2020. The role of maritime airports in transporting cargo is growing steadily, especially high value-added or particularly valuable and perishable cargo. They are gradually "taking away" these types of cargo from maritime transport.

Table 2. Cargo turnover of Japan's maritime airports, 2018-2020. Compiled by the authors according to [8].

<table>
<thead>
<tr>
<th>Rank</th>
<th>Airport</th>
<th>Prefecture</th>
<th>Cargo volume (tonnes)</th>
<th>Growth rate %</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Tokyo International Airport (Haneda Airport)</td>
<td>Tokyo</td>
<td>1 271 143</td>
<td>31.9%</td>
</tr>
<tr>
<td>3</td>
<td>Kansai International Airport</td>
<td>Osaka</td>
<td>828 662</td>
<td>-8.1%</td>
</tr>
<tr>
<td>6 (5)</td>
<td>Chubu International Airport</td>
<td>Aichi</td>
<td>214 434</td>
<td>38.7%</td>
</tr>
<tr>
<td>12 (11)</td>
<td>Kobe Airport</td>
<td>Hyogo</td>
<td>57 903</td>
<td>-21.2%</td>
</tr>
<tr>
<td>15 (14)</td>
<td>Nagasaki Airport</td>
<td>Nagasaki</td>
<td>13 309</td>
<td>149.6%</td>
</tr>
<tr>
<td>18 (25)</td>
<td>Kitakyushu Airport</td>
<td>Fukuoka</td>
<td>8 107</td>
<td>75.7%</td>
</tr>
<tr>
<td>Total (maritime airports)</td>
<td></td>
<td></td>
<td>2 393 558</td>
<td>18.2%</td>
</tr>
<tr>
<td>Total (30 airports in Japan)</td>
<td></td>
<td></td>
<td>5 650 866</td>
<td>18.5%</td>
</tr>
<tr>
<td>Share of maritime airports in cargo traffic (6/30)</td>
<td></td>
<td></td>
<td>42.36%</td>
<td></td>
</tr>
<tr>
<td>Share of maritime airports in the number of airports (6/30)</td>
<td></td>
<td></td>
<td>20%</td>
<td></td>
</tr>
</tbody>
</table>
Kansai International Airport consists of two parallel runways of 3.5 km and 4.0 km in length. The airport is connected to the mainland by a 3.75-kilometre bridge, known as the "Kansai International Airport Access Bridge" at a cost of about $1 billion. It is a two-storey bridge carrying six lanes of traffic with two railway lines below. Construction of the bridge started in 1987 and was completed by 1994 (Figure 2).

Fig. 2. Schematic diagram of Kansai International Airport in the 2nd phase of construction. Compiled by the authors according to [9].

The sea depth in the area where the Kansai airport was built was between 18 and 19.5 m. Soil brought from Wakayama and Hannan towns (Osaka Prefecture) and from the Mount Tsuna area of Awa-ji Island (Hyogo Prefecture) was used to create land in 'Phase 1'. In the second 'phase' the island was expanded by moving soil from the Tanagawa and Sennan areas of Osaka Prefecture and from Awaji Island in Osaka Bay. The volume of soil displaced from Honshu Island was about 27 million cubic meters and from Awaji Island 11.5 million cubic meters. [6].

A belt conveyor was installed to transport the soil from the extraction site to the pier, and then the soil was transported by sea when the land was created for the Kansai airport. According to Japanese reports, a specially built vessel equipped with an opening bottom was used. This device made it possible to quickly unload the soil at the required location, which accelerated the process of creating artificial islands [16].

The main technical problem in embanking the islands was the state of the ground under water. The main material used in construction was clay, which contained up to 70% water. To cope with this problem, Japanese engineers used sand drains—pipes hammered into the clay and packed with sand. When the pipes are removed, the sand absorbs the water contained within the clay, increasing its strength. In total, more than 2 million sand drains were installed during the construction of the Kansai airport.

Mountains that were used in the process of land and rock excavation have been fully or partially torn down over large areas. These areas are now being used for housing development or for the creation of solar power plants. The most famous example of reclamation at a site where rock quarrying took place is the Awaji Yumebutai ("Awaji Yumebutai") complex on Awaji Island. The complex includes a conference centre, a hotel, an outdoor amphitheatre and extensive garden and park spaces [16]. "Awaji Yumebutai" is the island's main tourist attraction.
The construction of Kansai International Airport has had both positive and negative effects on the Japanese government. Among the benefits are: reduced pressure on existing airports, increased international traffic (some existing airports on the mainland handled only domestic flights), development of the Kansai region as a whole (construction of the airport has served to increase the investment appeal of the region). An important environmental problem in urban areas has been solved: reducing aircraft noise and air pollution by building airports on reclaimed land.

However, a number of disadvantages should also be noted: the possibility of soil subsidence was not fully taken into account during construction, which in 2001-2002 affected the subsidence of islands and their flooding; the islands are exposed to frequent typhoons, one of the last of which occurred in 2018 and caused severe financial damage [6].

A separate disadvantage is highlighted by the so-called “three airport problem of the Kansai region”. “Kansai”, “Itami”, and “Kobe” are 3 airports within 20 kilometres of each other (Figure 3). As local economic conditions have become increasingly difficult, the three airports compete for domestic demand. As of 2020, the Kansai maritime airport is ahead of the other two airports in the region of the same name in both passenger turnover (63%) and cargo turnover (82%). It is significantly behind two other airports in the region, Itami Airport (30%, 13%) and Kobe Maritime Airport (7, 5%). They are also inferior in terms of maximum runway length (3000 m, 2500 m) (Table 3).

Fig. 3. The problem of three airports in the Kansai region. Compiled by the authors according to [9].

Table 3. General characteristics of three airports in the Kansai region. Compiled by the authors according to [8].

<table>
<thead>
<tr>
<th>Airport</th>
<th>Category</th>
<th>Year opened</th>
<th>Maximum runway length, m.</th>
<th>Passenger traffic, % 2018</th>
<th>Cargo turnover, % 2018</th>
</tr>
</thead>
<tbody>
<tr>
<td>Itami</td>
<td>Ashore</td>
<td>1939</td>
<td>3000</td>
<td>30%</td>
<td>13%</td>
</tr>
<tr>
<td>Kansai</td>
<td>Offshore</td>
<td>1994</td>
<td>4000</td>
<td>63%</td>
<td>82%</td>
</tr>
<tr>
<td>Kobe</td>
<td>Offshore</td>
<td>1997</td>
<td>2500</td>
<td>71%</td>
<td>80%</td>
</tr>
</tbody>
</table>
According to the latest reports, a plan to internationalize Kobe Airport will be launched after Expo 2025 Osaka-Kansai. Kobe Airport has been restricted to domestic flights in order to strengthen the international competitiveness of Kansai Airport, but the relevant local authorities have agreed to internationalize it as a 'complementary Kansai Airport'.

International scheduled flights will arrive and depart from Kobe Airport up to 40 times a day around 2030, while occasional international charter flights will be available as early as 2025.

4 Discussion

The creation of reclamation areas through land reclamation has been repeatedly considered by economists and lawyers, and by specialists in earth sciences and engineering technology. Japan's experience of creating maritime airports has been extensively used in other countries, especially in East and Southeast Asia [18, Emura Tsuyoshi and Tabata Takechiho]. Shimoyama's work [17, Kenji Shimoyama] stresses that the artificial islands and island constructions that are indicated in articles 56, 60 and 80 of the UN Convention on the Law of the Sea, should be built in the internal territorial waters and the exclusive economic zone, which are under the sovereignty of the considered state.

As the calculations we have published earlier [20, Amosov, Safina, Tolmacheva] have shown, in Japan, in functional zoning of the man-made islands, priority is given to location of industrial and transport infrastructure facilities (75%), and 25% is given to the non-production zones (residential quarters, parks, museums, office centres, shops). The priority in creation of reclamation land is given to the PIB region, which is the main industrial construction area and is characterized by high population density [20, Amosov, Safina, Tolmacheva]; it is also where the cost of land plots is the highest. A summary of materials on maritime airports in Japan, carried out in this paper, shows that all of them were created by draining the sea areas off the coast of southern Honshu and are located in the PIB region.

Retrospective analysis of Japanese artificial islands and sea cities for the period of 1950-1990 made by R. Pernice [15] shows, that more active creation of land reclamation areas was caused by the lack of flat areas for new construction in central parts of cities, and also by the necessity of renewal or improvement of existing transport infrastructure. One of the solutions to the problem both during that period and in the following years was the construction of maritime airports to be built on the reclamation territories [19, Amosov, Safina]. It was created at a time when the airports operating on natural land could not cope with the increasing growth of passenger and freight traffic, and also occupied valuable areas that could be used for urban development (construction of housing, industrial facilities, etc.). Among the publications concerning maritime airports in Japan, Kansai Airport has received the most attention [18]. A comparison of it with airports located on the island of Honshu (Itami Airport) reveals the advantages of maritime airports. They include round-the-clock operation of the complex without restrictions on the noise level [23, Shabiev, Stupin], unlimited possibilities of lengthening the runways, and the absence of obstacles (mountains and high-rise buildings) when approaching or taking off aircraft. In the Japanese context, an additional advantage is the possibility of building up the levelled terrain that occurs at rock extraction sites used in the construction of artificial islands. That said, the cost of building the Kansai airport is high, at $15bn, where the main expense item besides construction is controlling island subsidence, which leads to high landing costs for planes. For example, the airport charges $7,500 per Boeing 747, the second-highest cost after Tokyo's Narita Airport. However, according to financial experts, by 2024, all the costs of building Kansai Airport...
5 Conclusions

This study has shown that Japan is building unique infrastructure facilities, i.e., maritime airports, to solve transport problems. The study has shown that Japan is building unique infrastructure facilities, maritime airports. Their construction has been made possible by the new technology of Japanese engineers to overcome natural barriers to economic consolidation of the country through transport highways and intensive air service (maritime and land-based airports). The country has seen a steady increase in the number of maritime airports. They account for around 20% of the country's passenger traffic (over 44%) and cargo traffic (over 42%) and have a significant role to play. The main advantages of such airports are: no restrictions on runway lengths, no obstacles on approach (mountains and high-rise urban developments), and round-the-clock operation without restrictions on noise levels. In addition, the creation of maritime airports makes it possible to free up flat areas of natural land for other purposes, very valuable in Japanese conditions. The main problems in the construction of maritime airports are: high construction costs and damage to aquatic biological resources, and natural disasters (floods, typhoons).

The priority for the creation of maritime airports is given to the Pacific industrial belt and the Inner Japan Sea with a high concentration of industry and population density. In conclusion, the authors consider that the creation of maritime airports will tend to increase due to the country's high involvement in globalization processes and the large volume of high-tech products produced and exported. Maritime airports contribute to solving the country's problems with a shortage of flat land, reducing the pressure on existing land-based airports, increasing international and domestic traffic, and increasing the investment attractiveness of its regions.

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