Assessment of connectivity of Russian cities with passenger air transport links with Mongolia and China

I A Dets
Sochava Institute of Geography, Siberian Branch, Russian Academy of Sciences, Irkutsk, Russia
E-mail: igordets@ya.ru

Abstract. Aviation passenger traffic is becoming increasingly important in international economic relations. The development of the China-Mongolia-Russia economic corridor is no exception. Despite the fact that the media focuses on projects for the construction of the new high-speed Railways and oil and gas pipelines, a significant part of economic cooperation is implemented through air transport links. The study examines all the air routes between Russia and China, as well as Russia and Mongolia, available in the peak summer schedule of 2018. All routes connect 13 cities in Russia and 30 cities of China and the capital of Mongolia, forming a separate air corridor between the three countries studied. The population of cities is certainly one of the essential factors determining the level of development of aviation ties. Nevertheless, other factors play an important role: the high centrality of the Russian economy, the dominance of the Moscow air hub as a transfer point, the weak development of interregional air transport and others. Among the identified trends, it is a high proportion of flights to Irkutsk from Mongolia and China — with not so significant economic potential of the city, the main factor determining the leading position of the city was the tourist attraction of the region for travelers from the countries in the study.

1. Introduction
The intensive development of economic and social relations in the economic corridor "China-Mongolia-Russia" is reflected in the increase of transport links between the states. In recent years, the construction of the first oil trunk pipeline connecting Russia and China ("Eastern Siberia — Pacific Ocean" with a branch to China) was completed, the construction of the "Sila Sibir" ("Power of Siberia") gas pipeline and bridges across the Amur River was started. Other projects linking China and Russia, including the development of freight and passenger transport by high-speed rail, are also being discussed. The discussion of the perspective construction of gas transport infrastructure on the route Russia-Mongolia-China has also started. A significant part of the transport projects is supported by the Chinese initiative "One Belt and One Road".

Nevertheless, passenger traffic, currently mainly aviation, remains a vivid reflection of the existing economic ties between the territories. Passenger aviation flows illustrate the existing network of connections, its saturation, and highlight the cities important for economic relations within the framework of the economic corridor being formed. Undoubtedly, it is not an easy task to divide passenger traffic into tourist and business traffic, which have different economic significance. Nevertheless, it should be taken into account that tourist flows not only do create the potential for
economic growth of territories, but also form a common cultural image of countries, contributing to the development of further international cooperation.

2. Data and Methods

For the purposes of the study, all Russian airports with regular flights to the airports of Mongolia and China were selected. The largest number of regular flights in 2018, as in previous years, fell on the period from May to October, due to the more intense tourist flows in the summertime (the most frequent flights are in June, July and August). In the schedule of each airport, the weekly frequency of flights in different directions was analyzed, and adjacent flights were carefully verified. A fragment of the generated database is presented in Table 1, which shows the number of flights (one way) for the 4 most intensive destinations between Russia and China / Mongolia (more than 20 flights).

**Table 1.** Number of weekly flights (one way) between Russian cities and the most connected cities of China and Mongolia.

| People's Republic of China | Mongolia | All flights to these cities |
|---------------------------|----------|----------------------------|
| Beijing                   | Shanghai | Urumqi | Ulaanbaatar |
| Moscow                    | 41       | 28     | 9     | 10 | 88 |
| Saint-Petersburg          | 7        | 10     | 4     | -  | 21 |
| Yekaterinburg             | 4        | -      | -     | -  | 4  |
| Novosibirsk               | 10       | 1      | 6     | -  | 17 |
| Krasnoyarsk               | 2        | -      | -     | -  | 2  |
| Irkutsk                   | 11       | 2      | 2     | 8  | 23 |
| Ulan-Ude                  | 2        | -      | -     | 2  | 4  |
| Chita                     | 2        | -      | -     | -  | 2  |
| Khabarovsk                | 2        | -      | -     | -  | 2  |
| Vladivostok               | 6        | 2      | -     | -  | 8  |
| All flights to Russian cities | 81   | 41     | 21    | 20 | -  |

Among Russian cities, only 13 have scheduled flights with China and Mongolia in the summer flight schedule in 2018. Flights connect Russia with 30 cities in the PRC and the capital of Mongolia, i.e. on average, each Russian city accounts for 2.38 cities in China and / or Mongolia. In fact, the number of connections varies from 1 to 23 cities in the presence of only three cities with more than five connections (Moscow — 23, Irkutsk — 12, Novosibirsk — 6). St. Petersburg, Krasnoyarsk, Vladivostok and Khabarovsk had links with four cities; the other half of Russian cities had fewer connected points. Chinese cities have significantly lower connectivity rates to Russian cities, as the average number of connected cities is 2.3. The distribution of the number of routes between Chinese cities is less centralized: most Chinese cities are connected with one city in Russia. Only a few cities have more connections: Hong Kong — 4, Urumqi and Shanghai — 5, Harbin — 6, Sanya and Beijing — 9. Ulaanbaatar is connected with only 3 cities in Russia.

The apparent imbalance in the connectivity of cities is even greater when taking into consideration the weekly number of flights. The average number of flights per week for Russian city is 22.9, but of the total number of flights is about 300, almost half is in Moscow (49.4%). Irkutsk, which has half the number of connected cities, provides almost 3 times fewer flights per week (18.2%), and St. Petersburg and Novosibirsk have almost equal number of flights per week (7.7 and 7.4%, respectively). Further in the list of the number of flights are located Vladivostok (4.7%), Khabarovsk (3.0%), Krasnoyarsk and Yekaterinburg (2.7% each). For Chinese cities, the average number of flights per week is lower — 9.6. Beijing accounts for less than 1/3 of Chinese flights to Russia (31.4%), Shanghai — 15.5%, Urumqi — 7.6%, Guangzhou — 6.5%.

Based on the obtained database, graphs and maps with diagrams were created to analyze the existing economic and geographical factors and trends. Special attention was paid to the impact of
economic development of cities and tourist flows. The study also took into account the number of unique connections and the share of the city in flights in all directions.

3. Results and Discussion

The processed data allow us to present a map of the main regular air passenger links formed between Russia, Mongolia and China to date. The map shown in figure 1 represents all cities that have regular passenger flights with the rest of the countries in the study. The size of the symbol of the city allows to estimate the total number of flights to the countries of the study per week, the most intensive links between the cities are also displayed.

Figure 1. Cities of Russia, Mongolia and China with aviation links with the countries of study and the most intensive air routes with daily or more frequent flights.

Among the general trends, it is worth noticing first the over-concentration of communication with China and Mongolia in the European part of Russia: Moscow as the country's largest agglomeration draws on almost all aviation contacts with the countries of the study. Only St. Petersburg from the cities of the European part of Russia has its own communication with China, the next city in Russia with direct flights (Yekaterinburg) is already on the border with the Asian continent. In China, the concentration of air communications is not so noticeable-in several cities located close enough to Beijing there is a direct air communication with Russia.
In total, only 11 destinations between the countries of the study have more than seven departures per week (i.e., an average of 1 per day). In Russia, five of them are carried out in Moscow, three in Irkutsk, two in St. Petersburg and only one in Novosibirsk. Two of these flights go to Mongolian Ulaanbaatar, four to Beijing, two to Shanghai, one each to Hong Kong, Guangzhou and Ordos.

Among other things, the relationship between the number of flights per week from the Russian city and the size of its gross city product was analyzed. The linear correlation coefficient for these two indicators is 0.92, which is attributed to a very strong relationship. However, the urban gross product indicators have not been calculated for all the cities presented in the study in the existing statistical sources, which limits the possibility of using this indicator. The correlation between the number of flights and the population of Russian cities was almost as strong — 0.9. The use of this indicator is more preferable, even though the Moscow population indicator makes the graphical way of displaying the relationship less obvious — most cities form a very dense group of points due to the huge difference in population with Moscow (see figure 2).

![Figure 2](image_url)

**Figure 2.** The relationship between the urban population of Russian cities (vertical axis, million) and the weekly number of flights to China and Mongolia (one way).

Especially noticeable deviation from the average in Irkutsk — with an available population of about 620 thousand people, the number of departures per week is 54, which is 9–11 times greater than that of similar Russian cities. Such a great importance of the city in the structure of the Russian-Chinese air traffic is primarily due to the significant tourist attractiveness of Lake Baikal in China. Tourists come to the city from different parts of China (see figure 3), thus Irkutsk forms a dense network of air links with this country. Irkutsk is also connected with two directions unique for Russian cities — Shenyang and Ordos do not have other regular air routes to Russia. Nevertheless, the frequency of air traffic shows that the strongest ties in Irkutsk are with the Northern territories, and such directions as Shanghai and Hong Kong, which are the largest financial centers of China, do not send a large number of tourists to the region. Irkutsk's special role in relations with Mongolia is also notable - the number of flights to Ulaanbaatar is only slightly less than between this city and Moscow.
Irkutsk has a long tradition of close economic and cultural ties with Mongolia, which continues to affect its place in the aviation communication with this country.

Figure 3. Regular passenger air routes from Irkutsk and Vladivostok to the cities of China and Mongolia

Another important regional centre in the East of Russia — Vladivostok. This city has a much smaller number of regular flights to China, and has no links with Mongolia at all. Nevertheless, the city is connected not only with the most important cities of China: Beijing, Shanghai and Hong Kong, but also has a unique destination in Mudanjiang.

The relations of the two remaining Russian cities with the most intensive air traffic with China are shown in figure 4. Novosibirsk has 3.5 times fewer residents than St. Petersburg, but the number of regular routes to China is greater. The main economic center of Siberia is connected with the most important cities of China, as well as with Harbin, Urumqi and the resort city of Sanya. Such a good connection with the Chinese cities is due not only to the relative territorial proximity to this country, but also a kind of central factor of the Novosibirsk airport for neighboring major cities. This effect leads to the fact that of all the surrounding cities (among which several have a population of more than 0.5 million people) only Tomsk has regular flights with the only city in China — Sanya.

St. Petersburg is the second largest city in Russia and one of the most important tourist centers of the country. However, direct regular flights to China are only available from Beijing, Shanghai,
Urumqi and Chengdu. An important feature that limits the development of air communication with China, in this case is also the predominance of the aviation hub of Moscow. At the same time, Chinese travelers not only go to Moscow as a transit center, but also often visit both cities in one trip to Russia, which also reduces the need for direct flights to St. Petersburg.

![Image of regular passenger air routes from St. Petersburg and Novosibirsk to the cities of China and Mongolia](image)

**Figure 4.** Regular passenger air routes from St. Petersburg and Novosibirsk to the cities of China and Mongolia

The importance of the development of air communication between Russia, Mongolia and China has not yet found its place in the discussions on the project "one Belt and one Road". Currently, the main focus is on the construction of a high-speed railway from China to Europe via Russia [1]. While the development of domestic and international air traffic can be expected to have a positive effect on the growth of employment and gross national product [2] especially on the example of low-cost airlines [3] the development of high-speed rail services may not always lead to an unambiguous positive economic effect [4].

Another important area for further research may be the impact of air traffic between Russia, Mongolia and China on the development of tourism. As we can see on the example of Irkutsk, tourism is now one of the most important factors in the development of air traffic. However, further trends may be subject to significant changes under the influence of many factors [5]. Pop culture and destination images can also become such factors [6]. Nevertheless, in reality, only after a certain time it will be possible to determine the real effect of the established relationship: whether it will be a joint
co-evolution, whether the air communication will facilitate the development of trade or no significant effect for the connected cities and economies will be achieved [7].

4. Conclusion
In general, the results of the study show the presence of especially intensive independent (not passing through Moscow) ties with China and Mongolia in the Asian part of Russia with a prominent role of Irkutsk. At the same time, the important place of Irkutsk in the relations between Russia and Mongolia has its roots from the Soviet time, while the intensification of the city's relations with China occurred in recent years and is largely due to the growth of the tourist flow to Baikal.

The role of the Moscow aviation hub in the established regular air service is also evaluated as highly concentrated. This effect suppresses the development of almost all regional airports, which leads to the fact that significant air links with China appear within the framework of the Scientific Project No. 0347-2016-0006 "Socio-geographical factors of ecological and socio-economic transformations in the Siberian regions from the perspective of sustainable development".

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