# Network Analysis Project Report

## Context

The purpose of the project presented in the paper is to conduct network study in the field of spatial networks. In particular, I conducted a comparative study of airline passenger transportation networks of Russia (inside/to/from the country) in two different time spans: before and after international sanctions of 2014-2022. The main idea is to discover differences that occurred after the sanctions have been applied.

## Problem and Motivation

The idea for the project is driven by the change in the airline passenger transportation to/from/inside Russia happened due to Russian-Ukrainian conflicts in 2014-2022 and subsequent sanctions applied on Russia by different countries. As a consequence, many regular flights have been cancelled.

The study seeks to characterise and compare 2 airline networks of Russia: the one depicting the current (October 2022) state and the one depicting the state when international relations between Russia and other countries were more stable (June 2014). How have air paths between Russia and other countries changed? What are the efficient paths for travelling now?

Hence, the study can serve both practical and theoretical needs. In the former case, the current airline transportation network as of October 2022 and its characteristics can be of use for people who have to do cross-border travels nowadays. In the latter case, the comparative research can be of use for political scholars' further analysis of impacts of sanctions.

## Datasets

The data for the project was found online on various open web resources:

- Flight route data between world airports was found as datasets with tabular data on Airline Route Mapper (http://arm.64hosts.com). For the 2022 network I took the last updated dataset from the source – as of 31.10.2022. For the 2014 network I used Web Archive (https://web.archive.org) to retrieve archived flight route data previously stored on Airline Route Mapper; the most appropriate dataset found dated 28.06.2014. Both datasets have already been digitised and stored in .dat format. For further manipulation the data was converted into .tsv format.
    - Dataset of 28.06.2014 consists of 6 columns (airline, from, to, codeshare, stops, equipment) and 72 406 rows that correspond to 72 405 flights that occurred on 28.06.2014 all over the world.
    - Dataset of 31.10.2022 consists of 6 columns (airline, from, to, codeshare, stops, equipment) and 32 679 rows that correspond to 32 678 flights that occurred on 31.10.2022 all over the world.
- The list of IATA codes for Russian airports was taken from Wikipedia (https://en.wikipedia.org/wiki/List_of_airports_in_Russia) and stored as .csv.

- Dataset with tabular data on the geographic coordinates of airports was downloaded from OurAirports (https://ourairports.com/data/). The dataset has already been digitised and stored in .csv format. The dataset consists of 6 columns (name, latitude_deg, longitude_deg, iso_country, iso_region, iata_code) and 8 868 rows that correspond to 8 867 airports all over the world.

As a tool for data manipulation, visualisation and analysis I chose Jupyter Notebook platform and various Python libraries, mainly:

- Pandas, in order to read .tsv or .csv datasets and convert them to Python-friendly dataframes;
- NetworkX, main python library for network analysis which allows to draw graphs and compute their measures;
- Cartopy, in order to enable geographic representation.

## Validity and Reliability

Validity. There may be omission errors in the network representation and subsequent analysis due to limitations of the chosen data source: each dataset contains flight routes information for only one date. However, it is not entirely representative to take only one date for each of the two studying time periods to draw the networks and answer the research questions. It would be better to build the networks based on data gathered for one-two weeks of flights for each time period.
Reliability. I expect a high level of reliability given the objective datasets and objective measures. However, the data source does not appear to be completely reliable as it was free, rarely updated, and most likely had incomplete information. The data source was, nevertheless, chosen for several reasons. Firstly, it was free of charge, unlike the most of others, surely more complete and reliable, databases. Secondly, historical flight data databases are not easy to find online.

## Measures

All the measures described below were calculated for both networks (2014 and 2022) in order to enable comparison.

- General descriptive statistics of the networks such as number of nodes and edges, proportion of Russian and foreign airports: as an exploratory analysis and in order to give a general overview of the networks.
- Average shortest path length / closeness centrality (measuring the mean distance from a node to all the other nodes): in order to measure accessibility of particular cities and the air networks as a whole. Any city which is well connected to other cities (has high closeness centrality) in a network is said to be the most accessible.
- Degree centrality distribution (shows the number of connections to a node): in order to identify the most loaded cities, with many flights to/from it.

• Betweenness centrality distribution (shows the extent to which a node lies on paths between other nodes): in order to identify important mediation cities, through which shortest paths between other cities are passed the most often.

• K-cores (k-core is a connected set of nodes where each is joined to at least k of the others): in order to describe core-periphery structure of the networks. Cities within high k-cores are in the ‘core’, others are on the ‘periphery’.

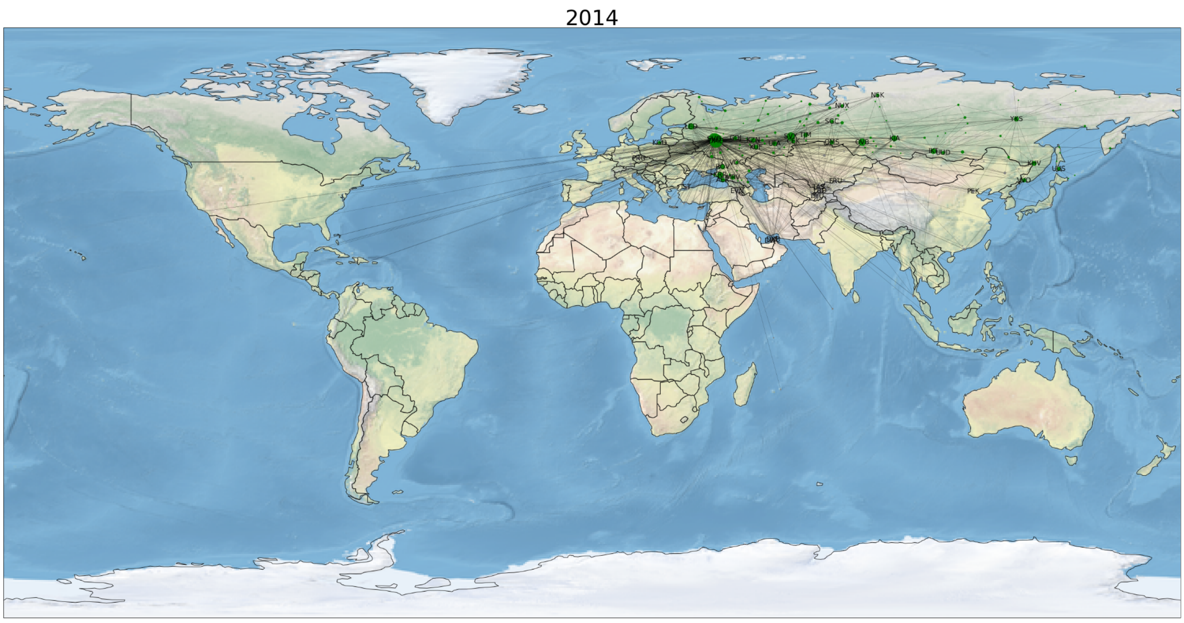
• K-components (k-component is a set of nodes such that each is reachable from each of the others by at least k node-independent paths): in order to identify how many there are alternative travel paths between any two cities. It is practically important because the prices may differ significantly.

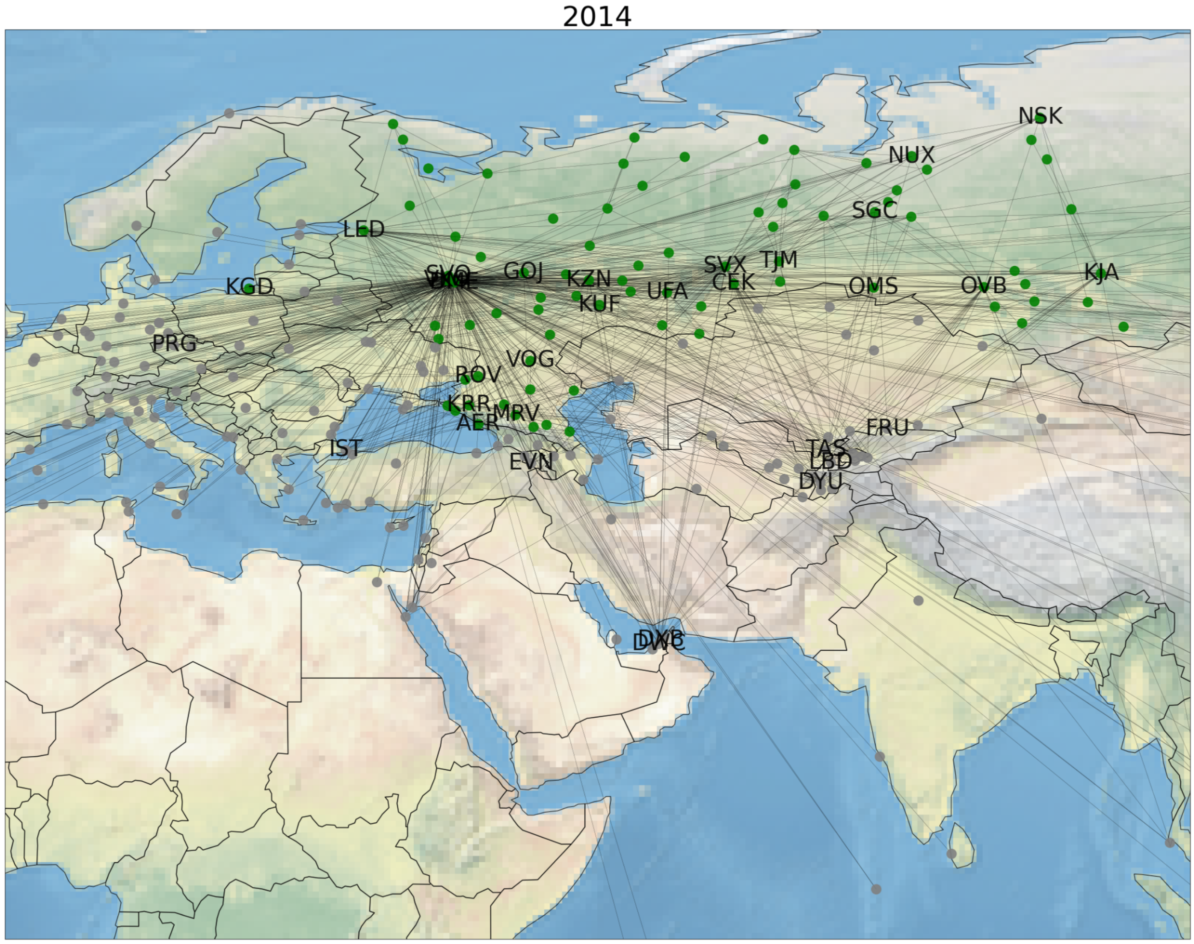
• Clustering coefficient of the networks (the likelihood of the neighbours of a node of being neighbours as well): in order to describe transitivity of the networks. The coefficient varies from 0 to 1 where 1 is perfect transitivity, the graph is complete. It is one of the measures describing how easy it is to travel between the cities.

• Connectivity, beta index (dividing the total number of arcs in a network by the total number of nodes). Another measure used to describe how well the network is connected.

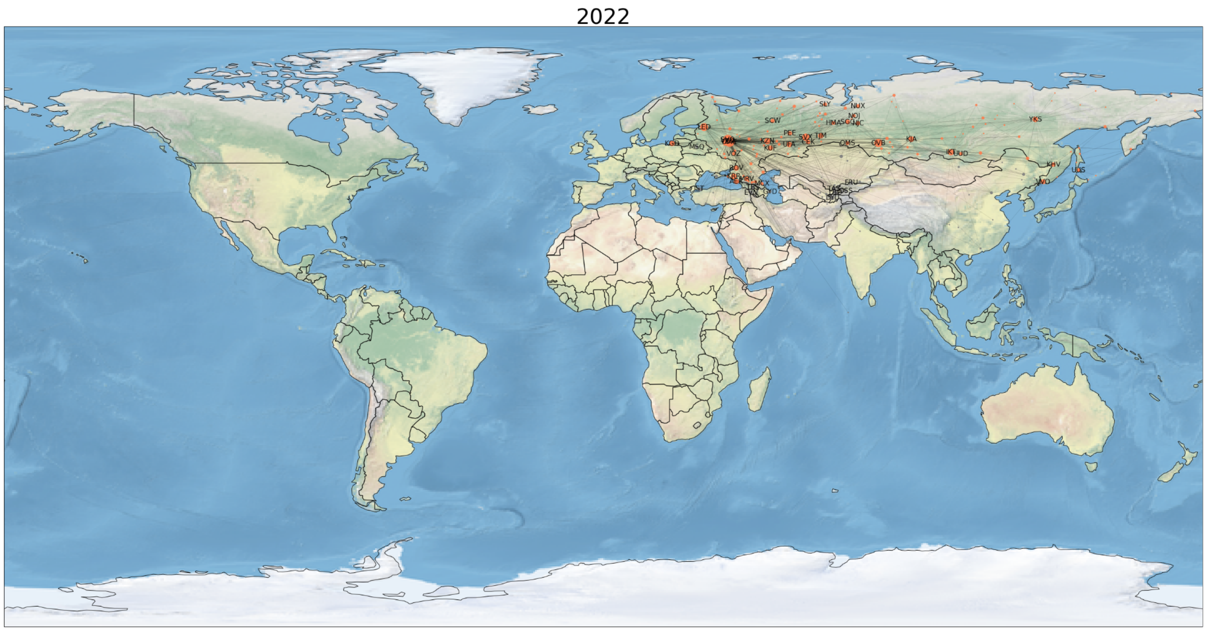
## Results

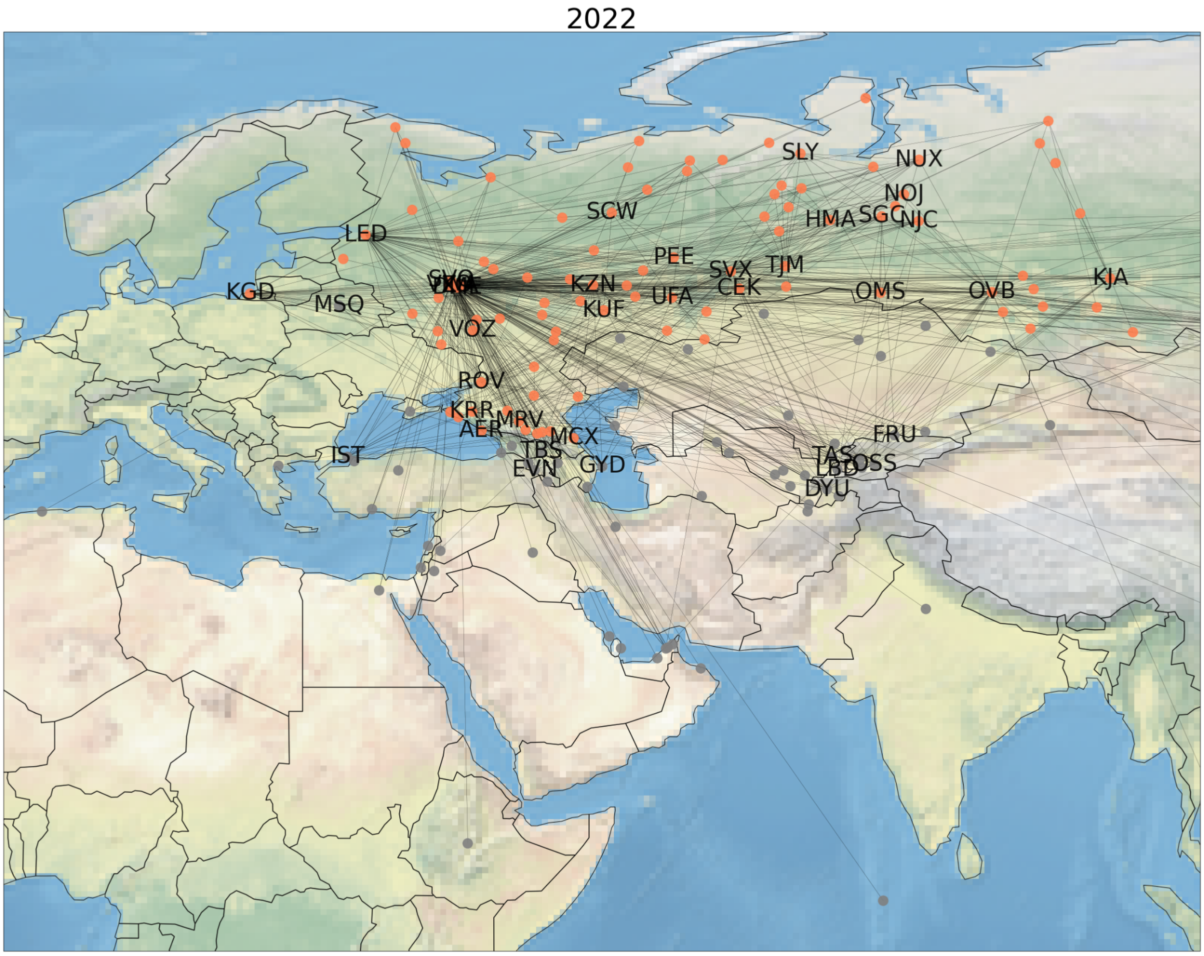
The first step in network analysis is data visualisation. Pictures 1 and 2 show a graphical representation of the two networks to which the analysis was applied. Both graphs are displayed on the geographical map and have the following characteristics: IATA codes of airports are graph nodes, flight connections between them – edges. Both graphs are undirected and single-edge. An edge is drawn between two airports only if there was at least one flight between those airports on a given date.






**Picture 1.** *Airline transportation network of Russia on 28.06.2014. Green nodes represent Russian airports; grey nodes are the airports which are located outside of Russia. The airport labels are displayed for the largest airports only (10 more connections to the node).*






**Picture 2.** *Airline transportation network of Russia on 31.10.2022. Coral nodes represent Russian airports; grey nodes are the airports which are located outside of Russia. The airport labels are displayed for the largest airports only (10 more connections to the node).*

At first glance, it can already be seen from the graphs that the number of cross-border connections in 2022 has decreased compared to 2014. Western destinations in 2022 are completely absent. I further apply network metrics to calculate the exact extent of this difference.

*Descriptive statistics*

To begin with, I apply descriptive statistics to explore the networks better. The table below summarises calculations.

| | 2014 | 2022 | % of change in 2022 compared to 2014 |
|---|---|---|---|
| Number of all airports in the network | 301 | 220 | Decreased by 27% |
| Number of all flights in the network | 877 | 826 | Decreased by 6 % |
| Number of russian airports in the network | 115 | 136 | Increased by 18% |
| Number of foreign airports in the network | 186 | 84 | Decreased by 55% |
| Proportion of foreign airports in the network | 61.8% | 38.2% | Decreased by 1.6 times |
| Transport network connectivity (beta index) | 2.91 | 3.75 | Increase by 1.2 times |
| Average clustering coefficient | 0.25 | 0.37 | Increase by 1.48 times |

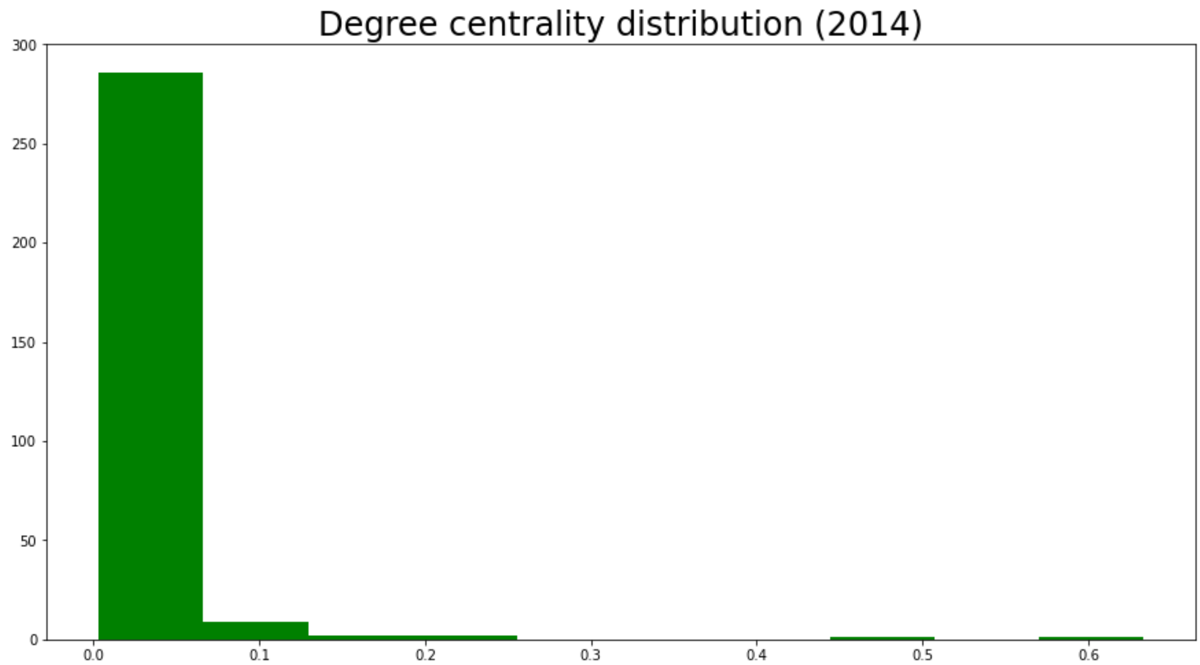
The total number of airports included in the network in 2022 decreased by 27%. At the same time, the absolute number of foreign airports (foreign destinations) decreased significantly, by more than 2 times (55%), the ratio of foreign airports in the network dropped accordingly: in 2014 the number of foreign destinations amounted to more than half of the total destinations (61.8%), in 2022 it is less than half (38.2%).

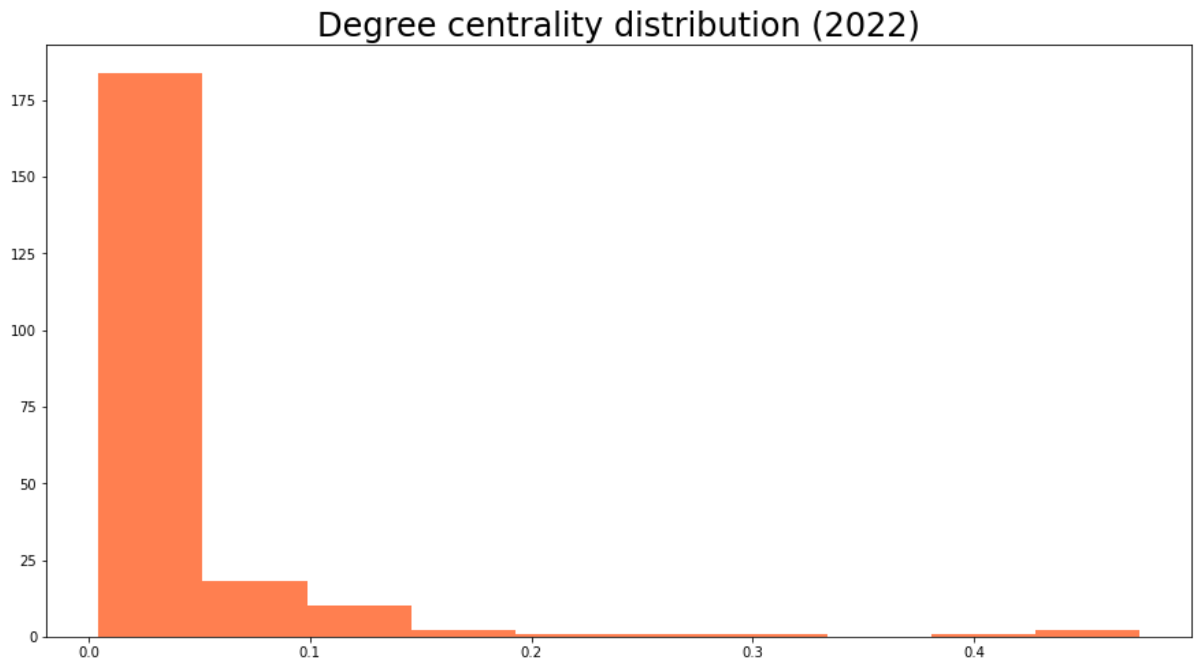
Such a big drop in the number of foreign destinations is compensated by an increase in the number of destinations within the country: the number of Russian airports in the network in 2022 increased by 18% and, accordingly, the Transport network connectivity (beta index) increased by 1.2 times, the network became denser due to domestic flights.

The result is supported by average clustering coefficient difference: the metric increased by 1.48 times which indicates that the transitivity of the network increased, it is more connected in 2022.

*Degree centrality*

Let's now look at the most loaded airports using degree centrality measures.



Airports with the highest (>=0.07: *the tail* of the distribution) degree centrality in 2014:

| | iata | country | degree |
|---|---|---|---|
| 0 | DME | RU | 0.63 |
| 1 | SVO | RU | 0.48 |
| 2 | VKO | RU | 0.25 |
| 3 | SVX | RU | 0.22 |
| 4 | OVB | RU | 0.18 |
| 5 | LED | RU | 0.13 |
| 6 | KRR | RU | 0.12 |
| 7 | KJA | RU | 0.10 |
| 8 | IKT | RU | 0.09 |
| 9 | YKS | RU | 0.08 |
| 10 | KHV | RU | 0.08 |
| 11 | ROV | RU | 0.07 |
| 12 | KZN | RU | 0.07 |
| 13 | KUF | RU | 0.07 |
| 14 | TAS | UZ | 0.07 |

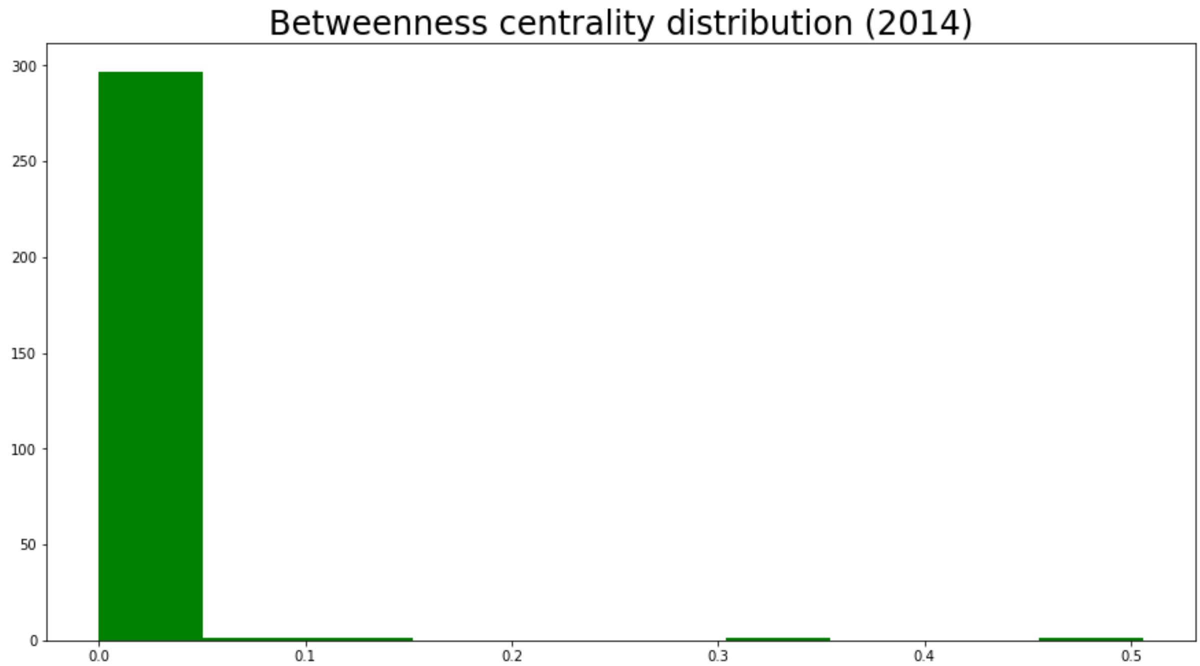
Airports with the highest (>=0.1: *the tail* of the distribution) degree centrality in 2022:

| | iata | country | degree |
|---|---|---|---|
| 0 | DME | RU | 0.47 |
| 1 | SVO | RU | 0.44 |
| 2 | VKO | RU | 0.40 |
| 3 | OVB | RU | 0.30 |
| 4 | LED | RU | 0.27 |
| 5 | SVX | RU | 0.24 |
| 6 | IKT | RU | 0.17 |
| 7 | KZN | RU | 0.17 |
| 8 | KJA | RU | 0.14 |
| 9 | KRR | RU | 0.14 |
| 10 | YKS | RU | 0.13 |
| 11 | KGD | RU | 0.13 |
| 12 | UFA | RU | 0.12 |
| 13 | TJM | RU | 0.12 |
| 14 | ROV | RU | 0.12 |
| 15 | AER | RU | 0.11 |
| 16 | KUF | RU | 0.11 |
| 17 | VVO | RU | 0.10 |

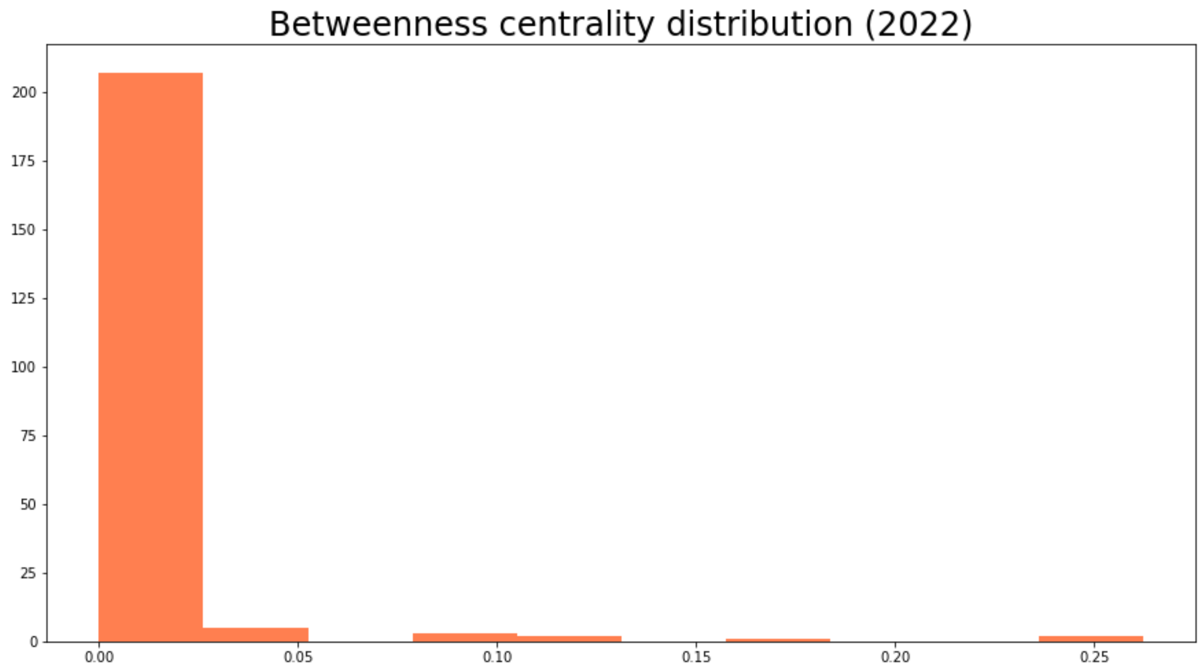
For both networks, the airports of the highest degree of centrality remain the same: DME, SVO, VKO, SVX, OVB, LED, KRR, KJA, IKT, YKS. All these airports are located in major Russian cities. In addition, one can observe that the metric itself even increased in 2022 across some of the top airports. This means that these airports accept even higher numbers of flights. Most likely, this is due to the increase in the number of domestic flights.

*Betweenness centrality*

Let’s now identify important mediation cities, through which shortest paths between other cities are passed the most often.



Betweenness centrality distribution (2014)
300
250
200
150
100
50
0
0.0
0.1
0.2
0.3
0.4
0.5

Betweenness centrality distribution (2022)
200
175
150
125
100
75
50
25
0
0.00
0.05
0.10
0.15
0.20
0.25

Airports with the highest (>=0.01: *the tail* of the distribution) betweenness centrality <u>in 2014:</u>

| | iata | country | betweenness |
|---|---|---|---|
| 0 | DME | RU | 0.51 |
| 1 | SVO | RU | 0.34 |
| 2 | VKO | RU | 0.12 |
| 3 | SVX | RU | 0.06 |
| 4 | LED | RU | 0.04 |
| 5 | YKS | RU | 0.04 |
| 6 | IKT | RU | 0.04 |
| 7 | UUS | RU | 0.03 |
| 8 | OVB | RU | 0.03 |
| 9 | KJA | RU | 0.03 |
| 10 | KHV | RU | 0.02 |
| 11 | VVO | RU | 0.02 |
| 12 | KRR | RU | 0.01 |
| 13 | ARH | RU | 0.01 |
| 14 | SCW | RU | 0.01 |
| 15 | AER | RU | 0.01 |

Airports with the highest (>=0.01: *the tail* of the distribution) betweenness centrality <u>in 2022:</u>

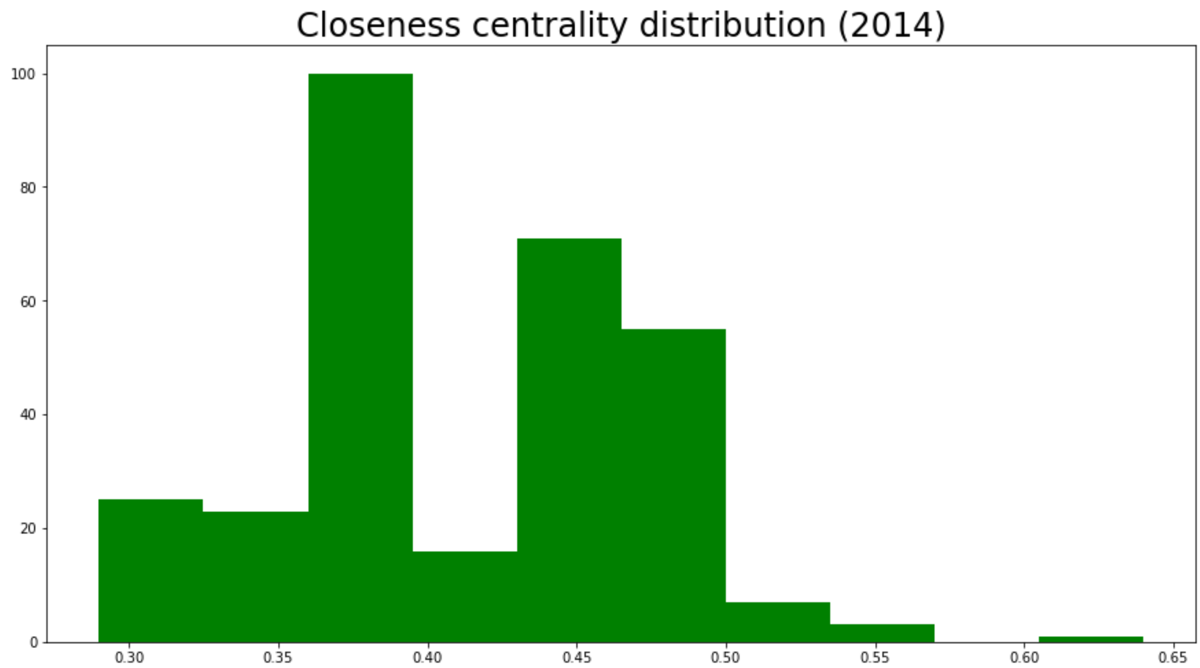
| | iata | country | betweenness |
|---|---|---|---|
| 0 | SVO | RU | 0.26 |
| 1 | DME | RU | 0.26 |
| 2 | VKO | RU | 0.18 |
| 3 | OVB | RU | 0.12 |
| 4 | YKS | RU | 0.11 |
| 5 | VVO | RU | 0.09 |
| 6 | IKT | RU | 0.09 |
| 7 | LED | RU | 0.08 |
| 8 | UUS | RU | 0.05 |
| 9 | KJA | RU | 0.04 |
| 10 | SVX | RU | 0.04 |
| 11 | SCW | RU | 0.04 |
| 12 | TJM | RU | 0.03 |
| 13 | GDX | RU | 0.02 |
| 14 | KHV | RU | 0.02 |
| 15 | KGD | RU | 0.01 |
| 16 | MRV | RU | 0.01 |

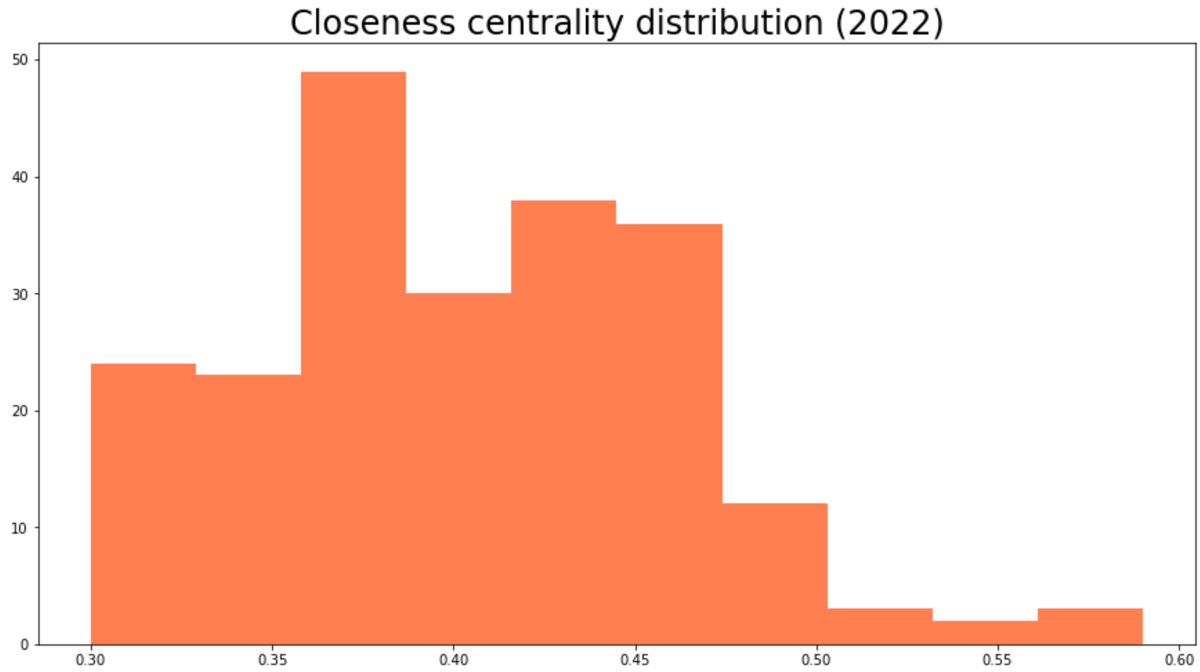
For both networks top betweenness centrality airports remain the same: DME, SVO, VKO, OVB, LED, UUS, KJA, IKT, YKS. All these airports are located in major Russian cities. Interestingly, it can be observed that the metric itself dropped in 2022 significantly only for two major Moscow international airports SVO and DME, but for the rest of the airports it increased, which, again, may be due to a change in domestic travels: in 2022 SVO and DME are still big mediation hubs but, firstly, they are no longer big *international* hubs, and secondly, other Russian airports have also become more loaded, in order to allow more domestic travels from distant Russian cities.

*Shortest path analysis*

Let's now measure the accessibility of particular cities and the air networks as a whole.

Average shortest path length of the network in 2014: **2.48**
Average shortest path length of the network in 2022: **2.55**
For average shortest path length in 2022 the numbers show only marginal increase which is, probably, not significant.



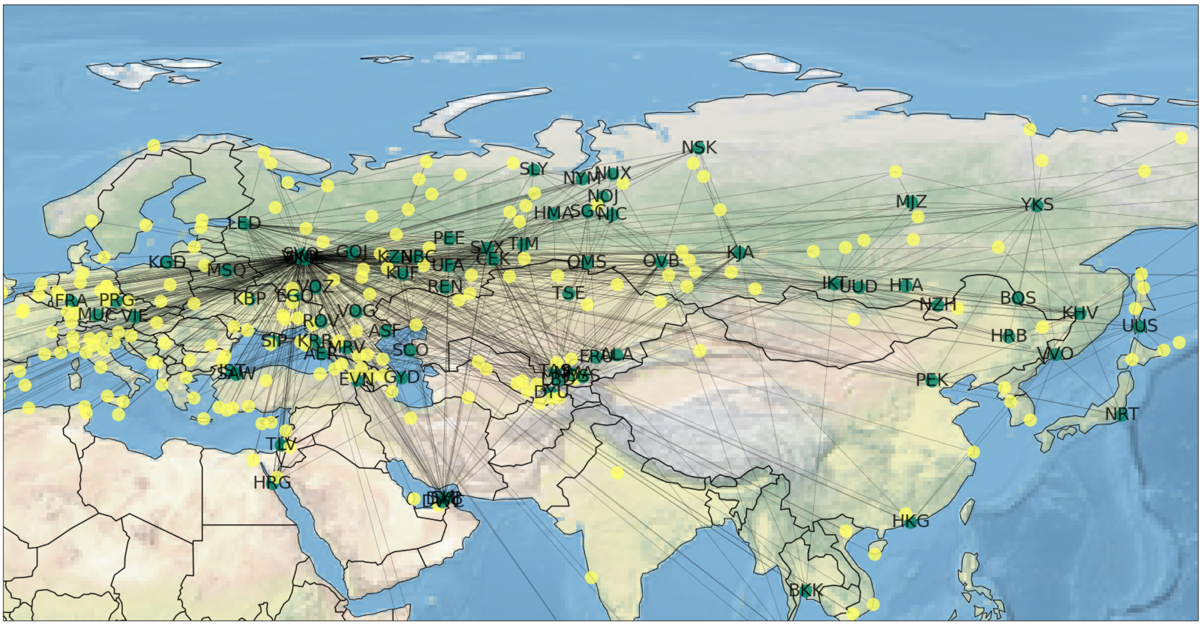

Closeness centrality distribution shows no visible change between 2014 and 2022. It indicates that, in general, average paths from any city to all the others in the network did not change their length over time; the overall network accessibility remained the same.

*K-core analysis*

K-cores describe the core-periphery structure of the networks. Airports within high k-cores are in the ‘core’, others are on the ‘periphery’.

<u>2014</u>

The numbers of k found in the network varied from 1 to 9. To draw a k-core network and define core-periphery structure of the network, one has to choose k. I decided to take the median value of k = 5 as the k-core number. Airports with core number >=5 are the core, the rest are on the periphery of the network.

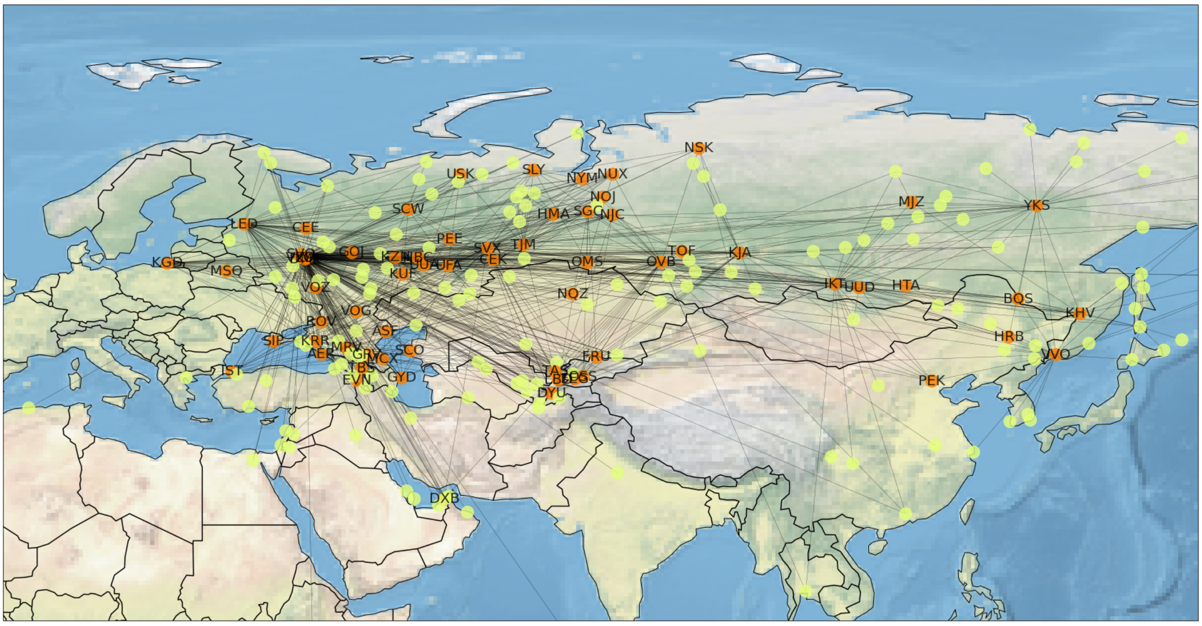



**Picture 3.** *K-core network structure in 2014. Green labelled nodes are the airports in the 5-core. Yellow nodes are periphery.*

Airports within thre 5-core network (2014): 'KGD', 'SCO', 'EVN', 'YKS', 'EGO', 'SVX', 'PEK', 'NRT', 'SIP', 'MUC', 'TJM', 'NBC', 'HKG', 'KHV', 'VIE', 'HRB', 'KRR', 'GOJ', 'REN', 'GYD', 'HRG', 'KJA', 'KUF', 'OVB', 'OMS', 'VOG', 'UUD', 'UUS', 'PEE', 'VKO', 'NZH', 'DME', 'BQS', 'LBD', 'CEK', 'IST', 'OSS', 'PRG', 'FRA', 'BKK', 'SLY', 'MSQ', 'TSE', 'ASF', 'LED', 'NJC', 'DYU', 'ROV', 'UFA', 'FRU', 'MJZ', 'KZN', 'NUX', 'VVO', 'MRV', 'AER', 'VOZ', 'TLV', 'SGC', 'SAW', 'DXB', 'NOJ', 'ALA', 'SHJ', 'HTA', 'NMA', 'KBP', 'TAS', 'IKT', 'NYM', 'SVO', 'NSK', 'DWC', 'HMA'.

<u>2022</u>

The numbers of k found in the network varied from 1 to 11. To draw a k-core network and define core-periphery structure of the network, one has to choose k. I decided to take the median value of k = 6 as the k-core number. Airports with core number >=6 are the core, the rest are on the periphery.




**Picture 4.** *K-core network structure in 2022. Orange labelled nodes are the airports in the 6-core. Yellow nodes are periphery.*

Airports within the 6-core network (2022): 'KGD', 'SCO', 'EVN', 'YKS', 'SVX', 'PEK', 'SIP', 'USK', 'TJM', 'NBC', 'KHV', 'FEG', 'HRB', 'KRR', 'GOJ', 'GYD', 'NQZ', 'KJA', 'KUF', 'OVB', 'OMS', 'UUD', 'VOG', 'CEE', 'PEE', 'VKO', 'OSS', 'DME', 'BQS', 'LBD', 'CEK', 'MCX', 'SCW', 'IST', 'ZIA', 'SLY', 'MSQ', 'ASF', 'LED', 'NJC', 'DYU', 'ROV', 'UFA', 'FRU', 'MJZ', 'KZN', 'NUX', 'VVO', 'MRV', 'AER', 'VOZ', 'GRV', 'SGC', 'DXB', 'UUA', 'NOJ', 'TBS', 'HTA', 'TOF', 'TAS', 'IKT', 'NYM', 'SVO', 'NSK', 'HMA'.

In the 2022 core airport list there are less international airports than in 2014. Western destinations of both core and periphery airports have disappeared from the map, the Asian destinations are still present, but they are more in the periphery than in the core.

### *K-components analysis*

K-components analysis helps to identify how many alternative travel paths there are between any two cities. The table below shows how the k-components of the network are nested within each other. The 9 components in 2014 and the 11 components in 2022 are the maximum numbers of k, meaning that all of the airports in these two lists form components in which each airport is accessible to each of the others by at most 9 or 11 distinct paths. Those are big numbers, so travelling between these airports should be easy, as there are many alternative ways to get to each.

| K components 2014 | |
|---|---|
| 9 components | 'EVN', 'SVX', 'TJM', 'KRR', 'GOJ', 'KJA', 'KUF', 'OVB', 'OMS', 'VOG', 'VKO', 'OSS', 'DME', 'LBD', 'CEK', 'PRG', 'IST', 'LED', 'DYU', 'ROV', 'UFA', 'FRU', 'KZN', 'MRV', 'AER', 'SGC', 'DXB', 'TAS', 'IKT', 'SVO', 'NSK', 'DWC' |
| 8 components | + 'EGO', 'GYD' |
| 7 components | + 'YKS', 'PEK', 'NBC', 'KHV', 'UUD', 'NJC', 'VVO', 'TLV', 'NMA', 'HMA' |
| 6 components | + 'KGD', 'MUC', 'FRA', 'BKK', 'MSQ', 'TSE', 'SLY', 'NUX', 'VOZ', 'ALA', 'KBP', 'NYM' |
| 5 components | + 'PEE', 'NZH', 'BQS', 'SAW', 'NOJ', 'SHJ', 'HTA', 'SCO', 'SIP', 'HKG', 'VIE', 'HRB', 'REN', 'HRG', 'UUS', 'ASF' |
| 4 components | + 'NER', 'ICN', 'NRT', 'KQT', 'FEG', 'SKD', 'OVS', 'HKT', 'HEL', 'MCX', 'ABA', 'MJZ', 'TOF', 'AYT', 'SSH', 'SKG', 'BUD', 'CEE', 'PYJ', 'RIX', 'BTK', 'PKC', 'FCO', 'TXL', 'GDX', 'LCA' |
| 3 components | + 'RTW', 'KVX', 'AGP', 'KIV', 'STW', 'NYA', 'PFO', 'VNO', 'NNM', 'LHR', 'SCW', 'URJ', 'IJK', 'ATH', 'ODS', 'ARH', 'MAD', 'MMK', 'CIT', 'DUS', 'MXP', 'HER', 'UUA', 'AAQ', 'EYK' |
| 2 components | + 'UCT', 'NCU', 'URC', 'DMB', 'MLA', 'TFS', 'ZRH', 'RHO', 'NBE', 'MLE', 'CDG', 'DLM', 'GVA', 'PUJ', 'SKX', 'YYZ', 'BCN', 'BOJ', 'NOZ', 'MQF', 'MIA', 'TBS', 'KEJ', 'ULK', 'VAR', 'JFK', 'USK', 'DYR', 'KGF', 'RMI', 'TJU', 'KLV', 'VCE', 'HAN', 'UGC', 'CAI', 'DNK', 'IEV', 'VKT', 'CSY', 'ULV', 'DOK', 'LAX', 'BRU', 'SGN', 'BAX', 'OHH', 'NCE', 'KRO' |
| 1 components | + the rest |

In 2014 the 9 component list included major Russian airports (which also have high degree and betweenness centralities) and several foreign airports (EVN, OSS, LBD, PRG, IST, DYU, FRU, DXB, TAS, DWC). The following eight lists show the successive addition of airports to form components with a smaller number of K. Let's focus on the three components as a good optimal number of alternative paths from which to choose a travel route. The list with airports that form three components is quite large, with 123 out of 301 airports contained in it; it includes many Russian and foreign, including European, airports.

| K components 2022 | |
|---|---|
| 11 components | 'KGD', 'SVX', 'TJM', 'KRR', 'PEE', 'KJA', 'KUF', 'OVB', 'VKO', 'DME', 'LBD', 'CEK', 'LED', 'DYU', 'NJC', 'ROV', 'UFA', 'KZN', 'NUX', 'MRV', 'AER', 'SGC', 'TAS', 'SVO' |
| 10 components | + 'EVN', 'OMS', 'OSS', 'IST', 'SLY', 'FRU', 'VOZ', 'IKT', 'TBS' |
| 9 components | + 'GYD', 'NQZ', 'NOJ', 'TOF' |
| 8 components | + 'SIP', 'GOJ', 'VOG', 'MCX', 'SCW', 'MSQ', 'DXB', 'NYM' |

| | |
|---|---|
| 7 components | + 'YKS', 'PEK', 'USK', 'KHV', 'FEG', 'HRB', 'UUD', 'BQS', 'ZIA', 'ASF', 'VVO', 'HMA' |
| 6 components | + 'NBC', 'MJZ', 'GRV', 'NSK', 'SCO', 'CEE', 'UUA' |
| 5 components | + 'NER', 'UCT', 'SKD', 'SAW', 'HTA', 'UUS', 'MMK', 'KYZ', 'BTK', 'PKC', 'BAX', 'ALA', 'GDX' |
| 4 components | + 'LWN', 'LPK', 'STW', 'URS', 'ABA', 'EYK', 'IJK', 'EGO', 'TLK', 'ARH', 'OGZ', 'PYJ', 'NMA', 'GSV' |
| 3 components | + 'RTW', 'EZV', 'OVS', 'NYA', 'NZH', 'NNM', 'DYR', 'KVK', 'BHK', 'TLV', 'TBW', 'AYT', 'CAN', 'CSY', 'REN', 'KEJ', 'CIT', 'ULN', 'ULV', 'KLF', 'AAQ', 'KVX' |
| 2 components | + 'IRM', 'BZK', 'KSQ', 'NAL', 'BQG', 'SHJ', 'SKX', 'PEZ', 'NOZ', 'PES', 'IKA', 'KSZ', 'ASB', 'ULK', 'NVI', 'CTS', 'NGK', 'IGT', 'BKK', 'URJ', 'KGF', 'TJU', 'KVD', 'UGC', 'CAI', 'KGP', 'RGK', 'VKT', 'GUW', 'OLZ', 'OHH', 'SBT', 'KRO' |
| 1 components | + the rest |

In 2022 the 11 component list includes major Russian airports (that also have high degree and betweenness centrality) and three foreign airports (LBD, DYU, TAS). The following two (10 and 9 component) lists add more foreign airports in this list, in particular IST and EVN which are very popular destinations for Russian citizens for both short trips and immigration. Thus, at the level of 9 components, the list of airports in 2022 remained practically unchanged. Rather, the number of airports has changed due to the exclusion of many foreign destinations from the network. The list of airports at the level of the three components is also quite large and amounts to 113 out of 220 airports in the entire network.

## Conclusion

Structural changes have indeed taken place in the Russian passenger air transportation network after the introduction of international sanctions. The study presents the following main findings.

On the one hand, in October 2022, the network became denser, its transitivity increased, which means it became easier to travel within the network. In addition, most airports in Russia became even busier in October 2022 due to an increase in the number of degree and betweenness centralities. On the other hand, the findings explain why international sanctions have made it harder for Russian citizens to travel. This applies to cross-border flights. The presence of foreign airports in the network in 2022 decreased both in numbers and in ratio. Western directions have disappeared from the map. This affected Russia's main international airports in Moscow, which reduced their overload and international significance.

Summing up, we can say that domestic flights for Russian citizens have probably become easier, but routes to far abroad countries, especially Western ones, are becoming more complicated in 2022.

## Critique

The findings provide a starting point for further theoretical analysis of political sanctions. By adding more parameters, the economic impact of sanctions can be measured. It can be useful to expand the study and to add qualitative data as well, through methods such as interviews or surveys.

In terms of practical needs, the study does not provide precise travel advice, nor does it speak of the shortest or cheapest routes, but it may provide practical clues for Russians, they may consider looking for ways to travel through nearby airports that appear to be mediation hubs that they did not know or did not think about.

In conclusion, the study only partially meets the research goals. To further strengthen the project idea, the following actions can be taken:

- To enrich the network with edge attributes 'average ticket price', 'time of the flight' and describe the networks with these new variables and new measures;
- To expand the network with train/bus routes and discover new complex paths for cross-border travels;
- To add the Boolean node attribute 'visa needed' to make the study serve more practical applications;
- To make the map automatically updated in order to keep the practical use of the project relevant.

## Annex

The GitHub repository contains additional information related to the study such as:

- Jupyter Notebook with data analysis process,
- all the raw data used for the project,
- lists with all the airports codes, corresponding cities' and countries' names.