THE SPATIAL DIMENSION OF DOMESTIC ROUTE NETWORKS OF RUSSIAN CARRIERS (2002 - 2008)

by

Matus Hudak

A thesis submitted in partial fulfillment of the requirements for the degree of

Master of Science

in

Human Geography and Planning

Universiteit Utrecht

July 2013

Supervisors: Jan Prillwitz, Dick Ettema

PREFACE

I am grateful to dr. Jan Prillwitz and dr. ir. Dick Ettema (Universiteit Utrecht) for their supervision, guidance, and support throughout this thesis, and I would like to thank to prof. dr. Martin Dijst (Universiteit Utrecht), who all went above and beyond their duties and allowed me to access the database upon which I based my research. Additionally, I must express my thanks to Sandra Vinciguerra for inspiring discussions in the early stage of my research. I am extremely grateful for help that I received from two Universiteit Utrecht alumni, Arjan Markus and Matté Hartog, who took their time to discuss my thoughts on theoretical and practical elements of network analysis. Finally, I would like to thank to three fellow students and friends for their encouragement and support: Tanveer Reza Rouf, Justin van Stuijvenberg, and Tom Croll-Knight.

ABSTRACT

The Russian airline industry has been considerably transformed since the collapse of the Soviet Union in 1991. The dissolution of the Soviet Aeroflot paved the way for creation of new private and government-owned carriers. Yet, the airline industry in Russia has not reached the stage of development equivalent to the state of sectors in the United States and the European Union member states. However, the lack of deregulation does not necessarily mean that the airline industry in Russia stagnated over the last decade. The thesis aims to examine three aspects of domestic route networks of Russian carriers: (i) the distribution and concentration of seat capacity (measured by the normalized Gini index); (ii) the morphology of networks (measured by the Freeman centrality index); and (iii) the centrality of airports (studied by means of the Bonacich centrality analysis). The first two aspects are meant to investigate airline networks from macro-level, whereas the third is focused on examination from micro-level. Thus, this thesis does not look at domestic route networks of Russian carriers only in their entirety, but it also takes into consideration their individual parts. The research findings tend to suggest that the majority of carriers operated networks with concentrated or very concentrated distribution of seat capacity in 2002 and 2008. Moreover, numerous Russian airlines allocated a substantial number of seats to routes to and from Moscow during the period of analysis. In regard to the morphology of networks, the predominance of carriers seemed to operate single-radial networks in 2002 and 2008. The utilization of spatially deconcentrated networks was rather scarce. During the period of analysis, the proportion of carriers reorganized their networks and adopted a multi-radial network configuration in order to complement a network of parent company or utilize airports in the Russian capital as bases. The results of the centrality analysis confirmed that Moscow's airports occupied rather central position in domestic route networks of Russian carriers over the last decade (2000 - 2009).

Keywords: airline network, spatial dimension, Russia, concentration, morphology, centrality

CONTENTS

LIST OF FIGURES AND TABLES

Figures

Tables

LIST OF ABBREVIATIONS

AOC	Air operator’s certificate
ASA	Air service agreement
CIS	Commonwealth of Independent States
ERPHO	East of England Public Health Observatory
EU	European Union
F	Freeman centrality index
G	Normalized Gini index
IATA	International Air Transport Association
KLM	Koninklijke Luchtvaart Maatschappij
LCC	Low-cost carrier
NC	Network concentration
OAG	Official Airline Guide
SARS	Severe acute respiratory syndrome
STC	State Transport Company
UAC	United Aircraft Corporation
US	United States
USSR	Union of the Soviet Socialist Republics

CHAPTER 1: INTRODUCTION

The air travel is an extremely dynamic mode of transportation. Airlines merge and go out of business, routes are launched and terminated, and airports are opened and closed in a continuous flux of events so characteristic for the airline industry. In similar fashion, airline networks expand or shrink as a result of numerous factors having either direct or indirect impact on the industry. What is more, the air travel is the fastest commercial mode of transportation. Therefore, it has a global effect on the world economy and society. Holloway (2008: 3) states that 'airlines carry well over 2 billion passengers and between 25 and 30 percent by value of world trade each year'. Although the air travel is often perceived as the means to link countries and continents, the development and regulations of industry vary between individual nation-states and economic and political associations.

Since the late 1970s, several governments have taken steps towards a radical liberalization of the civil aviation sector. In 1978, the airline industry in the US started to undergo the process of deregulation (Goetz and Sutton, 1997; Goetz and Vowles, 2009), followed by the EU, where the market was deregulated in three steps between 1987 and 1992 (Burghouwt, 2005: 45; Burghouwt and Hakfoort, 2002; de Wit, 1995: 185; Janić, 1997). Until then, the passenger air transportation in the US and the EU was strongly regulated by the respective governments. Various barriers were in existence to protect airlines, and the market was distorted by the state aid and subsidies (Burghouwt, 2005: 21). Under such circumstances, the airline business suffered from the lack of competitive environment as the government-owned carriers often benefited from privileges based on regulatory restrictions and bilateral agreements. The bilateral agreements are air service agreements (ASAs) which specify the traffic rights given to airlines operating between and through countries of the world (Bowen, 2002: 433; Burghouwt and de Wit, 2005; Holloway, 2008: 43; Morley, 2003: 16; Reggiani et al., 2010: 450).

Since the deregulation, the impact of bilateral agreements on the civil aviation sector in the US and the EU has decreased. The consensus between the governments of the US and the EU member states caused the withdrawal from individually negotiated air service agreements and regulations. The open skies concept allows for more liberal approach, frequently giving reciprocal rights to serve any airports at any given frequency (Burghouwt, 2005: 45; Cento, 2009: 16-17; Derudder and Witlox, 2009: 277; Holloway, 2008: 235; Reggiani et al., 2010: 450). In other words, the open skies and liberalization reduce restrictions and barriers to entry, while they increase the volatility of the market as it is no longer protected (Burghouwt, 2005: 43-48). Hence, the airline industry in the US and the EU has become more competitive since the deregulation. However, the proportion of markets, especially in Asia and Africa, still suffers from poor quality of service, protectionism, barriers to entry, and limited international connections as a result of bilateral agreements and lack of liberalization (Burghouwt, 2005; Doganis, 2001 in Holloway, 2008).

Several studies (e.g. Adler and Golany, 2001; Burghouwt et al., 2003; Burghouwt and Hakfoort, 2002; Burghouwt and de Wit, 2005; Derudder and Witlox, 2009; Goetz and Sutton, 1997; Malighetti et al., 2008; Reynolds-Feighan, 2001; de Wit, 1995) suggest that the deregulation in the US and the EU led to the reconfiguration of airline networks. According to

Cento (2009: 4-5), the deregulation in the US had two primary effects on the configuration of airline networks. Firstly, a number of US carriers serving mainline routes adopted hub-and-spoke networks. In a hub-and-spoke system, the traffic is concentrated (spatially and temporally) around one or more hubs in order to allow for transfer of passengers from one flight to another. The hub-and-spoke system also offers the cost benefits derived from concentration of fleet and facilities in hubs, e.g. effective maintenance and crew/fleet rotation (Reynolds-Feighan, 2001: 267-268). However, such cost advantages are not necessarily related to hub-and-spoke networks only. Secondly, low-cost airlines, offering low fares and no-frill service, adopted point-to-point networks (Burghouwt et al., 2003: 310; Reynolds-Feighan, 2007: 238). In contrast to hub-and-spoke networks, point-to-point networks are not optimally configured to facilitate the transfer of passengers. I pay more attention to the characteristics of these networks in Chapter 2.

Similar developments resulting from the deregulation could be observed in Europe. Some researchers (e.g. Burghouwt and de Wit, 2005: 186; Cento, 2009: 5) argue that the majority of European flag[1] carriers already operated radial[2] networks (equivalent to hub-and-spoke networks in terms of spatial dimension) before the deregulation in the US. However, the extent to which the system was set up to accommodate the transfer of passengers is questionable (Burghouwt and de Wit, 2005: 186).

The deregulation has not been the only process that has had consequences on the airline industry in the US and the EU. In recent years, sharp fluctuations in fuel prices (Cento, 2009: 27) and cycles of downturn and rise of economy have caused numerous carriers to merge. In addition to mergers, the privatization and alliances have had a significant impact on the business model of airlines (Dennis, 2005; Janić, 1997; Morley, 2003; Pels, 2001). Several researchers have recently studied spatial (Burghouwt et al., 2003; Derudder and Witlox, 2009; Reggiani et al., 2010; Reynolds-Feighan, 2001; Reynolds-Feighan, 2007) and temporal (Burghouwt and de Wit, 2005; Cento, 2009) dimension of airline networks. However, the majority of studies have been focused on the development in liberalized markets, especially in the US and the EU, while a little attention has been given to regulated or partly deregulated markets.

One example of such regulated market is the passenger air transportation sector in Russia[3]. Despite the lack of deregulation, the airline industry in Russia has undergone a considerable transformation since the collapse of the Soviet Union in 1991. To be precise, the overhaul of Aeroflot, once the only airline in the Soviet Union, led to the fragmentation of the Russian airline industry[4]. Hence, the Russian airline industry ceased to be monopolized, and numerous carriers have established themselves in the domestic market. Despite the fact that Russia lacks long-established airlines (besides pre- and post-1991 Aeroflot), a great number of privately-

---

[1] Also called ‘national’ carriers. Typically, these carriers have been established or nationalized by governments, e.g. Air France, Alitalia, Iberia (Janić, 1997: 169). Some flag carriers have been partly or fully privatized in recent decades.

[2] See Chapter 2, Section 2.2 for explanation of radial network.

[3] E.g. companies under the foreign ownership are not permitted to serve domestic routes in Russia (RIA Novosti, 2011).

[4] Several airlines were created as a result of the dissolution of the Soviet Aeroflot.

and publicly-owned carriers was set up across the Russian Federation over the last decade. In this respect, the airline industry in Russia has moved towards a similar organization as in the US and the EU, where a variety of carriers is present in the market. Yet, the academic research on airline networks in Russia is tremendously limited. The lack of research can be partly attributed to the scarcity of resources related to the Russian passenger air transportation. Moreover, the Russian airline industry is relatively young in comparison with the US and the EU counterparts[5].

Some studies (e.g. Shaw et al., 2009) suggest that changes in organization of airline networks might not be triggered solely by 'full scale' deregulation. Both extent and pace of liberalization are highly country-specific as they are dependent on the range of political, administrative, and legislative factors (Hooper et al., 1996: 396). In Russia, the transition from planned to market economy enabled the privatization of several publicly-owned companies. Additionally, privately-owned airlines (under the Russian ownership) can be established and compete in the domestic market. The privatization and private ownership alone can be seen as one of the first steps towards the deregulation. In addition, the Russian airline industry has been partly consolidated by a number of mergers and acquisitions. A few studies (Daramola and Jaja, 2011; Derudder and Witlox, 2009; Shaw et al., 2009) indicate that the privatization, mergers, and acquisitions have an impact on the configuration of airline networks. However, the extent to which Russian carriers reorganized their networks in recent years has not been comprehensively studied. Therefore, my research addresses this existing gap in academic literature.

1.1 The aim of the study and research question

The aim of this thesis is to study the organization and development of airline networks in Russia between 2002 and 2008[6]. Precisely, to give an insight on the spatial dimension of domestic route networks of Russian carriers. It is vital to mention that the topic of recent developments of airline networks in Russia should be considered as important not only due to a relative lack of the contemporary research, but also because of a considerable eventfulness within the Russian airline industry in the last decade. In recent years, several Russian airlines went bankrupt (Komarov, 2009a), while others merged (Komarov, 2005). Additionally, Sky Express established itself as the first low-cost airline in the Russian domestic market (Russian Aviation, 2011), and the flag carrier Aeroflot - Russian Airlines improved its image and brand awareness abroad when it became the first ever Russian airline to join the global airline alliance (Komarov, 2006). Alongside these direct factors, the Russian airline industry was also influenced by improved integration of the Russian economy into global financial and commodity markets as well as the growth in disposable income and consumer wealth (Airline Leader, 2011).

Although the emergence of low-cost airlines and presence of the global airline alliance signify a crucial initiative for the Russian passenger air transportation, they both represent current

[5] The passenger air transportation sector in Russia (as we know it today) has started to develop only after the fall of communism in 1991.

[6] The database available for the research covers two years, 2002 and 2008. While the access to the data for every year of the last decade would be ideal, it was not possible.

forces which have only recently started to shape up the future development of airline business in Russia. In its present-day state, the Russian airline industry is still predominantly affected by the Soviet period and the legacy of the past; i.e. a strong focus on Moscow. However, it does not automatically mean that one should reject the study of airline networks in Russia over the last decade.

To elaborate, the past study by Kolossov and Thorez (2009) concludes that for the most part, the passenger traffic (carried by air) is unevenly distributed across regions. The passenger air transportation is primarily focused on the airports in Moscow (for a number of political, economic, and social reasons). To illustrate, Moscow houses approximately 10% of the Russian population, but more than 40%[7] of passengers transported by air in Russia in 2006 used one of the Moscow's airports (Kolossov and Thorez, 2009). Furthermore, Kolossov and Thorez (2009) conclude that the link with Moscow is considered as the bread and butter route for a large number of Russian carriers. Moreover, a large proportion of Russian airlines based in Moscow seems to utilize a radial network configuration. Contrastingly, the use of transversal lines by-passing Moscow is less common. It is mostly utilized in the regions of the Russian Far East, Siberia, and the Urals, where distances between settlements can be large. However, the recent studies (Kolossov and Thorez, 2009; Thorez, 2010) have provided only a limited insight on airline networks in Russia from the company level[8].

Nonetheless, I expect the results of my analysis to be similar to the findings published in these studies. Primarily, I expect a great proportion of networks of Russian carriers to be concentrated and centralized on Moscow and its three principal airports (Domodedovo, Sheremetyevo, and Vnukovo)[9]. To elaborate, I anticipate a large portion of networks to be radial (especially networks of Moscow-based carriers). On the other hand, the morphology of networks of Russian carriers based outside of the capital might vary considerably. Yet, I assume that for a significant number of such carriers, the link between their base(s) and Moscow's airports has a crucial position in their networks (the 'bread and butter' route). While Moscow is often perceived as political, economic, and social center, it also occupies a primary position as the most important transport node of Russia. In relation to the passenger air transportation, Moscow fulfills the function not only as the origin or destination for passengers. Its potential as a transfer node between domestic and/or international flights should not be overlooked[10]. Secondly, I expect that mergers and acquisitions which took place between 2002 and 2008 have had an effect on the organization of Russian airline networks. Specifically, the absorption of Arkhangelsk Airlines by Aeroflot - Russian Airlines and the subsequent creation of Aeroflot Nord; as well as the developments within Rossiya and UTair Group. Finally, I assume that a proportion of Russian carriers has been able to exploit the

[7] Precisely, 41.6% in 2000 and 48.7% in 2006 (Kolossov and Thorez, 2009).

[8] The contemporary research (Kolossov and Thorez, 2009; Thorez, 2010) has been mainly focused on the complete network of connections in Russia, rather than networks of individual carriers. With regard to the research covered in this thesis, by networks, I have in mind individual networks of Russian carriers, not the entire network of connections in Russia. Hence, I look at networks from company level, rather than national one.

[9] In the following paragraphs (and more so in Chapter 4), I will specifically explain the measures of concentration and centrality applied in this research.

[10] A further research should be conducted in order to clearly identify the true nature of the implementation of hub-and-spoke system at Moscow's airports as well as its future potential.

profitability of routes to and from the Russian capital. Hence, such carriers might have taken an opportunity to set up their hubs in Moscow's airports over the last decade. Kolossov and Thorez (2009) have already touched on this subject, although not in detail. Even though I do not conduct the analysis of hub-and-spoke system as the part of this thesis, the examination of the morphology of networks should cast light on the utilization of Moscow's airports by Russian carriers. In order to support the assumptions that I made in this paragraph, I will answer the following research question:

1) How did the spatial dimension of domestic route networks of Russian carriers develop between 2002 and 2008?

By spatial dimension, I mean the examination of three aspects: (i) the distribution and concentration of seat capacity; (ii) the morphology of networks; and (iii) the centrality of airports in Russian airline networks[11]. Firstly, the distribution and concentration of seat capacity should provide an insight into the passenger traffic flows (based on the supply of seat capacity) across the domestic route networks of Russian carriers. The distribution and concentration of seat capacity is measured by the normalized Gini index (network concentration index). Secondly, the territory of the Russian Federation is rather sparsely populated in comparison with the US and the EU. The largest population centers are situated in the European part of the country, while settlements in a large portion of Russia, especially in the Arctic and Siberia, are few and far between. The analysis of the morphology of Russian airline networks (by means of the Freeman centrality index) should shed light on network types operated by Russian carriers. Lastly, I implement the Bonacich measure of centrality in order to examine the centrality of airports in domestic route networks of Russian carriers. Kolossov and Thorez (2009) examined the role of Russian airports in terms of passenger numbers, and their findings conclude that Moscow's airports (notably Sheremetyevo, Domodedovo, and Vnukovo) play a primary role as the busiest nodes. However, it does not necessarily mean that these nodes must also be the most central ones.

1.2 The structure of the thesis

Chapter 2 provides a theoretical review of two approaches (spatial and temporal) to the analysis of airline networks. With regard to the spatial approach, a special attention is given to the concentration and centrality measures as well as the graph theory [12]. Moreover, I review the topics of morphology and topology of airline networks. Lastly, I examine the network economies which partly determine the structure and design of networks. Chapter 3 is entirely dedicated to the passenger air transportation in the Soviet Union as well as post-1991 Russia. The chapter does not limit itself to the airline-oriented perspective, but it depicts the Russian civil aviation sector from wider point of view. Chapter 4 gives the detailed outline of methodology applied in the research. Furthermore, I describe the database on which I based the analytical part of the thesis. Chapter 5 is dedicated to the analysis of domestic route

[11] Obviously, the term 'spatial dimension' is not exclusively limited to these three aspects. Additionally, various measures can be implemented in order to examine the said characteristics of airline networks.

[12] These measures and theories directly relate to the practical perspective of the study of Russian airline networks.

networks of Russian carriers. Lastly, Chapter 6 is focused on conclusion and discussion related to the research.

CHAPTER 2: THEORETICAL PERSPECTIVE ON AIRLINE NETWORKS

In this chapter, I provide the theoretical overview on topics related to airline networks and their analysis. Firstly, I give the review of two approaches (spatial and temporal) to the analysis of airline networks as outlined in the book by Guillaume Burghouwt (2005: 32-36): "Airline network development in Europe and its implications for airport planning". With reference to the spatial approach, the graph theory and the measures of concentration and centrality are especially emphasized. Secondly, I cover the theory on the structure, configuration, and topology of airline networks. Lastly, I review the knowledge related to the network economies and network design.

2.1 The analysis of airline networks

The network studies have been attracting the attention of researchers active in various fields and disciplines. The network analysis is a multidisciplinary approach, and its application includes spheres such as communications and information technologies, the study of neural networks, the examination of social networks of friends or business collaborations, transportation studies, etc.

The airline network, being an example of transport infrastructure, is a complex system with great variety in terms of size, structure, and geometry. The complexity of airline networks is a result of the interaction of numerous factors which make up the entire system, e.g. airlines, airports, routes (Han et al., 2009: 72). Similarly, the analysis of airline networks can be rather multiplex matter. The continuous evolution of the airline industry has had a direct impact on research methods and techniques. Therefore, there is not 'the one and only' way to analyze airline networks. As this thesis is focused on the examination of spatial dimension of airline networks in Russia, the following section concentrates on the spatial approach to the analysis of airline networks.

2.1.1 Spatial approach

As a sole purpose of the air transportation is the movement of people and goods between cities, countries, and continents, it is not surprising that the spatial perspective of airline networks has attracted a considerable research interest. The spatial approach is focused on the geographical development of networks in space (Burghouwt, 2005). In the next paragraphs, I pay more attention to two approaches associated with the spatial analysis of airline networks: (i) the graph theory and (ii) the concentration and centrality indices.

The graph theory

The application of spatial approach can be traced back to 1960s when researchers adopted the graph theory in network studies (Tinkler, 1979: 85). In its early days, the graph theory was praised for its simplicity and ability to examine a system as a whole or examine its parts separately (Garrison, 1960 in Tinkler, 1979: 87). To date, the graph theory has been applied to fields of e.g. communications, transportation, and neurology (Huber, 2010: 552). According to Tinkler (1979: 86), the concept of the graph theory is based on two objects: (i) a limited set of labels and (ii) a limited set of pairs of labels. In relation to airline networks, the former is defined as nodes (airports) and the latter as edges/links (routes) between particular nodes (Burghouwt, 2005: 32).

In regard to the airline industry, the early use of the graph theory contributed towards the description and visualization of airline networks (Brooks Cates, 1978; Marsten and Muller, 1980). Beside the academic research, the graph theory became considerably practical and applicable in real-world scenarios. For instance, it was utilized by planners to generate the shortest flight paths as a part of scheduling procedure of American Airlines (Chan, 1979) or to organize the deployment of cargo fleet (Marsten and Muller, 1980). Even more recent studies utilized the graph theoretical approach. Although as Burghouwt (2005: 32) states, numerous researchers do not directly refer to it. Instead, the graph theoretical approach often plays a complementary role and is used in conjunction with other methods.

During its introduction, several limitations of the graph theoretical approach were recognized (Garrison, 1960 in Tinkler, 1979). Firstly, it was argued that the interpretation of the same study based on the graph theory can vary among individual researchers. However, the popularity of the graph theoretical approach led to the conceptualization of airline networks as different network types were recognized and coined (Burghouwt, 2005: 32). Secondly, the graph theory was criticized for its 'simplicity'. Nevertheless, the improvements in hardware and software (especially the graphic interface) have rendered this shortcoming less profound. Hence, the graph theory is still a viable approach to the spatial analysis of airline and other networks.

The concentration and centrality measures

As a result of the conceptualization of airline networks, the focus of researchers expanded towards the study of network concentration, morphology, and centrality. Similarly to the graph theoretical approach, the concentration measures have been applied to various fields, e.g. economics and law. Notable applications have included the measurement of distribution of income inequality among population, the evaluation of financial portfolio, or the measurement of extent of competition among companies (Burghouwt, 2005: 33). The most frequent concentration measures include the coefficient of variance, the Hirschman-Herfindahl index, the C4-firm concentration ratio, Theil's entropy measure, and the Gini index (Burghouwt et al., 2003; Huber, 2009).

With respect to the airline industry, the concentration measures have been applied in studies of e.g. airline market concentration (Belobaba and Van Acker, 1994), the traffic distribution of carrier networks (Reynolds-Feighan, 2001), or the analysis of hub-and-spoke networks (Martín and Voltes-Dorta, 2008; Martín and Voltes-Dorta, 2009). Additionally, the majority of studies, which utilize the concentration measures, have been focused on the airline industry in the United States or the European Union member states (e.g. Burghouwt et al., 2003; Reynolds-Feighan, 2007; Suau-Sanchez and Burghouwt, 2012). In my research, I apply the normalized Gini index (network concentration index) as the measure of the spatial distribution and concentration of seat capacity. I pay more attention to the Gini index in Chapter 4, Section 4.1.1.

The concentration indices measure the distribution of traffic in a network, whereas the centrality measures assess the importance of a node in relation to its position in overall structure of a network. Three principal concepts of centrality are widely recognized: *degree, closeness,* and *betweenness* (Borgatti and Everett, 2006: 467). The implementation of the centrality measures has included the studies of networks of organizations, employment opportunities, businesses and professionals, etc. (Borgatti and Everett, 2006: 467; Marsden, 2002: 414). As Cento (2009: 111) states, the application of the centrality measures in transportation studies, especially those regarding airline networks, has been rather limited[13]. I utilize two measures/methods based on the concept of centrality: (i) the Freeman centrality index and (ii) the Bonacich centrality analysis. I further elaborate on these centrality measures in Chapter 4.

Other theories related to the spatial approach

With regard to the spatial analysis of networks, the proportion of further approaches has been directly related to specific developments of 'real geographical' networks (e.g. transportation and communications networks). One of such examples is the hub location theory. Following the deregulation in 1978, a number of US airlines reorganized their networks and adopted the hub-and-spoke model. One of the main benefits of the hub-and-spoke concept is the ability to serve all nodes in the network via a number of connections radiating from the hub (Shaw, 1993: 47). The hub serves as a transfer point for passengers traveling between non-hub airports (spokes). However, the hub is the most important as well as the weakest link in the network, and any delays or disruptions at the hub can have severe consequences on overall network performance (O'Kelly, 2010). In comparison with a direct flight, the routing via one or more hubs incurs longer travel time and longer distance (as the crow flies). In addition to the flight time, the travel via hub(s) is subject to the *transfer time*[14], characterized as the period of time it takes to connect from one flight to another.

The hub location theory is focused on the geographic location of one or more hubs as well as the flow/routing of traffic in relation to the distribution of airline network (O'Kelly, 1998). The complexity of hub location increases with multiple hub models and various routing possibilities (Jaillet et al., 1999; O'Kelly, 1998; Shaw, 1993). The implementation of the hub location theory has not been exclusively limited to the spatial analysis of airline networks. In fact, the term 'hub', and the hub location theory itself, can be applied to other transportation networks (railways, subways) or facilities (border crossings, logistics facilities) where the transfer of people and/or goods takes place (O'Kelly, 2010: 174).

In recent years, alliances have become a notable player in the field of airline business. An alliance partnership provides considerable advantages to the member carriers. The membership also means various obligations and contributions from individual carriers as well as a partial loss of independence as the general consensus on strategy and tactics must be

[13] I came across two academic papers/books whose authors analyzed airline networks by means of the centrality measures: 'Assessment of new hub-and-spoke and point-to-point airline network configurations' by Alderighi et al. (2007) and 'The airline industry: Challenges in the 21st century' by Cento (2009).

[14] Also referred to as 'waiting time' (Burghouwt, 2005: 35) or 'connecting time' (Holloway, 2008: 376).

reached among the member airlines. However, the members often benefit from a competitive advantage over non-members, the extension of network, and access to new destinations and markets (Hsu and Shih, 2008). Furthermore, an alliance membership can have a profound influence on the network strategy and network configuration of partner airlines. Several researchers (e.g. Adler and Smilowitz, 2007; Hsu and Shih, 2008; Reggiani et al., 2010) have analyzed the impact of airline alliances on the spatial structure and organization of airline networks. Given the current trend of further admission of new members and expansion of airline alliances, we can expect more academic research in this field.

The portion of network studies has been progressively focusing on the analysis of complex networks. A notable attention has been given to the models of *small-world*[15] and *scale-free*[16] networks. A few academic researchers (e.g. Bagler, 2008; Barthélemy et al., 2005; Guimerà et al., 2005) have gone beyond the theoretical perspective, and they argue that several real-world networks exhibit the characteristics of these models. While the analysis of complex networks (such as small-world and scale-free) has been only recently applied to the field of airline networks, it presents a potential direction for future studies.

To sum up, all theories related to the spatial approach have been applied in studies of airline networks, although some more extensively than others. Moreover, all theories are proven, and they still have their place in the contemporary research. However, Burghouwt (2005: 34) asserts that the spatial approach neglects to consider the temporal dimension of airline networks. Although the data limitations do not allow for examination of the temporal dimension of Russian airline networks in my research, I nevertheless provide a general review focused on the temporal approach.

2.1.2 Temporal approach

The temporal approach has become increasingly relevant since the deregulation of passenger air transportation in the United States in 1978. Following the deregulation, a number of US carriers reconfigured their networks and adopted the hub-and-spoke system (Alderighi et al., 2007; Burghouwt, 2005; Hansen, 1990; Holloway, 2008; Shaw, 1993). Aguirregabiria and Ho (2010: 377) define the hub-and-spoke network as the following:

‘In a hub-and-spoke network, an airline concentrates most of its operations in one airport, called the hub. All other cities in the network (i.e., the spokes) are connected to the hub by non-stop flights such that travelers between two spoke cities must take a connecting flight to the hub’.

Hence, carriers utilizing the hub-and-spoke model partly rely on the concept of connections between the hub and spokes. In such arrangement, all spokes in a network can be connected via hub by fewer routes than direct services between all nodes would require (Holloway,

---

15 Networks which exhibit the ‘small-world’ characteristics have a small diameter (any two nodes in the network can be reached by just a few steps) and considerable degree of clustering (Han et al., 2009: 81; Reggiani et al., 2010: 451).

16 Reggiani et al. (2010: 451) argue that the ‘scale-free’ network model is based on two characteristics: (i) growth and (ii) preferential attachment. The former draws attention to the expansion of network as nodes are added and its size grows, whereas the latter points on the fact that additional nodes connect themselves to other nodes which have a high number of links. The hub-and-spoke system can be seen as a good example of real-world ‘scale-free’ network.

2008: 386). In other words, the hub-and-spoke network allows carriers to operate smaller number of flights than it would be in case of fully connected point-to-point network.

The concentration aspect of the hub-and-spoke network is not exclusively limited to the spatial concentration of flights. The hub-and-spoke network is also distinctive for its temporal concentration of traffic at one or more hubs. The temporal concentration is achieved as a consequence of flight scheduling (Alderighi et al., 2007: 532; Burghouwt, 2005: 35). The rationale behind the temporal concentration is an attempt to maximize the number of possible connections available to transferring passengers, while at the same time, keeping the length of transfer time acceptable (Holloway, 2008: 376). The core of the temporal aspect of the hub-and-spoke network is the so-called *wave-system* structure:

'A wave-system structure consists of a number of connection waves, which are a complex of incoming and outgoing flights, structured such that all incoming flights connect to all outgoing flights' (Bootsma, 1997 in Alderighi et al., 2007: 532).

Some authors describe a wave as a separate group of either incoming or outgoing flights, whereas others refer to it as the combination of both. *Banks* and *complexes* can be used as synonymic terms to describe waves (Holloway, 2008: 376).

To conclude, the concentration (both spatial and temporal) enables carriers operating hub-and-spoke networks to exploit indirect connections. However, the efficiency of hub-and-spoke operations heavily relies on scheduling. In comparison with the spatial dimension of airline networks, the temporal perspective has been investigated by only a few researchers (e.g. Alderighi et al., 2007; Burghouwt, 2005; Burghouwt and de Wit, 2005; Cento, 2009). While this section was concentrated on spatial and temporal approaches to the airline network analysis, the next section is focused on the definition of a network as well as the network structure and morphology.

2.2 The structure and configuration of airline networks

The previous section on spatial and temporal approaches shed light on the complexity of airline networks. In real-world, airline networks considerably differ from each other, and their intricacy and uniqueness frequently increase as they grow in size and extent. The configuration of networks is not an exception. As mentioned earlier, the graph theoretical approach led to the conceptualization of network types and their configuration features. In the following paragraphs, I present the theory on the structure and configuration of airline networks.

The theoretical findings on social networks characterize the network as a set of actors and relations (Hanneman and Riddle, 2005: 18). With reference to airline networks, I already defined actors as nodes (airports) and relations as connections (routes) between certain nodes. While the graph theoretical approach considers the configuration of networks purely on the basis of spatial concentration, Burghouwt (2005: 34) argues that the effect of temporal concentration should be taken into account, too. Hence, he perceives the existence of various network configurations as a consequence of interaction of both spatial and temporal

Level of spatial concentration	Level of temporal concentration at the hub	
	Coordinated	*Random*
Concentrated	Hub-and-Spoke	Random radial
De-concentrated	Coordinated chain	Point-to-Point

Table 2.2.1 The airline network configuration matrix
Source: Burghouwt (2005: 37)

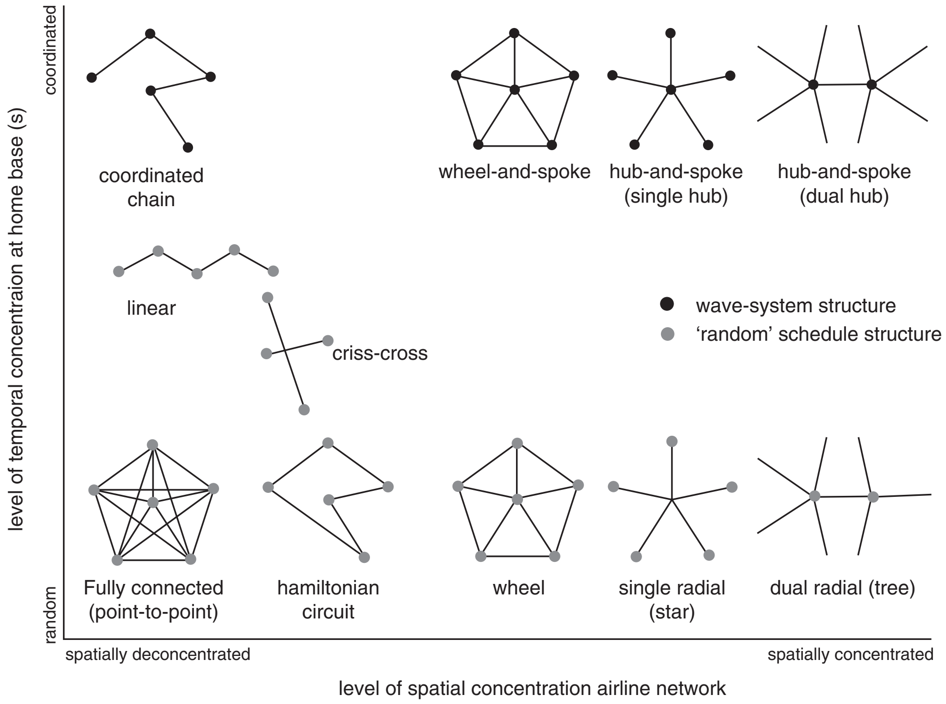

Figure 2.2.1 The network configurations
Source: Burghouwt (2005: 38)

concentration. Burghouwt (2005: 37) distinguishes four 'extreme' network types (Table 2.2.1) and several 'intermediate' network configurations. Figure 2.2.1 illustrates various network configurations and their relative position based on the levels of spatial and temporal concentration. In the following paragraphs, I further describe a few network configurations pictured in Figure 2.2.1.

<u>*The hub-and-spoke vs. the point-to-point network*</u>

In the previous section, I already outlined some of the most significant features of the hub-and-spoke network. The hub-and-spoke network presents a structure that is spatially concentrated and temporally coordinated (Figure 2.2.1). In 1978, the deregulation of the airline industry in the US enabled airlines to reconfigure their networks and adopt the hub-and-spoke system (Alderighi et al., 2007; Burghouwt et al., 2003; Derudder and Witlox, 2009). However, it does not necessarily mean that other network configurations were completely abandoned by carriers.

Point-to-point networks do not exhibit large levels of temporal concentration as their network organization is not primarily focused on indirect connectivity across the network. Yet, the level of spatial concentration can vary to a considerable extent in point-to-point networks. In the following paragraphs, I pay special attention to two network types, each figuring at the opposite end of spectrum with regard to the level of spatial concentration: (i) fully connected point-to-point network and (ii) radial network. Furthermore, I review a linear network, the type of network adopted by numerous US carriers before the deregulation of the US airline industry (Holloway, 2008: 373). The linear network is still a relevant network type, and it can constitute a portion of overall network structure of contemporary carriers. Radial and linear (as well as criss-cross, Hamiltonian circuit, wheel) networks are frequently referred to as variants of point-to-point networks.

Fully connected point-to-point network

The fully connected point-to-point network is an extreme example of network. One of the key features of the fully connected point-to-point network is both spatial and temporal deconcentration of traffic. From the passenger's point of view, the fully connected network presents an ideal configuration as all nodes in the network can be reached in one step, without any transfers. However, fully connected point-to-point networks are extraordinary in real-world due to a number of economic, political, and strategic reasons. Chiefly, not all city-pairs can generate enough demand to support the direct connection. Moreover, the capacity constraints and congestion in airports, the availability of landing slots, or the lack of governmental approval for flights may be seen as additional factors behind the lack of direct connections between particular city-pairs (Alderighi et al., 2007: 532).

Radial network

In contrast to the fully connected point-to-point network, the radial network exhibits a significant level of spatial concentration. The radial network is concentrated around one (in a single-radial network) or more (in a multi-radial network) bases from which flights radiate (Holloway, 2008: 374). In this regard, the radial network shares similar characteristics of the spatial concentration as the hub-and-spoke system. However, the temporal concentration of flights usually does not take place as the radial network lacks the temporal coordination (the wave-system structure). While indirect connections are usually not offered by airlines operating radial networks, passengers can book separate tickets in order to create their own connections. Yet, this procedure is not without risks for passengers as they may not be reimbursed the price of their tickets for second and any consecutive flight in case they miss it, either due to the cancellation of the first flight or significant delay. In addition, passengers with separate tickets are generally required to check-in and pass through the security checkpoint for every single flight.

Linear network

Before the deregulation in the US in 1978, the route network of several US carriers could be characterized as linear. Linear networks are frequently composed of one- or multi-stop routings (Holloway, 2008: 373). In the past, linear routings were a common feature of numerous *long-haul*[17] intercontinental services as the performance specifications (i.e. range) of certain aircraft types required a fuel stop. However, the aircraft performance was not the only reason for linear routings. During the period of the Cold War, the Soviet Union and China did not grant the rights to overfly their territories to a great number of primarily European, North American, and Asian carriers. Therefore, flights between e.g. Europe and the Far East had to avoid the Soviet and/or Chinese airspace and take alternative routes, either via the Canadian Arctic and Alaska or southerly route via the Middle East. The linear network configuration is relevant even nowadays as it enables carriers to link several connections into one route and transport passengers traveling between different segments on a single aircraft. For instance, the route from A to B and onward to C might attract passengers on segments A-B, B-C, and A-C (Holloway, 2008: 373). The level of temporal concentration can significantly vary in linear networks. The routes A-B and B-C can also be served as two different services which do not connect with each other. From the customer's point of view, the main disadvantage of linear routings can be associated with unattractiveness as multi-stop services and intermediate take-offs and landings increase the total travel time. However, a sufficient demand on all segments of linear route might justify the deployment of larger aircraft which in turn can bring considerable cost advantages to a carrier (Holloway, 2008: 373). I further outline these factors in the next section.

To sum up, this section focused on the structure and configuration of airline networks. The airline network is composed of (i) nodes (airports) and (ii) connections (routes) between particular nodes. Moreover, the airline network should be perceived as a result of interaction between the levels of spatial and temporal concentration. However, real-world airline networks rarely duplicate the exact configurations as pictured in Figure 2.2.1. Instead, they can be rather characterized as the mixture of different network configurations. Additionally, the network configuration is not influenced solely by the levels of spatial and temporal concentration, but it is also the result of the network economies.

2.3 The network economies and network design

The airline business can be briefly described as a service industry in which a carrier occupies the position of service provider with aim to transport passengers and/or cargo. From a commercial perspective, the supply of services is linked to costs related to the airline operations, whereas the passenger demand can be associated with revenue. Similarly, the airline network can be perceived as *user attracting system* on the one hand and *delivery system* on the other hand (O'Kelly, 1998: 172)[18]. In an ideal scenario (for carriers as well as passengers), the satisfaction of both sides of supply and demand would result in a network that perfectly mirrors the requirements of passengers. Only those connections that attract a sufficient demand would be served as it is not economically profitable to serve routes that do not generate enough revenue to cover operational costs. Thus, airlines must consider the passenger demand, as well as the cost implications, when committing to a particular network

---

[17] A long-haul flight can be described as a long distance flight of several thousand kilometers/miles (e.g. Paris - Buenos Aires, London - Tokyo, Moscow - New York).

[18] While O'Kelly (1998) characterizes the hub-and-spoke network model as a delivery and user attracting system, it should be noted that this statement applies to any kind of airline network.

configuration. In the next paragraphs, I examine various cost and revenue factors which relate to the spatial concentration of networks.

In reference to the airline industry and network operations, the economies of aircraft size present one of the most significant determinants of carrier's unit costs. The economies of aircraft size associate the increase in the seat capacity of a plane with the fall of average costs. Moreover, the average costs of operations of aircraft with particular capacity decrease as the stage-length increases. Assuming the specific capacity and stage-length, the average costs fall as the average load factor[19] increases (de Wit, 1995: 174). The primary reason for such non-linear relationship is that larger aircraft offers higher capacity, while the increase of costs is not proportional to the rise in aircraft size (Holloway, 2008: 300). As Holloway (2008: 300) argues, the fuel consumption of large aircraft per seat-mile[20] is comparable to that of smaller airplane, given they both have the same number of engines and are technologically on comparable level. Additionally, larger aircraft does not require more crew members in a cockpit than smaller plane. Also, the system commonality (e.g. Airbus A320/A330/A340 family) and the automatization of aviation systems made the position of flight engineer[21] redundant. However, Holloway (2008) does not consider further specific requirements of the aviation governing bodies, e.g. the need for the third pilot on lengthy long-haul flights, more cabin crew members needed (for safety reasons in case of emergency and/or evacuation) as the seat capacity of aircraft increases, etc. With regard to the economies of aircraft density, Caves et al. (1984 in Burghouwt, 2005: 49) assert that it is not dependent on the configuration or size of a network but rather:

'It is the traffic density on the individual routes that is important. Hence, economies of traffic density arise because of increasing traffic density in a network of a given size leads to lower average costs per passenger, given the scale economies at the route level'.

Furthermore, the economies of scope can arise as a result of the spatial concentration of resources and facilities in space. Such concentration enables carriers to benefit from various cost advantages associated with e.g. effective fleet utilization and crew rostering, the sharing of fixed airport costs, and intensive use of capital (Reynolds-Feighan, 2001 in Burghouwt, 2005: 49). However, the spatial concentration can also bring serious constraints to carriers in case of rather quick and unexpected events such as weather-related airport closures, workforce strikes, security threats and incidents, and last but not least, accidents.

As my research is focused on the spatial dimension of airline networks, I do not aim to thoroughly describe the network economies associated with temporal concentration and coordination in airline networks. I refer to Burghouwt (2005) and Holloway (2008) for

---

[19] The load factor can be described as the occupancy rate on a particular flight. 100% load factor denotes that all seats are occupied by passengers.

[20] The term 'seat-mile' is associated with cost per seat-mile. According to Holloway (2008: 467): 'Cost per seat-mile (or seat-kilometre) is attributable to absolute input costs and aircraft productivity'.

[21] Aircrafts such as Lockheed L-1011 TriStar and McDonnell Douglas DC-10 require three members of flight crew in a cockpit (captain, first officer, and flight engineer) due to their design specifications. Mainly, they lack the modern era glass instrument panel and other technological improvements found in highly computerized modern 'fly-by-wire' airliners such as Boeing 777 and Airbus A320/A330/A340 family.

detailed information on cost and demand factors in the hub-and-spoke network. All in all, the network design is dependent on the cost structure of a carrier in comparison with passenger demand (Burghouwt, 2005: 53). Certain network types have their characteristic benefits and disadvantages, and one cannot identify the network structure that is necessarily the most profitable. Pels et al. (2000 in Cento, 2009: 29) assert that the hub-and-spoke network is profitable to operate when the unit costs linked to the network operations are high, while the passenger demand is low, and the point-to-point network should be preferred by a carrier when the passenger demand is large in comparison with the unit costs. Based on the cost and demand factors, several researchers (e.g. Alderighi et al., 2007: 530; Burghouwt et al., 2003: 312) have recognized the hub-and-spoke network as being the domain of *full-service* carriers, whereas the business model of the majority of low-cost carriers seems to be based on the point-to-point configuration.

The business model of contemporary full-service carriers regularly combines the hub-and-spoke operations with a broad range of 'products' (e.g. business, premium economy, economy class) in order to offer direct and indirect connections and appeal to both business and leisure passengers. Hence, the cost structure of full-service carriers can be characterized as relatively complex. The hub-and-spoke network is expensive to build and maintain as an extensive infrastructure is needed in order to develop a competitive hub. Additionally, a wide offer and diversity of services (e.g. different cabin classes, long-haul and short-haul products) further increase the cost structure of full-service carriers. In general, low-cost airlines benefit from lower operational costs in comparison to full-service carriers (Alderighi et al., 2007: 530). Principally, the point-to-point operations of low-cost carriers are less complex. Low-cost airlines often operate a random schedule (without a wave-system structure), and they tend to focus on direct connections (Burghouwt, 2005: 53). Hence, they do not need to face costs that arise from the hub-and-spoke operations. Moreover, some low-cost airlines (e.g. Ryanair) serve secondary airports which are not congested and offer favorable landing fees. In comparison with full-service carriers, low-cost airlines rarely diversify their on-board product. They usually offer 'no frills' single class service without any complimentary meals or drinks. Further cost benefits can arise from fleet commonality, higher seating density, and more effective utilization of aircrafts and labor (Alamdari and Fagan, 2005; Dobruszkes, 2006). While networks of low-cost carriers are not temporally coordinated[22], they can exhibit large levels of spatial concentration as a consequence of the centralization of fleet, labor, and resources around one or more bases.

To conclude, this section described the impact of various cost and demand factors on the network design. I especially focused on the economies of aircraft size and the economies of scope, as well as the cost structure of full-service and low-cost carriers. However, it is important to keep in mind that the network design depends on numerous other elements. As Burghouwt et al. (2003: 310) state:

'Other factors include the size of the origin-destination market, historical background of the carrier and its network, number of stations in the network, intercontinental versus continental

[22] The majority of low-cost carriers do not offer indirect connections. However, several exceptions exist, e.g. Air Berlin, Southwest (Holloway, 2008: 49).

orientation, fleet composition, strategic airline management, hub capacity and the average stage-length'.

CHAPTER 3: THE PASSENGER AIR TRANSPORTATION IN RUSSIA

The geography of Russia greatly favors the passenger air transportation. The territory of the Russian Federation is of a vast size, and it stretches from the coast of the Baltic Sea to the Pacific Ocean. A substantial proportion of land is located in the continental climate zone and is associated with big temperature differences between summer and winter. The presence of permafrost over a considerable area of Russia has presented a difficult obstacle, rendering the construction of paved roads and railways too costly or impossible (Ambler et al., 1985; Symons, 1983). In addition, the navigation of the coast of the Arctic Ocean and of the main rivers discharging into it (e.g. Ob, Lena, and Yenisei) is possible only for a few months a year when waterways are ice-free.

The majority of the Russian population is concentrated in the European part of Russia, especially in and around main centers such as Moscow and Sankt Petersburg and along the rivers Volga (Samara, Kazan, Saratov, Nizhniy Novgorod) and Don (Rostov). In the Asian part of Russia, the main population centers are located around the Ural Mountains (Yekaterinburg), in Western Siberia (Novosibirsk, Omsk), around the Baikal Lake (Irkutsk), and in the Far East region (Vladivostok, Khabarovsk). The majority of these cities can be reached by the Trans-Siberian Railway, which stretches from the capital Moscow to Vladivostok on the coast of the Pacific Ocean. Yet, vast distances between main population centers of Russia increase the importance of the passenger air transportation. In addition, ample reserves of natural resources (e.g. oil, gas, diamonds, coal, timber) across Russia have led to the establishment of mining communities, principally in vast expanses of Siberia, the Arctic areas, and on the island of Sakhalin. The air transportation provides a convenient way to link these communities with major cities and towns. Also, the plane often presents the only viable option due to a difficult terrain. Hence, the passenger air transportation can be seen as an important mode of travel in Russia.

3.1 The passenger air transportation: the Soviet Union era

As the leader of the block of socialist countries, the economic organization of the former Soviet Union represented the opposite of a *laissez-faire*[23] policy implemented in capitalist countries. Thus, the Soviet passenger air transportation sector was controlled by the communist representatives. It is not my aim to fully explain the development and features of planned economy in the USSR (Union of the Soviet Socialist Republics) as it falls outside of the scope of this thesis. As Bradshaw and Lynn (1994: 439) state, the Soviet Union sought to protect and maintain its industries through a system of state monopolies. It also included the airline industry.

The unique position of the sole airline of the Soviet Union was held by Aeroflot. During the existence of the USSR, Aeroflot was the body responsible for the entire civil aviation sector. The company was divided into several divisions, each responsible for a certain part of operations (e.g. maintenance, catering). Moreover, Aeroflot was responsible for management

[23] A policy in which the governments do not interfere in the workings of the free market (Hornby et al., 1995).

of airports across the entire USSR (Kolossov and Thorez, 2009: 498). In other words, the airline industry in the former Soviet Union was a one-man band.

The route network of Aeroflot was centralized and concentrated towards the Soviet capital Moscow, mainly due to political, economic, and social reasons (Kolossov and Thorez, 2009: 498). Beside the Russian Soviet Federative Socialist Republic, the Soviet Union also included territories of today's Ukraine, Belarus, Moldova, Azerbaijan, Georgia, Armenia, and the republics in the Baltic and in Central Asia. Therefore, flights between these republics were considered as domestic (Kolossov and Thorez, 2009: 498). Such organization further reinforced the dominant position of Moscow as the principal center of the passenger air transportation in the Soviet Union.

As Kolossov and Thorez (2009: 500) explain, the concentration of air links on Moscow led to the complementarity of airports in the capital. Vnukovo (opened in 1941) was the first major airport in the Moscow region. In 1959, Sheremetyevo became the main gateway for international flights. In 1964, Domodedovo Airport was inaugurated and designated as the airport providing the link between Moscow and the Soviet republics in Central Asia (Kolossov and Thorez, 2009: 500). With regard to airlines, the position of Aeroflot as the only domestic carrier in the Soviet Union was unchallenged until the breakup of the USSR in 1991.

3.2 The civil aviation in Russia: post-1991

In the late 1980s, the politics of reforms promoted by the leader of the Soviet Union Mikhail Gorbachev changed the structure and organization of the Soviet Union. With increased voices for independence from the socialist republics making up the USSR, the pressure on the central Soviet government grew larger. The collapse of the country in 1991 had a tremendous impact on economy and politics of the republics once united under the banner of the USSR. The strong concentration of power on Moscow ceased as new countries sprang up on the world map, and the movement of people and goods shifted to a particular extent (Bradshaw and Lynn, 1994).

The collapse of the Soviet economy caused the stagnation of the passenger air transportation during initial years after 1991. The Commonwealth of Independent States (CIS) was founded as the partial successor of the Soviet Union. However, the traffic did not recover, and the passenger numbers in Russia considerably fell during the decade 1990 - 1999, from 91 million passengers in 1990 to 22 million in 1999 (Kolossov and Thorez, 2009: 496). Aeroflot, once the only airline representing the Soviet civil aviation sector, was divided into smaller companies. One part of the former Aeroflot became Aeroflot - Russian Airlines[24], the flag carrier of the post-communist Russia (Komarov, 2010a).

The decline in passenger numbers in 1990s led to the reduction of capacity and shrinkage of airline networks. The air traffic became increasingly concentrated at large airports. According to Kolossov and Thorez (2009: 504), approximately 1,300 airports were opened to traffic in the Russian part of the Soviet Union before 1991. In stark contrast to the situation prior to

[24] From this point onwards, I have in mind 'Aeroflot - Russian Airlines' when discussing the carrier Aeroflot unless I specifically refer to the Soviet Aeroflot.

Moscow (Domodedovo)	20,437,516
Moscow (Sheremetyevo)	15,066,354
Moscow (Vnukovo)	7,923,220
Sankt Petersburg (Pulkovo)	7,070,770
Yekaterinburg	2,437,919
Novosibirsk	1,941,483
Kaliningrad	1,874,460
Krasnodar	1,609,406
Sochi	1,575,312
Samara	1,391,884
Ufa	1,295,876
Rostov	1,257,261
Khabarovsk	1,095,780
Vladivostok	1,003,850
Surgut	1,001,882
Krasnoyarsk	1,001,303
Irkutsk	969,139
Tyumen	905,576
Mineralnye Vody	827,764
Kazan	763,846
Perm	681,411
Chelyabinsk	677,865
Yuzhno-Sakhalinsk	663,086
Nizhnevartovsk	652,273
Anapa	574,978
Yakutsk	544,827
Omsk	537,812
Novy Urengoy	510,837
Arkhangelsk	473,029
Volgograd	457,245
Petropavlovsk-Kamchatsky	447,464
Murmansk	403,729
Mirny	395,506
Norilsk	395,416
Orenburg	363,017

Table 3.2.1 The 35 largest Russian airports in terms of passenger (domestic and international) numbers for 2008
Source: Transport Clearing House (2009)

1991, only approximately 260 airports recorded some commercial traffic in 2007. Nonetheless, the importance of international traffic to and from Russia has increased. The rise in disposable income and the relaxation of visa requirements for travel to numerous countries mean that a higher proportion of the Russian citizens can afford to travel abroad than ever before. The leisure travelers heading to Cyprus, Turkey, and Egypt are of a particular importance to Russian carriers (Thorez and Zembri, 2006 in Kolossov and Thorez, 2009: 498).

Figure 3.2.1 The location of Russian airports with traffic of more than 1 million passengers (domestic and international) in 2008
Source: Transport Clearing House (2009) and Great Circle Mapper (Swartz, 2012)
See Appendix D for the explanation of airport codes

As Kolossov and Thorez (2009) state, the current traffic is still heavily concentrated on routes to and from Moscow as it was before 1991. The population of the capital is less than 10% of the entire population of Russia, but Moscow's airports accounted for approximately half of passengers carried in Russia in 2006. Table 3.2.1 provides the passenger numbers for the 35 largest Russian airports in 2008. However, the specialization of Moscow's airports is long gone, and the traffic concentration is partly based on the position and dominance of carriers at these specific airports, namely Sheremetyevo, Domodedovo, and Vnukovo (Kolossov and Thorez, 2009: 501).

In recent years, the Russian government and airport authorities have been improving the infrastructure and accessibility of airports. Railroad links to Sheremetyevo and Domodedovo were constructed, relieving already congested roads linking central Moscow with these airports. The smallest of Moscow's airports, Bykovo Airport, has been promoted as the airfield for general aviation, e.g. business jets (Kolossov and Thorez, 2009: 498). This step might have eased the air traffic congestion at Sheremetyevo and Domodedovo. The development of Russian airports is not exclusively bound to the governmental decisions as the proportion of airports is privately-owned. However, as Barrie and Komarov (2005) assert, the ownership of infrastructure in Russia presents a juridical issue. By the Russian law, the privatization of runways and navigational aids is prohibited, while the rest of airport facilities may be privately-owned. Such issues raise the question of future state investments to privatized airports such as Domodedovo. The ownership regulations make the future investments and airport planning (e.g. the runway maintenance/extension/construction) rather uncertain.

An example of the ban on ownership of runways and navigational aids illustrates the complex relationship between the public and private sectors in Russia. The interaction is also profound in relation to corporate matters, mergers, and acquisitions. In the last ten years, the global airline industry experienced one of the biggest turmoils as a consequence of terrorist attacks, rising fuel prices, and economic stagnation. Following the example of US and European carriers, several Russian airlines started to cooperate in order to gain a competitive advantage over their rivals. A few Russian carriers sought a safe heaven via mergers and acquisitions. However, the reorganization of unhealthy carriers (e.g. KD Avia, Krasnoyarsk Airlines) was not always a sustainable solution in spite of the governmental involvement (Komarov, 2009a). In the following section, I further elaborate on the interaction between Russian airlines and the Russian government.

3.3 The conflict of interests: the government versus airlines

The deregulation of airline industry in the United States and the European Union led to the competition under free market forces. In international traffic (EU-US market), bilateral agreements were abolished in favor of the open skies concept. In contrast, the passenger air transportation sector in Russia is still not deregulated (Komarov, 2006). However, the Russian domestic market is not exclusively served by government-owned carriers only as the presence of Russian privately-owned airlines is allowed. International flights to and from Russia are regulated on the basis of bilateral agreements negotiated between the Russian and foreign governments. Moreover, only a few Russian carriers are able to compare with airlines from the European Union or the United States in terms of safety records, maintenance, service standards, etc. Therefore, Russian airlines might be better off being protected by agreements which limit the presence of foreign carriers in Russia (Wall and Komarov, 2005). However, such organization leaves the civil aviation sector in Russia inefficient and uncompetitive.

Since the decline in 1990s, the passenger air transportation in Russia has exhibited a considerable growth. In 2007, Russian carriers transported approximately 45 million passengers, opposed to 22 million in 1999 (Kolossov and Thorez, 2009: 496). The leading international carrier, Aeroflot, has been successful in acquiring a modern fleet composed of state-of-the-art airliners such as Airbus A320 and A330. The possession of new planes has enabled Aeroflot to expand its network across Europe and other continents, while phasing-out inefficient and noisy Soviet-built planes such as Tu-134 and Tu-154 (Komarov, 2009c). In order to stay competitive on international routes, also other Russian airlines (e.g. S7 Airlines, Transaero Airlines) have opted to modernize their fleets.

Although the Russian legislation protects Russian carriers through bilateral agreements and entry deterrents, it burdens airlines with taxation. As Komarov and Taverna (2004) state, the import of aircrafts manufactured abroad is subject to 40% surcharge, making the purchase of Western-built planes costly for Russian carriers. The tax has been primarily imposed to force airlines into buying Russian planes. In the past, only two Russian airlines (namely Aeroflot and Transaero Airlines) were exempted from this tax (Komarov and Taverna, 2004). It is estimated that more than 1,000 new aircrafts will be needed in Russia over the next 20 years in order to satisfy the demand (Airbus, 2011). However, the extent of import tax and duty allows only a few carriers with necessary monetary reserves to purchase or lease aircrafts made outside of Russia. In such a scenario, one would turn to domestic aviation companies for new planes. In recent years, only Sukhoi has been relatively productive in the research, development, and subsequent production of passenger aircrafts. However, the Sukhoi production lines can hardly satisfy the needs of Russian carriers.

The proposed 18-month freeze of duties and tax payments on imported aircrafts and spares might boost the amount of orders much needed for expansion of Russian airlines (Komarov, 2008). Recently, Russia's United Aircraft Corporation (UAC) proposed a step to combine the abolition of tax on Western-built aircrafts and the stimulation of the Russian aerospace sector in one package. The UAC representatives suggested to abolish the tax, but only for airlines which would also be willing to buy Russian and/or Ukrainian airplanes (precisely the UAC's MS-21 or the Sukhoi Superjet, and/or Antonov An-148) (Komarov, 2010b). Such proposal should not be seen as a universal solution. Based on the idea of UAC, Russian carriers which would participate in the program might end up with too many different aircraft types in their fleets. As a consequence, it can cause havoc in the cost structure of airlines as they lose benefits related to the commonality of fleet, e.g. lower maintenance and crew training costs.

It is not just these days that the aerospace industry in Russia is suffering. The period of its downturn can be traced back to the Cold War era. Even then, the Soviets lacked behind the First World countries in the production of passenger aircrafts. One of the most successful long-range airliners of the jet era, Boeing 747, made its first commercial flight in 1970. The trijet DC-10 produced by McDonnell Douglas followed in 1971. It was not until 1980 when the Soviet Union presented a comparable aircraft, Ilyushin Il-86 (Ambler et al., 1985). However, some aircraft types from the Soviet era might make a comeback due to the lack of comparable planes in the market. The giant cargo aircraft Antonov An-124-100 has been a success due to its performance. The production was halted as a direct result of the collapse of the Soviet economy. The main operators of the type, including Russia's Volga-Dnepr Airlines, Polyot, and Ukrainian Antonov Airlines, offered to provide the funding for resurrection and update of An-124-100 program (Komarov and Taverna, 2005)[25]. Only time will tell if the aerospace industry in Russia can revive itself. For now, there is a lot left to be desired.

---

[25] Although Antonov was established as the Soviet government-owned enterprise, the company is currently registered in Ukraine. Nevertheless, the company closely cooperates with several Russian enterprises involved in the design stage and manufacture of airplanes (Antonov, 2012).

CHAPTER 4: METHODOLOGY

The center of attention of this chapter is the examination of three specific measures of concentration and centrality. They constitute the main tools of the spatial approach to the analysis of domestic route networks of Russian carriers. Precisely, I employ the normalized Gini index, the Freeman centrality index, and the Bonacich centrality analysis. Furthermore, I focus on the database used in this research as well as the categorization of Russian airlines.

4.1 The measures of spatial concentration and centrality

4.1.1 The normalized Gini index

Several researchers (e.g. Burghouwt et al., 2003; Burghouwt, 2005; Huber, 2009; Reggiani et al., 2010; Reynolds-Feighan, 2001; Reynolds-Feighan, 2007; Suau-Sanchez and Burghouwt, 2012) have applied the concentration measures in their studies of the spatial dimension of airline networks. The methodology of these studies has not been uniform, and the variety of concentration measures has been employed (e.g. the Hirschman-Herfindahl index, the Theil's entropy measure, and the Gini index). Some of these measures suffer from limitations based on both theoretical and methodological implications:

'The C4-index only reacts to changes in the traffic distribution in an airport population when the four largest airports are involved. The Herfindahl-index is only sensitive for changes in the extremes of the population. The coefficient of variance on the other hand, reacts well to changes in the population but is extremely sensitive to the underlying distribution. The Gini-index was the only index to satisfy all of the criteria. The Gini-index is not sensitive to the distribution of the population and reacts quite well to changes in all parts of a given population' (Burghouwt et al., 2003: 310).

The Gini index was developed by the Italian statistician Gini in 1912 (Bellù and Liberati, 2006: 2). The most frequent application of the Gini index is as a measure of the distribution of income inequality. In respect to the spatial concentration in the airline network, the Gini index can be defined as:

$$G = \frac{1}{2n^2\bar{y}} \sum_i \sum_j |y_i - y_j|$$

'where *y* is the air traffic at airport *i* or *j*, defined as the total number of supplied seats per week; *n* is the number of airports in the airline network' (Burghouwt et al., 2003: 310).

The Gini index is derived from 'absolute difference in seat capacity between every possible airport pair in the airline network scaled to the number of airports in that network and the average seat capacity per airport' (Huber, 2009: 152).

The Gini index can be graphically illustrated as the Lorenz curve. The 45° line (the equidistribution line) represents the situation of perfect equality when the seat capacity is

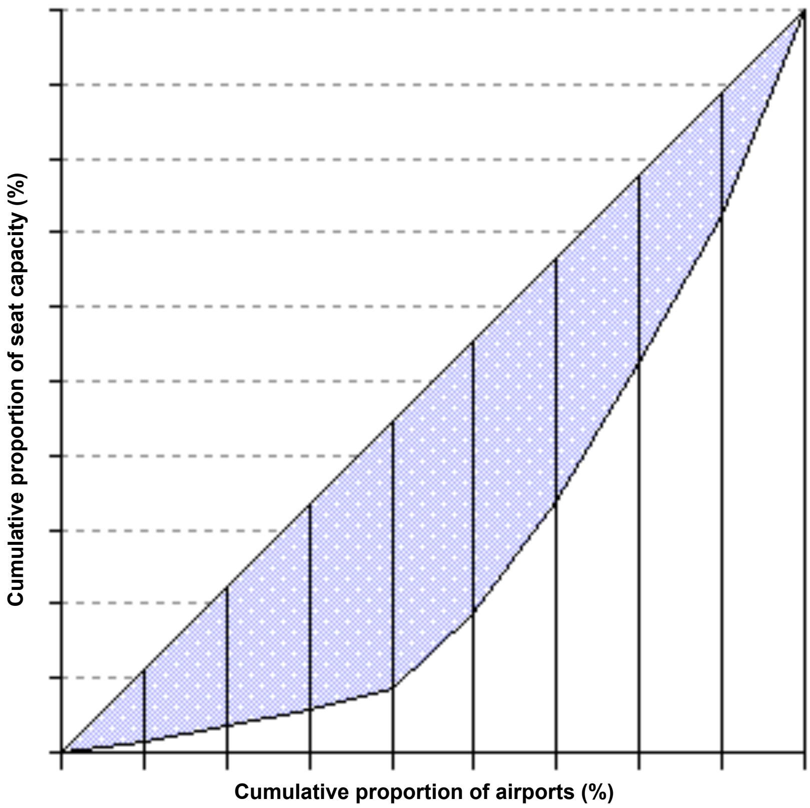

Figure 4.1.1 The Lorenz curve for the Russian carrier Kogalymavia (2002)
Source: OAG

equally distributed across the entire population of airports (Bellù and Liberati, 2006: 2). In such case, the Gini index is equal to 0. The value of the Gini index is equal to 1 when all seat capacity is concentrated in one airport, and no traffic is departing or arriving from any other airport in the network. However, in real-world, such scenario is not possible as usually no more than 50% of traffic is concentrated in one airport. Hence, the value of the Gini index cannot reach its maximum possible value of 1 (Burghouwt, 2005: 65-66; Martín and Voltes-Dorta, 2008: 170). Figure 4.1.1 shows the Lorenz curve for the Russian carrier Kogalymavia. The light-shaded dashed section between the Lorenz curve and the equidistribution line represents the concentration area. The Gini index measures the ratio of the concentration area to the area of maximum concentration[26] (Bellù and Liberati, 2006: 3). Appendix A provides the details on decomposition and calculation of the Gini index.

The maximum Gini index value is dependent on the network size and occurs when the air traffic in a single-radial/hub-and-spoke network is concentrated on one particular route. The maximum Gini index is expressed as a function as follows:

$$G_{\max} = 1 - \frac{2}{n}$$

[26] The area of maximum concentration can be defined as the sum of concentration area and the area under the Lorenz curve.

where *n* defines the number of airports in a network (Burghouwt et al., 2003: 311). Burghouwt corrected the Gini index for the size of airline network (the number of airports) by dividing the Gini index by its maximum value. The 'network concentration index' (the normalized Gini index) allows 'to compare the spatial structure of airline networks independent of network size' (Cento, 2009: 110). The network concentration index can be expressed as a function as follows:

$$\mathrm{NC} = \frac{G}{G_{\max}}$$

Similarly to the Gini index values, the network concentration (NC) index scores can theoretically range between 0 and 1. A value of 0 represents a network with equal distribution of traffic as all airports have the same traffic share, whereas a score close to 1 denotes a network with unequally distributed flows where traffic is concentrated on one route, e.g. very concentrated single-radial network (Martín and Voltes-Dorta, 2008). According to Burghouwt et al. (2003: 311), the increase in NC index values can be attributed to the following factors:

- Increasingly unequal distribution of traffic over the network routes, associated with the supply of capacity deployed by an airline.

- The removal of *hub-bypass* routes. In the hub-and-spoke network, some routes can bypass the hub. These routes are usually operated by an airline when there is a sufficient passenger demand to warrant the hub-bypass routing. The elimination of such routes increases the concentration of traffic in a hub. Therefore, it enables the airline to exploit the network economies on a greater scale.

- The reconfiguration of network from a single-hub to multi-hub. The rise of NC index values is caused by concentration of traffic in more hubs.

Additionally, Burghouwt (2005: 68) asserts that airline networks can be categorized with reference to the NC index value (based on the seat capacity[27]). I refer to the categorization as shown in Table 4.1.1 when describing networks on the basis of spatial distribution of seat capacity.

	Spatial distribution of seat capacity		**Morphology of the route network**	
NC value	**Large network (>20 nodes)**	**Small network (<=20 nodes)**	**Large network (>20 nodes)**	**Small network (<=20 nodes)**
<0.49	Deconcentrated	Deconcentrated	Non-radial	-
0.49-0.60	Moderately concentrated	Moderately concentrated	Non-radial/radial	-
0.61-0.70	Concentrated	Concentrated	Radial	-
0.71-0.82	Very concentrated	Very concentrated	Multi-radial	-

Table 4.1.1 NC index values and categorization of airline networks
Source: Burghouwt (2005: 68)

[27] The NC index values can be calculated by using different inputs, e.g. the seat capacity, frequency of flights. I refer to Burghouwt (2005: 67) for more details on the input variables.

4.1.2 The Freeman centrality index

The Freeman centrality index was designed in the context of social network analysis, and it measures the importance of a node in a network (Cento, 2009: 111). The concept of centrality is closely related to the level of 'power' exercised by certain nodes in a network. To elaborate, the node is powerful when it is directly connected to a number of other nodes. Hence, the power is a result of relations between nodes, and it can vary significantly in different network types (Hanneman and Riddle, 2005: 75). For instance, all nodes in a fully connected point-to-point network are equally powerful as they all have the same number of links. However, depending on the network design, being powerful does not necessarily mean being central.

Over the years, the theoretical knowledge on centrality developed considerably, and multiple measures were proposed in order to describe the concept. In general, the centrality can be categorized into three notions: degree, closeness, and betweenness. It is beyond the scope of this thesis to examine all of them[28]. In this section, I only focus on the betweenness centrality. In order to illustrate the rationality behind the betweenness centrality, I consider the hub-and-spoke network with single hub (as depicted in Figure 2.2.1) as an example. In the hub-and-spoke network, the node in the center (hub) has a favorable position as it is located on the path between all other pairs of nodes (spokes) in the network. In other words, one must pass through the hub in order to travel between any pair of spokes.

As Cento (2009: 112) states, the betweenness centrality measures are based on the notion of geodesic paths. The geodesic path is the shortest connection between two nodes. This path can pass through a number of nodes. However, no node should be visited more than once (Cento, 2009: 112). We can assume that information in the network travels the most efficiently when the exchange occurs over the shortest geodesic path. In relation to airline networks, some passengers might prefer to travel over the shortest geodesic path even when numerous alternatives are possible as it usually translates into the shortest travel time. The 'length' of the geodesic path can be expressed as the geodesic distance. To be precise, the geodesic distance is:

'the number of relations in the shortest possible walk[29] from one actor to another' (Hanneman and Riddle, 2005: 50).

Through the examination of concepts of the geodesic path and geodesic distance, we can conclude that the betweenness centrality relates to a number of connections that information needs to travel through between any two nodes in a network. As a function, the betweenness centrality can be expressed as follows:

$$C_k^{\mathrm{BET}} = \sum_i \sum_j \frac{g_{ikj}}{g_{ij}}$$

[28] I refer to Borgatti and Everett, 2006; Hanneman and Riddle, 2005; Ruhnau, 2000 for detailed review of the centrality measures.

[29] The length of a walk is determined by the number of edges (links) it contains (Borgatti and Everett, 2006: 468).

where ‘g_{ikj} denote the number of geodesic paths from node *i* to node *j* that pass through intermediary *k*’ (Borgatti and Everett, 2006: 474).

The normalized value of the betweenness centrality (the Freeman centrality index value) can vary between 0 and 1. According to Hanneman and Riddle (2005: 65), the index expresses ‘the degree of inequality or variance in our network as a percentage of that of a perfect star network[30] of the same size’. The Freeman centrality index value of 1 denotes a perfect single-radial (or hub-and-spoke) network, whereas the value of 0 indicates a fully connected point-to-point network. Thus, the index enables to determine the morphology of a network. Cento (2009: 115) asserts that in comparison with the Freeman centrality index, the normalized Gini index has limited capabilities to describe the morphology of airline networks. Precisely, he criticizes that in some cases, the normalized Gini index does not distinguish between numerous network configurations. This is supported by the examination of examples as

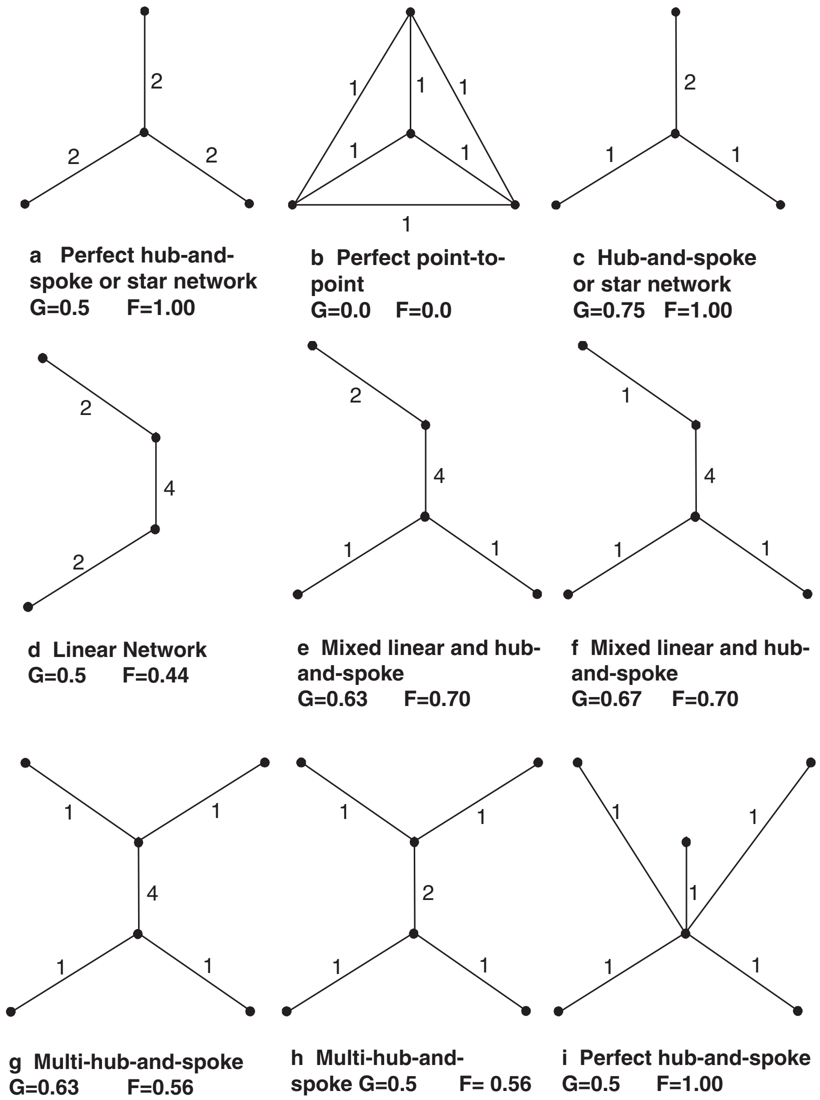

Figure 4.1.2 Examples of normalized Gini index (G) and Freeman centrality index (F) values
Source: Cento (2009: 116)

[30] Morphologically, a perfect star network is equivalent to a perfect single-radial network.

pictured in Figure 4.1.2. For instance, in cases A and H, the normalized Gini index is equal to 0.5, while the morphology of both networks differs considerably. Cento concludes that the normalized Gini index is sensitive to the concentration of frequencies[31] as is evident in e.g. cases G and H (G = 0.63 and 0.5, respectively). In contrast, the Freeman centrality index clearly detects the difference in morphology of various network configurations. In radial (or hub-and-spoke) networks, the Freeman centrality index value is equal to 1 (cases A, C, and I), whereas in multi-radial (or multi-hub-and-spoke) networks, the Freeman centrality index scores are considerably lower (cases G and H). Moreover, the Freeman centrality index does not seem to be affected by the concentration of frequencies, e.g. F = 0.70 in cases E and F, while the spatial distribution of frequencies varies in both networks. Hence, we can conclude that the normalized Gini index is sensitive to the concentration of frequencies, but it does not completely capture changes in the morphology of networks. Unlike the normalized Gini index, the Freeman centrality index is not sensitive to the concentration of frequencies, and it captures the change in configuration of networks. Thus, Cento (2009: 115) sees the Freeman centrality index as a better determinant of the morphology of airline networks. I employ both the normalized Gini index and the Freeman centrality index in order to capture the spatial distribution and concentration of seat capacity and determine the morphology of airline networks, respectively.

4.1.3 The Bonacich centrality analysis

Phillip Bonacich got beyond the three principal concepts of centrality (degree, closeness, betweenness) and proposed the so-called *eigenvector approach*. The aim of the eigenvector approach is to identify the most central nodes in a network. In contrast to other centrality measures, the eigenvector approach is focused on global (or 'the most pronounced') structure of a network, while it pays less attention to local patterns (Cento, 2009: 116-117). The eigenvector centrality can be defined as:
'the principal eigenvector of the matrix that represents the network (adjacency matrix). The defining equation of an eigenvector is:

$$\lambda \mathrm{v} = \mathrm{Av}$$

where *A* is matrix representing the network: *λ* is the eigenvalue; and *v* is eigenvector' (Cento, 2009: 115).

The factor analysis[32] is employed as a technique to identify eigenvalues and eigenvectors for each network. To elaborate, the eigenvalue represents the location of each node in relation to its distance from other nodes, and the eigenvector denotes the entire group of such eigenvalues (Hanneman and Riddle, 2005: 68). Tables 4.1.2 and 4.1.3 show the results of the factor analysis (eigenvalues) as well as the eigenvector centralities for the Russian carrier Vladivostok Air in 2002. The first eigenvalue (1st factor) reflects the global (dominant)

---

[31] Cento (2009) has used the frequency of flights as the input variable for calculation of the normalized Gini index scores.

[32] The detailed explanation of the factor analysis is beyond the scope of this thesis. The following website includes additional information on the factor analysis (Reese and Lochmüller, 1994):
http://www.chem.duke.edu/~clochmul/tutor1/factucmp.html [10 Aug 2012]

EIGENVALUES				
FACTOR	VALUE	PERCENT	CUMULATIVE %	RATIO
1:	9.276	76.7	76.7	3.290
2:	2.819	23.3	100.0	
3:	0.000	0.0	100.0	
4:	0.000	0.0	100.0	
	12.096	100.0		

Table 4.1.2 The results of the factor analysis for the Russian carrier Vladivostok Air (2002)
Source: OAG

BONACICH EIGENVECTOR CENTRALITIES		
	EIGENVECTOR	nEIGENVECTOR
1 Yekaterinburg	0.082	11.602
2 Irkutsk	0.254	35.874
3 Khabarovsk	0.303	42.829
4 Krasnodar	0.076	10.707
5 Moscow Sheremetyevo	0.303	42.829
6 Novosibirsk	0.076	10.707
7 Petropavlovsk-Kamchatsky	0.303	42.829
8 Vladivostok	0.702	99.325
9 Yakutsk	0.076	10.707
10 Yuzhno-Sakhalinsk	0.379	53.536

Table 4.1.3 The Bonacich eigenvector centralities for the Russian carrier Vladivostok Air (2002)
Source: OAG

pattern of distances among nodes, while the rest of eigenvalues capture local patterns of the network. The first factor explains 76.7% of variation in distances among nodes. Thus, the global pattern captures more than 3/4 of all distances among all nodes in the network. In case that the percentage of overall variation reflected by the first factor is lower than 70%, the dominant pattern does not completely describe the data (see Hanneman and Riddle, 2005: 69-70). Also, the increase of the first eigenvalue over time indicates that a network became more rationalized, whereas the decrease denotes the rise in complexity of a network. With regard to the eigenvector centralities (Table 4.1.3), higher values indicate that nodes are central to the global pattern of distances, whereas lower scores show that nodes are more peripheral. Thus, Vladivostok was the most central node, while Krasnodar, Novosibirsk, and Yakutsk were the most peripheral nodes in the network of Vladivostok Air in 2002.

4.2 The database and classification of carriers

Variable	Description
ORIGIN_CODE	The IATA code of the airport (origin)
ORIGIN	The name of the airport (origin)
DESTINATION_CODE	The IATA code of the airport (destination)
DESTINATION	The name of the airport (destination)
PUBLISHED_CARRIER_CODE	The IATA code of the carrier
PUBLISHED_CARRIER	The name of the carrier
DAYS_OF_OPERATION	Designates days on which certain routes are served
NUMBER_OF_OPERATIONS	The total number of weekly operations
SCHEDULED_SEATS	The number of seats available on a specific route

Table 4.2.1 The overview of variables included in the OAG database, 2002 and 2008
Source: OAG

Database sample									
Case Number	ORIGIN_CODE	ORIGIN	DESTINATION_CODE	DESTINATION	PUBLISHED_CARRIER_CODE	PUBLISHED_CARRIER	DAYS_OF_OPERATION	NUMBER_OF_OPERATIONS	SCHEDULED_SEATS
1	AAQ	Anapa Russian Fed.	DME	Moscow (Domodedovo) Russian Fed.	FV	Pulkovo Aviation Ente (NC)	3	1	72
2	AAQ	Anapa Russian Fed.	DME	Moscow (Domodedovo) Russian Fed.	FV	Pulkovo Aviation Ente (NC)	7	1	72
3	AAQ	Anapa Russian Fed.	DME	Moscow (Domodedovo) Russian Fed.	S7	Siberia Airlines	.	3	492

Table 4.2.2 The sample overview of the OAG database as seen in SPSS statistics software
Source: OAG

The database, used as the source material for my research, is based on the data collected by OAG (Official Airline Guide). The branch of OAG, OAG Aviation, is a leading company in data products (flight schedules), analysis (carrier performance data, fleet and traffic analysis, maintenance and overhaul, etc.), and passenger communications tools (real-time flights status) (OAG Aviation, 2012). The database includes the data for two years (2002 and 2008), and it covers the same time period (the third week of September) in order to avoid fluctuation in results derived from monthly or seasonal variations. The data provides information on origin and destination of flights, operating carrier, the number and days of operations in one week, and the number of scheduled seats available. Table 4.2.1 gives a complete overview of all variables included in the OAG database. The IATA (International Air Transport Association) codes in the database designate airports and operating carriers. The dataset does not contain any international flights originating or terminating in Russia. Only non-stop direct Russian domestic flights (passenger or *combi*[33]) are included. Also, taking into consideration that the research is focused on the study of Russian airlines, all non-Russian carriers are omitted[34] from the analysis.

[33] 'Combi' aircraft allows for carriage of both passengers and cargo on the same deck. Such arrangement allows for greater flexibility as the size of passenger cabin and cargo bay can be adapted on the basis of demand. Unlike combi airplanes, usual passenger airliners carry their cargo in dedicated cargo bays located underneath the cabin.

[34] With regard to the raw database for 2008, it includes Czech Airlines (the flag carrier of the Czech Republic) as the operating carrier on the route Moscow Sheremetyevo - Irkutsk. The cases in question are excluded from the research database. The dataset for 2002 contains only Russian carriers.

Furthermore, it is important to mention that the data is not perfectly symmetrical. To elaborate, the sum of scheduled seats available on all departing and arriving flights (to and from a particular airport) is supposed to be equal when dealing with symmetrical data. Analytical software applications (e.g. Ucinet) are able to treat and symmetrize the database but not without the distortion of the data. Therefore, I decided not to symmetrize the data.

The following input variables play a crucial role in the analytical part of the research: (i) the number of scheduled seats (the seat capacity) and (ii) the number of operations (the number of frequencies). In this paragraph, I explain the reasoning behind my decisions to use a particular variable as a measure of the air traffic. As I mentioned before, I apply three specific concentration and centrality measures in my research. Firstly, I use the seat capacity as the input variable for calculation of the normalized Gini index (the network concentration index) scores. In contrast to the number of frequencies, the seat capacity acting as the input variable allows to detect routes with rather large supply of scheduled seats. Although Cento (2009: 115) argues that the normalized Gini index has limited capabilities to identify the network morphology, the index is a good indicator of the traffic distribution in airline network. Secondly, the Freeman centrality index is not sensitive to the concentration of seat capacity or frequencies. Therefore, the calculation of this measure is not dependent on any of two variables. In other words, neither of two input variables is needed in order to calculate the Freeman centrality index scores. Lastly, the results of the Bonacich centrality analysis are calculated with the number of frequencies being the input variable. The rationale behind this decision is that nodes with a significant concentration of seat capacity might not necessarily be the most central (see Hanneman and Riddle, 2005: 60-76).

One of the most characteristic features of the contemporary Russian airline industry is its magnitude of fragmentation. According to Russian Aviation (2011), 168 Russian airlines were present in the domestic market in July 2010[35]. Hence, it might be essential to categorize airlines in groups based on the same or similar features and characteristics. In a few past studies (e.g. Alderighi et al., 2007; Cento, 2009; Reynolds-Feighan, 2001; Reynolds-Feighan, 2007), researchers opted for categorization based on the cost structure of airlines, e.g. full-service carriers, low-cost carriers. However, such type of categorization is not possible when dealing with Russian carriers. During the period of analysis, only one low-cost airline (Sky Express[36]) was present in the Russian domestic market. Moreover, the homogeneity of Russia as one nation-state does not allow for categorization of carriers on the basis of origin or country of registration. Thus, I categorize airlines into three groups according to the number of destinations served:

Group A carriers: carriers which served more than 20 destinations in Russia in 2002 and/or 2008. The Russian flag carrier, Aeroflot, is included in this category. In addition, carriers such as S7 Airlines, Dalavia, UTair Aviation, UTair Express, and others are included.

---

[35] Not all carriers which operated on domestic routes in Russia in 2002 and/or 2008 are included in the OAG database. See Chapter 6, Section 6.2.

[36] Sky Express lost its air operator's certificate (AOC) in 2011. The company restarted its operations under a new AOC with Russian regional carrier Kuban Airlines. Beside Sky Express, the Russian low-cost carrier Avianova had its AOC suspended in 2011. Avianova started flights in 2009, but the lack of funding from American and Russian investors forced the airline to cease operations in October 2011 (Air Transport World, 2011). However, Avianova is not included in the analysis as the carrier did not operate during the time period examined in the research (the years 2002 and 2008).

Group B carriers: carriers which served between 10 and 20 destinations in Russia in 2002 and/or 2008. For the most part, this category contains airlines which did not reach the scale of Group A carriers. For example, the group includes two subsidiaries of Aeroflot (Aeroflot-Don and Aeroflot Nord), several members of AiRUnion partnership (Domodedovo Airlines, Sibaviatrans, Samara Airlines), and the first Russian low-cost carrier Sky Express.

Group C carriers: all airlines which served less than 10 destinations in Russia in 2002 and/or 2008. E.g. Astrakhan Airlines, Bashkir Airlines, Centre-Avia Airlines, Kogalymavia, Sakhalinskie Aviatrassy, Tatarstan.

The full classification of carriers is available in Appendix B. It is important to mention that different categorizations of carriers are fully possible. Figure 4.2.1 provides a short recap of the main concepts and measures covered in this chapter. The next chapter is focused on the analytical part of the thesis.

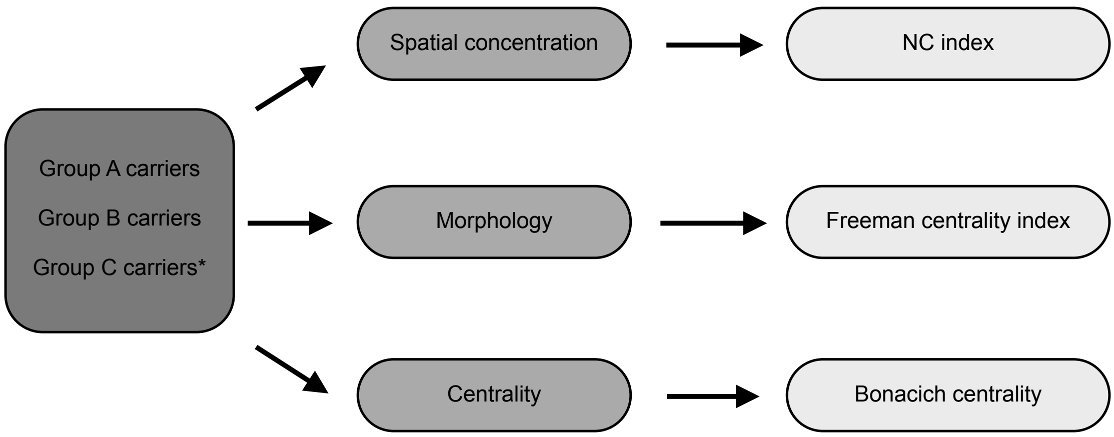

Figure 4.2.1 The scheme of the main concepts and measures implemented in the research
* The analysis of centrality (by means of the Bonacich centrality analysis) has not been conducted for Group C carriers as the character of their networks (i.e. small network size) makes the interpretation of results rather difficult.

CHAPTER 5: THE ANALYSIS OF DOMESTIC ROUTE NETWORKS OF RUSSIAN CARRIERS (2002 - 2008)

In this chapter, I employ the spatial approach to the analysis of airline networks in order to study domestic route networks of Russian airlines. In the first section, I provide the current perspective on the performance and expansion of Russian carriers over the last decade (2000 - 2009). This part should give us general information about the competition among carriers and both consolidating and divisive forces directly affecting the airline business in Russia. The second section of this chapter is focused on the spatial dimension of domestic route networks of three groups of Russian carriers.

5.1 General trends and development of the Russian airline industry

The Russian airline industry significantly expanded over the last decade. According to the OAG database, the total seat capacity increased by 109% from 2002 to 2008. Such growth can be partly attributed to the rise of disposable income among the Russian population (Airline Leader, 2011). The increase of income has enabled Russians to carry out more business and leisure trips. However, it should be noted that the demand for air travel in Russia over the last decade was also negatively affected by numerous events of global and regional importance. Notably, the worldwide airline industry crisis that resulted from the terrorist attacks on the World Trade Center in New York and the Pentagon in Washington DC in September 2001. Furthermore, the outbreak of SARS (severe acute respiratory syndrome) in East Asia in 2003 put the airline business into further recession (Cento, 2009: 52). What is more, the bomb attacks committed by Chechen terrorists in Russia in 2004 had a direct impact on Russian airlines and airports (Strauss, 2004).

These events did not stop the growth of Russian carriers over the last decade. During the period of analysis, the majority of Russian airlines increased the seat capacity available on domestic routes (Table 5.1.1). Since 2006, the Russian market has become more accessible to foreign carriers as Aeroflot joined the global airline alliance SkyTeam[37]. The inclusion into this exclusive club was not easy for the Russian flag carrier. The airline had to improve its operational standards, safety, and customer service. In addition, the carrier moved into its own terminal at Moscow Sheremetyevo. The new terminal should ease connections between domestic and international flights, so passengers traveling on flights operated by Aeroflot (or partner airlines) are not required to change terminals at Sheremetyevo Airport (Komarov, 2006).

S7 Airlines (previously operated as Siberia Airlines) was inaugurated as the second Russian carrier to join the global airline alliance, when the carrier was admitted into Oneworld[38] (RIA Novosti, 2010). In the beginning of the last decade, S7 Airlines strongly expanded both domestically and internationally. In 2006, the carrier served 36 domestic airports and additional 12 in the republics of the former Soviet Union (Komarov, 2006). However, the

---

[37] One of the three global airline alliances (besides Star Alliance and Oneworld), teaming together airlines such as Air France-KLM, Alitalia, Korean Air, Delta, Czech Airlines, China Southern, etc.

[38] The global airline alliance comprised of carriers such as American Airlines, British Airways, Iberia, Japan Airlines, Cathay Pacific, etc.

Transaero Airlines	809%
UTair Aviation*	444%
Aeroflot Nord*	378%
Vladivostok Air	284%
Orenburg Airlines*	281%
Saratov Airlines	247%
Tatarstan	244%
Ural Airlines	203%
Sakhalinskie Aviatrassy	154%
Kuban Airlines	145%
Aeroflot - Russian Airlines	126%
Aeroflot-Don	106%
S7 Airlines*	89%
UTair Express*	74%
Krasnoyarsk Airlines	72%
Severstal Aircompany	71%
Kavminvodyavia	69%
Yakutia*	57%
Kogalymavia	31%
Rossiya Russian Airlines+	18%
Yamal Airlines	17%
Centre-Avia Airlines	0%
Dalavia - Far East Airways	-22%
Omskavia Airlines	-26%
Sibaviatrans	-26%
Domodedovo Airlines	-31%
Samara Airlines	-39%
Volga-Dnepr Airlines	-59%
Average	133%

Table 5.1.1 The change (%) in seat capacity for selected carriers (2002 - 2008)
Source: OAG
* Airline operated under a different commercial name in 2002 and 2008 (see Appendix B)
+ In order to determine the change in seat capacity, the combined data for Pulkovo Aviation and State Transport Company Rossiya for 2002 was used as these companies merged to form Rossiya Russian Airlines (see Appendix B)

company decreased its market share of supplied seat capacity in the domestic market by 1.61% between 2002 and 2008 (Table 5.1.2). The reduction of market share of seat capacity available on domestic services might be attributed to the focus of S7 Airlines on international routes towards the end of the last decade and/or the temporary contraction of the Russian civil aviation market. Its main competitor Aeroflot saw relatively moderate increase (1%) of market share of seat capacity between 2002 and 2008.

The partnerships of Russian carriers were not exclusively limited to the cooperation with global airline alliances. In the middle of the last decade, Krasnoyarsk-based Krasnoyarsk Airlines launched the initiative to form AiRUnion, a joint cooperation among several Russian airlines. In 2006, Krasnoyarsk Airlines was the fifth largest Russian carrier in terms of the number of passengers carried (Komarov, 2006). The partnership also involved Samara

UTair Aviation*	7,59%
Aeroflot Nord*	2,20%
Transaero Airlines	1,74%
Vladivostok Air	1,47%
Aeroflot - Russian Airlines	1,00%
Ural Airlines	0,85%
Orenburg Airlines*	0,68%
Tatarstan	0,50%
Saratov Airlines	0,44%
Kuban Airlines	0,33%
Sakhalinskie Aviatrassy	0,11%
Severstal Aircompany	-0,03%
Aeroflot-Don	-0,04%
Volga Dnepr Airlines	-0,21%
Centre-Avia Airlines	-0,22%
UTair Express*	-0,22%
Kavminvodyavia	-0,39%
Sibaviatrans	-0,46%
Yakutia*	-0,52%
Omskavia Airlines	-0,56%
Kogalymavia	-0,80%
Yamal Airlines	-0,90%
Krasnoyarsk Airlines	-1,45%
S7 Airlines*	-1,61%
Samara Airlines	-2,34%
Domodedovo Airlines	-3,32%
Dalavia - Far East Airways	-3,36%
Rossiya Russian Airlines⁺	-5,34%

Table 5.1.2 The change (%) of market share of seat capacity for selected carriers (2002 - 2008)
Source: OAG
* Airline operated under a different commercial name in 2002 and 2008 (see Appendix B)
⁺ In order to determine the change of market share of seat capacity, the combined data for Pulkovo Aviation and State Transport Company Rossiya for 2002 was used as these companies merged to form Rossiya Russian Airlines (see Appendix B)

Airlines (based in Samara), Omskavia Airlines (Omsk), Domodedovo Airlines (Moscow), and Sibaviatrans (Krasnoyarsk). The cooperation of airlines grouped in AiRUnion did not last for long. The alliance was troubled by financial problems. As Table 5.1.2 reveals, the market share of seat capacity of all participating carriers fell between 2002 and 2008. AiRUnion collapsed in 2008, leaving a substantial portion of market to other competitors[39]. The leader and initiator of AiRUnion, Krasnoyarsk Airlines, alone recorded a total debt of approximately $445 million. The bankruptcy forced the Russian government to allocate $162 million as a compensation to carriers which transported stranded passengers holding tickets issued by former AiRUnion carriers (Komarov, 2009a). The collapse of AiRUnion came as a hard knock-out for the Russian airline industry as the Russian government had to intervene, and

[39] Although the demise of AiRUnion took place in 2008, the member carriers are included in the analysis.

the failure damaged the image of Russian carriers willing to seek cooperation and investment opportunities.

Two subsidiaries of Aeroflot, Aeroflot-Don and Aeroflot Nord[40], proved to be more successful in their respective markets than carriers united in AiRUnion. As Table 5.1.2 shows, Aeroflot Nord recorded the second largest increase in the market share of seat capacity between 2002 and 2008. The company was primarily focused on destinations in the Arctic and Northern Russia. Aeroflot-Don has mainly deployed its capacity on routes between cities in the South of Russia (e.g. Sochi, Rostov) and main Russian centers in other parts of the country.

The privately-owned Transaero Airlines achieved similarly impressive results. Moscow-based airline increased its seat capacity by more than 800% between 2002 and 2008 (Source: OAG). The exemption from tax imposed on Russian carriers willing to operate Western-built aircrafts could have given Transaero Airlines a trump card over the rest of Russian airlines. Beside Transaero Airlines, only Aeroflot was given such an advantage (Komarov and Taverna, 2004). Unlike the majority of Russian carriers, the core business of Transaero Airlines has been focused on long-haul operations (Komarov, 2009b). However, the carrier also operates to a number of domestic destinations. Apart from Transaero Airlines, UTair Aviation also experienced an exceptional growth during the period of analysis. The carrier increased its market share of seat capacity by 7.59% between 2002 and 2008, the most of all carriers included in the analysis (Source: OAG). UTair Aviation has become a successful carrier serving a wide array of domestic destinations as well as cities in neighboring countries of the former Soviet Union. The success of UTair Aviation can be attributed to its focus on Western Siberia (e.g. the cities of Surgut, Khanty-Mansiysk, and Syktyvkar), a rich region with heavy concentration of oil and gas industry.

To sum up, the total seat capacity available on domestic routes increased between 2002 and 2008. Carriers such as Transaero Airlines and UTair Aviation were able to increase capacity by 809% and 444%, respectively (Source: OAG). The rise in the market share of seat capacity was not so profound, with the exception of growth achieved by UTair Aviation. The Russian civil aviation sector saw numerous attempts at fostering cooperation among carriers. However, these were not always successful, e.g. the case of AiRUnion. Only two carriers (Aeroflot and S7 Airlines) were able to become the members of global airline alliance.

5.2 The spatial dimension of domestic route networks of Russian airlines

This section provides information on the spatial dimension of domestic route networks of Russian carriers between 2002 and 2008. The analysis is focused on the evaluation of spatial measure of concentration (the normalized Gini index), morphology (the Freeman centrality

---

[40] Aeroflot Nord operated independently as Arkhangelsk Airlines until 2004, when it was acquired by Aeroflot. The cooperation of Aeroflot and Aeroflot Nord was abandoned in September 2008 after the crash of Aeroflot Nord aircraft in Perm in Western Siberia (Aeroflot, 2004; Barents Observer, 2008).

	No. of airlines	No. of nodes	Seat capacity %
2002	37	10.5	2.7
2008	38	13.4	2.6

Table 5.2.1 Number of airlines, average number of nodes served, and average market share (%) of seat capacity, 2002 and 2008
Source: OAG

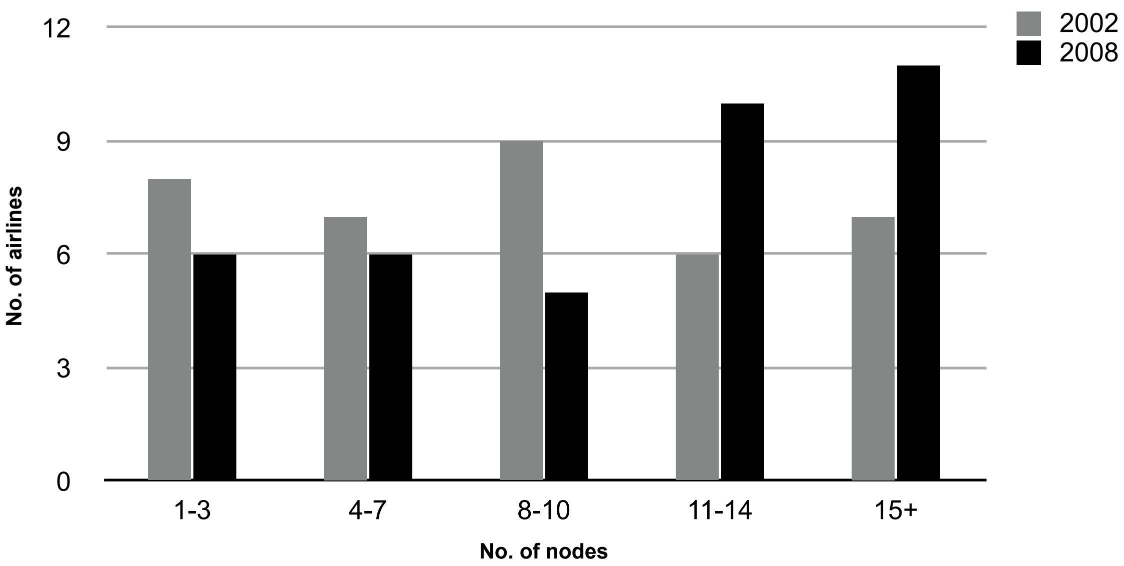

Figure 5.2.1 Frequency distribution of number of nodes served, 2002 and 2008
Source: OAG

index), and node centrality (the Bonacich centrality analysis)[41]. Appendixes C1 and C2 provide a visual material (route network maps) to accompany the results[42].

Between 2002 and 2008, the average market share of seat capacity remained stable (Table 5.2.1)[43]. During the period of analysis, only a few airlines ceased operations (e.g. Magadan Airlines, Astrakhan Airlines, Eurasia Airlines) due to the bankruptcy and other reasons. In general, it seems that Russian airlines were in the process of network expansion as the average number of nodes served increased during the period of analysis (Table 5.2.1). Furthermore, as Figure 5.2.1 shows, the Russian airline industry saw a significant increase in the number of carriers serving 11 or more nodes between 2002 and 2008. Hence, one might conclude that Russian carriers were growing and expanding. However, the database for 2008 includes carriers such as Krasnoyarsk Airlines and Sibaviatrans. These rather big airlines were the members of AiRUnion which went out of business towards the end of the decade. Therefore, the rising trend in network expansion among Russian carriers should not be seen as universal.

---

[41] The Gini index values have been calculated with the online calculator obtained from the website of 'the East of England Public Health Observatory' (ERPHO, 2005). The Freeman centrality index scores and the results of the Bonacich centrality analysis have been calculated with the software package for the analysis of social network data 'Ucinet 6' (Borgatti et al., 2002).

[42] The maps have been produced with the online mapping tool 'The Great Circle Mapper' (Swartz, 2012).

[43] Only carriers included in the OAG database have been considered.

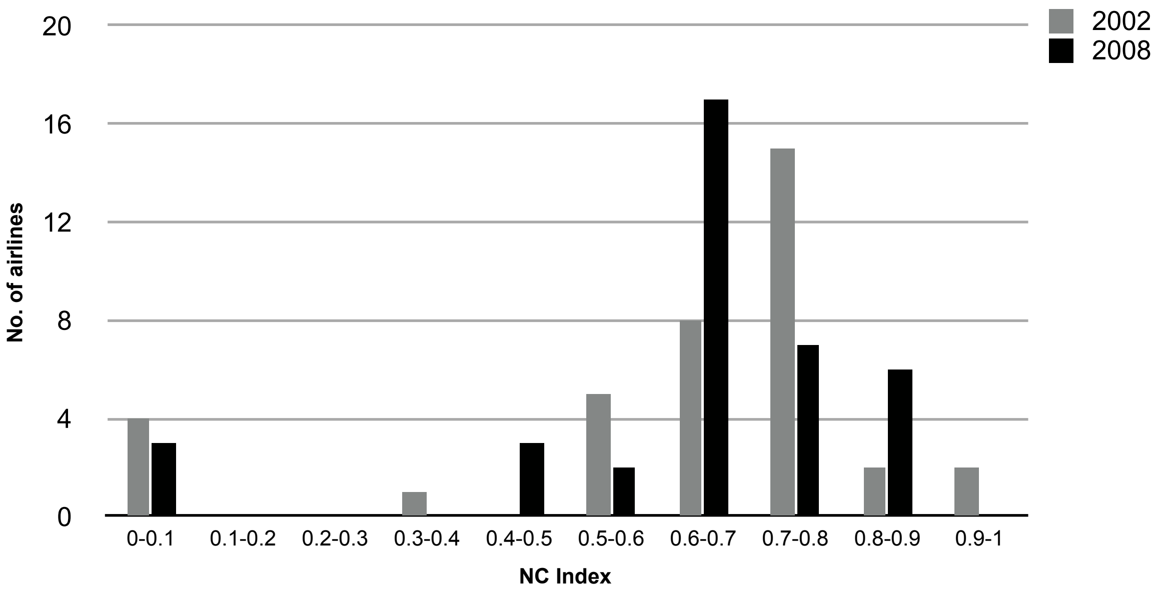

Figure 5.2.2 Frequency distribution of NC index values, 2002 and 2008
Mean: 2002 = 0.63; 2008 = 0.64
Source: OAG

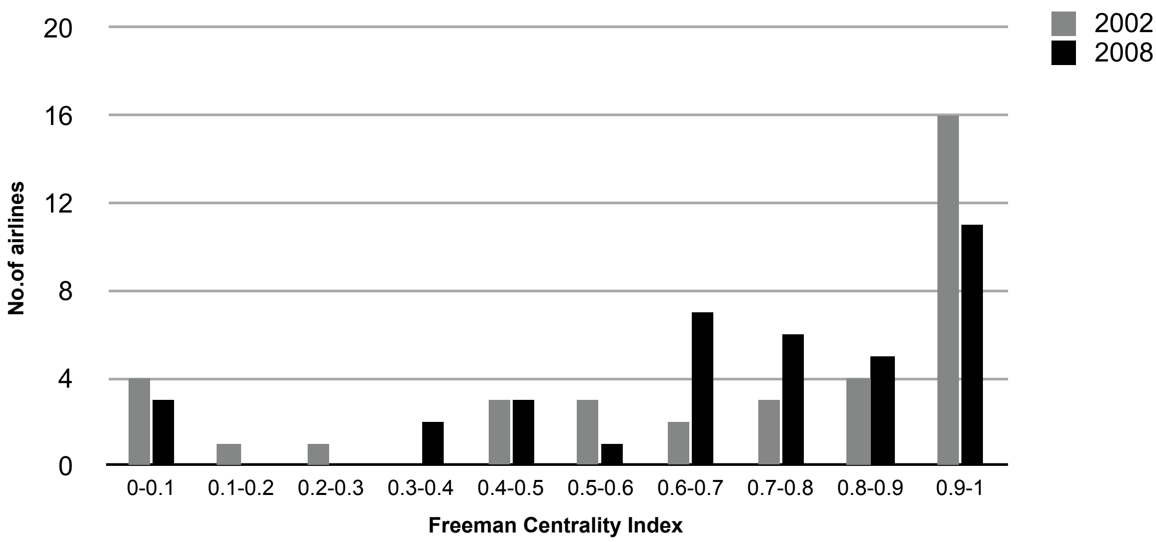

Figure 5.2.3 Frequency distribution of Freeman centrality index values, 2002 and 2008
Mean: 2002 = 0.70; 2008 = 0.70
Source: OAG

In order to evaluate the spatial dimension of Russian airline networks, the NC index and the Freeman centrality index scores were calculated for all airlines included in the OAG database. Figure 5.2.2 displays the frequency distribution of NC index scores for Russian carriers operating in 2002 and/or 2008. It reveals that a large number of airlines operated networks with very concentrated and concentrated distribution of seat capacity in 2002 and 2008, respectively. The average NC index value for all airlines did not change significantly during the period of analysis. With regard to the morphology of airline networks, the examination of the frequency distribution of the Freeman centrality index values (Figure 5.2.3) reveals that a substantial proportion of Russian carriers operated single-radial networks in 2002 and 2008. In 2008, we can observe an increase in the number of mixed radial and linear networks. The average Freeman centrality index score for all carriers did not fluctuate during the period of analysis. In the following sections, I elaborate on the spatial dimension of domestic route networks of three groups of Russian carriers. The classification of airlines is covered in Chapter 4, Section 4.2 and Appendix B.

5.2.1 Group A carriers

The majority of Group A carriers operated networks composed of more than 20 nodes in 2002 and 2008 (Figure 5.2.4). Table 5.2.2 shows that the number of airlines in this category as well as the average market share of seat capacity remained stable during the period of analysis. In terms of the spatial distribution of seat capacity (the NC index scores), the prevalence of networks of Group A carriers can be characterized as concentrated to very concentrated, with the exception of network of UTair Express in 2008 (Figure 5.2.5). The NC index scores ranged between 0.64 (Dalavia) and 0.79 (Pulkovo Aviation) in 2002, and 0.45 (UTair Express) and 0.78 (Rossiya) in 2008. The variation of the NC index values of individual carriers was marginal, UTair Express being the only carrier that scored considerably different values during the period of analysis. In comparison with the NC index scores, the variation of the Freeman centrality index values (Figure 5.2.6) of Group A carriers was substantial. The Freeman centrality index values varied between 0.46 (UTair Aviation) and 0.99 (Aeroflot) in 2002, and 0.38 (UTair Express) and 0.99 (Aeroflot) in 2008. The following paragraphs further elaborate on the spatial dimension of domestic route networks of specific Group A carriers.

Aeroflot, the Russian flag carrier, has built its domestic network around its base at Moscow Sheremetyevo. The NC index and the Freeman centrality index scores indicate that Aeroflot operated a single-radial network with rather concentrated distribution of seat capacity in 2002 and 2008. The results of the factor analysis (Table 5.2.4) show that the network of Aeroflot can be principally characterized by one factor[44]. Therefore, a global structure dominates the network of Aeroflot in 2002 and 2008. The carrier did not make considerable structural adjustments to its network during the period of analysis. As the results of the Bonacich eigenvector analysis (Table 5.2.3) confirm, Sheremetyevo Airport was more central than any other airport in the network of Aeroflot. The utilization of the single-radial network by Aeroflot might be attributed to the legacy of the past and an attempt for the optimization of resources at the same time. The focus on Sheremetyevo has enabled Aeroflot to benefit from the spatial concentration of fleet, facilities, and labor. Moreover, the significance of bilateral agreements should not be underestimated as one of the reasons for strong presence of the carrier at Moscow Sheremetyevo. However, the incorporation of international traffic and bilateral agreements falls out of scope of this thesis and should be the subject of further research.

---

[44] One factor explains approximately 96.4% (2002) and 91.9% (2008) of the distance variation (Table 5.2.4).

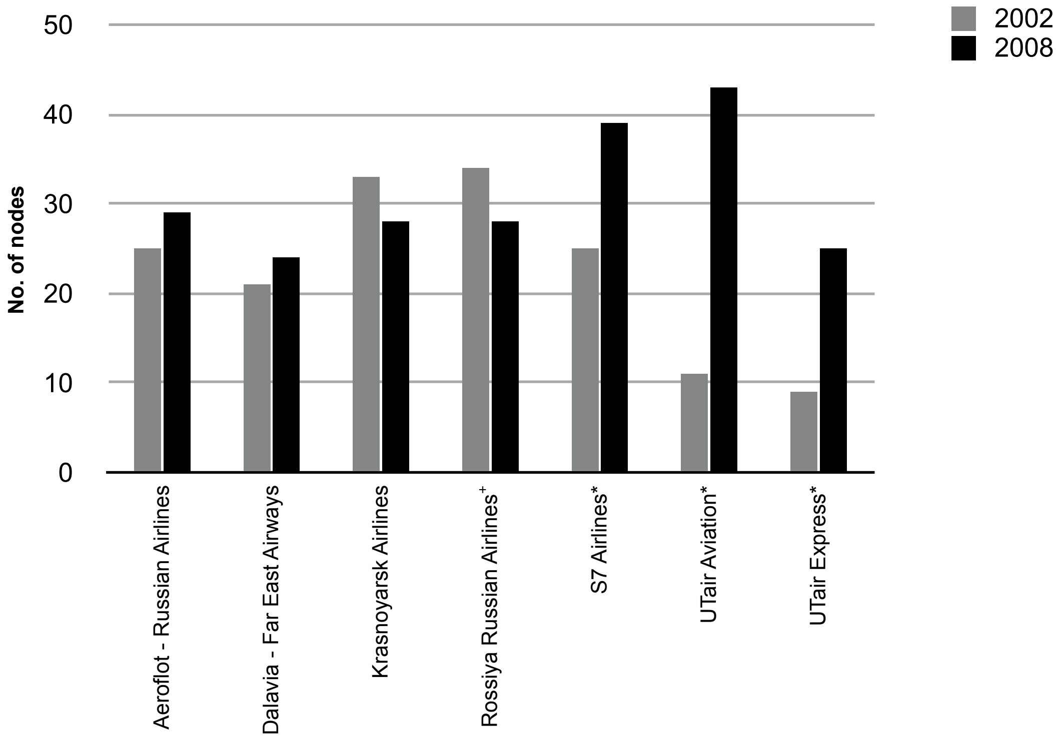

Figure 5.2.4 Number of nodes served by Group A carriers, 2002 and 2008
Source: OAG
* Airline operated under a different commercial name in 2002 and 2008 (see Appendix B)
[+] For 2002, the data for Pulkovo Aviation was used

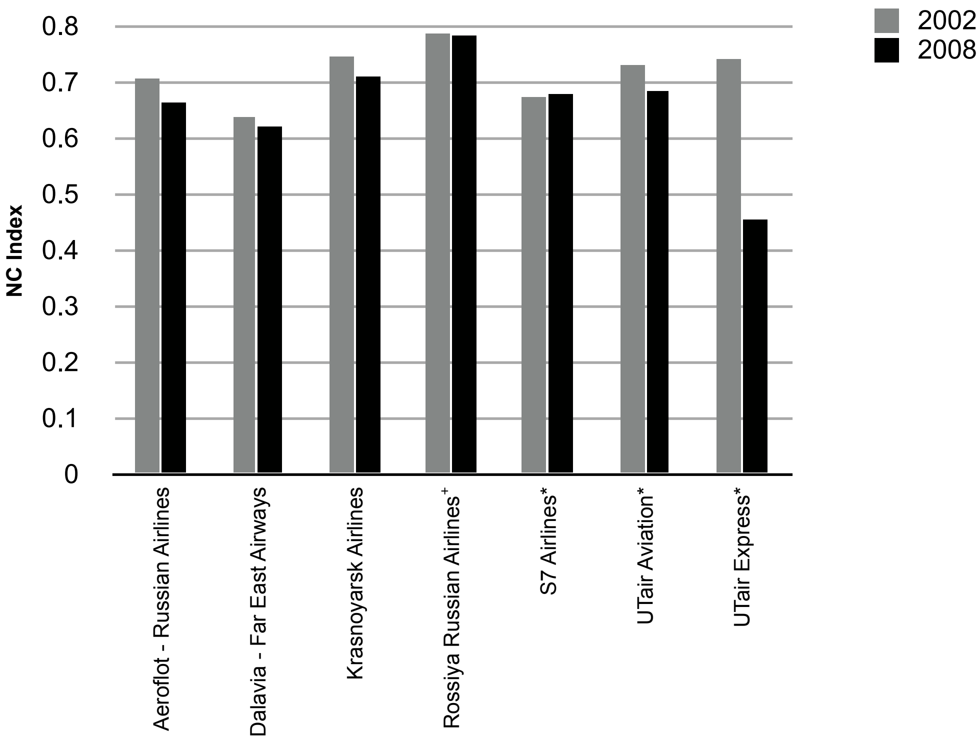

Figure 5.2.5 Network concentration index scores for Group A carriers, 2002 and 2008
Source: OAG
* Airline operated under a different commercial name in 2002 and 2008 (see Appendix B)
[+] For 2002, the data for Pulkovo Aviation was used

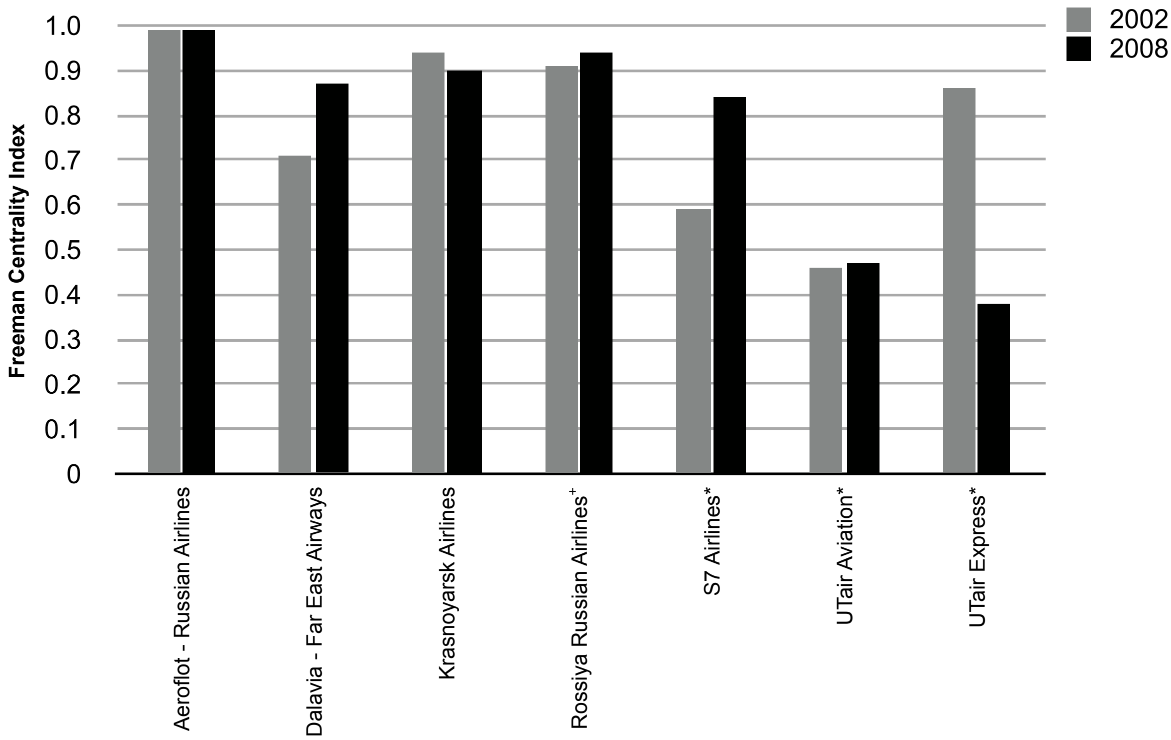

Figure 5.2.6 Freeman centrality index values for Group A carriers, 2002 and 2008
Source: OAG
* Airline operated under a different commercial name in 2002 and 2008 (see Appendix B)
+ For 2002, the data for Pulkovo Aviation was used

	No. of airlines	NC	F	Seat capacity %
2002	7	0.72	0.78	8.4
2008	7	0.66	0.77	8.2

Table 5.2.2 Number of airlines, average network concentration index values, average Freeman centrality index scores, and average market share (%) of seat capacity for Group A carriers, 2002 and 2008
Source: OAG

S7 Airlines, one of the biggest competitors of Aeroflot on both domestic and international routes, exhibited similarly concentrated distribution of seat capacity across its network in 2002 and 2008 (Figure 5.2.5). The increase of the Freeman centrality index score (Figure 5.2.6) of S7 Airlines in 2008 can be put down to a larger centralization of network on Moscow Domodedovo, while the role and centrality of Novosibirsk as a node decreased. The number of destinations served directly from Moscow Domodedovo increased by 17 between 2002 and 2008, whereas the number of destinations directly reachable from Novosibirsk was reduced by 2 during the same time period (Source: OAG). The decline in centrality of Novosibirsk is also evident from the results of the Bonacich eigenvector analysis (Table 5.2.3). Consequently, the network of S7 Airlines can be described as more rationalized in 2008 than in 2002. The rationalization is also supported by the factor analysis[45] (Table 5.2.4).

[45] The first factor recorded an increase in 2008 in comparison with 2002. Hence, the network of S7 Airlines was more rationalized in 2008 than it was in 2002.

2002		2008	
Aeroflot - Russian Airlines			
Moscow Sheremetyevo	100.0	Moscow Sheremetyevo	99.9
Sankt Petersburg	52.1	Sankt Petersburg	54.9
Volgograd	39.1	Krasnodar	33.0
Sochi	29.8	Sochi	28.2
Dalavia - Far East Airways			
Khabarovsk	96.6	Khabarovsk	96.7
Yuzhno-Sakhalinsk	65.2	Sovetskaya Gavan	51.0
Moscow Domodedovo	51.5	Okha	45.3
Irkutsk	37.5	Moscow Domodedovo / Moscow Sheremetyevo	39.1
Krasnoyarsk Airlines			
Krasnoyarsk	94.8	Krasnoyarsk	95.2
Moscow Domodedovo	71.5	Moscow Vnukovo	59.8
Norilsk	43.2	Norilsk	59.8
Sochi	19.7	Kemerovo	31.3
Rossiya Russian Airlines+			
Sankt Petersburg	99.9	Sankt Petersburg	99.8
Moscow Sheremetyevo	96.4	Moscow Sheremetyevo	82.9
Kaliningrad	10.6	Moscow Domodedovo	41.5
Sochi	9.4	Moscow Vnukovo	21.7
S7 Airlines*			
Moscow Domodedovo	95.7	Moscow Domodedovo	97.9
Novosibirsk	62.1	Novosibirsk	42.4
Irkutsk	38.4	Perm	32.1
Sochi	36.4	Rostov	31.1
UTair Aviation*			
Moscow Vnukovo	90.1	Moscow Vnukovo	80.9
Surgut	71.6	Tyumen	45.7
Tyumen	50.8	Surgut	44.5
Nizhnevartovsk	47.0	Samara	37.2

Table 5.2.3 The Bonacich eigenvector analysis results for Group A carriers
Source: OAG
* Airline operated under a different commercial name in 2002 and 2008 (see Appendix B)
+ For 2002, the data for Pulkovo Aviation was used

	2002		2008
UTair Express*			
Moscow Sheremetyevo	90.7	Beloyarsky	78.2
Syktyvkar	83.7	Tyumen	58.2
Usinsk	55.6	Surgut	53.2
Ukhta	31.2	Khanty-Mansiysk	38.8

Table 5.2.3 The Bonacich eigenvector analysis results for Group A carriers (continued)
Source: OAG
* Airline operated under a different commercial name in 2002 and 2008 (see Appendix B)

	2002	2008	2002	2008
Carrier	Aeroflot - Russian Airlines		Dalavia - Far East Airways	
Factor 1	96.4	91.9	57.9	62.5
Factor 2	100.0	96.5	76.3	74.5
Factor 3		100.0	82.8	81.8
Factor 4			86.3	87.9
Carrier	Krasnoyarsk Airlines		Rossiya Russian Airlines+	
Factor 1	74.1	59.1	84.5	83.1
Factor 2	84.5	78.3	88.6	94.4
Factor 3	90.0	89.2	92.0	97.8
Factor 4	93.7	93.3	94.8	100.0
Carrier	S7 Airlines*		UTair Aviation*	
Factor 1	75.3	80.0	81.3	43.6
Factor 2	87.0	88.4	93.0	62.2
Factor 3	92.9	92.1	100.0	71.6
Factor 4	95.9	95.1		79.2
Carrier	UTair Express*			
Factor 1	87.8	25.3		
Factor 2	100.0	48.6		
Factor 3		69.8		
Factor 4		81.5		

Table 5.2.4 The factor analysis results for Group A carriers (in cumulative %)
Source: OAG
* Airline operated under a different commercial name in 2002 and 2008 (see Appendix B)
+ For 2002, the data for Pulkovo Aviation was used

Likewise, the rise of the Freeman centrality index score for Dalavia in 2008 indicates that the carrier's network became more centralized throughout the period of analysis. The NC index scores show that the level of spatial concentration of seat capacity in 2002 and 2008 was slightly lower than the levels recorded by Aeroflot and S7 Airlines. The results of the Bonacich eigenvector analysis reveal that Moscow Domodedovo became less central in 2008, while Khabarovsk retained its position as the most central node. With regard to Moscow's airports, Dalavia also served Sheremetyevo beside Domodedovo in 2008. However, the question of node centrality in the network of Dalavia cannot be answered with complete clarity. A high centrality score for Moscow Domodedovo in 2002 might be attributed to the routing of services via the airport[46] rather than it being the base of Dalavia. Due to the data limitations (see Chapter 6, Section 6.2), it is not possible to resolve the issue in this research. The factor analysis indicates a modest rationalization of network of Dalavia in 2008.

The network of Krasnoyarsk Airlines is characterized by an unequal distribution of seat capacity as the NC index scores exceeded 0.7 in 2002 and 2008. High NC index values can be attributed to the allocation of a substantial proportion of seat capacity to routes to and from Moscow (especially Moscow Domodedovo - Krasnoyarsk and vice versa). In 2002, the carrier flew directly to three destinations from Moscow Domodedovo, from the total of 33 destinations making up the entire network, while 16.7% of airline's seat capacity was deployed on routes between these three destinations and Moscow Domodedovo (Source: OAG). The examination of the Freeman centrality index values suggests that the network of Krasnoyarsk Airlines resembled a single-radial network during the period of analysis. Moreover, the results of the Bonacich eigenvector analysis indicate that the airline transferred the part of its operations from Moscow Domodedovo to Moscow Vnukovo at some point between 2002 and 2008, but neither of these two Moscow's airports developed significantly to rival the position of Krasnoyarsk as the most central node. However, the focus on two Moscow's airports substantially contributed to the increase in complexity of network of Krasnoyarsk Airlines in 2008 (Table 5.2.4).

The carrier Rossiya exhibited above the average NC index values in 2002 and 2008, indicating a very concentrated distribution of seat capacity across its network. Similarly to Krasnoyarsk Airlines, a considerable proportion of seat capacity of Rossiya was deployed on routes to and from Moscow. Hence, high NC index scores can be assigned to 'the capacity effect'. The examination of the Freeman centrality index scores reveals that the network of Rossiya showed the characteristics of a single-radial network during the period of analysis. According to the results of the factor analysis, the network can be described by one global structure as the first factor explains more than 80% of the variation in distance in the network in 2002 and 2008. From Table 5.2.3, we see that Sankt Petersburg Pulkovo represented the most central node in 2002 and 2008. In 2008, Moscow Vnukovo became the fourth most central airport in the network of Rossiya. The rise in centrality of Moscow Vnukovo resulted from the merger of State Transport Company (STC) Rossiya and Pulkovo Aviation in 2006 (Rossiya - Airlines, 2011). Before the merger, Pulkovo Aviation was substantially larger carrier (in terms of destinations served as well as the market share of seat capacity) than STC Rossiya.

[46] E.g. a triangular route Khabarovsk - Moscow Domodedovo - Petropavlovsk-Kamchatsky - Khabarovsk.

With respect to UTair Aviation, high NC index scores for both 2002 and 2008 can be merely attributed to the capacity effect as a significant share of airline's seat capacity (41.9% and 31.0% in 2002 and 2008, respectively) was allocated to routes to and from Moscow. The Freeman centrality index scores suggest that the network of UTair Aviation was not highly centralized during the period of analysis. Instead, the network of UTair Aviation in 2002 and 2008 can be described as the multi-radial network with a substantial number of bypass point-to-point links. Moscow Vnukovo acted as the most central node in 2002 and 2008. In 2002, the carrier flew directly to six destinations from Vnukovo, whereas in 2008, the number of destinations increased to 26. Yet, the results of the factor analysis show that no global structure dominates the network of UTair Aviation in 2008 as three factors explain more than 70% of the distance variation. Therefore, it can be concluded that the network of UTair Aviation was more complex in 2008 than in 2002.

Finally, the fluctuation of the NC index and the Freeman centrality index values indicates that the network of UTair Express (the subsidiary of UTair Aviation) underwent a significant transformation during the period of analysis, both in terms of the spatial concentration of seat capacity and morphology. The examination of the Freeman centrality index scores reveals that the network of UTair Express corresponded to a single-radial network in 2002, whereas in 2008, it resembled the mixture of linear and multi-radial network. Consequently, the distribution of seat capacity across the network became deconcentrated as evidenced by the decline in the NC index score in 2008. The shift towards spatially deconcentrated configuration is also supported by the factor analysis results. The network of UTair Express in 2002 can be described by one global structure as more than 87% of the distance variation among nodes is reflected by one factor. Contrastingly, 81.5% of the distance variation is reflected by four factors in 2008. Thus, the network of UTair Express was considerably more complex in 2008 than in 2002. The further examination of the results of the Bonacich eigenvector analysis reveals that Moscow Sheremetyevo lost its position as the most central node in 2008. It might be attributed to the role of UTair Express as the subsidiary of UTair Aviation. In the last decade, UTair Express developed into a regional carrier with primary focus on Siberia, while its parent company UTair Aviation served larger cities and towns in Russia. Hence, UTair Express offered only a limited number of connections to and from the Russian capital in 2008.

5.2.2 Group B carriers

During the period of analysis, the majority of Group B carriers operated substantially smaller networks than airlines included in Group A. Nevertheless, several carriers (notably Vladivostok Air, Aeroflot Nord, and Ural Airlines) added an impressive number of destinations to their networks between 2002 and 2008 (Figure 5.2.7). Yet, all members of AiRUnion included in Group B (Domodedovo Airlines, Samara Airlines, Sibaviatrans) reduced the size of their networks between 2002 and 2008. Table 5.2.5 reveals that the number of carriers in this group did not vary significantly during the period of analysis. The average market share of seat capacity of Group B carriers was substantially lower in comparison with Group A airlines.

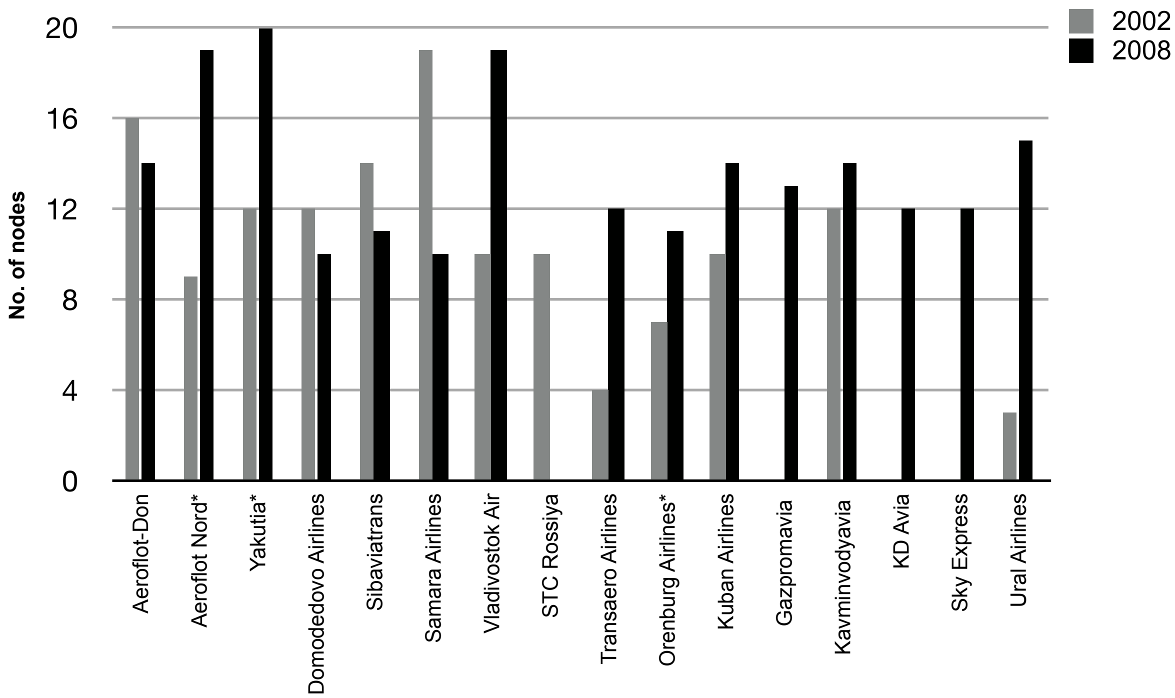

Figure 5.2.7 Number of nodes served by selected Group B carriers, 2002 and 2008
Source: OAG
* Airline operated under a different commercial name in 2002 and 2008 (see Appendix B)

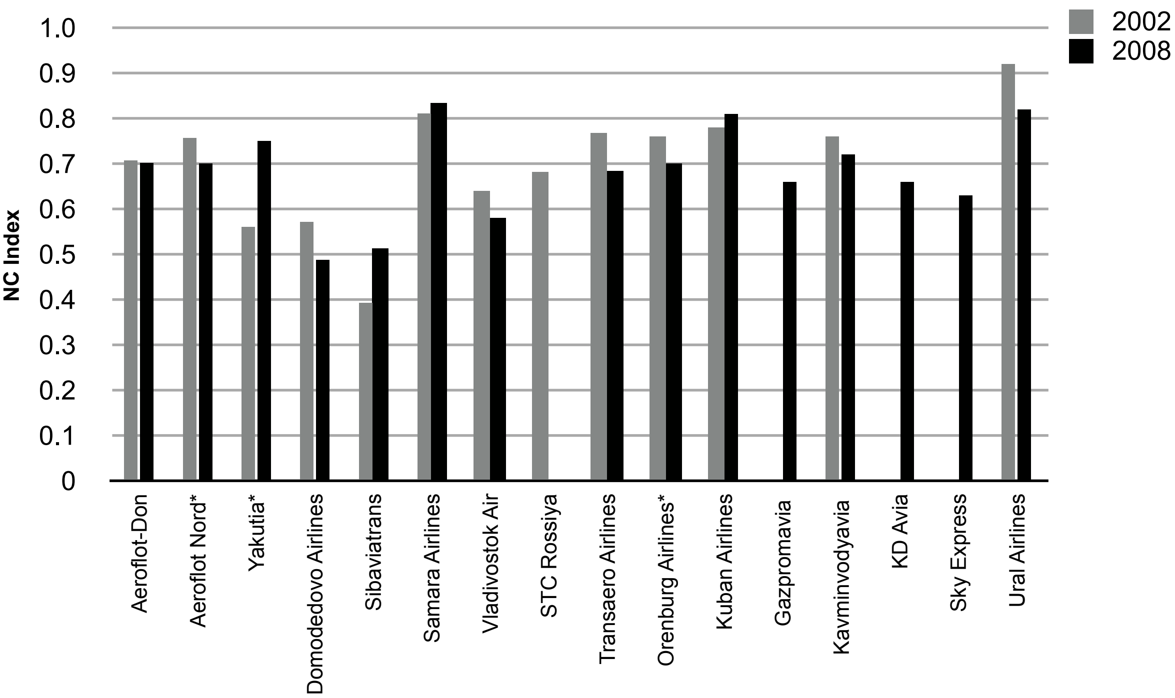

Figure 5.2.8 Network concentration index scores for selected Group B carriers, 2002 and 2008
Source: OAG
* Airline operated under a different commercial name in 2002 and 2008 (see Appendix B)

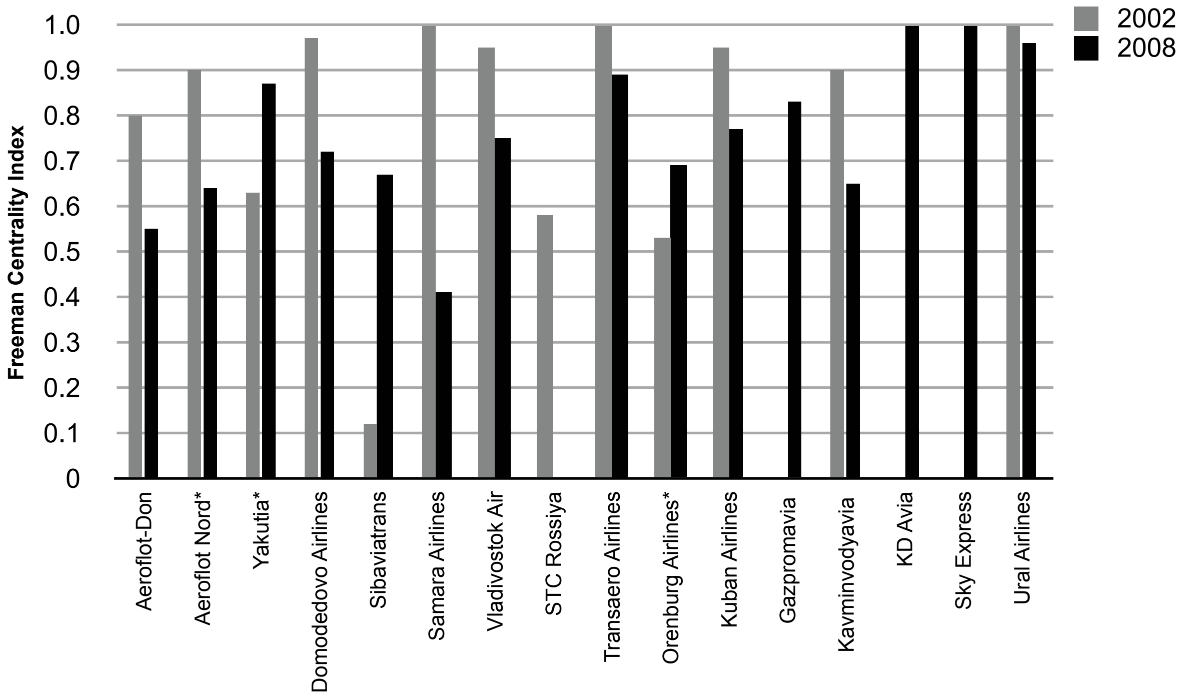

Figure 5.2.9 Freeman centrality index values for selected Group B carriers, 2002 and 2008
Source: OAG
* Airline operated under a different commercial name in 2002 and 2008 (see Appendix B)

	No. of airlines	NC	F	Seat capacity %
2002	17	0.69	0.76	1.9
2008	16	0.68	0.75	2.2

Table 5.2.5 Number of airlines, average network concentration index values, average Freeman centrality index scores, and average market share (%) of seat capacity for Group B carriers, 2002 and 2008
Source: OAG

With regard to the spatial distribution of seat capacity, the average NC index values for all Group B carriers (Table 5.2.5) were comparable to those of Group A airlines. However, we can observe a large variation in range of the NC index scores of individual carriers (Figure 5.2.8). The NC index scores ranged between 0.39 (Sibaviatrans) and 0.92 (Ural Airlines) in 2002, and 0.49 (Domodedovo Airlines) and 0.83 (Samara Airlines) in 2008. In general, networks with an unequal distribution of seat capacity had an ample presence among Group B carriers. Correspondingly, the Freeman centrality index scores (Figure 5.2.9) show a large disparity. The values ranged between 0.12 (Sibaviatrans) and 1.00 (Samara Airlines, Transaero Airlines, Ural Airlines) in 2002, and 0.41 (Samara Airlines) and 1.00 (KD Avia, Sky Express) in 2008. Furthermore, as Figure 5.2.9 shows, several carriers (especially Sibaviatrans) considerably altered their networks during the period of analysis.

Numerous Group B carriers can be characterized as ‘regional’ as their networks are rather geographically confined. As Holloway (2008: 380-381) states, regional airlines can serve as a valuable source of traffic feed for partner carriers. The network design of regionals can result

	2002		2008
	Aeroflot Nord*		
Arkhangelsk	98.1	Moscow Sheremetyevo	84.2
Moscow Sheremetyevo	79.7	Arkhangelsk	73.9
Naryan-Mar	47.0	Naryan-Mar	50.7
Sankt Petersburg	28.1	Murmansk	39.7
	Aeroflot-Don		
Rostov	95.5	Rostov	95.2
Moscow Vnukovo	81.8	Moscow Vnukovo	75.2
Moscow Sheremetyevo	55.8	Moscow Sheremetyevo	64.2
Sochi	23.5	Novosibirsk	17.3
	Kavminvodyavia		
Moscow Vnukovo	98.4	Mineralnye Vody	94.3
Mineralnye Vody	90.1	Moscow Vnukovo	86.3
Stavropol	43.3	Moscow Domodedovo	49.2
Sankt Petersburg	11.3	Stavropol	31.4
	Sibaviatrans		
Krasnoyarsk	NA	Krasnoyarsk	85.1
Irkutsk	NA	Igarka	56.2
Igarka	NA	Norilsk	52.6
Ust-Ilimsk	NA	Novosibirsk	46.3
	Vladivostok Air		
Vladivostok	99.3	Vladivostok	81.6
Yuzhno-Sakhalinsk	53.5	Moscow Vnukovo	65.6
Khabarovsk / Petropavlovsk	42.8	Khabarovsk	47.6
Moscow Sheremetyevo	42.8	Yekaterinburg	36.6
	Yakutia*		
Yakutsk	92.2	Yakutsk	88.1
Neryungri	85.5	Moscow Vnukovo	71.9
Aldan	47.2	Neryungri	47.2
Moscow Sheremetyevo	33.3	Khabarovsk	41.4

Table 5.2.6 The Bonacich eigenvector analysis results for selected Group B carriers
Source: OAG
* Airline operated under a different commercial name in 2002 and 2008 (see Appendix B)

Note: No results are available for Sibaviatrans network in 2002 as several negative eigenvectors have been recorded. It is possible to achieve the shift of eigenvectors towards positive values. However, such procedure is beyond the scope of this thesis. For those seeking more information, Richards and Seary (2000) address this issue in detail.

	2002	2008	2002	2008
Carrier	Aeroflot Nord*		Aeroflot-Don	
Factor 1	88.2	71.2	56.3	66.6
Factor 2	97.7	86.7	74.5	86.0
Factor 3	100.0	97.5	83.1	93.9
Factor 4		100.0	87.9	97.1
Carrier	Kavminvodyavia		Sibaviatrans	
Factor 1	82.7	34.0	19.0	51.4
Factor 2	90.5	41.1	37.8	100.0
Factor 3	95.7	44.6	51.0	
Factor 4	100.0	46.4	58.5	
Carrier	Vladivostok Air		Yakutia*	
Factor 1	76.7	55.4	73.7	63.9
Factor 2	100.0	84.3	79.3	92.9
Factor 3		91.9	83.2	97.2
Factor 4		98.9	86.9	100.0

Table 5.2.7 The factor analysis results for selected Group B carriers (in cumulative %)
Source: OAG
* Airline operated under a different commercial name in 2002 and 2008 (see Appendix B)

from such kind of strategy. While this approach has been mainly developed by US and European carriers, Aeroflot became the pioneer in the Russian Federation. The first of two subsidiaries of Aeroflot, Aeroflot-Don appeared to operate the network with rather concentrated distribution of seat capacity in 2002 and 2008. The decline in the Freeman centrality index score in 2008 indicates that the carrier changed its network configuration from the mixture of single-radial and linear network to multi-radial network. The results of the factor analysis (Table 5.2.7) show that the network of Aeroflot-Don was not dominated by a global pattern in 2002 or 2008. However, the carrier slightly rationalized its network in 2008. In 2002, Rostov and Moscow Vnukovo acted as the most central nodes (Table 5.2.6). In 2008, Moscow Sheremetyevo exhibited an increase in centrality, but it did not develop enough to rival the position of Rostov or Moscow Vnukovo.

In comparison with Aeroflot-Don, the network of Aeroflot Nord underwent similar changes between 2002 and 2008. The variation of the Freeman centrality index scores points to a significant change in the morphology of network. In 2002, the network of Aeroflot Nord resembled a single-radial network, whereas its configuration became multi-radial in 2008. The results of the factor analysis reveal that the value of the first factor decreased in 2008 in comparison with 2002. Hence, the network of Aeroflot Nord became more complex throughout the period of analysis. Additionally, the results of the Bonacich eigenvector analysis indicate significant changes in centrality of certain nodes. In 2002, Arkhangelsk acted as the most central node in the network. In 2008, Moscow Sheremetyevo was noticeably developed, whereas the centrality of Arkhangelsk diminished at the same time. In 2002, only two destinations could be reached directly from Sheremetyevo, whereas the number increased to 12 in 2008. It is important to keep in mind that in 2002, the carrier operated independently as Arkhangelsk Airlines. Therefore, the rise in the level of centrality of Sheremetyevo can be seen as a consequence of acquisition of the carrier by Aeroflot in 2004. In this respect, we can observe partial similarities in the development of Sheremetyevo and its respective role in the networks of Aeroflot-Don and Aeroflot Nord.

Similarly to Group A carriers, the majority of Group B airlines operated networks with spatially concentrated or very concentrated distribution of seat capacity during the period of analysis. Only one Group B carrier utilized spatially highly deconcentrated type of network. The network of Sibaviatrans in 2002 resembled a linear network with deconcentrated distribution of seat capacity[47]. The results of the factor analysis indicate that the network of Sibaviatrans became more rationalized in 2008. Additionally, the network configuration bore strong characteristics of the mixture of multi-radial and linear network in 2008. The rationalization partly occurred due to the network contraction as the carrier served less destinations in 2008 than in 2002. The rationalization is also reflected in the NC index value as the distribution of seat capacity across the network became more unequal in 2008.

For a number of Group B carriers not based in the Russian capital, unusually high NC index values are merely caused by the allocation of seat capacity to high density routes to and from Moscow. For instance, the route Samara - Moscow (and vice versa) was the principal route for Samara Airlines in both 2002 and 2008[48]. As a consequence, Moscow became the second most important destination of Samara Airlines in terms of seat capacity, considerably outperforming other airports in carrier's network except for Samara Kurumoch Airport. Beside Samara Airlines, e.g. Kuban Airlines and Ural Airlines allocated a significant proportion of seat capacity to routes connecting Moscow's airports and their respective bases in 2002 and/or 2008.

We can observe a few similarities among the networks of three Group B carriers, namely Kavminvodyavia, Yakutia, and Vladivostok Air. The results of the factor analysis show that the networks of these carriers were more complex in 2008 than in 2002. With respect to Kavminvodyavia, the Freeman centrality index scores indicate that the carrier's network resembled a single-radial network in 2002, whereas the network configuration could be described as multi-radial in 2008. Moscow Vnukovo was more central than any other node in the network of Kavminvodyavia in 2002. In 2008, Mineralnye Vody replaced Vnukovo as the most central node, however, the overall centrality of Moscow's airports increased as Moscow Domodedovo developed into the third most central node. Aside from the network of Kavminvodyavia, the centrality of Moscow's airports also increased in the networks of Yakutia and Vladivostok Air in 2008. Although the Freeman centrality index score indicates that the network of Yakutia was more centralized in 2008 than in 2002, in fact the complexity

[47] The Freeman centrality index score for Sibaviatrans in 2002 falsely indicates that the carrier utilized nearly fully connected point-to-point network. Such indication is caused by an isolated portion of network of Sibaviatrans. In addition to Sibaviatrans, the Freeman centrality index score for Samara Airlines in 2008 reveals that the network of Samara-based carrier can be characterized as rather spatially deconcentrated. However, this is also caused by one isolated portion of the network (precisely the route Ufa - Krasnoyarsk and vice versa). In reality, the network of Samara Airlines resembled a single-radial network.

[48] Samara Airlines served Moscow Sheremetyevo and Moscow Domodedovo in 2002, and Moscow Vnukovo in 2008.

of network increased throughout the period of analysis. While the carrier designed its network around Yakutsk and Neryungri in 2002, Moscow Vnukovo grew into the second most central node in 2008. Yet, the proportion of destinations that Yakutia flew directly to from Vnukovo was already served from Yakutsk in 2008. Thus, the decline in rationalization of the network of Yakutia in 2008. Similarly to Yakutia, Vladivostok Air considerably expanded its presence in Moscow in 2008 in comparison with 2002. In 2002, Vladivostok acted as the most central node, and the carrier did not utilize any airport in Moscow as its base. According to the Bonacich eigenvector analysis results, Moscow Vnukovo became the second most central node in the network of Vladivostok Air in 2008.

5.2.3 Group C carriers

In comparison with the previous two categories, Group C carriers operated noticeably smaller networks. More than one third of all Russian airlines included in the OAG database served less than ten domestic destinations in 2002 and 2008. The proportion of Group C carriers served just two destinations during the period of analysis (Figure 5.2.10). While the number of carriers in this category remained fairly stable (Table 5.2.8), some carriers left and others entered the market during the period of analysis. E.g. Astrakhan Airlines, Bashkir Airlines, and Eurasia Airlines ceased operations at some point between September 2002 and September 2008. Hence, several carriers do not figure in the database for both 2002 and 2008. Therefore, the comparison of carriers which remained in business throughout the entire period of analysis is based on a rather small sample.

The range of the NC index scores of Group C carriers (Figure 5.2.11) was the largest from all three categories studied. The NC index scores varied between 0.00 and 0.98 in 2002, and between 0.00 and 0.88 in 2008. The average NC index scores for all Group C airlines (Table 5.2.8) were considerably lower in comparison with Group A and Group B carriers. However, the average NC index scores were affected by individual NC index values of carriers with networks composed of two nodes, e.g. Astrakhan Airlines, Atlant-Soyuz, Airport Bratsk, Gromov Air (Figure 5.2.10). To elaborate, the distribution of seat capacity was perfectly equal in the networks of these carriers. Therefore, their NC index scores were equal to 0. Particularly small airlines, such as those with networks composed of only two nodes, can significantly distort the average NC index score for all carriers. I included even very small carriers in Group C category for the sake of completeness of analysis, yet the average NC index score should be carefully interpreted. Provided that networks composed of only two nodes are excluded, the average NC index scores are 0.73 and 0.72 in 2002 and 2008, respectively. The variation of the Freeman centrality index scores (Figure 5.2.12) was also the largest from all three groups analyzed. The average Freeman centrality index values for all Group C airlines (Table 5.2.8) were significantly lower than those for Group A and Group B carriers, but similarly to the average NC index scores, the results should be carefully interpreted. Provided that we omit all networks composed of two nodes, the average Freeman centrality index values are equal to 0.84 and 0.78 in 2002 and 2008, respectively.

Similarly to several Group B carriers, a number of Group C airlines (e.g. Bashkir Airlines and Buryat Airlines in 2002; Tatarstan and Volga-Dnepr in 2008) scored profoundly high NC index values due to the allocation of seat capacity to high density routes. Even though several

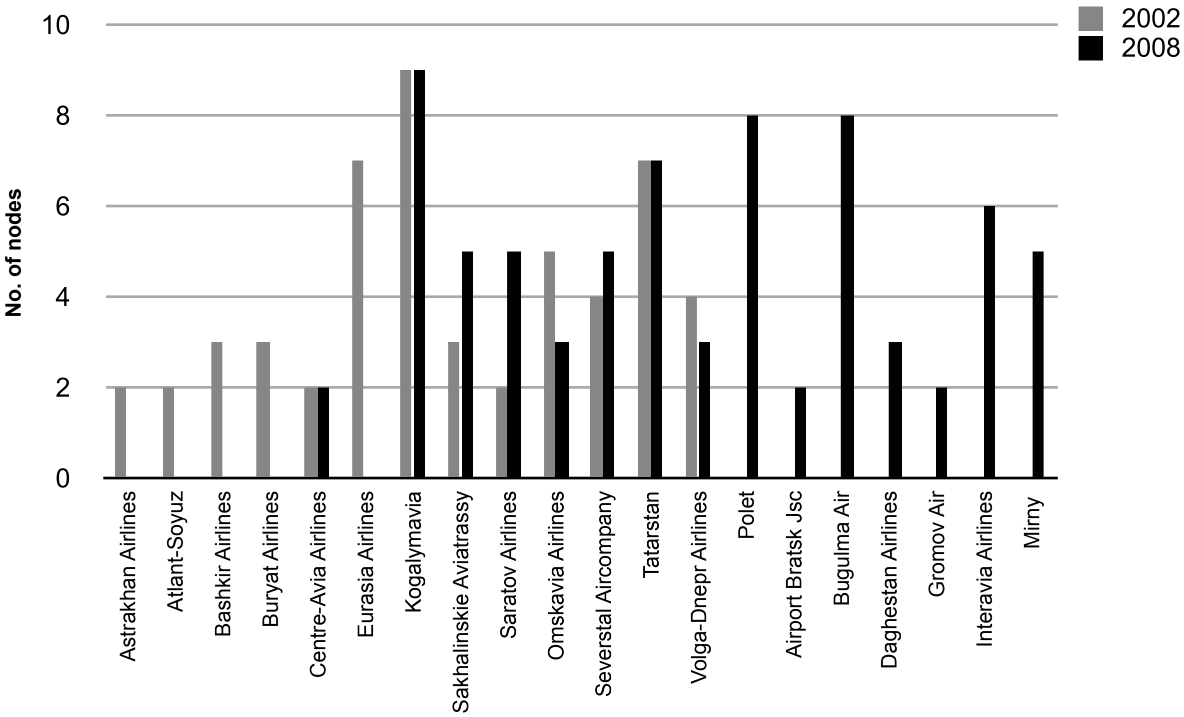

Figure 5.2.10 Number of nodes served by Group C carriers, 2002 and 2008
Source: OAG

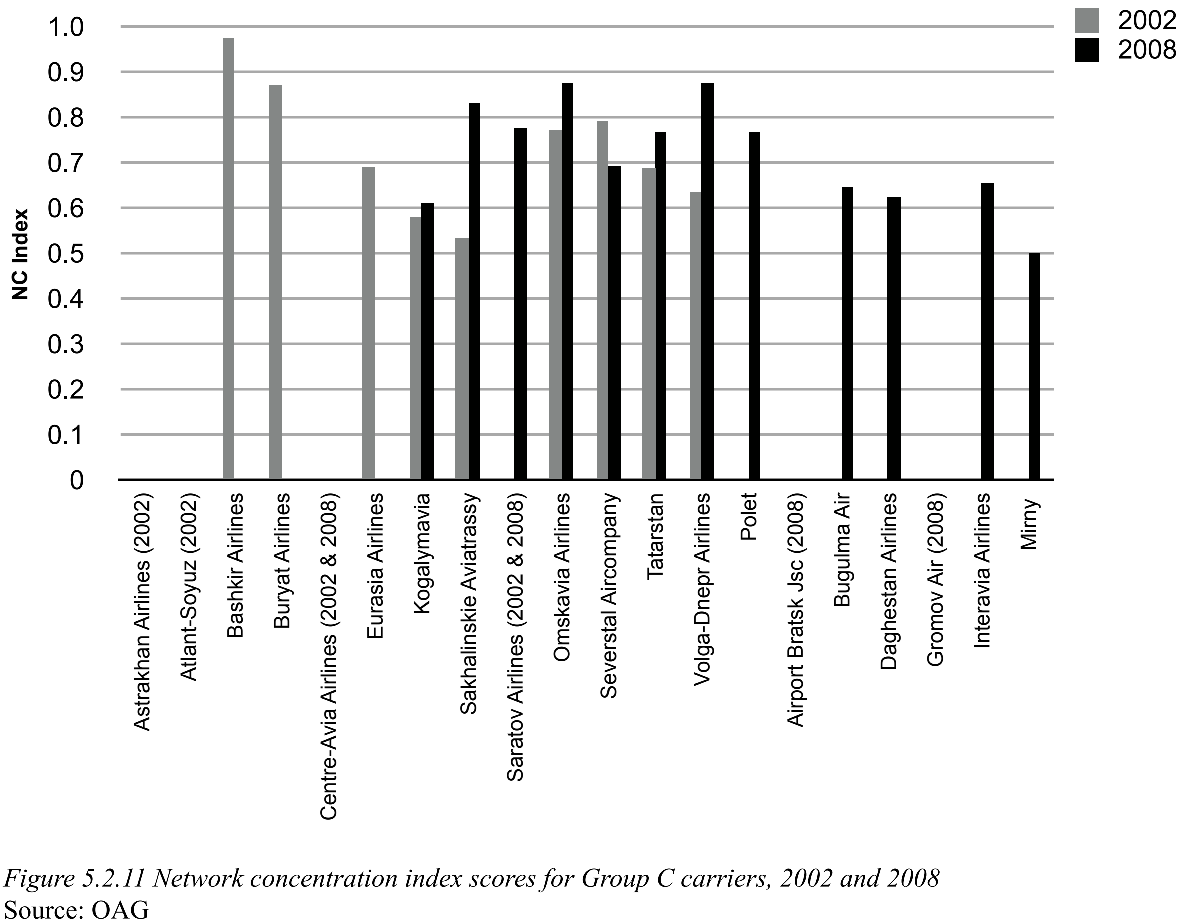

Figure 5.2.11 Network concentration index scores for Group C carriers, 2002 and 2008
Source: OAG

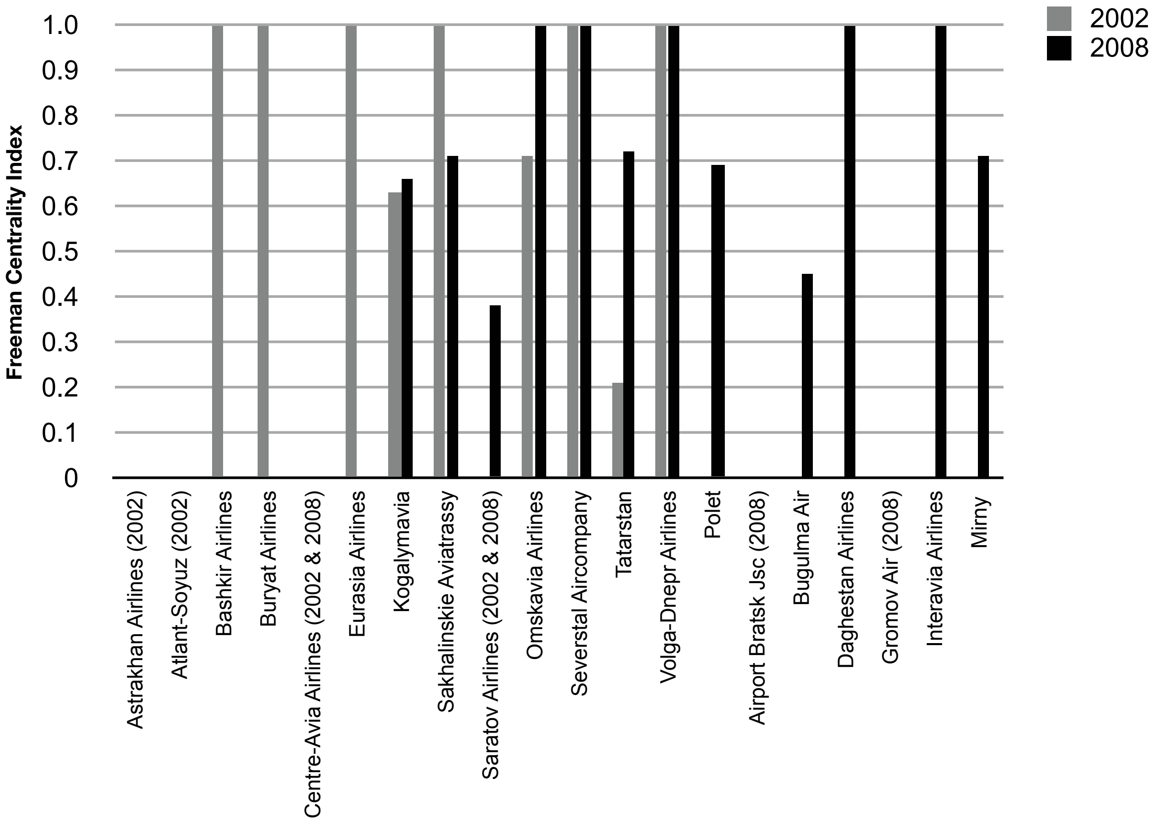

Figure 5.2.12 Freeman centrality index values for Group C carriers, 2002 and 2008
Source: OAG

	No. of airlines	NC	F	Seat capacity %
2002	13	0.50	0.58	0.7
2008	15	0.58	0.62	0.5

Table 5.2.8 Number of airlines, average network concentration index values, average Freeman centrality index scores, and average market share (%) of seat capacity for Group C carriers, 2002 and 2008
Source: OAG

Group C carriers served just a handful of destinations in 2002 and/or 2008, they frequently allocated a large number of seats to routes to and from Moscow. Moreover, the connection with Moscow was the only route for two carriers (Astrakhan Airlines and Saratov Airlines in 2002) not based in the Russian capital. Strong focus on Moscow's airports was not only a phenomenon of a small number of carriers. Only a few Group C airlines[49] did not serve any airport in Moscow during the period of analysis. Hence, we can conclude that the focus on Moscow was relatively profound among Group C carriers.

With regard to the morphology, numerous Group C carriers (serving 3 and more nodes) operated either perfect single-radial networks or single-radial networks with a share of linear connections in 2002 and/or 2008 (Figure 5.2.12). Beside Kogalymavia[50], no other carrier

[49] Atlant-Soyuz and Sakhalinskie Aviatrassy (2002); Airport Bratsk Jsc and Sakhalinskie Aviatrassy (2008).

[50] In 2002 and 2008, the airports of Surgut and Kogalym were utilized as the main bases by Kogalymavia. The carrier did not provide the direct connection between these two airports. However, both airports were indirectly connected via Moscow Domodedovo. Hence, the network of Kogalymavia in 2002 and 2008 can be theoretically regarded as multi-radial.

utilized a multi-radial network configuration during the period of analysis. The multi-radial configuration is rather rare among carriers which operate small networks composed of only a few nodes. Although it is possible to perform the Bonacich eigenvector analysis and the factor analysis for Group C airlines, the size of their networks makes the interpretation of results rather difficult. Therefore, I do not analyze the networks of Group C carriers by means of the Bonacich centrality analysis.

CHAPTER 6: CONCLUSION AND DISCUSSION

This chapter concludes the results and findings of the analysis of domestic route networks of Russian carriers. To be precise, I answer the research question which I specified in Chapter 1. Moreover, I touch upon the limitations of my research as well as suggestions for future direction of studies of airline networks of Russian carriers.

6.1 Answering the research question

I have already outlined the complexity and multidimensional character of airline networks. Airline networks are rather unique and specific structures which differ from each other. What is more, airline networks do not change and develop only spatially but also temporally. Additionally, the application of new scientific methods and techniques enables to look at airline networks from a completely new perspective. To cover all aspects of airline networks in one study would be rather gruesome task. Therefore, I have limited myself to the following research question:

How did the spatial dimension of domestic route networks of Russian carriers develop between 2002 and 2008?

To elaborate, I have elected to study the spatial dimension of domestic route networks of Russian carriers on the basis of three particular characteristics: (i) the distribution and concentration of seat capacity; (ii) the morphology of networks; and (iii) the centrality of airports. The normalized Gini index (the network concentration index) has served as a measure of the distribution and concentration of seat capacity. While the index suffers from limitations, and it does not completely capture the configuration of airline networks, it is sensitive to the concentration of seat capacity or the frequency of flights. In addition, the network concentration index enables to compare airline networks independent of network size (Cento, 2009: 110). The morphology of networks has been captured by the Freeman centrality index. The Freeman centrality index is able to detect changes in the configuration of networks, while it does not react to variations in the concentration of seat capacity or the frequency of flights. Both the network concentration index and the Freeman centrality index focus on the network from macro-level. Contrastingly, the Bonacich centrality analysis permits to study the network from micro-level as this method is focused on the centrality of individual airports.

The predominance of Russian carriers seemed to add new destinations to their networks between 2002 and 2008. Nevertheless, the collapse of AiRUnion partnership in 2008 led to a subsequent demise of several carriers (namely Krasnoyarsk Airlines, Sibaviatrans, Samara Airlines, Domodedovo Airlines, Omskavia Airlines), leaving a substantial portion of the market to rival competitors. In recent years, the Russian airline industry has been undergoing the process of consolidation. In July 2010, 168 airlines were granted the permission to operate commercial services. This number diminished to 128 airlines in November 2011 (Russian Aviation, 2011). The prognosis points to further consolidation of the Russian airline industry, although the solid position of the largest carriers (Aeroflot, S7 Airlines, Rossiya, UTair

Aviation, UTair Express) should not be challenged in the near future unless these airlines encounter severe economic difficulties (Russian Aviation, 2011).

In general, the examination of the network concentration index values reveals that a large number of Russian carriers operated networks with very concentrated and concentrated distribution of seat capacity in 2002 and 2008, respectively. With reference to the morphology of networks, a significant proportion of Russian carriers utilized a single-radial network configuration during the period of analysis. Additionally, the number of carriers which operated mixed radial and linear networks increased in 2008. The utilization of spatially deconcentrated point-to-point networks was scarce. The following paragraphs conclude the results of analysis of three categories of Russian airlines: (i) Group A composed of carriers which served more than 20 domestic destinations in 2002 and/or 2008; (ii) Group B comprised of airlines which served between 10 and 20 domestic destinations in 2002 and/or 2008; and (iii) Group C carriers which served less than 10 destinations in Russia in 2002 and/or 2008.

The majority of networks of Group A carriers could be characterized as large radial networks with concentrated to very concentrated distribution of seat capacity in 2002 and 2008. Fluctuations in the level of network concentration of seat capacity were relatively small during the period of analysis (except for the carrier UTair Express). The focus of networks on Moscow's airports was a principal characteristic of several Group A carriers. Yet, the features were not uniform and they differentiated to a particular extent between individual carriers. Aeroflot - Russian Airlines and S7 Airlines, carriers with a dominant position in the Russian market, have had a strong presence at Moscow Sheremetyevo and Moscow Domodedovo, respectively. As a consequence, these carriers might have benefited from the feed between international and domestic parts of their respective networks, although I have not been able to examine such kind of interaction due to the data limitations (see Section 6.2). Moreover, one Group A carrier (Rossiya) increased its presence at Moscow's airports as a result of the merger. On the other hand, the focus on Moscow's airports in the network of UTair Express (the daughter company of UTair Aviation) was considerably reduced between 2002 and 2008 as the carrier primarily focused on the region of Siberia and complemented the extensive network of its parent company UTair Aviation. Nevertheless, UTair as a group increased its presence at airports serving the Russian capital between 2002 and 2008. Hence, a predominant trend among the majority of Group A carriers (with exception of financially struggling carriers Dalavia and Krasnoyarsk Airlines) was an increase in focus on Moscow's airports.

In comparison with networks of Group A carriers, the networks of Group B airlines exhibited larger variations of the distribution of seat capacity. The distribution in the networks of Group B carriers ranged from deconcentrated to very concentrated and from moderately concentrated to very concentrated in 2002 and 2008, respectively. Moreover, fluctuations in the level of network concentration of seat capacity of individual carriers were generally larger than those of Group A airlines between 2002 and 2008. For the proportion of Group B carriers (e.g. Samara Airlines, Kuban Airlines, and Ural Airlines), a highly concentrated distribution of seat capacity in 2002 and/or 2008 could be attributed to the allocation of a significant number of seats to high density routes to and from Moscow. Similarly to Group A airlines, the utilization of spatially deconcentrated point-to-point networks among Group B carriers was minimal, the only exception being the network of Sibaviatrans in 2002. Several Group B carriers based outside of Moscow seemed to be more active in reorganization of their networks than Group A airlines. Additionally, a small proportion of Group B carriers developed their networks in a similar manner during the period of analysis. Firstly, three Group B airlines (namely Kavminvodyavia, Yakutia, and Vladivostok Air) did not utilize Moscow's airports as primary bases. However, these carriers increasingly focused on airports in the capital (precisely Moscow Vnukovo and Moscow Domodedovo) and utilized them as secondary bases in 2008, i.e. the shift towards a multi-radial network configuration. Secondly, Aeroflot Nord, the subsidiary of Aeroflot (Group A carrier), reconfigured its network from single-radial to multi-radial between 2002 and 2008. It can be attributed to the acquisition of the company by Aeroflot in 2004[51] (Aeroflot, 2004). The multi-radial configuration enabled Aeroflot Nord to complement the network of the parent company Aeroflot and another subsidiary Aeroflot-Don. Therefore, a noteworthy tendency of several Group B carriers was to develop and utilize multi-radial networks between 2002 and 2008. Moreover, the centrality of Moscow's airports in networks of numerous Group B airlines increased during the period of analysis, i.e. stronger focus on airports in the capital.

Lastly, the networks of Group C carriers could be described as rather small networks with a large variation of the distribution of seat capacity. The proportion of networks of Group C carriers was composed of only two nodes in 2002 and/or 2008. Theoretically, the distribution of seat capacity is usually perfectly equal in the networks made up of just two connected nodes. The average network concentration index values for Group C carriers were marginally larger than those recorded by Group A and Group B carriers[52]. The distribution of seat capacity in the majority of networks of Group C carriers appeared to be more concentrated in 2008 than in 2002. Yet, a number of Group C airlines does not figure in the OAG database for both 2002 and 2008. Hence, it is rather difficult to generalize the results of analysis as the comparison of networks of Group C carriers between 2002 and 2008 is based on a small sample. Similarly to several Group B carriers, a number of Group C airlines allocated a considerable share of seat capacity to routes to and from Moscow. However, Group C carriers did not seem to utilize the multi-radial network configuration in 2002 or 2008 (except for Kogalymavia). This could be assigned to a relatively small size of networks of Group C carriers. Thus, the majority of Group C airlines operated either perfect single-radial networks or single-radial networks with a portion of linear connections in 2002 and/or 2008.

With regard to the foreseeable future, it is safe to say that links to and from Moscow's airports will still occupy a significant position as these routes are often the 'bread and butter' for Russian carriers. A large division between Group A and Group C carriers is likely to remain unless a major consolidation of carriers will take place. The division might even widen as more Group A airlines join alliances, while the lack of means to expand might reduce a number of Group C carriers in the market. Moreover, the future competition from foreign entrants in the market, especially dynamic Asian carriers and low-cost airlines, might lead to greater consolidation of the Russian airline industry.

---

[51] Aeroflot Nord operated independently as Arkhangelsk Airlines until 2004.

[52] Considering that the networks of Group C carriers composed of only two connected nodes were excluded.

6.2 The limitations and future direction of the research

In this section, I would like to focus on the shortcomings of my research as well as suggestions for future orientation of studies of airline networks in Russia. It is crucial to mention that the research does not provide the complete picture of domestic route networks of Russian carriers. Firstly, I already mentioned that not all airlines, which operated in Russia in 2002 and 2008, are included in the OAG database on which I based my research. To be precise, 37 and 38 airlines are incorporated in the database for 2002 and 2008, respectively. In reality, nearly 170 airlines operated on domestic routes in July 2010 (Russian Aviation, 2011). Consequently, several notable Russian airports are not included in the database[53], although it did not present a significant research barrier as the thesis is primarily focused on airlines rather than airports. Secondly, the available data covers the third week of September 2002 and 2008. The analysis of the data for alternative months and weeks of respective years might have produced slightly different results as a consequence of seasonal shifts in demand. For instance, Russian carriers might offer more seats on routes to and from airports serving vacation spots along the Black Sea coast (e.g. Sochi, Anapa) during the summer period in order to cope with an increased demand from individual holiday-makers and tour operators. Thirdly, the data on the number of seats is based on the supply offered by carriers. Therefore, it does not reflect the actual passenger demand. In other words, the seat capacity data conveys that the occupancy rate (the load factor) is 100 percent. Additionally, the database includes only the details about domestic routes of Russian carriers. Hence, I could not take into consideration the international traffic carried by Russian airlines to and from airports in Russia. Finally, the scheduling of flights (arrival and departure times) is omitted from the OAG database. In theory, such shortcoming does not limit the researcher in the study of spatial aspects of airline networks, although it does not allow for the analysis of temporal dimension. While the significance of the spatial dimension of airline networks should not be compromised, several researchers have incorporated the temporal dimension into the studies of airline networks (Burghouwt, 2005; Burghouwt and de Wit, 2005; Cento, 2009). For one thing, the incorporation of temporal dimension in my research would have enabled to include indirect connections in the analysis, in contrast to the capability of spatial approach applied in this thesis, which is solely limited to the study of direct connections between nodes. In return, it would have made possible to examine the presence and utilization of hub-and-spoke networks and wave-system structures by Russian carriers. Hypothetically, I could have regarded all possible connections as viable options. However, as Burghouwt (2005: 35) states, the effectivity of indirect connections in hub-and-spoke networks directly relates to two main factors: (i) the routing of indirect flights and their deviation in comparison with direct routing or other indirect variants; and (ii) the length of transfer time. Consequently, not all indirect connections can be feasible. Therefore, the analysis of temporal dimension of hub-and-spoke networks should be constructed around the examination of routings as well as the scheduling of wave-system structures.

Naturally, the shortcomings of my research can be addressed in future studies of route networks of Russian carriers. The analysis of spatial dimension revealed that airports in Moscow (precisely Moscow Domodedovo, Moscow Sheremetyevo, Moscow Vnukovo)

---

[53] For example, airports serving the cities of Belgorod, Perm, Vladikavkaz, and Voronezh are not included in the database for 2002.

played a leading role in domestic route networks of Russian airlines over the last decade. In order to complement the results of this dissertation, future studies should be focused on the examination of the temporal dimension of airline networks in Russia. I have already brought up the topic of utilization of hub-and-spoke networks and wave-system structures by Russian airlines. The prospective research might also concentrate on the analysis of hub location and identification of spatial flows in hub-and-spoke networks. While the analysis of the spatial dimension of route networks of Russian carriers have partially examined traffic flows, more rigorous research is needed in order to produce clarified results. Subsequently, the research can concentrate on the international traffic to and from Russia carried by Russian airlines in order to complement the analysis of domestic route networks of Russian carriers. At present, the impact of global airline alliances in Russia is rather limited as only two Russian airlines (Aeroflot and S7 Airlines) became the associated members. However, a further incorporation of Russian carriers into alliance partnerships might prompt a future academic interest. While the past studies were mainly focused on airline networks in the US and the EU member states, future growth and development of the passenger air transportation in Russia might spur a greater interest in this ‘field’ in academic circles.

APPENDIX A

A1.1 The decomposition and calculation of the Gini index

In this appendix, I demonstrate the decomposition and calculation of the Gini index. Usually, researchers and planners are able to bypass these procedures as the calculation of the Gini index can be effectively handled by software packages (e.g. Microsoft Excel) and specifically designed online calculators. However, I became aware that numerous studies fail to provide a thorough explanation and decomposition of the Gini index. The ‘pen and paper’ approach might be seen as time-consuming and inadequate, especially when one needs to handle a vast amount of data. However, I think that a simple example can go a long way, and it can help us better comprehend the Gini index as the measure of inequality.

Graphically, the Gini index can be illustrated as the ratio of the area of concentration (located between the Lorenz curve and the equidistribution line) to the area of maximum concentration[54]. The closer is the value of the Gini index to 1, the more concentrated/unequal is the distribution. As an equation, the Gini index can be defined as the following:

$$G = 1 - \sum_{i=0}^{N} \left(\sigma Y_{i-1} + \sigma Y_i\right)\left(\sigma X_{i-1} - \sigma X_i\right)$$

where ‘σX and σY are cumulative percentages of Xs and Ys (in fractions) and N is the number of elements (observations)’ (Rodrigue et al., 2009, Chapter 4). The following table demonstrates the example of calculation of the Gini index for Severstal Aircompany in 2008[55]:

Airport	Traffic	X	Y	σX	σY	σX_{i-1}-σX_i (B)	σY_{i-1}+σY_i (A)	A*B
CEE	1,312	0.2	0.5	0.2	0.5	0.2	0.5	0.1
VKO	672	0.2	0.256	0.4	0.756	0.2	1.256	0.251
DME	256	0.2	0.098	0.6	0.854	0.2	1.61	0.322
LED	192	0.2	0.073	0.8	0.927	0.2	1.781	0.356
PES	192	0.2	0.073	1.0	1.000	0.2	1.927	0.385
Total	2,624	1.0	1.000					1.415

Table A1.1.1 The calculation of the Gini index for Severstal Aircompany (2008)
Source: OAG

[54] See Chapter 4, Section 4.1.1 for full explanation.

[55] The traffic at the airports has been measured by the number of seats available per week. Airports are designated by their IATA codes. See Appendix D for the explanation of IATA airport codes.

The final step of the calculation is the subtraction of *Total A*B* from 1. As the Gini index ranges between 0 and 1, the result of calculation should be treated as the absolute value (modulus). Hence, the calculation can be expressed in mathematical symbols as $|1-1.415|$, and the value of the Gini index for this airline network is 0.415.

APPENDIX B

B1.1 The classification of the Russian airlines

Airline	2002	2008	Classification	Notes
Aeroflot - Russian Airlines	X	X	Group A	Subsidiaries: Aeroflot-Don and Aeroflot Nord (former).
Dalavia - Far East Airways	X	X	Group A	
Krasnoyarsk Airlines	X	X	Group A	The former member of AiRUnion.
Pulkovo Aviation	X		Group A	Merged with State Transport Company Rossiya to form Rossiya.
Rossiya		X	Group A	The company formed by the merger between State Transport Company Rossiya and Pulkovo Aviation.
S7 Airlines	X	X	Group A	In 2002 operated as Siberia Airlines.
UTair Aviation	X	X	Group A	Subsidiary: UTair Express. In 2002 operated as Tyumenaviatrans.
UTair Express	X	X	Group A	Subsidiary of UTair Aviation. In 2002 operated as Komiinteravia.
Aeroflot Nord	X	X	Group B	The former subsidiary of Aeroflot. In 2002 operated independently as Arkhangelsk Airlines.
Aeroflot-Don	X	X	Group B	Subsidiary of Aeroflot.
Yakutia	X	X	Group B	In 2002 operated as Yakutaviatrans.
Domodedovo Airlines	X	X	Group B	The former member of AiRUnion.
State Transport Company Rossiya	X		Group B	Merged with Pulkovo Aviation to form Rossiya.
Transaero Airlines	X	X	Group B	
Samara Airlines	X	X	Group B	The former member of AiRUnion.
Sibaviatrans	X	X	Group B	The former member of AiRUnion.
Tyumen Airlines	X		Group B	
Yamal Airlines	X	X	Group B	
Vladivostok Air	X	X	Group B	
Orenburg Airlines	X	X	Group B	In 2002 operated as State Orenburg Avia.
Kuban Airlines	X	X	Group B	
Gazpromavia		X	Group B	
Kavminvodyavia	X	X	Group B	
KD Avia		X	Group B	

Table B1.1.1 The classification of the Russian airlines
X specifies that the data is available for the year indicated

Airline	2002	2008	Classification	Notes
Sky Express		X	Group B	The first low-cost airline in the Russian domestic market.
Ural Airlines	X	X	Group B	
Karat	X		Group B	
Magadan Airlines	X		Group B	
Astrakhan Airlines	X		Group C	
Atlant-Soyuz	X		Group C	
Bashkir Airlines	X		Group C	
Buryat Airlines	X		Group C	
Centre-Avia Airlines	X	X	Group C	
Eurasia Airlines	X		Group C	
Kogalymavia	X	X	Group C	
Omskavia Airlines	X	X	Group C	The former member of AiRUnion.
Sakhalinskie Aviatrassy	X	X	Group C	
Saratov Airlines	X	X	Group C	
Severstal Aircompany	X	X	Group C	
Tatarstan	X	X	Group C	
Volga-Dnepr	X	X	Group C	
Polet		X	Group C	
Airport Bratsk Jsc		X	Group C	
Bugulma Air		X	Group C	
Daghestan Airlines		X	Group C	
Gromov Air		X	Group C	
Interavia Airlines		X	Group C	
Mirny Enterprise		X	Group C	

Table B1.1.1 The classification of the Russian airlines (continued)
X specifies that the data is available for the year indicated

APPENDIX C1

C1.1 The domestic route networks of Group A carriers

Figure C1.1.1 The domestic route network of Aeroflot - Russian Airlines in 2002
Source: OAG and Great Circle Mapper (Swartz, 2012)

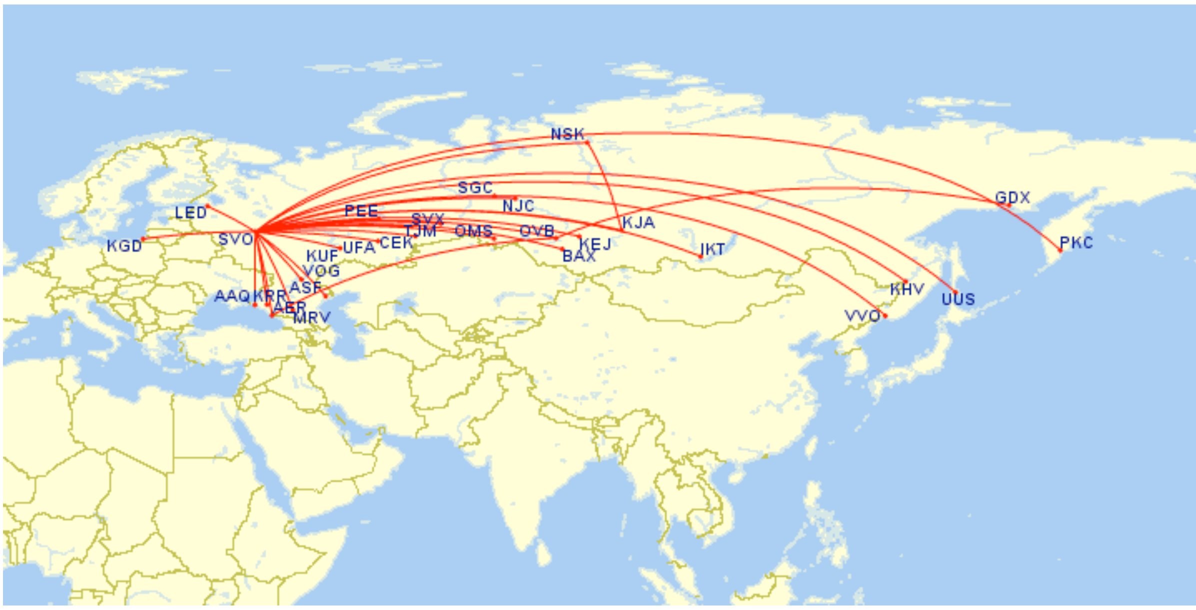

Figure C1.1.2 The domestic route network of Aeroflot - Russian Airlines in 2008
Source: OAG and Great Circle Mapper (Swartz, 2012)

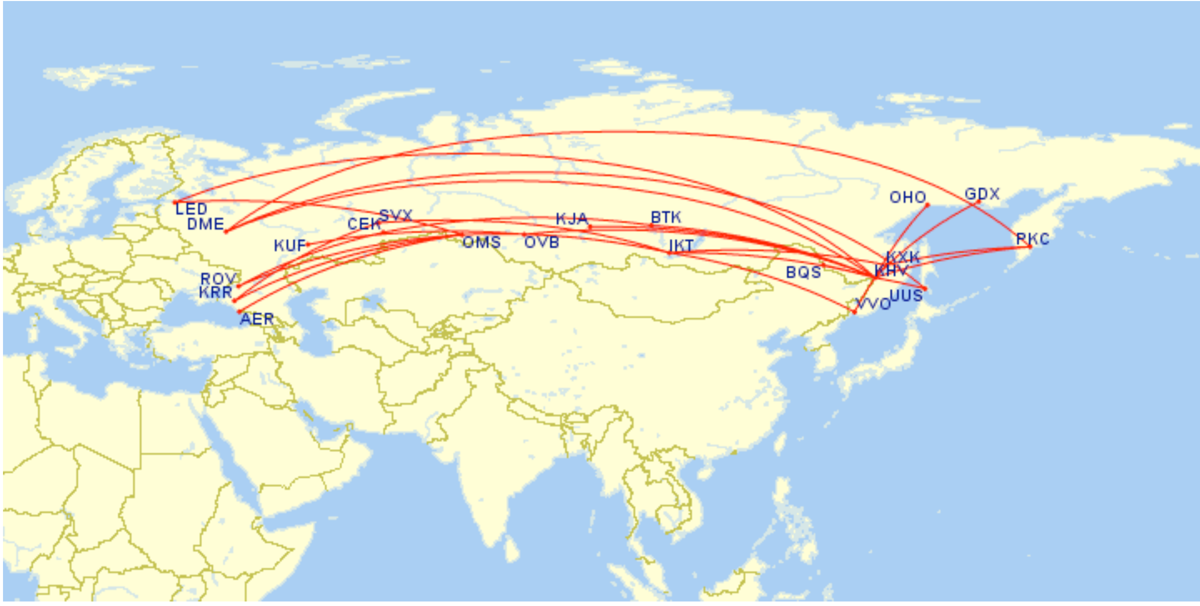

Figure C1.1.3 The domestic route network of Dalavia - Far East Airways in 2002
Source: OAG and Great Circle Mapper (Swartz, 2012)

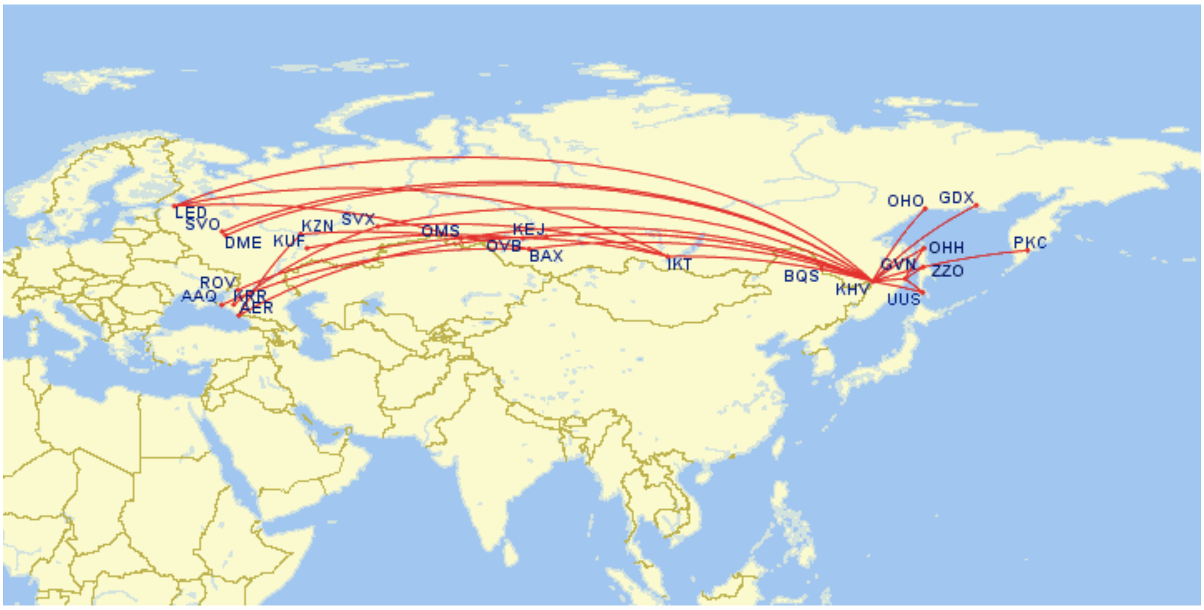

Figure C1.1.4 The domestic route network of Dalavia - Far East Airways in 2008
Source: OAG and Great Circle Mapper (Swartz, 2012)

Figure C1.1.5 Krasnoyarsk Airlines domestic route network in 2002
Source: OAG and Great Circle Mapper (Swartz, 2012)

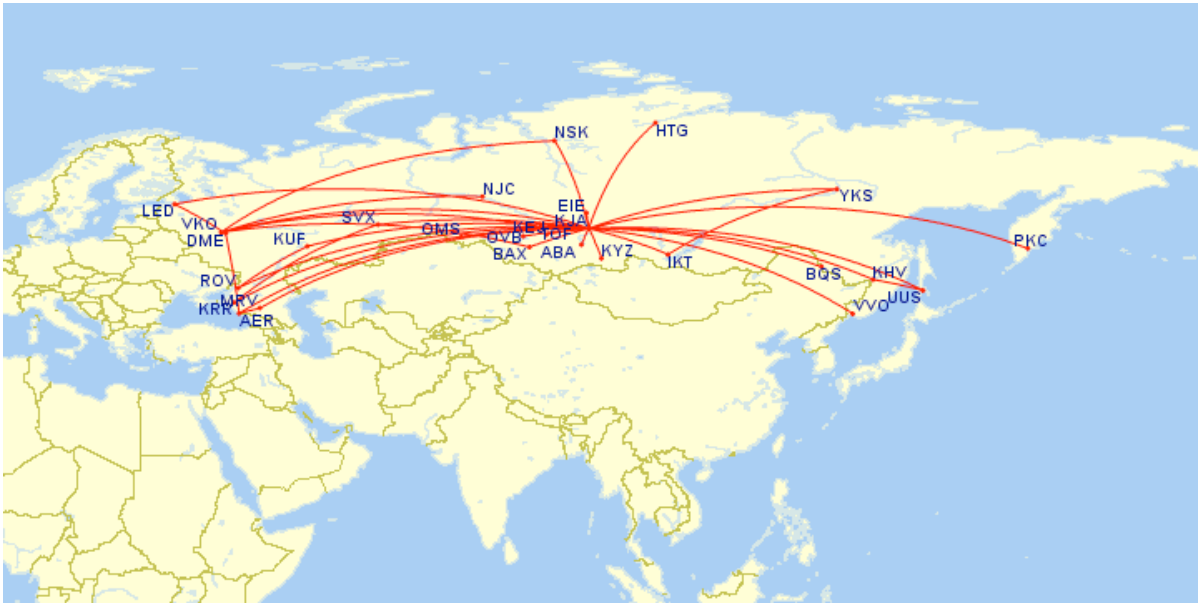

Figure C1.1.6 Krasnoyarsk Airlines domestic route network in 2008
Source: OAG and Great Circle Mapper (Swartz, 2012)

Figure C1.1.7 The domestic route network of Pulkovo Aviation in 2002
Source: OAG and Great Circle Mapper (Swartz, 2012)

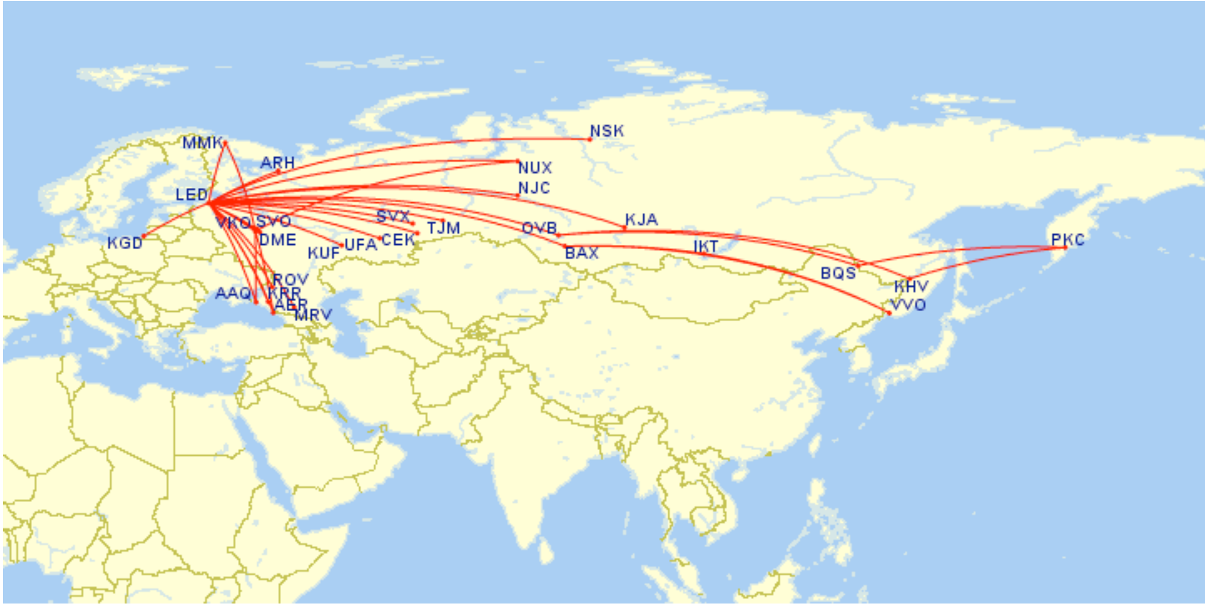

Figure C1.1.8 The domestic route network of Rossiya Russian Airlines in 2008
Source: OAG and Great Circle Mapper (Swartz, 2012)
Note: Rossiya Russian Airlines was established as a result of the merger between State Transport Company Rossiya and Pulkovo Aviation

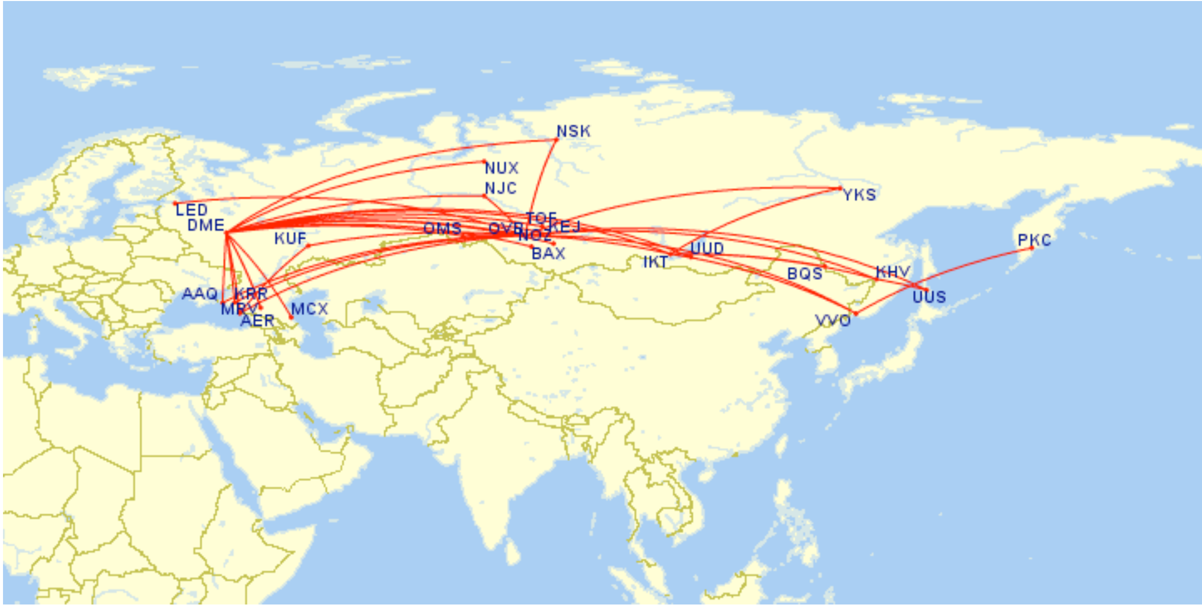

Figure C1.1.9 S7 Airlines domestic route network in 2002
Source: OAG and Great Circle Mapper (Swartz, 2012)
Note: The carrier operated under the name 'Siberia Airlines' in 2002

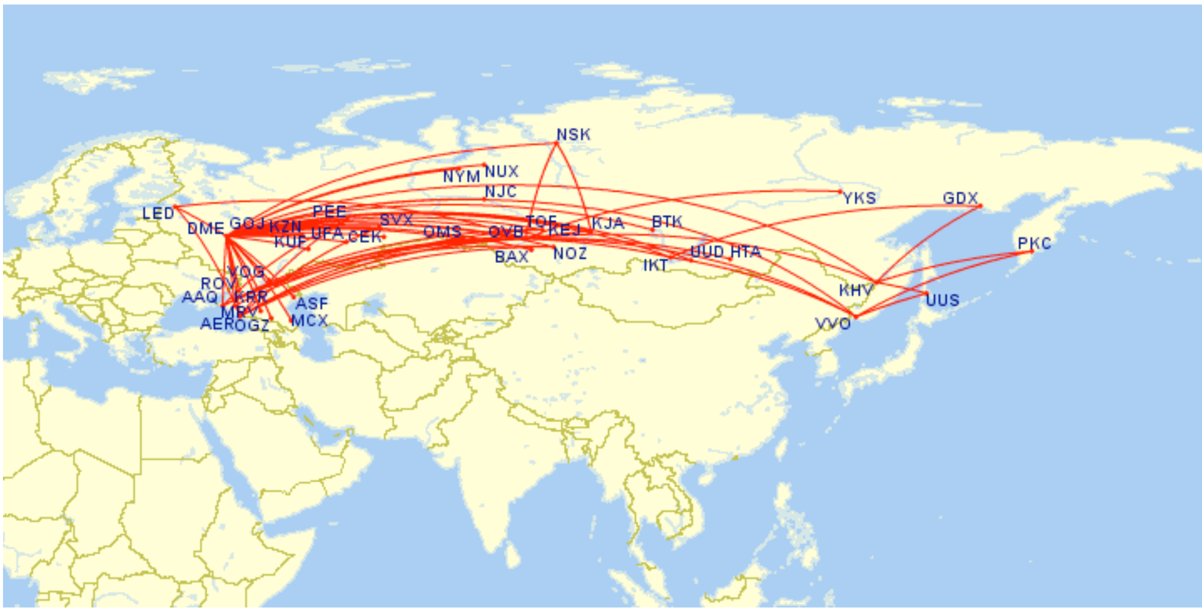

Figure C1.1.10 S7 Airlines domestic route network in 2008
Source: OAG and Great Circle Mapper (Swartz, 2012)

Figure C1.1.11 UTair Aviation domestic route network in 2002
Source: OAG and Great Circle Mapper (Swartz, 2012)
Note: The carrier operated under the name 'Tyumenaviatrans' in 2002

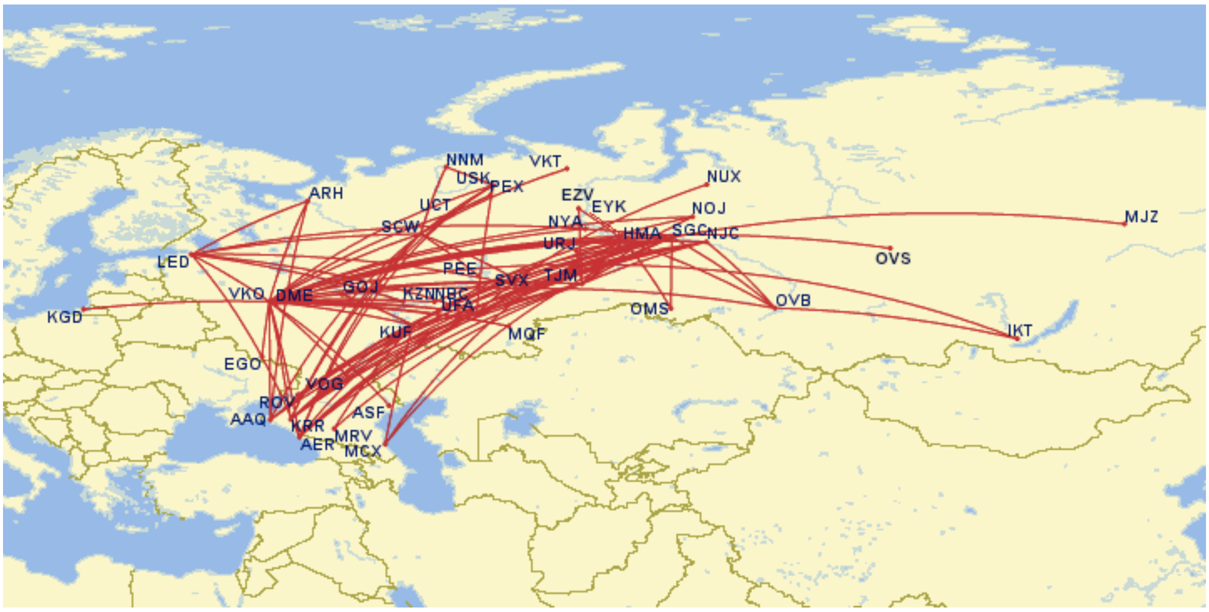

Figure C1.1.12 UTair Aviation domestic route network in 2008
Source: OAG and Great Circle Mapper (Swartz, 2012)

Figure C1.1.13 UTair Express domestic route network in 2002
Source: OAG and Great Circle Mapper (Swartz, 2012)
Note: The carrier operated under the name 'Komiinteravia' in 2002

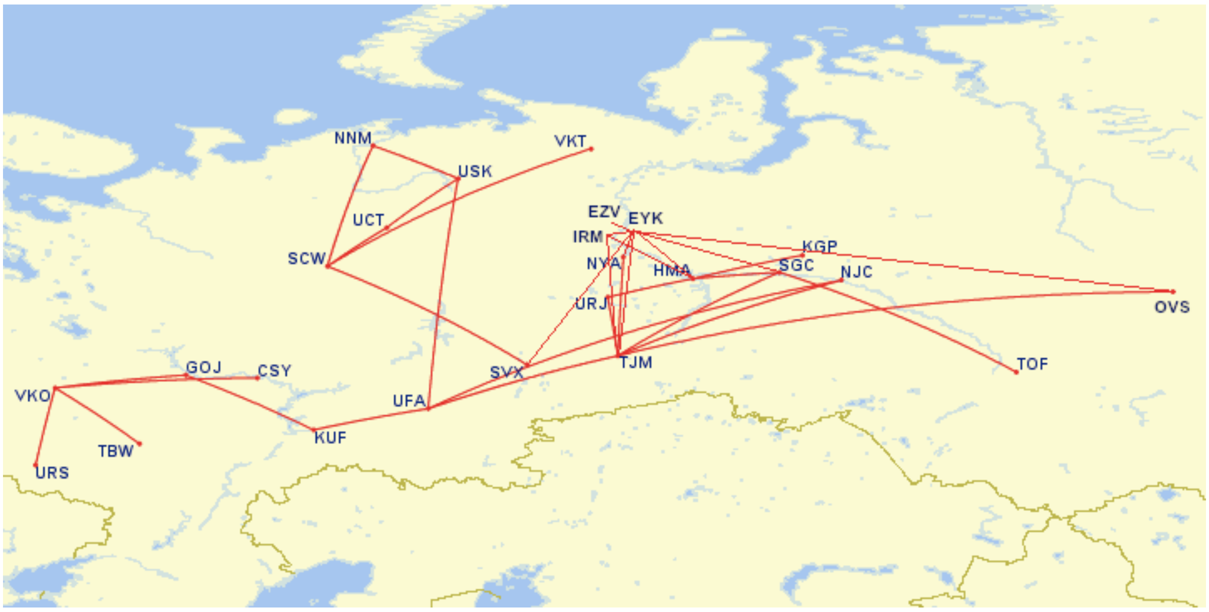

Figure C1.1.14 UTair Express domestic route network in 2008
Source: OAG and Great Circle Mapper (Swartz, 2012)

APPENDIX C2

C2.1 The domestic route networks of selected Group B carriers

Figure C2.1.1 The domestic route network of Aeroflot-Don in 2002
Source: OAG and Great Circle Mapper (Swartz, 2012)

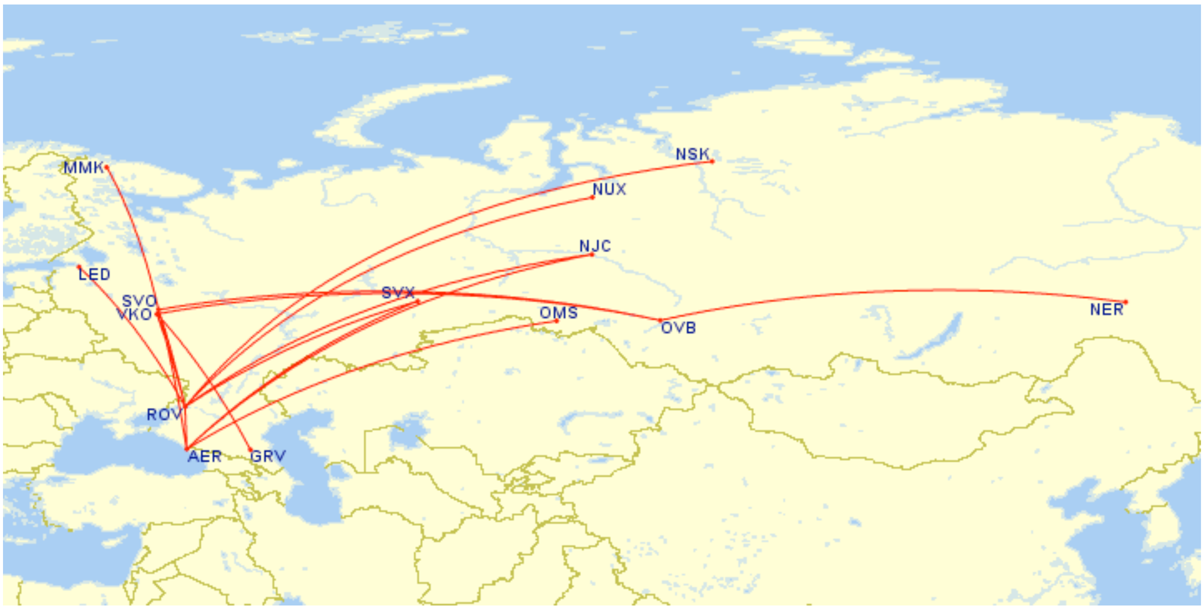

Figure C2.1.2 The domestic route network of Aeroflot-Don in 2008
Source: OAG and Great Circle Mapper (Swartz, 2012)

Figure C2.1.3 Aeroflot Nord domestic route network in 2002
Source: OAG and Great Circle Mapper (Swartz, 2012)
Note: The carrier operated under the name 'Arkhangelsk Airlines' in 2002

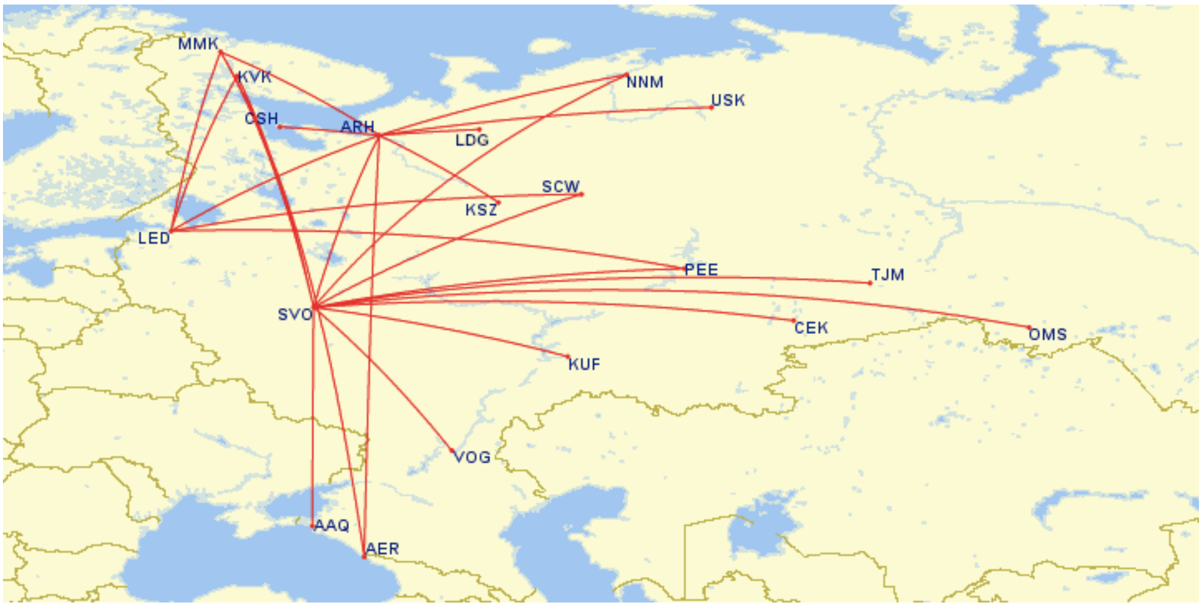

Figure C2.1.4 The domestic route network of Aeroflot Nord in 2008
Source: OAG and Great Circle Mapper (Swartz, 2012)

Figure C2.1.5 Sibaviatrans domestic route network in 2002
Source: OAG and Great Circle Mapper (Swartz, 2012)

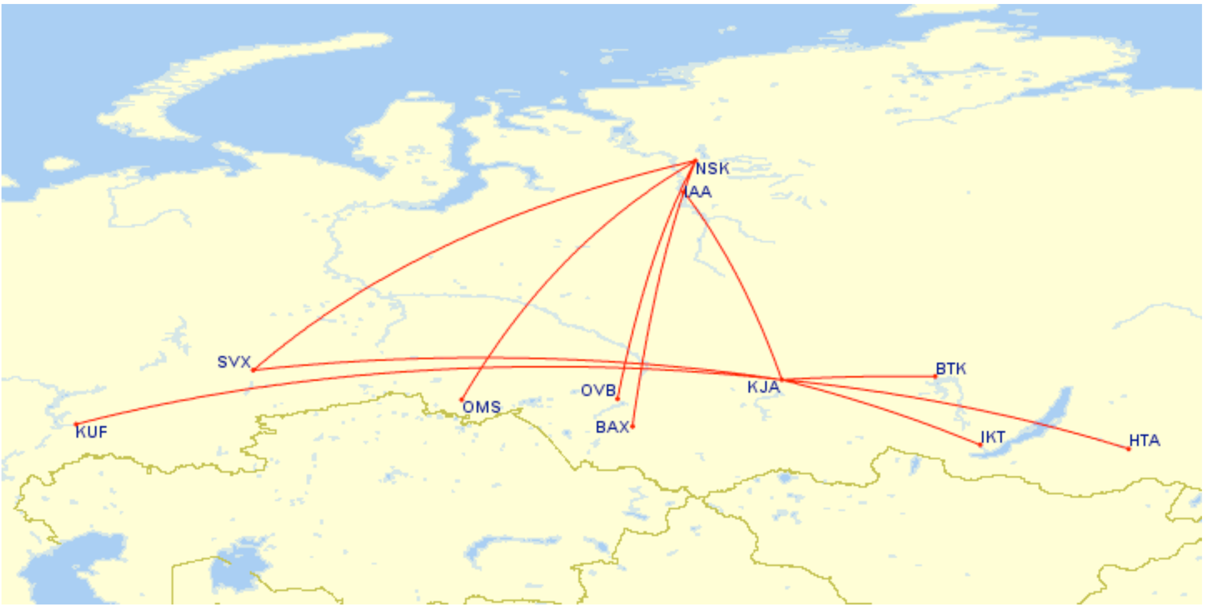

Figure C2.1.6 Sibaviatrans domestic route network in 2008
Source: OAG and Great Circle Mapper (Swartz, 2012)

Figure C2.1.7 The domestic route network of Kavminvodyavia in 2002
Source: OAG and Great Circle Mapper (Swartz, 2012)

Figure C2.1.8 The domestic route network of Kavminvodyavia in 2008
Source: OAG and Great Circle Mapper (Swartz, 2012)

Figure C2.1.9 Yakutia domestic route network in 2002
Source: OAG and Great Circle Mapper (Swartz, 2012)
Note: The carrier operated under the name ‘Yakutaviatrans’ in 2002

Figure C2.1.10 Yakutia domestic route network in 2008
Source: OAG and Great Circle Mapper (Swartz, 2012)

Figure C2.1.11 The domestic route network of Vladivostok Air in 2002
Source: OAG and Great Circle Mapper (Swartz, 2012)

Figure C2.1.12 The domestic route network of Vladivostok Air in 2008
Source: OAG and Great Circle Mapper (Swartz, 2012)

Figure C2.1.13 The domestic route network of Sky Express in 2008
Source: OAG and Great Circle Mapper (Swartz, 2012)

APPENDIX D

D1.1 The list of IATA[56] airport codes

IATA airport code	Destination	IATA airport code	Destination
AAQ	Anapa	IKS	Tiksi
ABA	Abakan	IKT	Irkutsk
ADH	Aldan	INA	Inta
AER	Sochi	IRM	Igrim
ARH	Arkhangelsk	JOK	Joshkar-Ola
ASF	Astrakhan	KEJ	Kemerovo
BAX	Barnaul	KGD	Kaliningrad
BKA	Moscow (Bykovo)	KGP	Kogalym
BQS	Blagoveschensk	KHV	Khabarovsk
BTK	Bratsk	KJA	Krasnoyarsk
CEE	Cherepovets	KRR	Krasnodar
CEK	Chelyabinsk	KSZ	Kotlas
CKH	Chokurdah	KUF	Samara
CKL	Chkalovsky	KVK	Kirovsk
CSH	Solovetsky	KVR	Kavalerovo
CSY	Cheboksary	KXK	Komsomolsk Na Amure
CYX	Cherskiy	KYZ	Kyzyl
DME	Moscow (Domodedovo)	KZN	Kazan
DYR	Anadyr	LDG	Leshukonskoye
EGO	Belgorod	LED	St. Petersburg (Pulkovo)
EIE	Eniseysk	LPK	Lipetsk
EYK	Beloyarsky	MCX	Makhachkala
EZV	Berezovo	MJZ	Mirnyj
GDX	Magadan	MMK	Murmansk
GDZ	Gelendzik	MQF	Magnitogorsk
GOJ	Nizhniy Novgorod	MRV	Mineralnye Vody
GRV	Groznyj	NBC	Nizhnekamsk
GVN	Sovetskaya Gavan	NER	Neryungri

Table D1.1.1 IATA airport codes

[56] International Air Transport Association

IATA airport code	Destination	IATA airport code	Destination
HMA	Khanty-Mansiysk	NJC	Nizhnevartovsk
HTA	Chita	NNM	Naryan-Mar
HTG	Hatanga	NOJ	Noyabrsk
IAA	Igarka	NOZ	Novokuznetsk
NSK	Norilsk	STW	Stavropol
NUX	Novy Urengoy	SVO	Moscow (Sheremetyevo)
NYA	Nyagan	SVX	Yekaterinburg
NYM	Nadym	TBW	Tambov
OGZ	Vladikavkaz	TJM	Tyumen
OHH	Okha	TLY	Plastun
OHO	Ohotsk	TOF	Tomsk
OMS	Omsk	UCT	Ukhta
OSW	Orsk	UFA	Ufa
OVB	Novosibirsk	UIK	Ust-Ilimsk
OVS	Sovetsky	ULY	Ulyanovsk
PEE	Perm	URJ	Uraj
PES	Petrozavodsk	URS	Kursk
PEX	Pechora	USK	Usinsk
PEZ	Penza	UUA	Bugulma
PKC	Petropavlovsk-Kamchatsky	UUD	Ulan-Ude
PKV	Pskov	UUS	Yuzhno-Sakhalinsk
PWE	Pevek	VKO	Moscow (Vnukovo)
PYJ	Polyarnyj	VKT	Vorkuta
RAT	Raduzhnyi	VLK	Volgodonsk
REN	Orenburg	VOG	Volgograd
ROV	Rostov	VOZ	Voronezh
RTW	Saratov	VVO	Vladivostok
SCW	Syktyvkar	YKS	Yakutsk
SGC	Surgut	ZZO	Zonalnoe
SLY	Salekhard		

Table D1.1.1 IATA airport codes (continued)

REFERENCES

Adler, N. and Golany, B. (2001) 'Evaluation of deregulated airline networks using data envelopment analysis combined with principal component analysis with an application to Western Europe', *European Journal of Operational Research,* vol. 132, no.2, pp. 260-273.

Adler, N. and Smilowitz, K. (2007) 'Hub-and-spoke network alliances and mergers: Price-location competition in the airline industry', *Transportation Research Part B: Methodological,* vol. 41, no. 4, pp. 394-409.

Aeroflot (2004) *Aeroflot-Nord acquired Arkhangelsk airlines company,* [Online], Available: http://www.aeroflot.ru/cms/en/new/1111 [10 Aug 2012].

Aguirregabiria, V. and Ho, C.-Y. (2010) 'A dynamic game of airline network competition: Hub-and-spoke networks and entry deterrence', *International Journal of Industrial Organization,* vol. 28, no. 4, pp. 377-382.

Air Transport World (2011) *Russia's first LCC, Sky Express, will lose AOC,* [Online], Available: http://atwonline.com/airline-finance-data/news/russia-s-first-lcc-sky-express-will-lose-aoc-1017 [10 Aug 2012].

Airbus (2011) *More than 1,000 aircraft will be needed within the next 20 years in Russia,* [Online], Available: http://www.airbus.com/newsevents/news-events-single/detail/more-than-1000-aircraft-will-be-needed-within-the-next-20-years-in-russia/ [10 Aug 2012].

Airline Leader (2011) *Russian Aviation on the brink of something special,* [Online], Available: http://www.airlineleader.com/country-in-focus/russian-aviation-on-the-brink-of-something-special [10 Aug 2012].

Alamdari, F. and Fagan, S. (2005) 'Impact of the adherence to the original low-cost model on the profitability of low-cost airlines', *Transport Reviews,* vol. 25, no. 3, pp. 377-392.

Alderighi, M., Cento, A., Nijkamp, P. and Rietveld, P. (2007) 'Assessment of new hub-and-spoke and point-to-point airline network configurations', *Transport Reviews,* vol. 27, no. 5, pp. 529-549.

Ambler, J., Shaw, D.J.B. and Symons, L. (1985) *Soviet and East European transport problems,* London: Croom Helm.

Antonov (2012) *ANTONOV history,* [Online], Available: http://www.antonov.com/about/antonov-history [10 Aug 2012].

Bagler, G. (2008) 'Analysis of the airport network of India as a complex weighted network', *Physica A: Statistical Mechanics and its Applications,* vol. 387, no. 12, pp. 2972-2980.

Barents Observer (2008) *Aeroflot-Nord becomes Arkhangelsk Airlines,* [Online], Available: http://www.barentsobserver.com/en/node/21405 [10 Aug 2012].

Barrie, D. and Komarov, A. (2005) 'Runway wrangle', *Aviation Week and Space Technology,* vol. 162, no. 16, pp. 48.

Barthélemy, M., Barrat, A., Pastor-Satorras, R. and Vespignani, A. (2005) 'Characterization and modeling of weighted networks', *Physica A: Statistical Mechanics and its Applications,* vol. 346, no. 1-2, pp. 34-43.

Belobaba, P.P. and Van Acker, J. (1994) 'Airline market concentration. An analysis of US origin-destination markets', *Journal of Air Transport Management,* vol. 1, no. 1, pp. 5-14.

Bellù, L.G. and Liberati, P. (2006) *Inequality analysis. The Gini Index,* Rome: Food and Agriculture Organization of the United Nations (FAO).

Borgatti, S.P. and Everett, M.G. (2006) 'A graph-theoretic perspective on centrality', *Social Networks,* vol. 28, no. 4, pp. 466-484.

Borgatti, S.P., Everett, M.G. and Freeman, L.C. (2002) *Ucinet for Windows: Software for Social Network Analysis,* Harvard, MA: Analytic Technologies.

Bowen, J. (2002) 'Network change, deregulation, and access in the global airline industry', *Economic Geography,* vol. 78, no. 4, pp. 425-439.

Bradshaw, M.J. and Lynn, N.J. (1994) 'After the Soviet Union: the post-Soviet states in the world system', *The Professional Geographer,* vol. 46, no. 4, pp. 439-449.

Brooks Cates, D. (1978) 'Short-run structural change in an airline network of declining connectivity', *Professional Geographer,* vol. 30, no. 1, pp. 9-13.

Burghouwt, G. (2005) *Airline network development in Europe and its implications for airport planning,* Utrecht: Faculty of Geosciences, Utrecht University.

Burghouwt, G. and de Wit, J.G. (2005) 'Temporal configurations of European airline networks', *Journal of Air Transport Management,* vol. 11, no. 3, pp. 185-198.

Burghouwt, G. and Hakfoort, J. (2002) 'The geography of deregulation in the European aviation market', *Tijdschrift voor Economische en Sociale Geografie,* vol. 93, no. 1, pp. 100-106.

Burghouwt, G., Hakfoort, J. and van Eck, J.R. (2003) 'The spatial configuration of airline networks in Europe', *Journal of Air Transport Management,* vol. 9, no. 5, pp. 309-323.

Cento, A. (2009) *The airline industry: Challenges in the 21st century,* Heidelberg: Physica-Verlag.

Chan, Y. (1979) ‘A graph-theoretic method to quantify the airline route authority’, *Transportation,* vol. 8, no. 3, pp. 275-291.

Daramola, A. and Jaja, C. (2011) ‘Liberalization and changing spatial configurations in Nigeria’s domestic air transport network’, *Journal of Transport Geography,* vol. 19, no. 6, pp. 1198-1209.

Dennis, N. (2005) ‘Industry consolidation and future airline network structures in Europe’, *Journal of Air Transport Management,* vol. 11, no. 3, pp. 175-183.

Derudder, B. and Witlox, F. (2009) ‘The impact of progressive liberalization on the spatiality of airline networks: a measurement framework based on the assessment of hierarchical differentiation’, *Journal of Transport Geography,* vol. 17, no. 4, pp. 276-284.

de Wit, J.G. (1995) ‘An urge to merge?’, *Journal of Air Transport Management,* vol. 2, no. 3/4, pp. 173-180.

Dobruszkes, F. (2006) ‘An analysis of European low-cost airlines and their networks’, *Journal of Transport Geography,* vol. 14, no. 4, pp. 249-264.

ERPHO (2005) *Gini calculator,* [Online], Available: http://www.erpho.org.uk/viewResource.aspx?id=12222 [10 Aug 2012].

Goetz, A.R. and Sutton, C.J. (1997) ‘The geography of deregulation in the U.S. airline industry’, *Annals of the Association of American Geographers,* vol. 87, no. 2, pp. 238-263.

Goetz, A.R. and Vowles, T.M. (2009) ‘The good, the bad, and the ugly: 30 years of US airline deregulation’, *Journal of Transport Geography,* vol. 17, no. 4, pp. 251-263.

Guimerà, R., Mossa, S., Turtschi, A. and Amaral, L.A.N. (2005) ‘The worldwide air transportation network: Anomalous centrality, community structure, and cities’ global roles’, *Proceedings of the National Academy of Sciences of the United States of America,* vol. 102, no. 22, pp. 7794-7799.

Han, D.-D., Qian, J.-H. and Liu, J.-G. (2009) ‘Network topology and correlation features affiliated with European airline companies’, *Physica A,* vol. 388, no.1, pp. 71-81.

Hanneman, R.A. and Riddle, M. (2005) *Introduction to social network methods,* Riverside: University of California, [Online], Available: http://faculty.ucr.edu/~hanneman/ [10 Aug 2012].

Hansen, M. (1990) ‘Airline competition in a hub-dominated environment: An application of noncooperative game theory’, *Transportation Research Part B,* vol. 24, no. 1, pp. 27-43.

Holloway, S. (2008) *Straight and Level. Practical Airline Economics,* 3rd edition, Aldershot: Ashgate Publishing Limited.

Hooper, P., Hutcheson, S. and Nyathi, M. (1996) 'The challenge of liberalising domestic airline competition in a less developed country', *Transportation,* vol. 23, no. 4, pp. 395-408.

Hornby, A.S., Crowther, J., Kavanagh, K. and Ashby, M. (1995) *Oxford Advanced Learner's Dictionary of Current English,* 5th edition, Oxford: Oxford University Press.

Hsu, C.-I. and Shih, H.-H. (2008) 'Small-world network theory in the study of network connectivity and efficiency of complementary international airline alliances', *Journal of Air Transport Management,* vol. 14, no. 3, pp. 123-129.

Huber, H. (2009) 'Spatial structure and network behaviour of strategic airline groups: A comparison between Europe and the United States', *Transport Policy,* vol. 16, no. 4, pp. 151-162.

Huber, H. (2010) 'Statistical mechanics for analytic planning: an application to domestic air traffic in China', *Transportation Planning and Technology,* vol. 33, no.7, pp. 551-567.

Jaillet, P., Song, G. and Yu, G. (1999) 'Airline network design and hub location problems', *Recherche-Transports-Securite,* vol. 62, pp. 195-212.

Janić, M. (1997) 'Liberalisation of European aviation: analysis and modelling of the airline behaviour', *Journal of Air Transport Management,* vol. 3, no. 4, pp. 167-180.

Kolossov, V. and Thorez, P. (2009) 'Métropolisation et place des réglions dans le transport aérien en Russie', *Bulletin de l'Association de géographes français,* vol. 86, no. 4, pp. 496-511.

Komarov, A. (2005) 'Shotgun marriage', *Aviation Week and Space Technology,* vol. 163, no. 6, pp. 55-56.

Komarov, A. (2006) 'Routes to Russia', *Aviation Week and Space Technology,* vol. 164, no. 17, pp. 68-69.

Komarov, A. (2008) 'Russian roulette', *Aviation Week and Space Technology,* vol. 169, no. 16, pp. 47.

Komarov, A. (2009a) 'Second wave', *Aviation Week and Space Technology,* vol. 171, no. 10, pp. 46.

Komarov, A. (2009b) 'Reverse trend', *Aviation Week and Space Technology,* vol. 171, no. 15, pp. 53.

Komarov, A. (2009c) ‘Rationing rationale’, *Aviation Week and Space Technology,* vol. 171, no. 1, pp. 33-34.

Komarov, A. (2010a) ‘Market shake-up’, *Aviation Week and Space Technology,* vol. 172, no. 6, pp. 36-37.

Komarov, A. (2010b) ‘Tax incentive’, *Aviation Week and Space Technology,* vol. 172, no. 8, pp. 37-38.

Komarov, A. and Taverna, M.A. (2004) ‘Flight of the Condor’, *Aviation Week and Space Technology,* vol. 160, no. 5, pp. 50-51.

Komarov, A. and Taverna, M.A. (2005) ‘New life for An-124?’, *Aviation Week and Space Technology,* vol. 162, no. 15, pp. 40-41.

Malighetti, P., Paleari, S. and Redondi, R. (2008) ‘Connectivity of the European airport network: ‘Self-help hubbing’ and business implications’, *Journal of Air Transport Management,* vol. 14, no. 2, pp. 53-65.

Marsden, P.V. (2002) ‘Egocentric and sociocentric measures of network centrality’, *Social Network,* vol. 24, no. 4, pp. 407-422.

Marsten, R.E. and Muller, M.R. (1980) ‘A mixed-integer programming approach to air cargo fleet planning’, *Management Science,* vol. 26, no. 11, pp. 1096-1107.

Martín, J.C. and Voltes-Dorta, A. (2008) ‘Theoretical evidence of existing pitfalls in measuring hubbing practices in airline networks’, *Networks and Spatial Economics,* vol. 8, no. 2-3, pp. 161-181.

Martín, J.C. and Voltes-Dorta, A. (2009) ‘A note on how to measure hubbing practices in airline networks’, *Transportation Research Part E: Logistics and Transportation Review,* vol. 45, no. 1, pp. 250-254.

Morley, C.L. (2003) ‘Globalisation, airline alliances and tourism: A strategic perspective’, *Asia Pacific Journal of Tourism Research,* vol. 8, no. 1, pp. 15-25.

OAG Aviation (2012) *About UBM Aviation,* [Online], Available: http://www.ubmaviation.com/about-UBM-Aviation [10 Aug 2012].

O’Kelly, M.E. (1998) ‘A geographer’s analysis of hub-and-spoke networks’, *Journal of Transport Geography,* vol. 6, no. 3, pp. 171-186.

O’Kelly, M.E. (2010) ‘Routing traffic at hub facilities’, *Networks and Spatial Economics,* vol. 10, no. 2, pp. 173-191.

Pels, E. (2001) ‘A note on airline alliances’, *Journal of Air Transport Management,* vol. 7, no. 1, pp. 3-7.

Reese, C.E. and Lochmüller, C.H. (1994) *Introduction to factor analysis,* [Online], Available: http://www.chem.duke.edu/~clochmul/tutor1/factucmp.html [10 Aug 2012].

Reggiani, A., Nijkamp, P. and Cento, A. (2010) ‘Connectivity and concentration in airline networks: a complexity analysis of Lufthansa’s network’, *European Journal of Information Systems,* vol. 19, no. 4, pp. 449-461.

Reynolds-Feighan, A. (2001) ‘Traffic distribution in low-cost and full-service carrier networks in the US air transportation market’, *Journal of Air Transport Management,* vol. 7, no. 5, pp. 265-275.

Reynolds-Feighan, A. (2007) ‘Competing networks, spatial and industrial concentration in the US airline industry’, *Spatial Economic Analysis,* vol. 2, no. 3, pp. 237-257.

RIA Novosti (2010) *Russia’s S7 Airlines joins Oneworld alliance,* [Online], Available: http://en.rian.ru/business/20101115/161341543.html [10 Aug 2012].

RIA Novosti (2011) *Russia may admit foreign airlines to domestic market,* [Online], Available: http://en.rian.ru/business/20110407/163417605.html [10 Aug 2012].

Richards, W. and Seary, A. (2000) ‘Eigen analysis of networks’, *Journal of Social Structure,* vol. 1, no. 2, pp. 1-17.

Rodrigue, J.-P., Comtois, C. and Slack, B. (2009) *The Geography of Transport Systems,* 2nd edition, New York: Routledge.

Rossiya - Airlines (2011) *History,* [Online], Available: http://www.rossiya-airlines.ru/en/about/aboutus/history [10 Aug 2012]

Ruhnau, B. (2000) ‘Eigenvector-centrality - a node-centrality’, *Social Networks,* vol. 22, no. 4, pp. 357-365.

Russian Aviation (2011) *The consolidation of the Russian airline industry,* [Online], Available: http://www.russianaviation.org/index.php/latest-news/1139-the-consolidation-of-the-russian-airline-industry [10 Aug 2012].

Shaw, S.L. (1993) ‘Hub structures of major US passenger airlines’, *Journal of Transport Geography,* vol. 1, no. 1, pp. 47-58.

Shaw, S.-L., Lu, F., Chen, J. and Zhou, C. (2009) ‘China’s airline consolidation and its effects on domestic airline networks and competition’, *Journal of Transport Geography,* vol. 17, no. 4, pp. 293-305.

Strauss, J. (2004) *Russia is put on alert as two planes crash,* [Online], Available: http://www.telegraph.co.uk/news/worldnews/europe/russia/1470190/Russia-is-put-on-alert-as-two-planes-crash.html [10 Aug 2012].

Suau-Sanchez, P. and Burghouwt, G. (2012) 'Connectivity levels and the competitive position of Spanish airports and Iberia's network rationalization strategy', *Journal of Air Transport Management,* vol. 18, no. 1, pp. 47-53.

Swartz, K.L. (2012) *Great Circle Mapper,* [Online], Available: http://www.gcmap.com [10 Aug 2012].

Symons, L., Dewdney, J.C. and Hooson, D.J.M. (1983) *The Soviet Union: a systematic geography,* London: Hodder and Stoughton.

Thorez, P. (2010) 'Aéroports, ville et espace urbain: le cas de Moscou', *Belgisch Tijdschrift voor Geografie,* vol. 1-2, pp. 109-118.

Tinkler, K.J. (1979) 'Graph theory', *Progress in Human Geography,* vol. 3, no.1, pp. 85-116.

Transport Clearing House (2009) *Перевезено пассажиров через аэропорты России за январь - декабрь 2008 года (международные и внутренние перевозки),* [Online], Available: http://www.tch.ru/doc/1451/AP_pass-vsego.pdf [10 Aug 2012].

Wall, R. and Komarov, A. (2005) 'Preparing to talk', *Aviation Week and Space Technology,* vol. 163, no. 6, pp. 56-57.