Selection of Logistics Centres Location: Case of Russia

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Abstract

Currently Russian forwarding service development is at a comparatively low level. One of the considered priority objectives, which is defined in the Transport Strategy of Russia 2030, is a construction of logistics centres in every region of Russia. This thesis presents a new evaluation system for the logistics centre allocation and applies spatial analysis tools to near optimally allocate logistics centres on the territory of the Russian Federation. Using ArcGIS Network Analyst, the most suitable cities for logistics centres allocation are selected based on railway networks accessibility within the Russian Federation, proximity to domestic and foreign contiguous cities and regional socio-economic situation as well as infrastructure development and regional investment attractiveness. The project aims at selecting cities for allocation of logistics centres of federal importance. The policy recommendations are provided to Maksim Sokolov, Minister of Transport in Russia as of 2016.

Keywords: logistics centre, facility location problem, road network analysis, spatial analysis.

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Glossary

CIS	**C**ommonwealth of **I**ndependent **S**tates
EEIG	**E**uropean Logistics Platforms Association
GIS	**G**eographic **I**nformation **S**ystem
GRP	**G**ross **R**egional **P**roduct (GDP of region)
LC	**L**ogistics **C**enter
Minregion	**M**inistry of Regional Development of the Russian Federation (abolished in 2014)
Mintrans	**M**inistry of Transport of the Russian Federation
NACIS	**N**orth **A**merican **C**artographic **I**nformation **S**ociety
PPDAC	**P**roblem - **P**lan - **D**ata - **A**nalysis - **C**onclusions (Methodology)
PPP	**P**ublic - **P**rivate **P**artnership
PPPI	Unified **I**nformation System on **P**ublic **P**rivate **P**artnership in Russia
Rosstat	**R**ussian Federal State **S**tatistics Service
RZhD	**R**ussian Railways company

Introduction

Russian forwarding service development is assumed to be at a low level. One of the considered priority objectives is the construction of logistics centres. The 2030 Transport Strategy of Russia states that 'all subjects of the Russian Federation are necessary to implement measures to develop a network of logistics centres for the provision of freight forwarding services' (Mintrans, 2014).

The socio-economic literature gives a number of definitions for a logistics centre (See section 1.1). I use the definition formulated by the European Logistics Platforms Association (EEIG) that defines a logistics centre as 'the hub of a specific area where all the activities relating to transport, logistics and goods distribution - both for national and international transit - are carried out, on a commercial basis, by various operators' (EEIG, 2014). According to the EEIG, the development of a logistics centre is expected to provide such benefits as optimization of the logistics chain, lorry utilization, warehouse utilization, and manpower organization. It decreases the total transport costs, total industrial costs, personnel costs, and increases the transport operators total turnover.

Research Problem. Currently, logistics centres in Russia are concentrated in the Western part of the country. The majority of them are located in Moscow, the Moscow region, and in Saint-Petersburg. There is one logistics centre in Novosibirsk, construction is ongoing in Rostov-on-Don, Sviyazshsk (Kazan area), Yekaterinburg and the Murmansk area (See Figure 1). The Transport Strategy 2030 clearly states the problem of the development of such terminals in Russia, in particular, it highlights the necessity of a logistics centres network development (Mintrans, 2014).

Figure 1: Currently realised or planned projects of LCs construction

Research Goal. The aim of this thesis is to help policy makers prioritise the sequence of cities for a logistics centres network development in Russia. I select the priority cities for the allocation of logistics centres that are important at the federal level and address my recommendations to a Minister of Transport of Russia.

Research Question. To achieve this goal, the thesis answers the main research question: *What are the best locations in Russia for logistics centres development?*

To answer this question I address the following issues:

- what is the role of a logistics centre?
- what types of logistics centres are there?
- what state programs and strategies concerning logistics centres exist?
- how well is the problem of facility location studied in literature?

- what is an appropriate methodology for the logistics centres selection taking into account Russian background?

Theoretical Framework and Methodology. This thesis combines several approaches. The broad framework of the research is based on a geospatial analysis. Conceptually, geospatial approach is a subset of techniques that are applied to a two-dimensional data that relate to terrestrial activities (Smith, Goodchild, Longley, 2015). Within this framework, I use network and location analysis techniques. Network analysis examines 'the properties of natural and man-made networks in order to understand the behaviour of flows within and around such networks' (Smith, Goodchild and Longley, 2015). Geographic network analysis usually addresses the problems such as route selection, facility location, flows directions (e.g., in hydrology). Location analysis is 'a technique for discovering, assessing and specifying the optimal placement of an organization's people, information, activities, and materials' (Advanced Strategies, 2016). Location analysis relates to operations research and computational geometry that is concerned with the optimal placement of facilities to minimise transportation costs. Network and location analysis techniques are separate fields, however, they may be combined. In particular, in my thesis I solve a location problem with reference to the existent railway network.

I develop a set of criteria for candidate cities evaluation based on approaches used in Rao et al. (2015), Kirillov and Tselin (2015), Zak and Weglinski (2014), Rakhmangulov and Kopilova (2014).

Section 3.3, which contains the application of geospatial network analysis, solves the location problem. The line of research started by Hakimi (1964) was expanded by Love and Lindquist (1995), Parker and Campbell (1998) and Cromley and McLafferty (2002), Hansen and Mladenovic (1997), Kara and Tansel (2000), Campbell, Lowe, Li Zhang (2005), Ernst et al. (2008). My research resembles Melachrinoudis and Min (2007), Algharib (2011) and Alshwesh et al. (2016). Hillsman editing process (1984) and Teitz and Bart vertex substitution heuristic (1968) are applied when using the ArcGIS Network Analyst software.

The structure of the final part of this thesis corresponds with PPDAC methodology. PPDAC refers to a following sequence: Problem - Plan - Data - Analysis - Conclusions. This methodology is widely used by professional analysts in the field. Smith, Goodchild and Longley (2015) note that 'the PPDAC methodology can be applied to problems in which the collection and analysis of particular datasets is the central task, as may be the case with primary environmental, socio-economic or epidemiological research.' As this research focuses on collection and analysis of spatial data, in particular, data on settlements and railways location, this methodology is appropriate for this thesis.

The role of logistics centres and their importance are described in Farook et al. (2007), Prokofieva (2012), EEIG (2014), Kuzmenko and Turlaev (2015). An extensive review of logistics centres types and hierarchy is done by Higgins, Ferguson and Kanaroglou (2012). The most comprehensive review of models for supply chain production and transport planning can be found in Mula et al. (2009).

Relying on these researches, I offer a new system of evaluation criteria of Russian cities. Providing the lists of priority locations, I solve the issues that are not sufficiently tackled in the Transport Strategy of Russia. The main contribution of the present thesis to the literature on logistics centres allocation is that it is the first to use ArcGIS Network Analyst for the selection of the best places for logistics centres construction.

Thesis Structure. This thesis is structured as follows. The first chapter (page 8) provides an overview of existent LC definitions in literature and describes LC structure. The second chapter (page 16) analyses current legal documents and state strategies, as well as the commercial projects that are realized on the territory of the Russian Federation and defines the stakeholders. In the third chapter (page 28), I explain in detail the methodology and data I use and present my findings. The final part of the thesis discusses the outcomes and addresses the policy recommendations to Mr Maksim Sokolov, Minister of Transport of the Russian Federation as of 2016.

Chapter 1

Description of a Logistics Centre

This is an introductory chapter that givers a very short overview of the logistics centre definitions and its typologies, and describes how the logistics centre works and what parts it usually consists of.

1.1 Overview of LC definitions in literature

Intermodal logistics centres area of study is relatively new. It suffers from a lack of clarity and consensus among the researchers of this subject. Higgins, Ferguson and Kanaroglou (2012) do a comprehensive study on LC definition and typology and reveal that a number of different terms used in literature relate to logistics centres. The list of terms related to logistics centres include the following (number of authors who used the term is in brackets):

Air cargo port (1), bulk terminal (1), container yard (1), distribution centre (3), distribution terminal (1), dry port (4), freight village (4), gateway (1), hinterland terminal (1), industrial park (1), inland clearance depot (1), inland container depot (2), inland customs depot (1), inland port (1), inland terminal (1), intermodal and multimodal industrial park (1), intermodal freight centre (1), intermodal railroad terminal (1), intermodal terminal (1), load centre (1), logistics centre (4), logistics node (1), maritime feeder inland port (1), nodal centres for goods (1), satellite terminal (2), seaport (1), trade and transportation centre in-

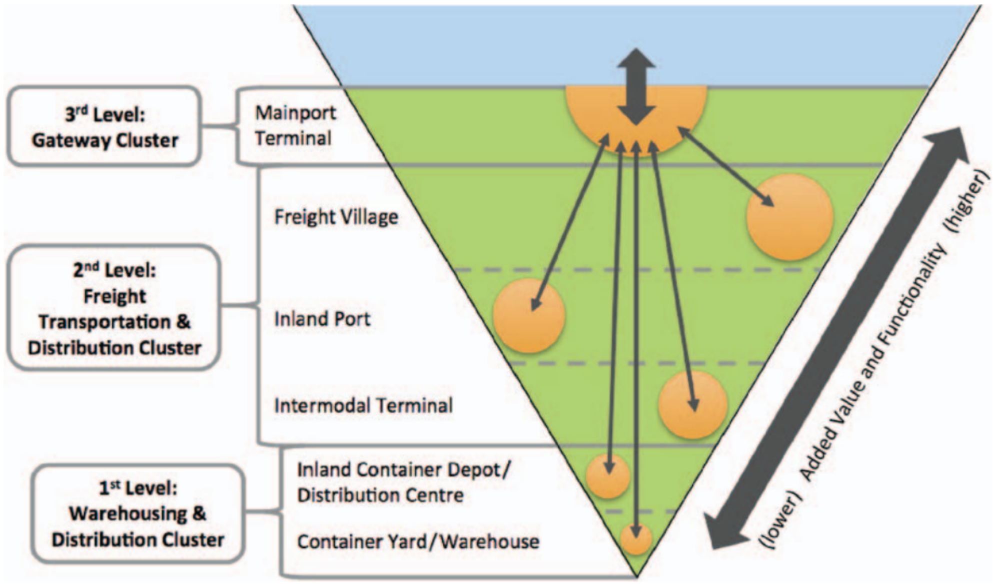

Figure 1.1: Standardised logistics centres hierarchy developed by Higgins, Ferguson and Kanaroglou (2012)

land port (1), transfer terminal (1), transmodal terminal (1), transport terminal (1), urban consolidation centre (1), urban distribution centre (1), warehouse (1).

This huge list of terms demonstrates the deep unconformity regarding the logistics centres in literature.

Higgins, Ferguson and Kanaroglou (2012) make an attempt to reach such a consistency and managed to group all these terms related to logistics centres into three main clusters according to their size (See Figure 1.1): *Warehousing and distribution cluster* as the first level cluster, *Freight transportation and distribution cluster* as the second level cluster and *Gateway cluster* as the largest third level cluster. I find their attempt to classify existing terms the most ambitious. Let us consider classifications made by other authors.

Hamzeh, Tommelein and Baller (2007) argue that there are two categories of LC definitions that describe different performing functions. The first examines LC as a part of transportation infrastructure. The LC 'provides access to different shipment modes, performs broad logistic functions, serves a wide range of users, presents information technology solutions, and

Figure 1.2: Logistics Centre in Switzerland

offers value added services' (Hamzeh, Tommelein and Baller, 2007; EEIG, 2004). The second category defines the LC as a stimulus to generate business, acting as an impulse for business and economic development. Since 'not all companies are able to build their own logistics centres or acquire the latest support technologies (software, radio frequency identification systems, real time communication network, etc.) and management skills, logistics centres offer these services without the added risk or infrastructure costs' (Hamzeh, Tommelein and Baller, 2007).

Kuzmenko and Turlaev (2015) define the LC as a multifunctional facility, which operates on the basis of a commercial enterprise, aimed at the coordinated management of transport and logistics processes, including at least one terminal. They propose to classify the LCs by their:

1. Zone of territorial coverage.

    - International logistics centre (transport area covers the whole world, or most of it);

- Interregional logistics centre (transport area within a radius of two neighboring regions);
- Regional logistics centre (transport area within the region);
- Local (municipal) logistics centre (transport area within the city).

2. Type of serviced vehicles.
   - Air;
   - Rail;
   - Sea;
   - Road;
   - Multimodal.
3. Type of cargo handled.
   - Specialised;
   - Universal;
   - Mixed;

Thus, there are different classifications of the logistics centres and a number of related terms. Researchers try to find a consensus, however, there is a long road that lays ahead. Present thesis uses the definition provided by the European Platforms Logistics Association, which identifies the LC as 'the hub of a specific area where all the activities relating to transport, logistics and goods distribution - both for national and international transit - are carried out, on a commercial basis, by various operators' (EEIG, 2014).

1.2 Structure of a Logistics Centre

According to the EEIG (2014), the development of a logistics centre can reduce the total costs of transport, production costs, personnel costs and increase the total turnover of the

Figure 1.3: Taiyuan Logistics Centre in China (concept)

Figure 1.4: Taiyuan Logistics Centre in China (concept)

transport operators. The territory of logistics centres may reach hundreds of hectares. There may be located customs authorities, post offices, bus stations, stations for the handling operations, warehouses, quarantine zone, packing service, restaurants, cafés, gas stations and car washes.

The headcount of the largest logistics centres may reach dozens thousands of people (up to 45 thousand employees).

I will shortly cover the structure of a recently built logistics centre Prilesie in Belarus (See Figure 1.5 on page 14). This logistics centre meets the requirements of the highest level of international multimodal transport hubs (Prilesie, 2016). Most of the Russian planned logistics centres (See for example Figures 2.1 on page 18 and 3.3 in Appendices) have the same structure. Therefore this structure can be examined as a case.

The logistic centre has the following features:

1. Combined rail-road transport modes
2. Warehousing
3. Centralized utilities
4. Customs clearance services
5. Enhanced security system
6. Centralized waste disposal
7. Public transport facilities
8. Truck services and support facilities
9. Public parking facilities
10. Office rental
11. Catering

The facilities of the warehouse are divided into two functional areas: public and non-public. The non-public area has the following facilities:

Figure 1.5: Prilesie Logistics Centre in Belarus

1. Warehouses
   (a) Dry warehouses
   (b) Cold warehouses
   (c) Customs warehouses
   (d) Warehouses for hazardous materials
2. Intermodal Terminal
   (a) Administration of the Intermodal Terminal
   (b) Customs Area
   (c) Garage and Workshop
   (d) Transshipment Area, Gantry Crane
   (e) Yard of Customs
   (f) Gatehouse for Customs Area
   (g) Guard House
3. Utilities
   (a) Gas supply Station
   (b) Telecommunication Centre
   (c) Water Treatment Plant
   (d) Power Station
   (e) Building for Emergency Power Generator
   (f) Detention Reservoir
   (g) Pump Station and Extinguishing Water Reservoir

A public zone of the centre consists of:

1. Roadside Service Area
   (a) Hotel/restaurant
   (b) Truck maintenance workshops
   (c) Fuel station, carwash, shop
   (d) Truck parking area
2. Administration area may include:
   (a) Administration offices
   (b) Banks/insurance offices
   (c) Local authorities offices
   (d) Management building
   (e) Police station, clinic
3. Exhibition and Sale area has:
   (a) Show rooms
   (b) Offices/back up warehouses

Thus, the logistics centre plays not only commercial function but social as well. Figure 1.2 demonstrates a unique design of the LC in Switzerland. Figures 1.3 and 1.4 show a prominent concept of a logistics facility in China.

Chapter 2

Existent Policies and State Documents Related to Logistics Centres in Russia

In the previous chapter we learnt that a logistics centre is a large-scale project, therefore its development requires a good strategic vision. The present chapter overviews existent strategic documents and programmes regarding the development of logistics centres in Russia. I compare state and business strategic programmes and reveal how consistent they are and whether they follow a single line in terms of logistics centres construction. In section 2.1 I review state strategies. In section 2.2 I analyse the concept of terminal and logistics centres development of the Russian biggest transport company Russian Railways (RZhD) and some specificities of public-private partnership in Russia.

2.1 State Strategic Documents

The following official documents reflect the state of conceptual developments regarding Logistics Centres in Russia:

- *Transport Strategy of the Russian Federation until 2030* (Ministry of Transport, 2012)
- *Development Strategy of Railways Transport in Russia until 2030* (Ministry of Transport, 2008)

Transport Strategy. General overview and strategies of the transport system development can be found in *Transport Strategy of the Russian Federation until 2030*, which was drafted in 2008 and a revised version was approved by the government in 2014. The Strategy comprises policy priorities. There are general priorities and priorities related to the network of logistics centres placement. Kolik et al. (2015) highlight the following general strategic goals in the transport sector that are defined by the Transport Strategy:

- creating the integrated transport space in the Russian Federation;
- ensuring access to quality transport-logistic services;
- ensuring access to quality transport services for the population;
- integration into the international transport system, increasing the transport services exports and transit;
- increasing the level of transport safety;
- reducing the negative environmental impact of transport.

They argue that the key multi-year federal financing programme (State Programme 'Development of Transport System') is synchronised with the Strategy, which is expected to better link investments with long-term priorities, as well as minimise the influence of short-term political and budgetary considerations (Kolik et al. 2015). Regarding the logics centres issues, the Strategy identifies the need to develop a network of terminal and logistics centres and 'dry' ports on the railways (Mintrans, 2014). Due to the high importance of creating an integrated network of logistics centres there is a matter of choosing the best places for logistics centres.

One of the logistics centres-related objective set in the Strategy is the necessity of development of 'a unified system and information environment of multimodal technological interaction between various types of transport, cargo and other participants in the transport process, customs and state control bodies' (Mintrans, 2014). It should be noted that currently the

Figure 2.1: Beliy Rast Logistics Centre in Russia (concept)

costs of domestic transport and logistics, incurred by Russia, are among the highest in the world. Total internal and external costs of transport and logistics in Russia make up about 20% of GDP, while in China - 15%, in Europe - 7-8% (Kuzmenko, Turlaev, 2015).

A special attention is paid to the development of the Eastern part of the country. The Strategy suggests to concentrate measures not only in the metropolitan area but in the cities with a significant innovation and human capital as well. Namely, the Strategy highlights such cities as Tomsk, Novosibirsk, Krasnoyarsk and Irkutsk. These cities are considered the cities that have accumulated a considerable amount of innovative potential.

The Strategy expects that the completion of major transport systems and multimodal logistics centres construction will lead to an 'infrastructure effect' in the formation of new metropolitan areas.

The target indicators of the Strategy are the following:

- reducing the overloaded spans of transport network.
- commissioning of new and reconstructed objects of transport infrastructure by mode of transport, including multimodal transport hubs.

The target indicators of Strategy reflect a balance between the properties, stability, and advanced level of development of transport infrastructure in relation to the demand for transportation. The Strategy indicates that the minimization of overloaded spans would lead to the absence of bottlenecks and imbalances in the development of adjacent sections of the network (Mintrans, 2014).

The Strategy highlights the importance of development of the infrastructure of multimodal logistic centres for container transport both for small and medium businesses. It says that the logistics centres are expected to stimulate the expansion of the use of container transport technologies. In this light the use of data on carriage of goods in containers in my research is justified (See more in 3.1.2 on page 33).

Priorities in container transportation development on railways include infrastructure and rolling stock for containers development, information provision, development of technologies for container concentration, increasing speed of containers delivery and improvement of tariff regulation. The Strategy believes that the solution of these problems will allow to raise the application infrastructure technologies containers and piggyback semi-trailers to a qualitatively new level and increase the quality and reliability of transport services (Mintrans, 2014). In addition, this strategic document highlights that it is necessary to develop the network of service and repair stations, food stores, campsites and hotels, parking lots and other objects of roadside service. All these objects are usually placed on the territory of the logistics centre as well. The Strategy argues that this will contribute to creating favourable conditions for the implementation of quality transportation, and will improve their reliability and safety (Mintrans, 2014).

The Strategy presents five projects of the logistics centres development (See Table 2.2). Currently the logistics centres are constructed in Rostov-on-Don, Dmitrov (Moscow region) and Vikhodnoy (Murmansk region). In 2013 the logistics centre was finished in Sviyazshk (Republic of Tatarstan). In 2017 the construction of a logistics centre in Yekaterinburg begins. All

City	Project
Sviyazhsk, Republic of Tatarstan	Construction of Sviyazhsk interregional multimodal logistics centre for receiving, temporary storage, processing, distribution, registration documents and sending cargo to a destination by different modes of transport, providing service for regional and international freight flows along the corridors 'East - West' and 'North - South'.
Rostov-on-Don, Rostov region	The development of multimodal transport and logistics hub 'Rostov universal port'.
Dmitrov, Moscow region	Developing of integrated transport and logistics network in Moscow region, including construction of Dmitrov interregional multimodal logistics centre.
Vikhodnoy, Murmansk region	Complex development of Murmansk transport hub
Yekaterinburg, Sverdlovsk region	Construction of a warehouse complex of open joint-stock company 'Euro-Asian international transport and logistics centre'. Development of transport infrastructure, including the construction of a new railway station Sverdlovsk-Tovarniy, automotive interchange on the 11th km of Serov path and road entrance to the objects of transport and logistics centre.

Table 2.2: Logistics Centres development projects according to Transport Strategy 2030

these projects are claimed to be implemented within the *public-private partnership* scheme.

Railways Development Strategy. Another topic-related state document is the *Strategy of railway transport development in Russia until 2030*. The original document was published in 2008, I use the latest 2015 edition.

This railway strategy also notes that the creation of a terminal and logistics centres network in major transport hubs will form a unified technological and information space (Mintrans, 2015). This strategy defines the LC as 'a major technological complex for the processing, storage, customs clearance of cargo and containers, that provides a full range of additional services' (Mintrans, 2015). This definition corresponds with international general ones (See Section 1.1).

One of the goals of the strategy is the creation of a network of logistics centres and upgrading the existent terminal infrastructure. In addition, it pays attention to the development of the interaction of all types of transport modes (Mintrans, 2015). The railway strategy highlights the lagging behind the most-developed European countries. It says that given the lower level of transport equipment and logistics infrastructure in Russia, as well as the quality and complexity of transport services comparing to leading European countries, the task of effective development of the logistics market is decisive for the entire Russian transport system (Mintrans, 2015). According to the railway strategy achieving, this goal involves development of transport, logistics and customs brokerage activities. Similarly to the Transport Strategy, this railway strategy identifies the construction of terminal and logistics centres in the major transportation hubs of the country as one of the priorities. The strategy shows the importance of the development of logistics centres network in the Moscow transport hub. This is believed to ensure the optimal redistribution of cargo traffic in the Moscow region. In Moscow the construction of four terminal and logistics centres is planned, namely *Hovrino*, *Lublino*, *Kuntsevo-2* and *Moscva-Tovarnaya-Yaroslavskaya (Severyanin)*, which are intended for the treatment of goods for the needs of the city that arrive by rail. This aims to the greatest extent remove the freight operations from the Small ring of Moscow railways. In the Moscow region the construction of complex objects of terminal and logistics infrastructure, including *Beliy Rast* (See Figure 2.1), *Stupino SLG* and *FESCO-Usady* is planned. The following operators construct logistics centres in other regions of Russia: *Evrosib* (Saint-Petersburg, Novosibirsk), *Logoprom* (Moscow, Nizhny Novgorod), *National Container Company* (Saint Petersburg).

2.2 Russian Railways Strategy

Russian Railways Concept. In this section I will review the strategic document of the biggest railway company in Russia - Russian Railways (RZhD) - and compare its content to the official state strategies.

- *The concept of terminal and logistics centres development on the territory of the Russian Federation* (Russian Railways, 2012)

The concept argues that it is based on the Railways Development Strategy and is interrelated with the strategies of socio-economic development of the Russian regions (RZhD, 2012). The concept highlights the necessity of improvement of customs administration and development of combined transport. It is quite a comprehensive study that analyses current situation as of 2012 and key trends. The concept conducts market analysis, provides system solutions, project management scheme and presents the results of realisation. In addition, it analyses risks and proposes the most important measures.

In the framework of this concept the functional classification of LCs is provided. It discusses the requirements to the main parameters of technological and organizational processes of the creation and operation of a network of LCs in Russia. The LC network allows to prioritise the construction of facilities and provide the capacities at the initial stage of formation of the 'backbone' of a wider network. The concept argues that this will serve as a motivating factor for potential investors and cause a 'chain reaction' of LCs development in the regions of Russia (RZhD, 2012).

In the first place RZhD proposes to develop transport infrastructure in the following cities:

- Railway port 'Baltiysky' (Saint Petersburg)
- Railway port 'Tamansky'(Krasnodar)
- Railway port 'Primorsky' (Vladivostok)
- Logistics centre 'Beliy rast' (Moscow region)
- Logistics centre in Yekaterinburg
- Logistics centre 'Kleschikha' (Novosibirsk)
- Logistics centre in Kaliningrad
- Logistics centre in Nizhny Novgorod
- Logistics centre in Kazan
- Transport hub in Volgograd

The logistics centres, railway ports and transport hubs in these cities would become the main base for a further transport infrastructure development.

In addition, RZhD attributes the following cities to priority ones:

- Khabarovsk;
- Samara;
- Voronezh;
- Bryansk;
- Kirov;
- Ufa;
- Ulan-Ude;
- Krasnoyarsk;

The authors of the concept argue that the LC network developed in these cities will attract additional 100-120 million tons of cargo. Positive effects will include cost reduction, improvement of investment activities, optimisation of the transport infrastructure.

On the second stage they propose to construct logistics centres in 1. Rostov; 2. Kaluga; 3. Murmansk; 4. Saratov; 5. Irkutsk; 6. Omsk; 7. Arkhangelsk; 8. Tyumen; 9. Chita; 10. Smolensk; 11. Astrakhan; 12. Orenburg; 13. Chelyabinsk; 14. Yaroslavl; 15. Zabaikalsk; 16. Perm; 17. Ulyanovsk; 18. Makhachkala; 19. Kursk; 20. Belgorod; 21. Penza; 22. Mineralniye vodi; 23. Vanino; 24. Novokuznetsk; 25. Lipetsk; 26. Tambov; 27. Izhevsk; 28. Ryazan.

The analysis of RZhD experts was based on four criteria. First, they counted the number of international transport corridors of the city. Then they counted the number of multimodal transport nodal points, analysed the relevant market size and the conditions of transport infrastructure. In my thesis I propose an alternative methodology of priority locations selection and show that some of the locations that RZhD considers less important should be addressed in the first place.
RZhD risk analysis suggests that the success of the project realisation depends on the attraction of significant amount of investments from different sources. Thus, it is important to realise the projects within the public-private partnership (PPP).

2.3 Public-Private Partnership in Russia and Stakeholders of LC development

Specificities of Public-Private Partnership in Russia. Kopilova (2011) argues that countries usually follow one of the three main strategies, when developing the logistics centres:

1. 'Authoritarian', which implies direct state intervention in the transport sector (typical

of Finland);

2. Public-private partnership model where the state creates favourable conditions for logistics development (typical of Germany, Hungary, Austria);

3. Business prevalence, when the construction of logistics centres is an initiative of the private companies (typical of UK).

For Russia, the third model is more common. Currently, the state demonstrates a limited willingness to participate in LCs construction. However, the state strategies consist of several projects of logistics development that are claimed to be based on the public-private partnership (See Section 2.1). In addition, these strategies highlight the necessity of placing the logistics centres in each region of Russia (Mintrans, 2014). Kopilova (2011) believes that public-private partnership is the model Russia should follow.

In Russia until recently there was no existing Federal law providing a regulatory definition of a PPP, but one could refer to the concept of PPP enshrined in the draft law 'On principles of state-private partnership in the Russian Federation' (Pobedin and Fedulov, 2015). The document described the PPP as the cooperation between public and private partners under the agreement on public-private partnership (concluded by results of competitive procedures), aimed at improving the quality and providing the availability of services to the population, to attract private investment into the economy, according to which private and public partners take on certain obligations. However, in absence of a federal law, a number of subjects of the Russian Federation adopted laws on a regional level.

In December 2015, the Federal Law on 'Public-private partnerships, municipal-private partnership in the Russian Federation and the Introduction of Amendments to Certain Legislative Acts of the Russian Federation' was finally adopted. The document defined the PPP as 'legally adopted for a certain period and based on the pooling of resources, risk-sharing cooperation between the public partner, on the one hand, and the private partner, on the other hand, which is carried out on the basis of the agreement on public-private partnership, concluded in accordance with this Federal law for the purpose of attracting private investment, providing public authorities and local governments with the availability of the goods, works, services and improving their quality' (ConsultantPlus, 2016).

Currently in Russia there are 1341 PPP projects, 72 of them are realised in the sphere of transport (pppi.ru, 2016). A unified information system on public private partnership in Russia (PPPI) reports that the transport sector is a leader in PPP investments in monetary terms (pppi.ru, 2016). The total investments in the projects of PPP in the transport sector count for more than 1.1 trillion roubles (USD 15.5 billion), which is 70% of the total market. Makarov (2013) defines the following forms of presence of private capital and its interaction with the state:

1. Private companies-operators of freight and passenger transport (EU countries and North America).

2. Private and (or) are in collaboration with regional authorities (municipalities) vertically-integrated regional railway companies.

3. Concession.

Makarov (2013) believes that currently in Russia only form (1) and form (3) are possible for implementation. However, he highlights the importance of potential benefits from usage of form (2), since the world experience (mainly in North America and the EU) in operation of private railway companies shows that in many cases they are more efficient than state-owned ones.

The main specifics of public private partnership in Russia is a universal role of the state. The realisation of projects in transport areas without the state is nearly impossible, while in the Western practice, private business has more opportunities (Makarov, 2013). All existing rules of the game involve active public participation in any area. Moreover, the business has a role more of a little brother, who only helps the state in big and important matters (Druzhinnikov, 2015). Even the road building, in particular, the determination of its trajectory, size, quality, etc. are regulated by the state. Druzhinnikov notes that the real goal of such regulations are not purely commercial but social and strategic.

However, the realisation of a wide-scale project such as a logistics centre requires the participation of a number of actors and without state's help its implementation is difficult. EEIG (2014) notes that coordinated planning and funding is necessary when developing logistics centres.

Stakeholders. To understand a policy context of the logistics centres development, one should identify the stakeholders in the construction of such centres. Among the stakeholders there are, of course, the major logistics companies, including operators and logistics service providers. Local communities, local municipal and regional authorities are also stakeholders taking into account the scale of LC development and expected benefits. Since the problem of allocation of the logistics centre of federal importance is solved, the federal authorities are also stakeholders. The whole transport network of Russia may be better off from the accurate placing of logistics centres.

The decision to choose the LC location is taken by an investor or a group of investors. The decision should take into account sometimes conflicting interests of stakeholders and produce a compromise. Investor's decision is important for local, regional and federal authorities, as LC attracts money, creates jobs and improves overall business attractiveness of the city and the region. The local population is interested in minimizing possible inconveniences associated with construction and operation of the centre (such as noise and pollution).

Thus, the choice of location of the logistics centre is a complex decision, which includes consideration of many factors. The next chapter is devoted to the identification of these factors and decision-making mechanisms.

Chapter 3

Location Problem in Transportation and Allocation of Logistics Centres in Russia

Previous Chapters describe the concept of logistics centres and specificities of transport system in Russia. Now having the understanding of the context, this Chapter selects LC locations describing the analytical process proceeding the selection. In section 3.1, I review the literature to show different approaches choosing the set of evaluation criteria. Because of the Russian context a new system of evaluation criteria should be established. Thus, I describe the formation of candidate cities weights based on the consultations with experts and studied literature. Section 3.2 describes the methodology I use for geospatial allocation of logistics centres on the Russian railway network and it reviews relevant literature. Section 3.3 is devoted to the application of described methodology. It defines data, conducts network analysis, showing the stages of working process and presents the results.

3.1 The development of evaluation criteria for logistics centres allocation in Russia

3.1.1 Related literature

The location selection of a logistics centre is a comprehensive decision that includes consideration of many factors, including political, economic, infrastructural, environmental, competition, development, regional/city specialization, logistics costs and customer service levels (Rao et al., 2015). Researchers, considering the evaluation criteria for logistics centre allocation, conduct analysis on different levels, depending on the type of task they aim to solve. One can find literature that selects a logistics centre location on macro (regional) or micro (municipal, district) levels, or combines macro and micro analysis. Thus, I divide existent literature into three groups: studies that conduct analysis on (a) macro level, (b) micro level and those who use a (c) combined approach.

Macrolevel studies. Kirillov and Tselin (2015) used the following general criteria for evaluating the region: 1. business climate, 2. financial attractiveness (general and logistics costs), 3. the environmental conditions, 4. consumer market proximity, 5. presence of a competitive environment, 6. logistics infrastructure, 7. availability of professionally trained personnel, 8. market suppliers, 9. political risks, 10. competitive advantages.

Mironyuk (2012) also proposes the macrolevel approach. According to him, the main criteria for the placement of logistics centres at the regional level are: 1. the intersection of traffic flow of one or more modes of transport; 2. availability of transport, warehousing, logistics infrastructure for the processing of traffic and customer service; 3. ability to handle multiple types of transport; 4. urban areas should have high population density; 5. significant transport potential nodal points, placed at a distance of at least 100 km from the LC; 6. placements should relate to regional development goals. Hence, Mironyuk is more focused on transport factors.

Microlevel studies. Researchers Uysal and Yavuz (2014) conducted the analysis at the micro level, using Electre method that solves the problem of multi-criteria decision-making and is based on the ratio of winning percentage. They used criteria such as proximity to seaports and airports, distance to residential areas, availability of labour, security of the environment, availability of highways and roads, traffic density.

Rao et al. (2015) examine the allocation possibilities at the micro level and for this purpose they develop the following criteria for the placement of the logistics centres:

1. *economic*, which includes the price of the leased land, delivery flexibility to change plans or circumstances preventing delivery, accessibility, level of service and human potential.

2. *environmental* comprising a level of environmental protection, the impact on the environment, the natural conditions.

3. *social*, which includes the criteria of the state of basic infrastructure, safety, environmental compliance, the criteria for the impact of the planned LC on nearby residents and its impact on traffic congestion.

Kalenteev (2012) divides the chosen factors into two integral indices. He calls the first integral index *social significance of the project*, which includes indicators such as unemployment, district budget, level of investment in the economy of the municipality, level of turnover of retail trade in food and non-food products per capita, average wages, area of municipality, the average population density. The second integral index measures the level of business attractiveness. This includes the level of potential demand for services and current situation in the municipality.

Combined studies. Zak and Weglinski (2014) suggest using a two-tier system of analysis. First, they conduct macroanalysis and choose the most suitable region for the LC development. Then the analysis proceeds to the micro-level and the place selection is carried out taking into account the more detailed settings (such as proximity to the airport, cost of construction in a given area of the city, air pollution etc.) When choosing the location of the logistics centre in Poland they use Electre method.

Rakhmangulov and Kopylova (2014) also divide the factors affecting the efficiency of logistics infrastructure into the macro- and micro-levels. They consider the following groups of factors the key-factors: 1. socio-economic, 2. geographic, 3. infrastructural, 4. political and legal, 5. transport performance indicators.

The authors grouped regions into clusters according to the following criteria: population, per capita income, gross regional product per capita, industrial output per person (Manufacturing), the volume of exports to the human soul, density of railways communications, roads density, climate zone.

Thus, the researchers evaluate the candidates for logistics centres placement on macro-, micro levels and combining these two techniques. In the next subsection I present a new evaluation system for Russia based on a combined approach. I cannot simply apply any of the existent approaches as they are, because of the context of the Russian Federation and unavailability of some data, especially microlevel data and data regarding environmental issues.

3.1.2 New evaluation criteria for Russia

Based on studied literature and consultations with experts, I develop a new evaluation system for logistics centres allocation. I present five groups of criteria: *Economic*, *Social*, *Transport*, *Financial* as well as the criterion of *Warehousing conditions* (See Figure 3.1).

This thesis forms a list of evaluation criteria based on a combined approach. In the first place, I choose not a region but focus directly on cities. I simultaneously control the development factors of both the city and the region. This method is more suitably applied for Russia and her specificities regarding the historically uneven concentration of production and a more dynamic economic growth in administrative centres and big cities. I analyse 73 Russian cities with the population over 250 thousand people. The choice of this threshold value is based on classification provided in the urban planning document of the former Ministry of

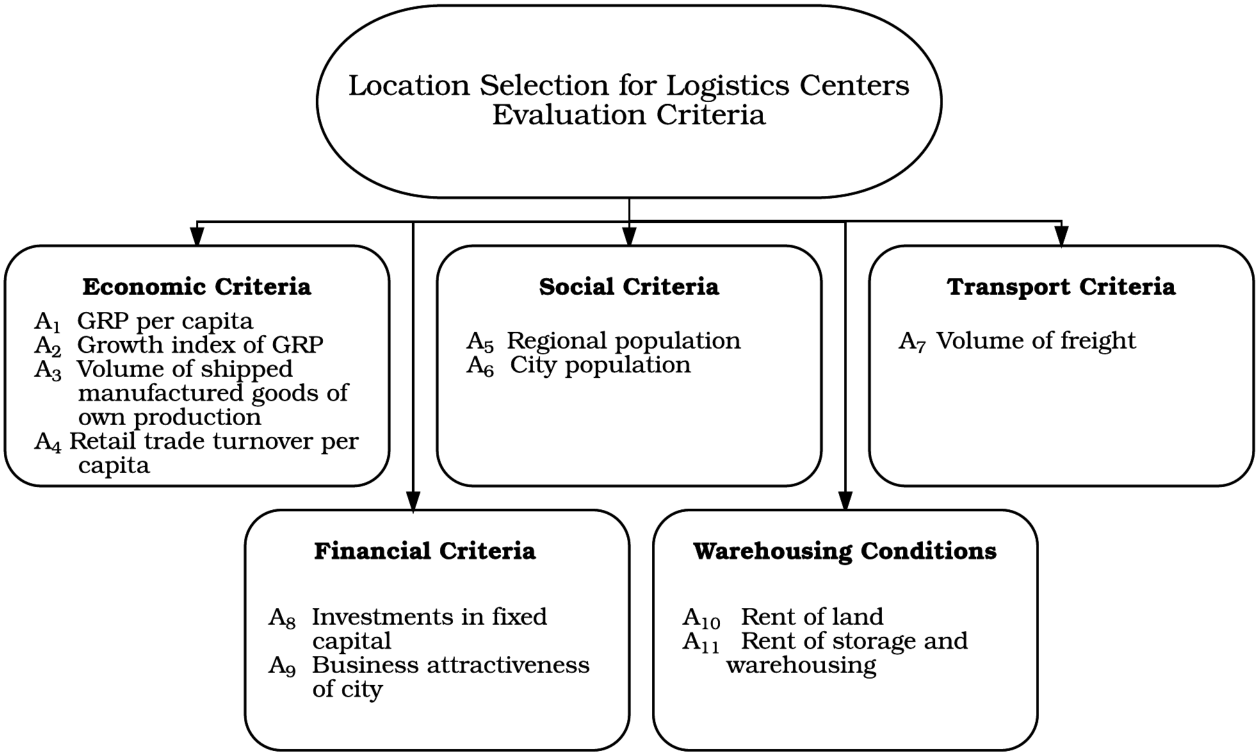

Figure 3.1: Location Selection for Logistics Centres Evaluation Criteria

Regional Development of Russia (2014), according to which cities with population of more than 250 thousand are considered 'large'.

Economic criteria.

- A_1 - GRP (*Gross Regional Product per capita*). This factor is considered to be a key in determining the location of logistics facilities.

- A_2 - *GRP growth index* allows to take into account the dynamics of growth in the region.

- A_3 - *Volume of shipped manufactured goods* shows the level of industrialization in the region of a candidate city.

- A_4 *Retail trade turnover*. This is another parameter that reflects the economic activity in the region.

All economic criteria are based on data of Russian Federal State Statistics Service (Rosstat, 2014) and are maximised with the objective function (See equations 3.1-3.4 on page 36).

Social Criteria. This group of criteria includes

- A_5 - *municipal population* and
- A_6 - *regional population.*

Since the LC is a large-scale infrastructure project, it is necessary to have adequate *city population* that is able to fill the jobs. *Regional population* is a lower priority setting, but also important due to the fact that LC should provide the needs of the region as well. Researchers note that the logistics centres established in cities with high social indicators provide effective solutions for the problems of intercity freight traffic and positively influence the quality of life (Uysal & Yavuz, 2014). Some researchers also take into account the proportion of people with higher education and the level of wages in the industry (Rao et al. 2015). Social criteria use data from Rosstat (2014) and are maximised with the objective function (See equations 3.5 and 3.6 on page 36).

Transport Criteria.

A_7 - *Volume of freight.*

This is one of the most important factors. Inadequate volume of cargo makes the construction of a logistics centre unfounded. Mamontov (2014) in his PhD dissertation indicates that the container transport account for approximately 51% of the total volume of traffic (Mamontov, 2014). I have access only to the data traffic of the RZhD daughter company *TransContainer.* Nevertheless, these data provide an overall picture of traffic on railway networks, which is sufficient for this study. At the same time, the transportation factor is not determinative. The Russian Transport Strategy highlights the importance of the development of transport nodes and transport and logistics centres, 'not only in the field of the existing concentration of freight traffic, but in an optimized product distribution network nodes, including new transport links' (Mintrans, 2014, p. 69). The task of identifying such sites is solved at the next stage of the study during the geospatial analysis.

This criterion is based on TransContainer data on container flows in railway stations in Mamontov (2014) and is maximised with the objective function (See equation 3.7 on page 36).

Information about TransContainer. *TransContainer is a leading intermodal container transportation company in Russia. They provide the services relating to container transportation, container handling and logistics. Their goal is 'to increase federal freight's market capitalisation by increasing the scale of business and its efficiency' (TransContainer, 2016). TransContainer operates on railways, roads and waterways. Container transportation by rail: 26.305 flatcars, 62.367 high capacity containers (2014). It has 66 railways container terminals. Headcount of the company is 3 816 workers. 219 load-lifting mechanisms.*

Financial Criteria.

- A_8 - *Investments in fixed capital.* The volume of investments characterises the overall financial attractiveness of the region. However, the high activity of companies in the region can also mean a higher level of competition. This criterion is based on Rosstat data (2014). The investment criterion is maximised by equation 3.8 (on page 36).

- A_9 *Attractiveness for doing business.* To account for this parameter Kirillov and Tselin (2014) in their work use the Expert RA rating. Present thesis uses the results of a study done by Forbes experts (Forbes, 2013) who made up the list of the 30 best cities for doing business in Russia. See maximisation function in equation 3.9 on page 36

Lease and Building Conditions Criteria.

- A_{10} - *Rent of land*

- A_{11} - *Rent of storage and warehousing*

Name	Factor	Weight	Type	Level
A_1	GRP per capita	0.2	Benefit	Region
A_2	Growth index of GRP	0.05	Benefit	Region
A_3	Volume of shipped manufactured goods	0.17	Benefit	Region
A_4	Retail trade turnover	0.07	Benefit	Region
A_5	Region population	0.03	Benefit	Region
A_6	City population	0.05	Benefit	City
A_7	Volume of freight	0.19	Benefit	City
A_8	Investments in fixed capital	0.13	Benefit	Region
A_9	Attractiveness for doing business	0.07	Benefit	City
A_{10}	Rent of land	0.03	Cost	Region
A_{11}	Rent of storage and warehousing	0.01	Cost	Region

Table 3.1: Criteria of LC selection used by the author

These are minimised criteria that indicate favourable conditions for the lease of land and warehouse space. The data source is Rosstat (2014). The criteria are minimised with the objective function written in equation 3.10 on page 36.

3.1.3 Decision method for LC allocation

The problem of the location selection of logistic centres in this thesis is described as follows. We select an optimal location among m candidate cities to develop new logistics centres. The set of candidate cities is denoted as $B = \{B_1, B_2.....B_{73}\}$. The set of evaluation criteria is denoted as $A = \{A_1, A_2.....A_{11}\}$. The set of weights for these criteria is denoted as $W = w_1, w_2.....w_{11}$, where $0 \leq w_j \leq 1$ and $\sum_{j=1}^{11} w_j = 1$.

If $J = \{1.....N\}$ is the the set of candidate cities indices, and $I = \{1, 2, ...11\}$ is the the set of criteria indices, then w_i^j is a weight of an index m for the city j and A_i^j is an evaluation criterion i for the city j.

Given this, I define criterion functions for each group of factors as follows. First, I maximise economic factors, which are *GRP per capita*, *Growth index of GRP* in each region, the *Volume of shipped manufactured goods* and *Retail trade turnover*.

$$w_1^j A_1^j \longrightarrow max \tag{3.1}$$

$$w_2^j A_2^j \longrightarrow max \tag{3.2}$$

$$w_3^j A_3^j \longrightarrow max \tag{3.3}$$

$$w_4^j A_4^j \longrightarrow max \tag{3.4}$$

The next step is a maximization of a regional population factor.

$$w_5^j A_5^j \longrightarrow max \tag{3.5}$$

And maximization of each city's population factor.

$$w_6^j A_6^j \longrightarrow max \tag{3.6}$$

Then the volume of freight factor is maximised.

$$w_7^j A_7^j \longrightarrow max \tag{3.7}$$

Then I maximise investments and business attractiveness factors.

$$w_8^j A_9^j \longrightarrow max \tag{3.8}$$

$$w_9^j A_9^j \longrightarrow max \tag{3.9}$$

Cost factors, which are rent of land and rent of storage and warehousing, should be minimised.

$$\sum_{i=10}^{11} w_i^j A_i^j \longrightarrow min \tag{3.10}$$

Let us assume that

$$0 \leq w_i^j \leq 1$$

and

$$\sum_{i=1}^{11} w_i^j = 1.$$

To obtain the final weight for each candidate city, let us define V_k as a weight of factor and k as an index of criterion functions. Thus we can get the aggregated weight Q_i^j by solving the following equation:

$$Q_i^j = (\sum_{k=1}^{10} V_k)/10 \tag{3.11}$$

The set of obtained aggregated numbers I use as a weight factor when solving a location problem in ArcGIS Network Analyst. This allows me to select the best places for logistics centres development out of the set of candidate cities $\{B_1, B_2.....B_{73}\}$. The full list of allocated weights can be found in Table 3.14 on page 62.

The obtained results allow me to divide candidate cities into four groups based on a total weighted parameter. The first most prioritised group includes 10 cities, second - 16, third - 18, and the last one includes 31 cities (See Table 3.1.3)

Limitations. Aspects of this stage of work that are a subject to improvement in the future research, include the lack of criteria assessing the availability and turnover of river and sea ports. Many researchers note the importance of LC's proximity to a port.

Another aspect concerns competition. Researchers Zak and Weglinski (2014) assess the competition in the region. The collection of such data from the open sources in Russia at the moment is difficult. In future studies, this test can be used.

In addition in this thesis, environmental factors are not considered due to a lack of reliable data.

Due to a very unbalanced development of different parts of Russia, the unified evaluation

Group	Cities
I	Moscow, Tyumen, Nizhnevartovsk, Surgut, St-Petersburg, Krasnoyarsk, Irkutsk, Yekaterinburg, Kazan, Khabarovsk.
II	Omsk, Nizhniy Novgorod, Ufa, Tolyatti, Kaliningrad, Krasnodar, Samara, Tomsk, Vladivostok, Lipetsk, Voronezh, Magnitogorsk, Cherepovets, Murmansk, Tula, Saratov.
III	Yaroslavl, Rostov-on-don, Izhevsk, Ryazan, Kemerovo, Novosibirsk, Krasnoyarsk, Naberezhnye Chelny, Perm, Nizhny Tagil, Chelyabinsk, Arkhangelsk, Komsomolsk-on-Amur, Belgorod, Astrakhan, Sochi, Novorossiysk, Volgograd.
IV	Other cities with population over 250 thousand people.

Table 3.3: Priority groups of candidate cities

system may not assess the cities equally because of a heterogeneous specialisation of Russian regions.

My evaluation criteria, unlike in some other research papers, do not include the density of roads. However, this is not a limitation of the study, since the problem of transport accessibility is solved on the next stage of the study.

The next step is a geospatial analysis of the railway network of Russia. An analysis based on heuristic algorithms for solving p-median problem is carried out in a specialized software ArcGIS Network Analyst.

3.2 Methodology for geospatial network analysis

This section describes one of the research stages that solves a location problem of placement of logistics centres of federal importance. My analysis covers the territory of the Russian Federation, in particular, settlements location and railway networks. I conduct my analysis on a federal level, trying to allocate the logistics centres of federal importance. The calculations are conducted in ArcGIS Network Analyst.

3.2.1 GIS software review

Many GIS packages provide a limited set of functions designed to answer spatial questions related to transport. This subsection reviews the transport analysis software.

Packages provide different tools with optional add-ins, such as used in this thesis ESRI ArcGIS Network Analyst. There are also ESRI ArcGIS for Transportation Analytics and Manifolds Business Tools. Other packages, such as Caliper TransCAD (built using the Maptitude GIS platform) and Citilab Cube suite (built using ArcGIS libraries), provide an integrated GIS for Transportation suite with an extensive range of routing and modelling facilities (Smith, Goodchild and Longley, 2015). It should be noted that different location-allocation models produce different results when applied to the same problem (Alshwesh et al., 2016). In addition, different algorithms to specific facility location optimisation and demand, depending on the spatial characteristics of the demand surface.

Practical application of p-median can be found in the following papers: ReVelle and Swain (1970); Serra and Marianov (1999); Vlachopoulou, Silleos and Manthou (2001); Jia, Ordonez and Dessouky (2007); Huifeng and Aigong (2008); Comber et al. (2011); Algharib (2011), García-Palomares et al (2012), Ashwell et al. (2016).

3.2.2 ArcGIS Network Analyst methodology

The mechanics of location-allocation solver of the Network Analyst is as follows. Initially the model has n candidate facilities and m demand points with weights. We choose a subset of the facilities, p, so that the sum of the weighted distances from each m to the closest p would be minimised. Solving this, the tool generates an origin-destination matrix of shortest-path costs between all the facilities and demand point locations along the network. Then the Hillsman editing process constructs a new version of the cost matrix. It enables the same overall solver heuristic to solve a variety of different p-median problem types such as to select p facility sites from among n locations to minimise the average distance from the populations at the n locations to their nearest facility (Hillsman, 1984).

The solver then generates a set of semi-randomized solutions and applies a Teitz and Bart's vertex substitution heuristic. This solves a random pattern of p facilities that are given initially, and then facilities are repeatedly moved in sequence to vacant places to reduce total costs. The local search process stops when no movement of any single facility decreases the value of cost minimization (Hansen and Mladenovic, 1997). A metaheuristic uses this group of good solutions to create better solutions. If additional improvement is not possible, the best solution found is returned.

In this thesis, I solve the problem of facility allocation using the following Network Analyst tools:

- *Minimise impedance.* This finds the optimum locations of p facilities such that the sum of the weighted distance between each demand location and the nearest facility is minimised. The objective is described by Teitz and Bart (1968) and the equation can be found in Cromley and McLafferty (2002), Algharib (2011), Alshwesh et al. (2016).

- *Maximise capacitated coverage.* This technique chooses facilities in such a way that the greatest amount of demand could be provided without exceeding the capacity of a facility. This problem type is usually used to locate warehouses which inventory is limited. Facilities are located such that as many demand points as possible are allocated to solution facilities within the impedance cutoff. The equation of this model can be found in Cromley and McLafferty (2002) and Algharib (2011).

- *Minimise facilities.* This minimises the number of candidate cities to cover the demand points most efficiently. Facilities are located such that as many demand points as possible are allocated to solution facilities within the impedance cutoff. The number of facilities required to cover demand points is minimised. Locating assumes that there is no budget limit.

For all techniques, I use five levels of impedance cutoff: 190 km, 260 km (reflecting the 12 hours access time) and 800 km (reflecting average cargo delivery distance by rail in Russia). These levels reflect the farthest distance the logistics centre is able to cover to meet the demand. These impedance cutoff distances are based on the average speed of a freight wagon delivering goods on the Russian railway and two types of time access limit: 12 hours access time and unlimited access time (See Table 3.4). 12 hours access time is an accepted standard of cargo delivery (Melachrinoudis, 2007).

Type of delivery	**Average speed**	**Access time**	**Distance cutoff**
Normal	15.8 km/h	12 hours	190 km
Container	21.7 km/h	12 hours	260 km
Any	N/A	N/A	800 km

Table 3.4: Distance cutoff by type of wagon

Using the aggregated weights, obtained through the equation 3.11 on page 37, I define 73 cities as candidate cities for placement of a logistics centre. One of the logistics centre main roles is cargo handling and distribution. Thus, I use 1335 cities with the population over 10,000 people as demand points. Based on the Russian urban classification, the settlement with population over 10,000 people can be considered town (Minregion, 2014). To reflect the size of the demand-city correctly I use weights for the destination points as well. Thus, the settlements with population less than 20,000 have weight 0.1, while the largest cities with population of more than 1,000,000 have weight 1 (See the full list in Table 3.5). Classification presented in Table corresponds with the document of Ministry of Regional Development of Russia, and Dijkstra's and Poelman's (2012) publication regarding the new OECD-EC definition of European cities.

City class	Sizes in population (ths)	Weight
Largest	of more than 1 000	1
Extra Large	500 - 1 000	0.8
Large	250 - 500	0.7
Medium	100 - 250	0.6
Small	50 - 100	0.4
Smallest	20 - 50	0.2
Tiny	less than 20	0.1

Table 3.5: Classification of city size and weight distribution

The following location-allocation models are available in ArcGIS to solve different types of problems with different assumptions: 1. Minimize Impedance, 2. Maximize Coverage, 3. Minimise Facilities, 4. Maximise Attendance, 5. Maximise Market Share, 6. Target Market Share. This thesis applies first three techniques that are most related to its spatial problem.

I apply Location-allocation modelling as the method for optimizing the locations of logistics centres. I determine the most important locations, where the logistics centres should be placed to cover the majority of demand within 12 hours access time and based on the average cargo delivery distance in Russia by rail (800 km).

3.3 Application using PPDAC approach

I use a PPDAC analytical approach, which is widely practised by GIS field experts (Smith, Goodchild and Longley, 2015). This approach is considered mainstream and its simple logic allows to structure the stages of spatial research. Following the logic of this approach, this section is divided into five parts: subsection 3.3.1 corresponding with **P**roblem, subsection 3.3.2 containing **P**lan, subsection 3.3.3, which describes **D**ata, subsection 3.3.4 with **A**nalysis, subsection 3.3.5 containing **C**onclusions that include the results and discussion.

3.3.1 Spatial problem formulation

A spatial problem of my research can be formulated as follows. There is no model of nearly optimal distribution of logistics centres according to Russian needs in logistics infrastructure development on the railway network. The geospatial network analysis allows to select priority cities out of 73 candidates with population of more than 250,000 people.

3.3.2 Plan of application

The method is applied in seven steps. They are: 1. Preparing data; 2. Configuring the Network Analyst environment; 3. Creating the network analysis layer; 4. Adding network analysis objects; 5. Setting network analysis layer properties; 6. Performing the analysis and displaying the results; 7. Interpreting the results (See 3.2). On the first step I choose spatial data source, download and prepare data, solving any issues that may negatively affect the results. Then I transform the shape of railway line into the network object and configure the Network Analyst environment. On the next step I create the Location-Allocation layer and load candidate and demand cities. On the fifth step I configure the properties of the Location-Allocation layer, setting the number of chosen facilities, direction of travelling, impedance distance cutoff level and then I acquire the results solving the location problem. Last step is the result interpretation.

3.3.3 Data description and their preparation

Open geospatial sources. This thesis uses geospatial data from Open Street Map, which is a non-profit foundation aimed at supporting free global geospatial data (Opens Street Map, 2016). The data were additionally processed by the team of the Russian GIS-Laboratory (2016) experts. I use the datasets of all Russian federal districts as of May 2016. These data are recent and relevant at the time of writing. The dataset includes the geospatial information on all Russian settlements, railway network and all levels of administrative borders. Subdata

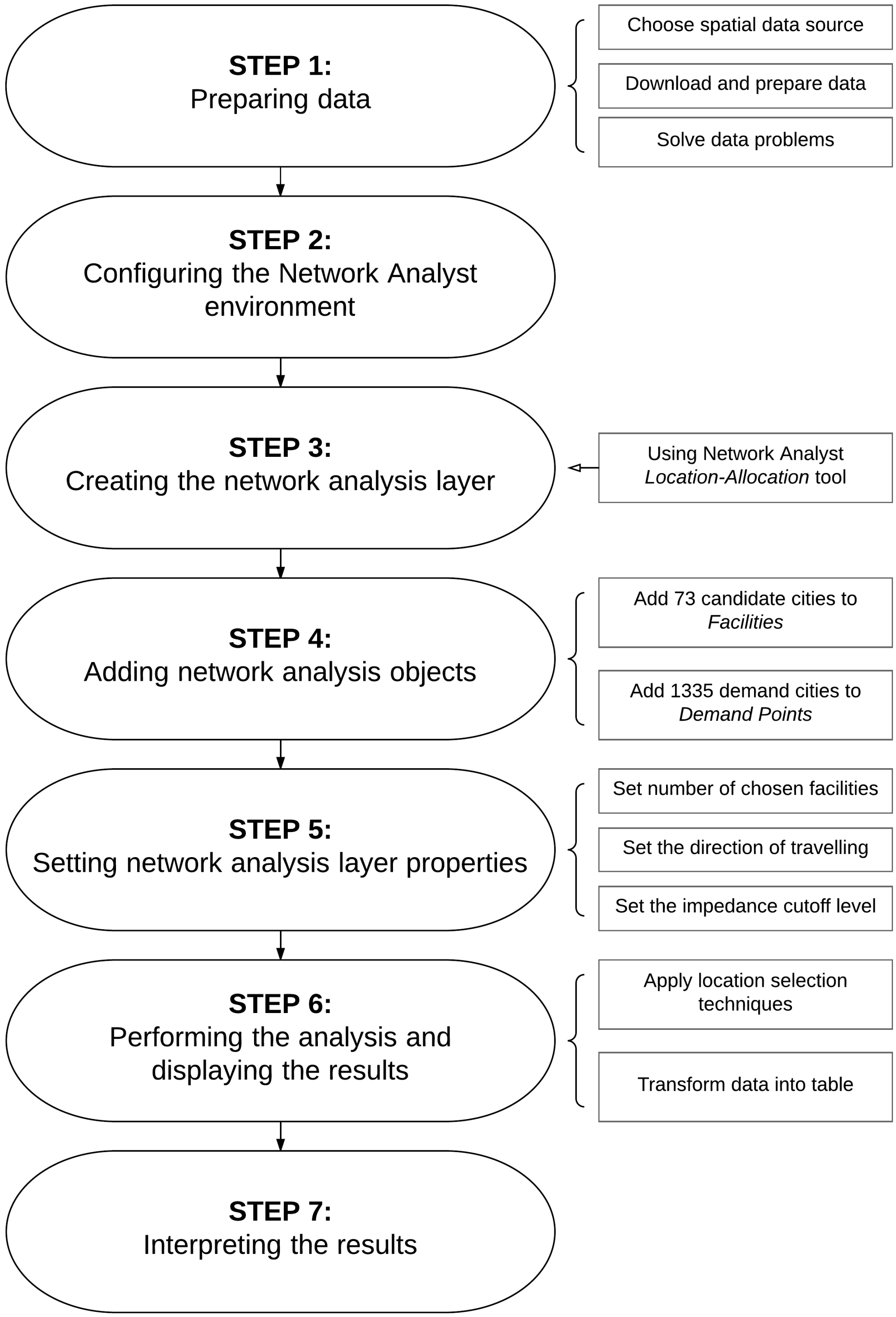

Figure 3.2: Stepwise application of LC allocation methodology

of geographic surface were downloaded from Natural Earth (2016), a public domain map dataset featuring tightly integrated vector and raster data. These data include land mass, water and coast line. Natural Earth is maintained by volunteers and is supported by North American Cartographic Information Society (NACIS).

Working with settlements. Initially the dataset contained 165,716 settlements. In my thesis I work only with settlements with population over 10,000 people. According to the City management document of the Ministry of Regional Development of Russia, the settlements with population of more than 10,000 are considered towns. Thus, the sample was reduced to 1335 settlements including 73 cities with population of more than 250,000.

Cleaning network and solving railways connectivity problems. Open Street Map, being the comprehensive and the only publicly available source with data of such size, however, has limitations. Its limitations are associated with the way the data are collected. They are collected not in a centralised manner but by hundreds of activists, who gather and upload geospatial data on the website. This brings a lot of inaccuracies that have to be addressed when conducting the analysis. Below I describe the problems I faced using these data. First complication is unnecessary data. The shape of the railway network initially had more than 150 thousand particles (objects that consist the railway line, each object has characteristics and geospatial data), which complicated the computations and created an additional burden on the machine. Manual cleaning of the network allowed to decrease the number of particles to about 130 thousand. Metro, train lines and unused or abandoned railways were deleted. To facilitate more, I merge all the particles into one using ArcGIS Editor.

Another problem is a discontinuity of the network, therefore the next step was checking the network connectivity. With the *Near* analysis tool in ArcGIS, the unconnected particles were identified and cleaned. Visual check allowed to detect several more connectivity problems, which were solved. In addition, it should be noted that source data did not have the connection between Kaliningrad and the rest part of Russia, which in reality is not accurate.

Kaliningrad is connected to Russia through Belarus and Lithuania. Hence, this connection was drawn manually. However, a manually added connection means that the cargo can be delivered there with the average speed of the whole Russian railway network without interruptions at the international borders.

3.3.4 Russian railways network analysis and LC allocation

Configuring the Network Analyst environment. When the data are prepared, connectivity and other problems are solved, I activate the Network Analyst environment in ArcGIS and transform the existent shape file of the railways into the network containing nodes (junctions) and edges. The Network Analyst builds the network transforming lines into the edges and their intersection points into the nodes (junctions). This makes it possible to treat the shape object as the network and apply the network analysis tools. The detailed example of the Network Analyst application can be found in Falzarano, Ketha and Hawker (2007) and Captivo and Climaco (2010).

Creating the network analysis layer. When the network is ready for the analysis, I add the new network analysis layer, which in our case is the Location-Allocation.

Adding network analysis objects. We already know that the location-allocation tool contains three main components (See Subsection 3.2.2): 1. demand locations; 2. candidate locations for facilities; 3. distance or travelling time between candidate facilities and demand locations. At this step I load the objects in the layer components. First, I load 1335 settlements with designated weights as demand locations. Then I add 73 cities with population over 250,000 people and specified weights as candidate locations.

Setting network analysis layer properties. To run the analysis I need to adjust the settings of the location-allocation tool. I do the following: I limit the number of facilities to be located to 12. I set the direction of the travelling to 'Facility to Demand' (because the logistics centre should supply the demand locations). I use the impedance cutoff distance to constrain the maximum distance of cargo delivery (based on parameters in Table 3.4). With these specifications the demand point can be considered covered when it is located within a pre-defined impedance cutoff distance from its nearest service facility. Any demand points that are located farther than the impedance cutoffs are considered not covered.

Performing the analysis. Having all the objects added on the layer, I can 'solve' the problem of location allocation, running the analysis with each of the settings described in subsection 3.2.2.

3.3.5 Results and further discussion

After running the analysis with all the specifications, I have seven sets of results: results obtained with *Minimise impedance* method at three distance cutoff levels (representing 12 hours access time for normal and container delivery and an average distance of cargo delivery by railway in Russia), *Maximise Capacitated Coverage* method at three distance cutoff levels (same distances as in *Minimise impedance*), and *Minimise Facilities* with one distance cutoff level (only average distance of cargo delivery by railway). I present the results in the form of a table (See Tables 3.6, 3.7, 3.8, 3.9, 3.10 and 3.11) and a form of a map (See Figures 3.4, 3.5, 3.6, 3.7, 3.8 and 3.9 in the Appendices). The maps simply show how the chosen cities are distributed on the territory of Russia, while the tables show a number of demand cities connected to the chosen city (**Demand** column), the allocated weight of connected demand cities (**Weighted_Demand**), the total length of the connection lines (**Length**) and the weight of the total length (**Weighted_Length**). See Figures 3.10 and 3.12 for several examples of how the chosen cities are connected to the demand locations.

190 km impedance cutoff distance. The results obtained at 190 km cutoff distance are similar for both *Minimise impedance* and *Maximise Capacitated Coverage* methods. The model selected federal centres Moscow and Saint Petersburg. It selected two cities in Central

Federal district (Voronezh and Ivanovo), three cities in Southern Federal district (Krasnodar, Rostov-on-Don and Vladikavkaz), two cities in Urals Federal district (Yekaterinburg and Chelyabinsk), two cities in Volga Federal district (Samara and Nizhniy Novgorod) and one city in Siberian Federal district (Novosibirsk). No candidates in Fareastern and Northern Federal districts were selected (See Table 3.6 and Figure 3.4).

City	**Demand**	**Weighted_Demand**	**Length**	**Weighted_Length**
Moscow	133	37.5	10796.04	2822.09
Krasnodar	56	11.2	4695.14	974.05
Saint Petersburg	45	10.9	3211.89	762.617
Rostov-on-Don	40	9.69	3840.78	845.74
Vladikavkaz	38	8.1	3505.98	751.89
Yekaterinburg	26	7.3	2423.62	537.28
Ivanovo	20	6.19	1842.5	592.09
Voronezh	21	5.79	2372.98	593.49
Chelyabinsk	22	5.29	1331.71	259.98
Samara	13	4.89	1265.06	376.93
Nizhni Novgorod	18	4.8	1298.88	210.31
Novosibirsk	16	4.6	1416.10	374.04
Total	448	116.5	38000.72	9100.556

Table 3.6: The selection of candidate cities based on minimising impedance and maximising capacitated coverage at 190 km cutoff level.

The uneven distribution of the logistics centres in this model is associated with the unbalanced distribution of population in the Russian Federation. The majority of population is concentrated in the Western part of Russia, therefore at such a distance cutoff level, more cities are expected to be selected in the Western part. A low number of candidates selected in Central Federal district is explained by a very high level of Moscow connectivity (133 demand points are supplied by Moscow, see Table 3.6). The same situation is in Northern Federal district. According to a model, Saint Petersburg is able to satisfy 45 demand locations within 190 km distance.

260 km impedance cutoff distance. *Minimise impedance* technique at the distance cutoff level 260 km selects a different set of candidates (See Table 3.7 and Figure 3.5). Similarly to a previous model with 190 km threshold level, Moscow, Krasnodar, Vladikavkaz, Yekaterinburg, Saint Petersburg, Voronezh, Nizhniy Novgorod and Novosibirsk were selected. A current model selects one new city in Central Federal district (Yaroslavl), two new cities in Volga Federal district (Saransk, Ufa) and a new city in Southern Federal district (Volzhsky).

City	Demand	Weighted_Demand	Length	Weighted_Length
Moscow	152	42	14854.12	3768.92
Krasnodar	86	18.7	10993.84	2567.99
Vladikavkaz	58	13.2	8139.21	1910.45
Yekaterinburg	46	12.8	6826.5	1776.24
Saint Petersburg	50	11.9	4288.97	969.22
Voronezh	39	9.1	6405.53	1330.9
Saransk	23	8.7	3425.44	1361.95
Nizhny Novgorod	29	7.9	3679.18	891.53
Ufa	30	7.7	4829.79	1159.62
Yaroslavl	23	6.8	3337.91	887.76
Novosibirsk	23	5.6	3050.39	606.89
Volzhsky	22	4.9	2703.9	519.29
Total	581	149.4	72534.78	17750.76

Table 3.7: The selection of candidate cities based on minimising impedance at 260 km cutoff level.

The set of cities chosen with *Maximise Capacitated Coverage* technique bears a resemblance with previous results. This model chooses Moscow, Krasnodar, Vladikavkaz, Yekaterinburg, Saint Petersburg, Voronezh, Nizhniy Novgorod, Ufa, Yaroslavl, Rostov-on-Don, Saransk but does not choose Novosibirsk and Volzhsky. Instead it chooses Kaluga (Central Federal district).

800 km impedance cutoff distance. Having compared the cutoff levels based on the 12 hours access time of normal and container delivery types, I conduct the same analysis using 800 km threshold, which represents the average distance of cargo delivery by railway in Russia.

The results I obtain using a longer distance cutoff are significantly different from the previous ones (See Table 3.9 and Figure 3.7). *Minimise impedance* technique selected one Federal city (Moscow), one city in North-Western Federal district (Murmansk), one city in Southern Federal district (Krasnodar), two cities in Volga Federal district (Saratov, Perm), two cities in Urals Federal district (Tyumen, Magnitogorsk), three cities in Siberian Federal district (Novosibirsk, Krasnoyarsk, Ulan-Ude) and two cities in Fareastern Federal district (Vladivostok and Khabarovsk). Thus, the geographic area covered by chosen candidates was considerably expanded.

Maximise Capacitated Coverage method selected two federal cities (Moscow and Saint Petersburg), three cities in Central Federal district (Boronezh, Yaroslavl, Bryansk), one city in Southern Federal district (Krasnodar) , two cities in Volga Federal district (Nizhniy Novgorod, Saratov), two cities in Urals Federal district (Yekaterinburg, Magnitogorsk), two cities in Siberian Federal district (Tomsk and Ulan-Ude) (See Table 3.10 and Figure 3.8).

City	**Demand**	**Weighted_Demand**	**Length**	**Weighted_Length**
Moscow	138	38	12460.1	3109.72
Vladikavkaz	58	13.12	8139.21	1910.45
Krasnodar	62	12.9	6049.28	1354.1
Yekaterinburg	46	12.8	6826.5	1776.24
Saint Petersburg	50	11.9	4288.97	969.22
Rostov-on-Don	46	10.4	5133.82	996.03
Voronezh	39	9.1	6405.53	1330.9
Saransk	23	8.7	3425.44	1361.95
Nizhny Novgorod	29	7.9	3679.18	891.53
Ufa	30	7.7	4829.79	1159.62
Yaroslavl	23	6.8	3337.91	887.76
Kaluga	28	6.4	4173.11	839.84
Total	572	145.8	68748.84	16587.36

Table 3.8: The selection of candidate cities based on maximising capacitated coverage at 260 km cutoff level.

800 km impedance cutoff distance for facility minimisation. The last technique *Minimise facilities* I apply only at the 800 km distance cutoff. This method chooses the

City	Demand	Weighted_Demand	Length	Weighted_Length
Moscow	377	93.8	133096.94	30237.46
Krasnodar	198	44.2	60910.28	13736.97
Saratov	105	27.3	42639.02	10821.44
Tyumen	81	20.7	36277.33	9086.91
Perm	66	16.3	25005.78	5952.78
Magnitogorsk	54	15.1	24996.27	6689.63
Novosibirsk	55	13.6	16759.09	3944.81
Krasnoyarsk	27	6.8	9754.3	2287.2
Ulan-Ude	23	5.7	10474.42	2414.36
Murmansk	19	4.1	3933.67	973.88
Vladivostok	13	4.	1923.2	426.16
Khabarovsk	15	3.8	6104.54	1443.37
Total	1033	255.4	371874.82	88014.97

Table 3.9: The selection of candidate cities based on minimising impedance at 800 km cutoff level.

minimum number of the most important hubs that are able to supply the country's demand. The model selected 23 cities (See Table 3.11 and Figure 3.9). This set of chosen cities covers all parts of Russia in a balanced manner.

Discussion. This subsection is the last element of PPDAC methodology that is conclusions. I applied three techniques of the ArcGIS Network Analyst with different specifications. The 190 km distance threshold represents a 12 hours access time of the cargo delivered by Russian rail. Container delivery is slightly faster, hence, I used the 260 km threshold for container delivery. Finally, 800 km threshold is the average cargo delivery distance in Russia. Each distance was analysed with *Minimise Impedance* and *Maximise Capacitated Coverage*.

The results are the same on the 190 km cutoff level. As distance grows, the results begin to vary. Logically, the bigger the distance cutoff, the more area is covered and more demand cities are connected (See Table 3.12).

Thus, at the distance level 190 km, only 448 (out of 1335) demand cities are connected, which is 33.5%. The maximum weighted demand is 321.6, therefore this model covers 36.1% of the weighted demand. At the distance level 260 km, the *Minimise Impedance* model covers 46%

while the *Maximise Capacitated Coverage* model connects candidate cities to 45% of weighted demand. At the distance 800 km, the difference is growing. The first model covers 79%, the second - only 74%. The *Minimise Facilities* model covers 86% of the weighted demand.

In light of this, I conclude that the first model *Minimise Impedance* (p-median), is more robust. This result is in line with the previous researches on this subject, where the p-median is a common method for the selection of logistics centres location.

Preparing the recommendations for the Ministry of Transport, I rely more on the results obtained with *Minimise Impedance* technique. In addition, I compare these results with the priority grouping of the cities in Table 3.3 on page 38. The cities that were not included in the groups I, II and III would not appear in the Policy recommendations because of their too low socio-economic and business development.

Within the framework of this thesis I obtain comprehensive results and each part of my thesis suggest the future investigation as the boundaries of the research constantly expand and new ideas appear. Thus, several technical issues can be improved in the further analysis.

Currently I apply the average speed of cargo delivery to the whole railway network. In the reality the average speed varies depending on the network segment. The speed is lower in the Western part of Russia because of a number of big stations and long stops. Going East, the speed increases, because the distance between the settlements grows. Thus, in the future research I will divide my network into segments (based on Federal districts) and apply different average speed to each segment. I assume that Siberian and Far Eastern candidate cities will be better off with such an improvement.

The area of the analysis can be expanded to the neighbouring countries, including CIS countries, China, West- and East-European states. This would avoid the situation of autarky for Russia allowing the international trade and distribution.

Some of the allocation models show an apparent inefficiency when a demand point is allocated to a facility that isn't the nearest solution facility. ESRI says that this 'may occur when demand points have varying weights and when the demand point in question is covered by more than one facility's impedance cutoff (or there are no impedance cutoffs at all). This kind of result indicates the nearest solution facility didn't have adequate capacity for the weighted demand, or the most efficient solution for the entire problem required one or more local inefficiencies' (ESRI, 2016). ESRI argues that in either case, the solution is correct.

City	**Demand**	**Weighted_Demand**	**Length**	**Weighted_Length**
Moscow	177	48.8	27606.15	6951.71
Krasnodar	193	43.3	58342.06	13265.86
Yekaterinburg	127	31.7	44912.92	10796.07
Saratov	88	24.1	34399.3	9341.54
Tomsk	62	16.2	27943.77	7152.69
Saint Petersburg	75	16.2	14180.5	2780.87
Magnitogorsk	54	15.1	24996.27	6689.63
Nizhny Novgorod	52	12.2	13729.34	2830.77
Voronezh	52	11.2	10201.1	1946.24
Yaroslavl	29	8.2	5812.19	1425.77
Bryansk	37	6.6	6314.54	1146.2
Ulan-Ude	23	5.7	10474.42	2414.36
Total	969	239.3	278912.56	66741.71

Table 3.10: The selection of candidate cities based on maximising capacitated coverage at 800 km cutoff level.

City	Demand	Weighted_Demand	Length	Weighted_Length
Moscow	299	77.9	80644.51	19520.33
Vladikavkaz	147	32.7	52270.69	11211.46
Volgograd	115	25.5	49714.48	10810.97
Yekaterinburg	98	24.3	27997.74	6466.89
Saransk	74	19.6	25920.63	6123.52
Saint Petersburg	77	17	15334.77	3260.79
Novosibirsk	52	13.1	14689.56	3597.85
Magnitogorsk	41	11.3	16895.65	4270.39
Izhevsk	34	8.6	8936.55	2267.29
Krasnoyarsk	26	6.6	9021.54	2140.66
Surgut	17	5	3963.21	1163.57
Irkutsk	14	4.4	2690	681.67
Murmansk	19	4.1	3933.67	973.88
Vladivostok	13	4	1923.2	426.16
Khabarovsk	15	3.8	6104.54	1443.37
Makhachkala	15	3.1	852.88	164.91
Omsk	15	3.1	3655.45	525.75
Stavropol	12	3	760.19	218.25
Chita	19	3	5408.66	802.43
Kaliningrad	12	2.3	765.85	122.25
Arkhangelsk	6	1.4	770.12	168.07
Yakutsk	3	1.3	1269.51	405.56
Komsomolsk-on-Amur	4	1.1	99.13	11.98
Total	1127	276.2	333622.53	76778

Table 3.11: The selection of candidate cities based on minimising facilities at 800 km cutoff level.

Dist.	Min.Imp.	Max.Cov.	Min.Fac.
190 km	36.1%	36.1%	N/A
260 km	46%	45%	N/A
800 km	79%	74%	86%

Table 3.12: Percentage of total weighted demand covered in different models

Conclusions

Overview of the results. The present thesis addresses the problems related to logistics centres development in Russia that are stated in the Transport Strategy of Russia until 2030 (Mintrans, 2014). The Strategy believes that the logistics centres should be constructed in each region of Russia, however, the Strategy does not reveal the priority places for logistics centres development and does not provide any recommendations on how to select the logistics centres locations.

This thesis presents a new evaluation system for logistics centre allocation by integrating several dimensions of evaluation criteria - namely, economic, social, financial, transport and lease conditions - and proposes an application of a combination of location and network analysis methods as a decision making tool.

The thesis lists chosen candidate cities and prioritises the sequence of cities, where it is necessary to construct the logistics centres. The thesis selects candidate cities for allocation of logistics centres based on three distance cutoff levels and using three location-allocation techniques. The cutoff levels reflect the 12 hours access time for normal and container cargo delivery, and average cargo delivery distance on Russian railway.
Stepwise implementation of this objective included the examination of LC definitions, its types, and the socio-economic role of the LCs. The thesis highlighted the aspects of the two state transport strategies and the business concept of LC development put forth by the

Russian Railway company (RZhD). The thesis summarised the stakeholders and described the specificities of state-business partnership in Russia.

The present thesis applied geospatial network analysis techniques and identified seven sets of candidate cities. The sets were based on three methodologies of location-allocation tool in ESRI's Network Analyst (namely, *Minimise Impedance*, *Maximise Capacitated Coverage* and *Minimise Facilities*), access time and average cargo delivery distance. The study showed that the results obtained by use of different techniques varied depending on the spatialities of the problem and the demand surface characteristics.

The main goals of planners and decision makers are to reduce either access time or weighted distance of cargo delivery between the facilities and demand locations. The presented approach aimed to minimise the weighted distances between supply and demand locations.

Way forward. Smith, Goodchild and Longley (2015) believe that 'spatial patterns are rarely if ever uniquely determined by a single process'. They argue that usually spatial analysis is only the start of further research and rarely an end of it. Even in case the distance and contiguity are important or significant, they emphasise the necessity of a further research. Future research should use more decision making techniques to make the analysis more complex. The evaluation system will be improved and adjusted to each of the region specialisation. This approach would better address the structure of demand for logistics centre services and characteristics of a particular region.

Main contribution. In the final analysis, this thesis extends previous research on the subject by being the first to use ArcGIS Network Analyst for selecting the best places for logistics centres allocation. The produced lists of priority cities complement the Transport Strategy, offering an alternative (to one of RZhD) plan of action regarding the development of logistics centres network in Russia.

Policy Recommendations

Thus document is addressed to Maksim Sokolov, Minister of Transport (Rozhdestvenka Street, 1, bldg.1, Moscow, 109012, Russian Federation), December 2016.

In light of a relatively low Russian forwarding service utilisation, compared to the European partners, and considering that the Government have declared a necessity of a logistics centres network development, this thesis offers a number of recommendations, which policy makers should consider to guarantee the successful implementation of Transport strategy 2030.

These policy recommendations complement the Transport Strategy and develop the ideas of Russian Railways Company (RZhD) concept within the framework of LCs construction, providing the lists of the most important locations for logistics centres development in the short-term for normal and container delivery based on a 12 hours access time; in the short-term based on the average delivery distance by railway; and proposing the list of core-cities of a future network in the medium-term. The construction of the logistics centres in proposed locations will ensure the decrease of total transport costs, total industrial costs and personnel costs. This will improve overall transport network of Russia and increase the transport operators total turnover, which will stimulate the whole economic sector.

A. To ensure the adequate development of a logistics centre network and optimise normal delivery processes by railway in the short-term based on a 12 hours time

access, it is necessary to construct the logistics centres in the following cities:

Rank	**City**	**Rank**	**City**
1	Moscow	7	Voronezh
2	Krasnodar	8	Chelyabinsk
3	Saint Petersburg	9	Samara
4	Rostov-on-Don	10	Nizhni Novgorod
5	Vladikavkaz	11	Novosibirsk
6	Yekaterinburg		

B. To ensure the adequate development of a logistics centre network and optimise container delivery by railway in the short-term based on a 12 hours time access, it is necessary to construct the logistics centres in the following cities:

Rank	**City**	**Rank**	**City**
1	Moscow	6	Nizhni Novgorod
2	Krasnodar	7	Ufa
3	Yekaterinburg	8	Yaroslavl
4	Saint Petersburg	9	Novosibirsk
5	Voronezh	10	Rostov-on-Don

C. To ensure the adequate development of a logistics centre network and optimise goods delivery by railway in the short-term based on the average delivery distance by railway, it is necessary to construct the logistics centres in the following cities:

Rank	City	Rank	City
1	Moscow	7	Novosibirsk
2	Krasnodar	8	Krasnoyarsk
3	Saratov	9	Murmansk
4	Tyumen	10	Vladivostok
5	Saint Petersburg	11	Khabarovsk
6	Magnitogorsk	12	Ulan-Ude

D. To ensure the adequate development of a logistics centre network and optimise goods delivery by railway in the medium-term, it is necessary to construct the logistics centres in the following cities:

Rank	City	Rank	City
1	Moscow	10	Irkutsk
2	Volgograd	11	Murmansk
3	Yekaterinburg	12	Vladivostok
4	Saint Petersburg	13	Khabarovsk
5	Novosibirsk	14	Omsk
6	Magnitogorsk	15	Kaliningrad
7	Izhevsk	16	Arkhangelsk
8	Krasnoyarsk	17	Komsomolsk-on-Amur
9	Surgut		

If these recommendations are not taken into consideration, the stakeholders will not be able to ensure the coordinated work on the development of the network of logistics centres in Russia. The transport infrastructure will remain uncompetitive and will not attract various operators. RZhD notes that a delayed implementation leads to the loss of market positions, significant amount of income and reduces the competitiveness of the railway transport (RhZhd, 2012). This thesis strongly recommends to develop all the logistics centres within the state-business partnership. The Government should be pro-active, initiating the projects of LC construction in the proposed regions of Russia.

The implementation of these recommendations is expected to improve the speed of goods passage, enhance the competitiveness of enterprises, increase the industrial production and modernise the industrial capacity, create jobs, optimise supply chains and distribution networks, support transport services export. Hence, this is expected to increase transportation activities, decrease transport costs and improve the investment activities efficiency.

Appendices

Figure 3.3: Sviyazhsk Logistics Centre in Russia (concept)

Rank	City	Weight	Rank	City	Weight
1	Moscow	0.192	38	Arkhangelsk	0.067
2	Tyumen	0.162	39	Komsomolsk-on-Amur	0.066
3	Nizhnevartovsk	0.134	40	Belgorod	0.065
4	Surgut	0.132	41	Astrakhan	0.646
5	Saint Petersburg	0.128	42	Sochi	0.064
6	Krasnoyarsk	0.118	43	Novorossiysk	0.064
7	Irkutsk	0.116	44	Volgograd	0.064
8	Yekaterinburg	0.115	45	Volzhskiy	0.063
9	Kazan	0.119	46	Vologda	0.063
10	Khabarovsk	0.110	47	Orenburg	0.063
11	Omsk	0.106	48	Sterlitamak	0.062
12	Nizhny Novgorod	0.105	49	Kaluga	0.062
13	Ufa	0.104	50	Makhachkala	0.061
14	Tolyatti	0.104	51	Tambov	0.061
15	Kaliningrad	0.104	52	Barnaul	0.059
16	Krasnodar	0.103	53	Taganrog	0.059
17	Samara	0.101	54	Kursk	0.058
18	Tomsk	0.1	55	Penza	0.058
19	Vladivostok	0.099	56	Petrozavodsk	0.058
20	Lipetsk	0.097	57	Vladikavkaz	0.057
21	Voronezh	0.096	58	Chita	0.057
22	Magnitogorsk	0.096	59	Tver	0.057
23	Cherepovets	0.095	60	Saransk	0.057
24	Murmansk	0.095	61	Oryol	0.057
25	Tula	0.094	62	Smolensk	0.057
26	Saratov	0.094	63	Ulyanovsk	0.056
27	Yaroslavl	0.093	64	Bryansk	0.056
28	Rostov-on-Don	0.092	65	Stavropol	0.055
29	Izhevsk	0.089	66	Grozny	0.055
30	Ryazan	0.088	67	Kurgan	0.055
31	Kemerovo	0.084	68	Kostroma	0.054
32	Novosibirsk	0.083	69	Ulan-Ude	0.053
33	Yakutsk	0.079	70	Ivanovo	0.051
34	Naberezhnye Chelny	0.074	71	Novokuznetsk	0.049
35	Perm	0.074	72	Vladimir	0.049
36	Nizhny Tagil	0.073	73	Kirov	0.047
37	Chelyabinsk	0.072			

Table 3.14: List of all candidate cities with weights

Figure 3.4: Chosen candidate cities (minimise impedance and maximise capacitated coverage, 190 km cutoff level

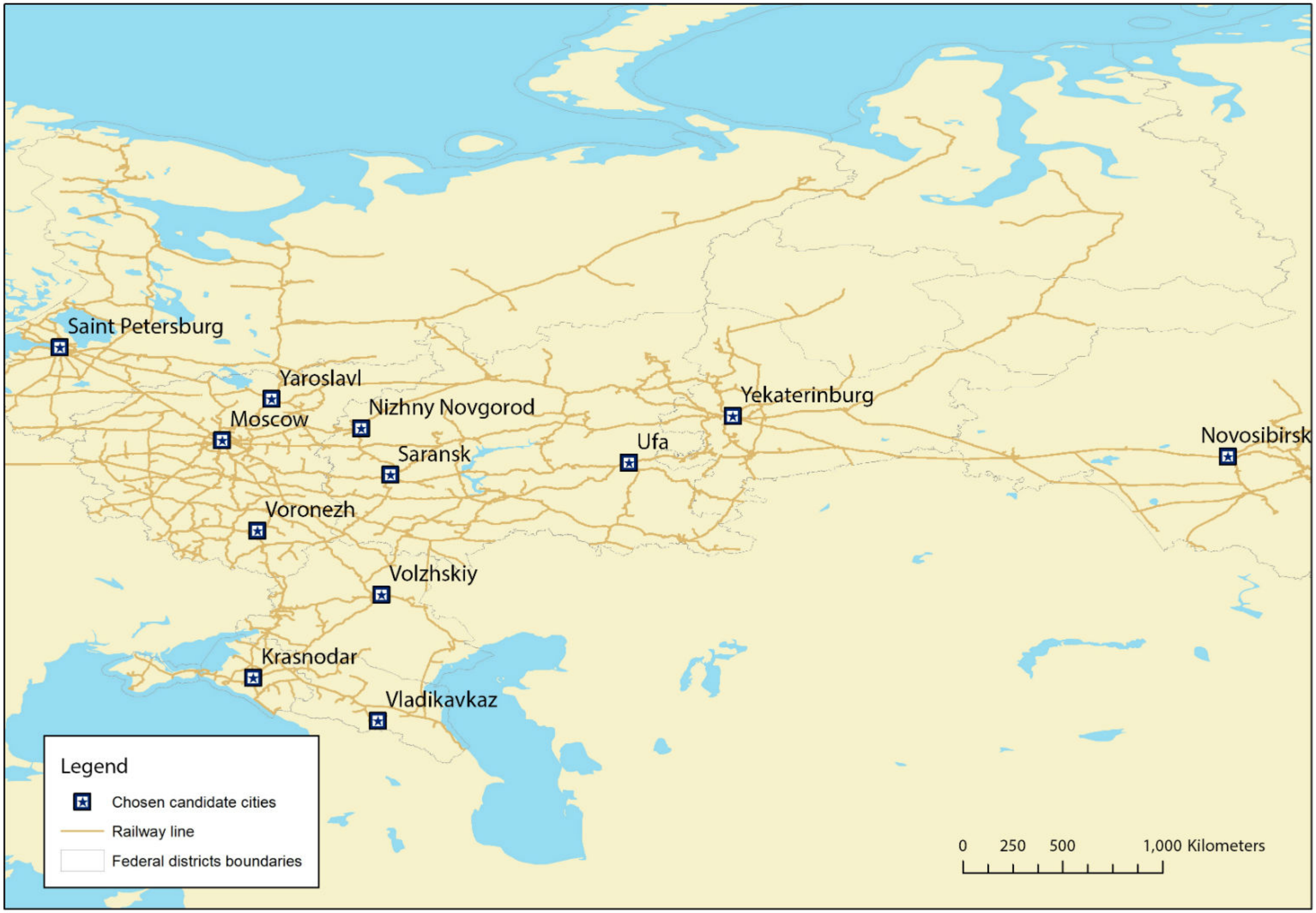

Figure 3.5: Chosen candidate cities (minimise impedance, 260 km cutoff level

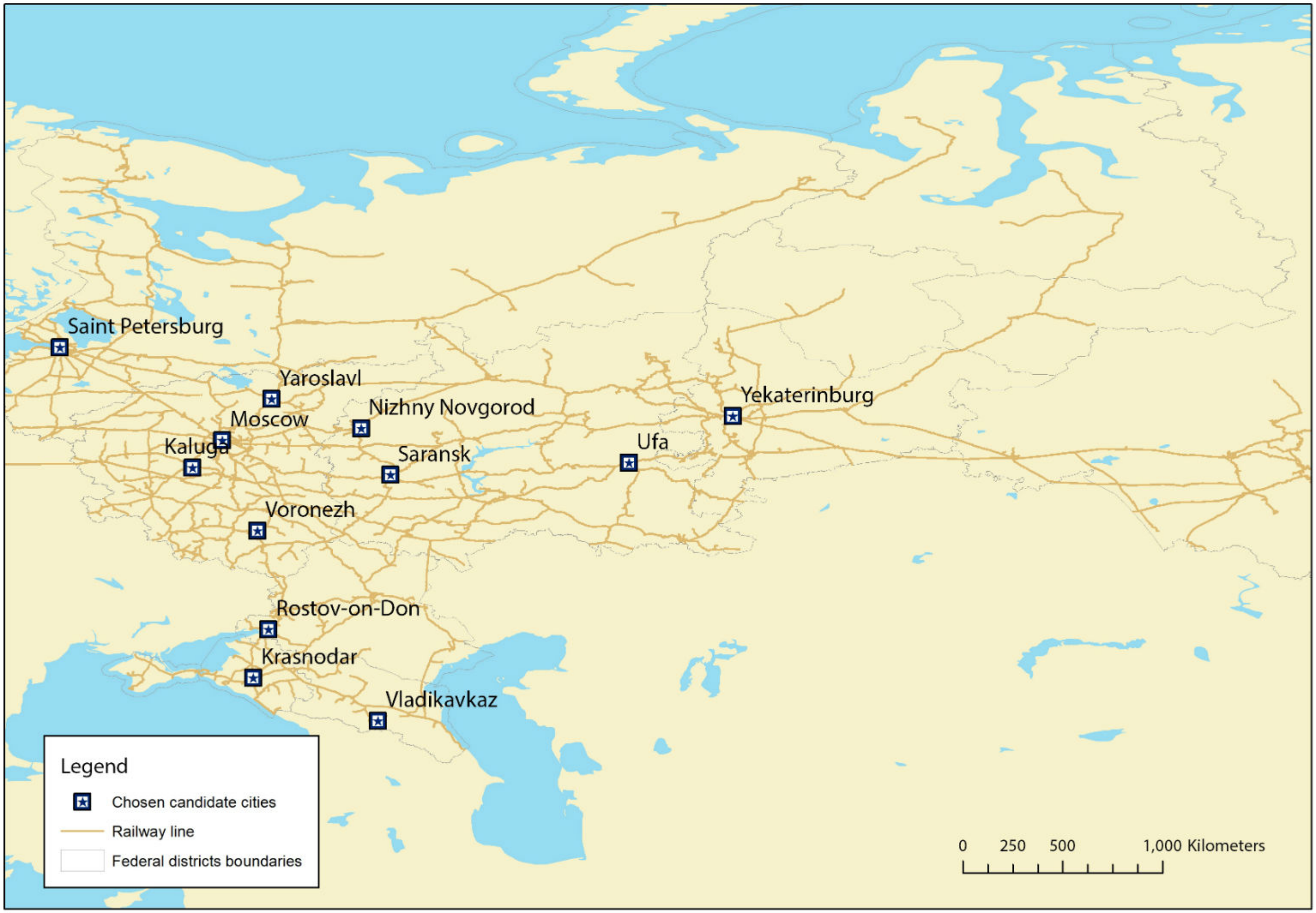

Figure 3.6: Chosen candidate cities (maximise capacitated coverage, 260 km cutoff level

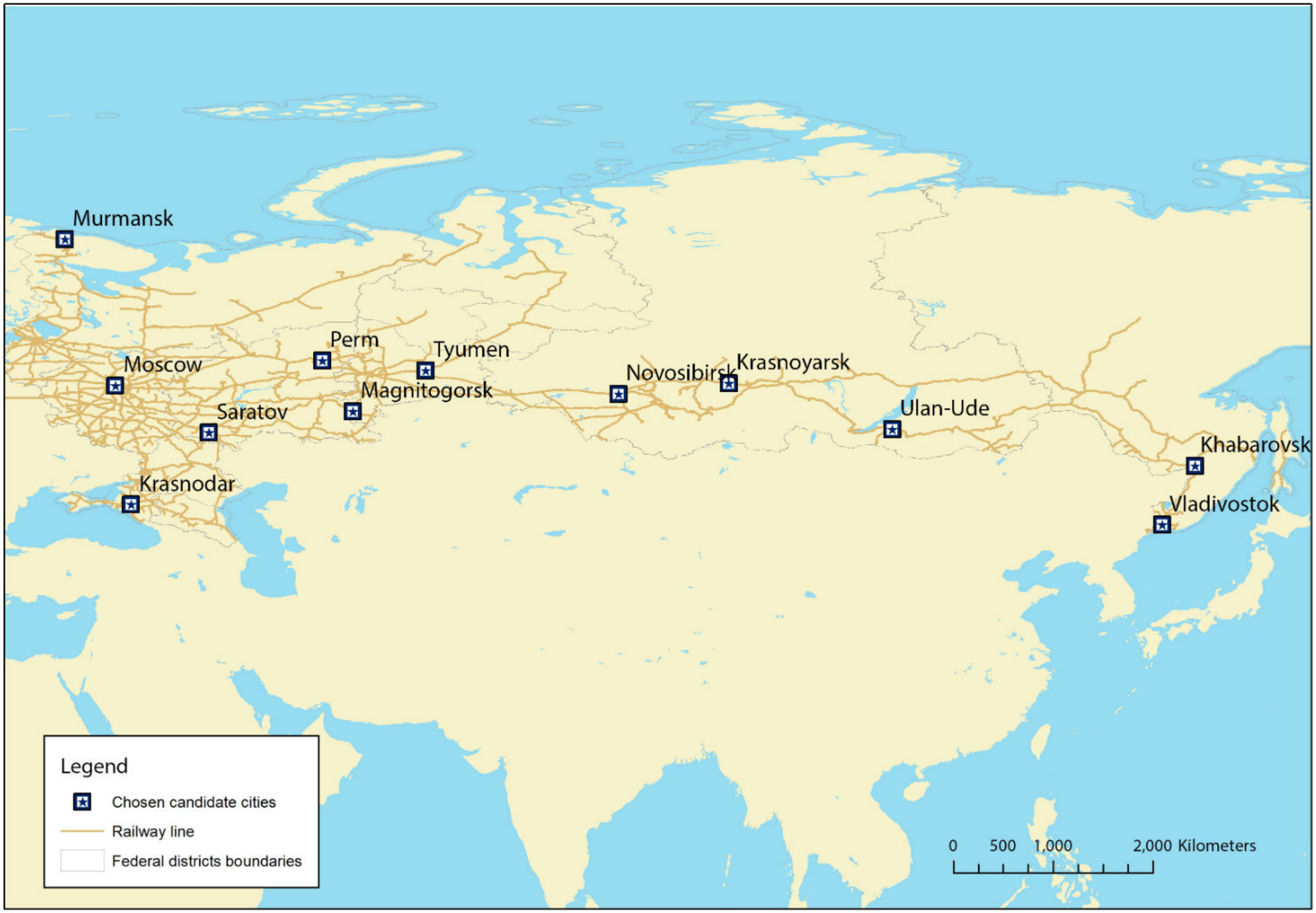

Figure 3.7: Chosen candidate cities (minimise impedance, 800 km cutoff level

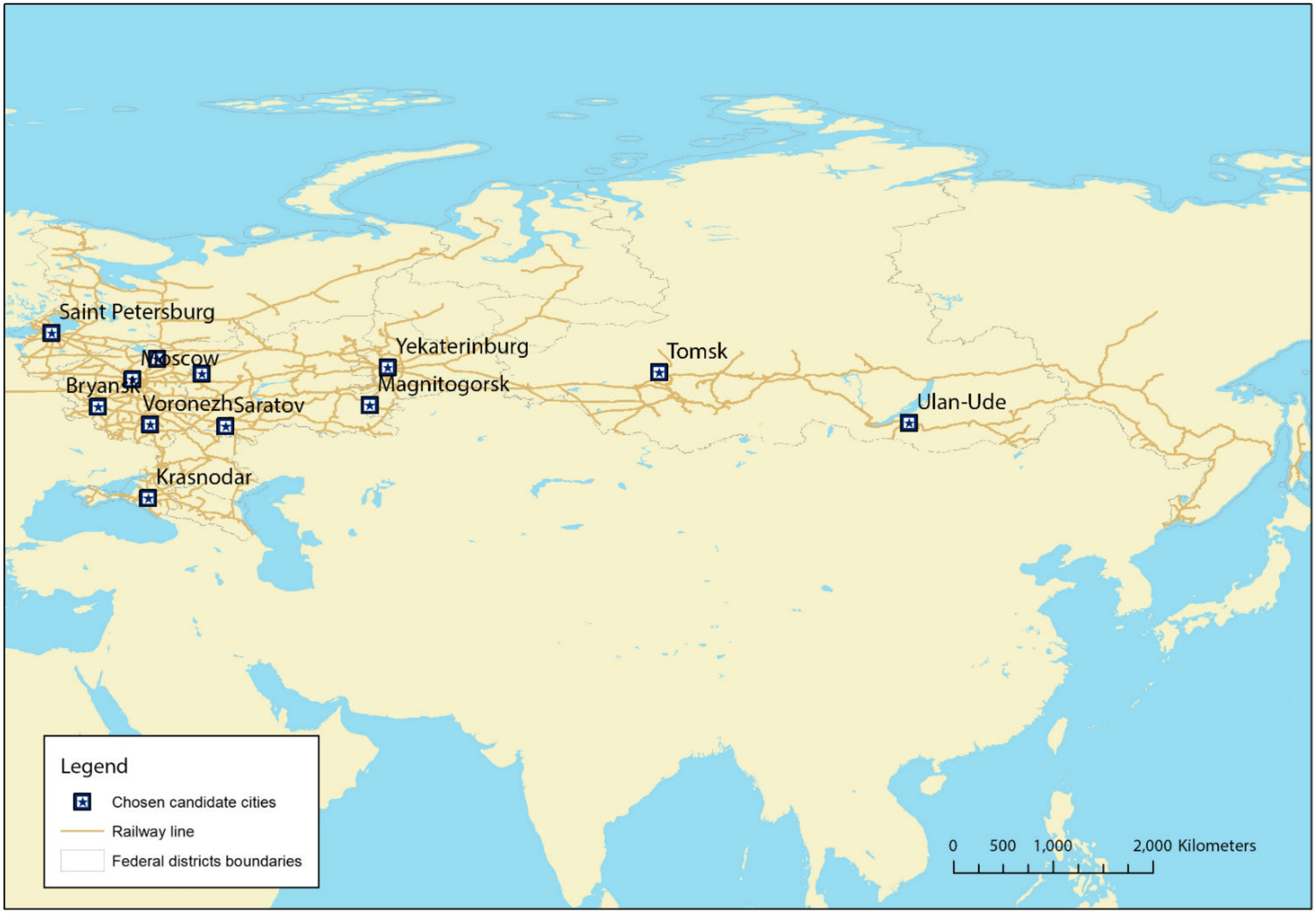

Figure 3.8: Chosen candidate cities (maximise capacitated coverage, 800 km cutoff level

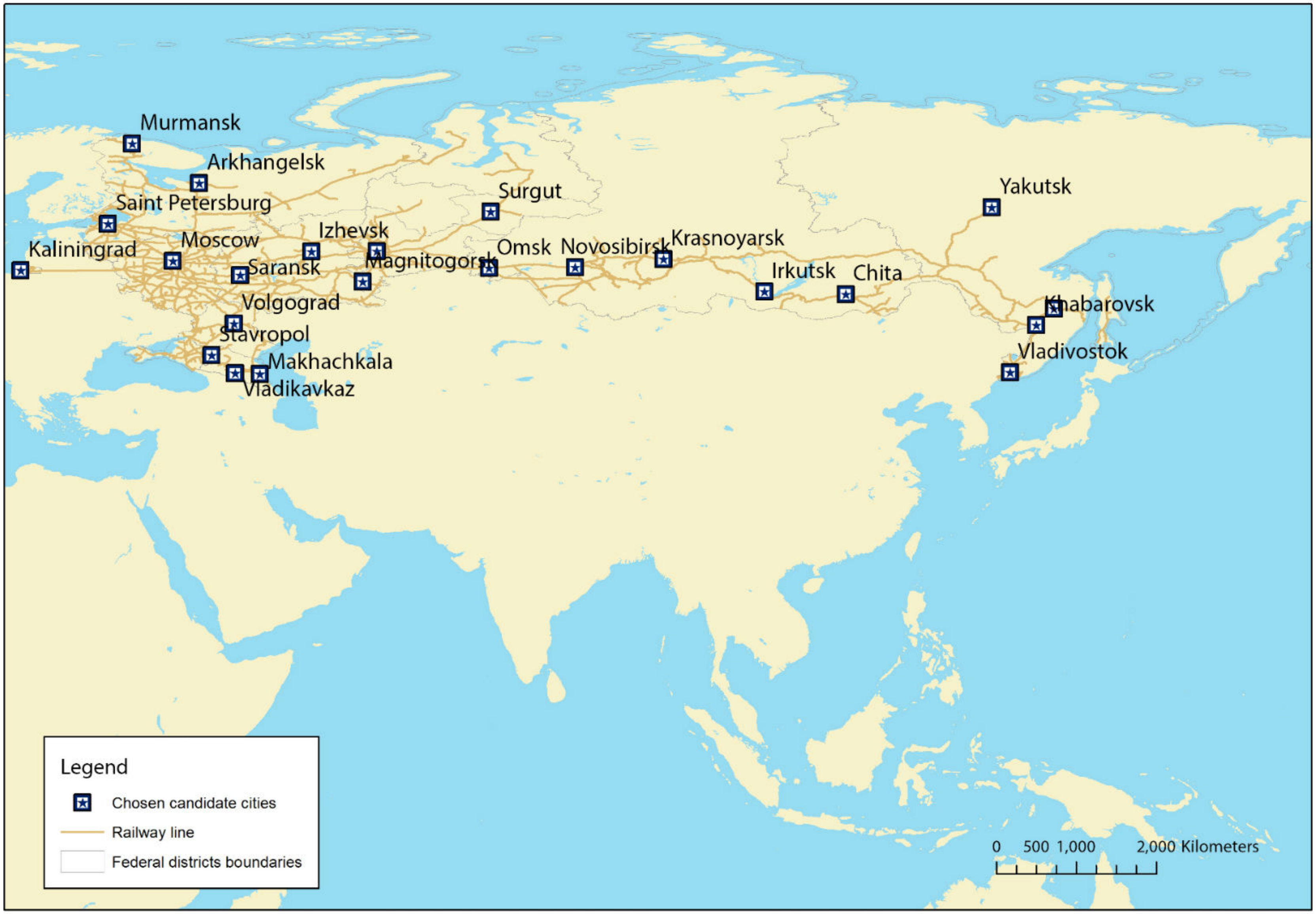

Figure 3.9: Chosen candidate cities (minimise facilities, 800 km cutoff level

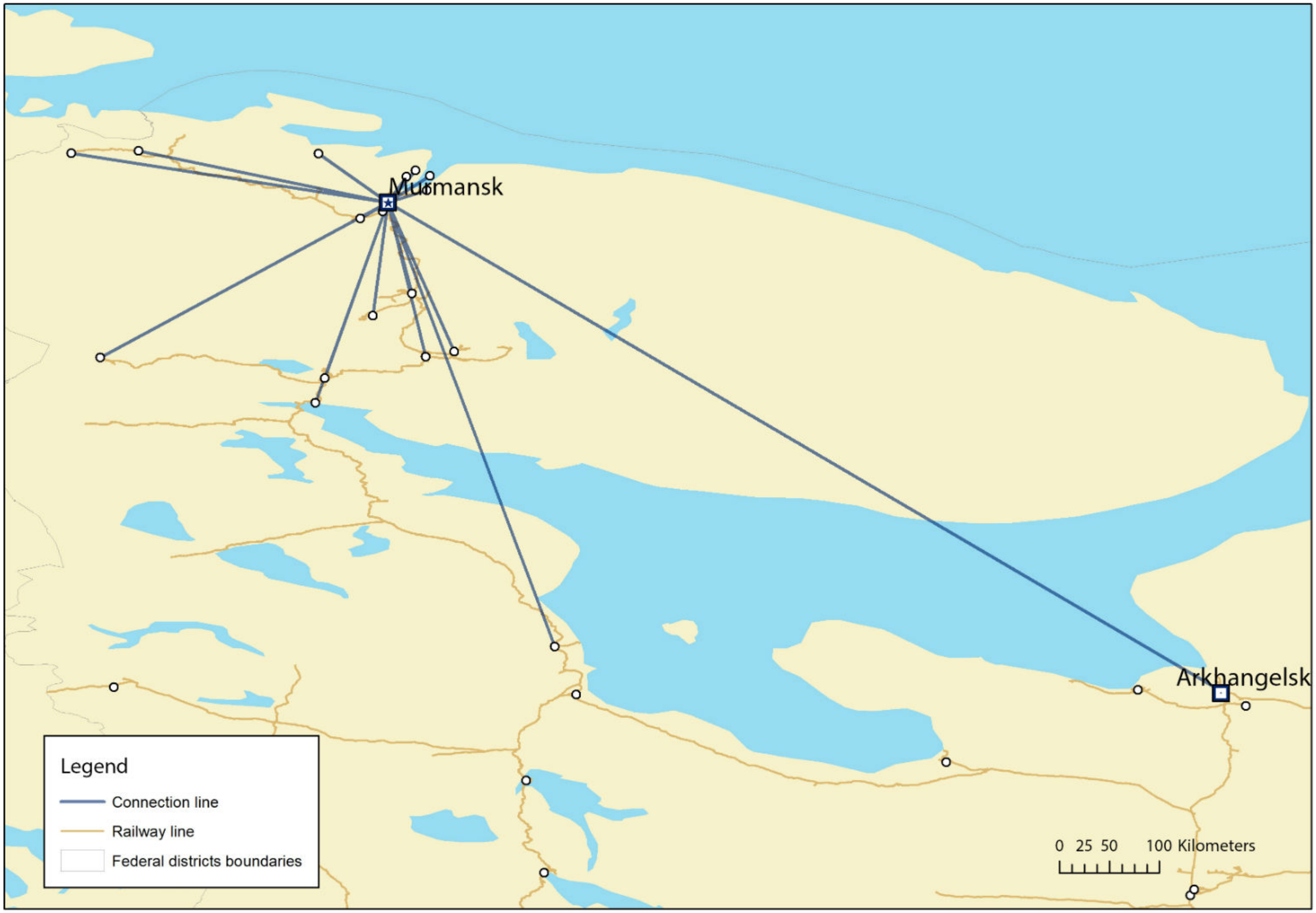

Figure 3.10: Connections in North-Western Russia (minimise impedance, 800 km)

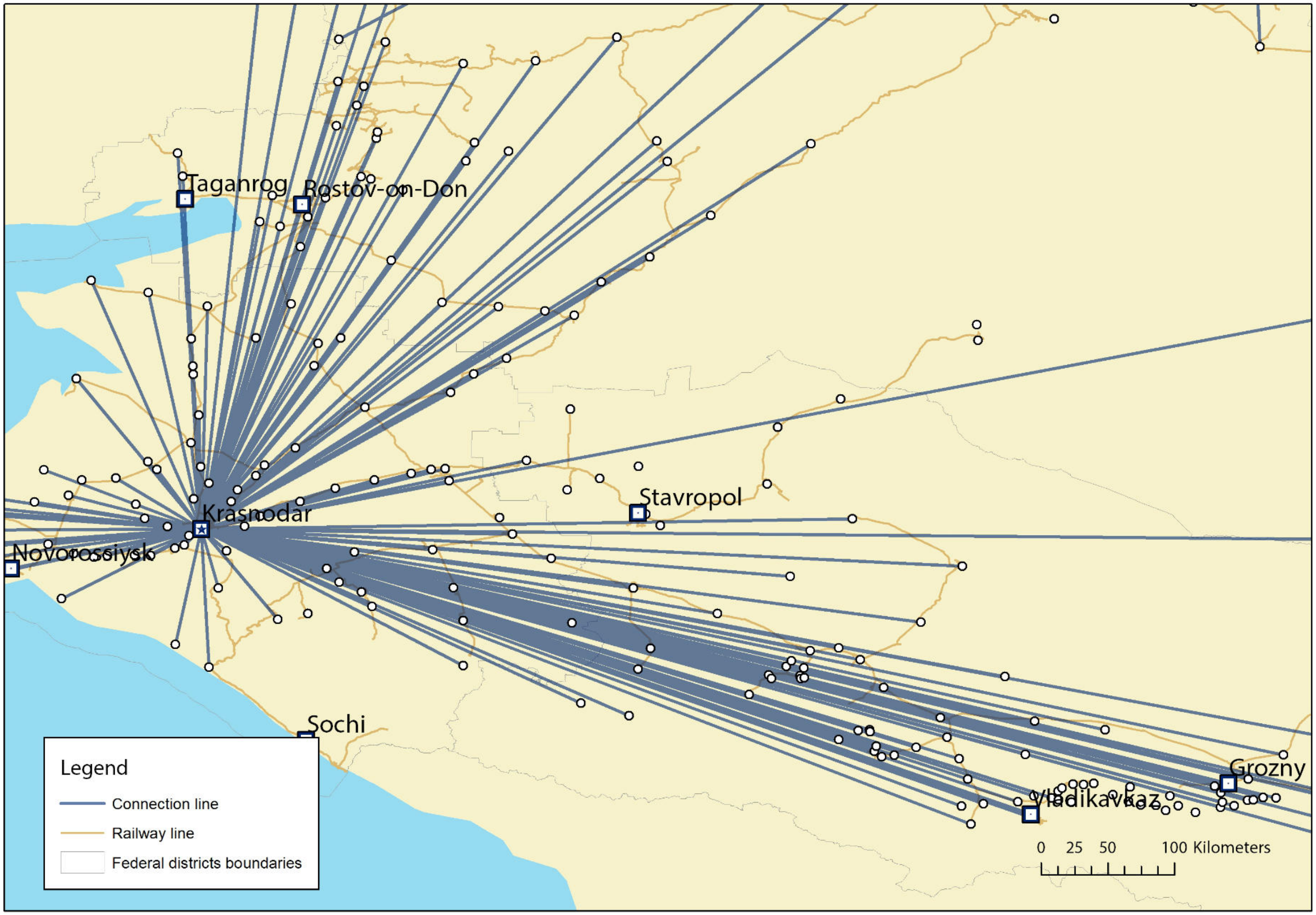

Figure 3.11: Connections in South-Western Russia (minimise impedance, 800 km)

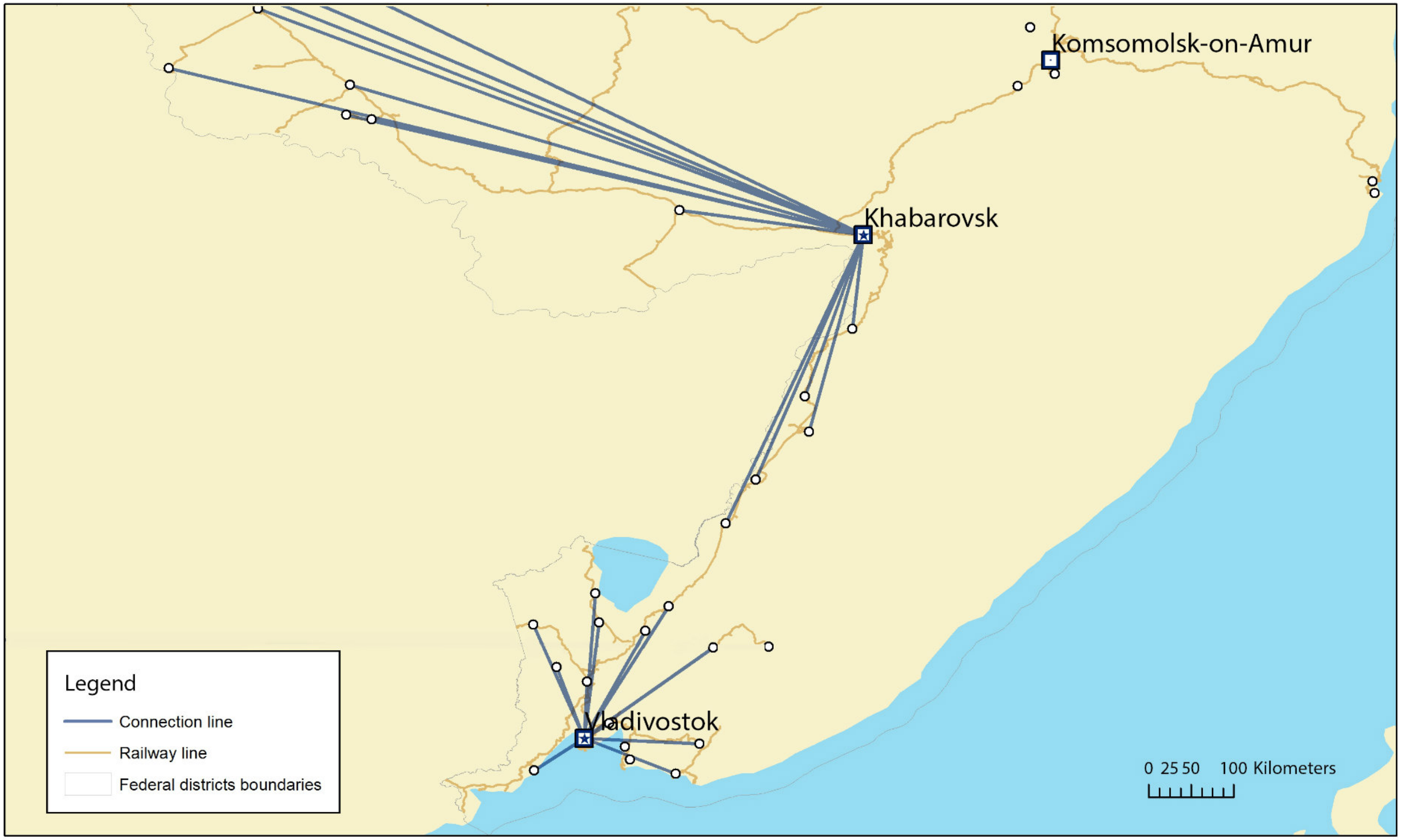

Figure 3.12: Connections in Eastern Russia (minimise impedance, 800 km)

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