Transport and economic justification of road routing options (on the example of Arkhangelsk - Naryan-Mar automobile route)

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Abstract. The Arctic region has received increasing attention in recent years. One of the topical areas of transport system development in the Russian Federation is the transit potential of the Arctic region as well as transport connections with the Barents region countries. The purpose of the research is to make a transport and economic research of variants of automobile transport network development in the Barents region - the transport route Arkhangelsk - Naryan-Mar. The research objectives are: to analyse regional transport network of Nenets Autonomous District; to develop versions of Arkhangelsk - Naryan-Mar transport routes; to estimate transport and economic characteristics and choose a variant of motor transport route. Two variants of the Arkhangelsk - Naryan-Mar road route have been considered in the course of this work. The first one is 887 kilometres long and goes along the sparsely populated territory, through the village Volokovaya. The second route is 940 km long. It is situated in the north through 10 settlements, including the town of Mezen, the administrative centre of Mezen municipal district. A more feasible route is the second option, which runs along the shores of the Mezen Bay of the White Sea and the Chesh Bay of the Pechora Sea. In spite of the fact that this route is 77 km longer than Route 1, it will be a transport artery, passing through 10 settlements, among which is the town of Mezen, the administrative centre of Mezen municipal district.

1 Introduction

One of the main drivers of sustainable socio-economic, technological, innovative development of the country is its infrastructure [1-4]. In Russia, priority is given to projects for the construction (reconstruction) of engineering, social and road-transport infrastructure, infrastructure for housing construction and urban development [2, 4-10]. With its vast territory (1/8 of the Earth’s land mass) and a length of about 10,000 km west-east and 4,000 km north-west, Russia has a particular need for a well-developed transport infrastructure. In recent years increasing attention has been paid to the Arctic region because of its growing potential as a source of natural resources as well as the development of the

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Northern Sea Route (NSR) transport corridor. The transit potential of the Arctic region [7-9] is one of the most important areas of development of the Russian Federation's transport system: [7-9] as well as the transport links with the Barents region [11,12] (Fig.1).

![Fig.1. Priority transport corridors/routes of the Barents region.](image)

Analysing the map (Fig. 1), it can be concluded that in the Nordic countries the transport corridors consist of a combination of rail, road and maritime networks. This is not the case between Russia's western border to the east and to the north. Only the main northern ports, Murmansk and Arkhangelsk, have rail and road connections. It is from these ports that the modern SPM project originates and develops.

At the moment, the main transport hubs in the Russian part of the Barents region, which should provide a unified transport network for the region, are the port of Indiga and Naryan-Mar.

![Fig. 2. Perspective direction of Barents region transport system development.](image)

The construction of the Indiga port is planned for 2023-2028. It will be the terminus of a vertical railway transport corridor from the Pacific to the Arctic Ocean and a major hub for the transshipment of international goods in transit.

On the other hand, Naryan-Mar is considered to be a point of vertical transport corridor from the Pacific to the Arctic Ocean, and a major hub for transshipment of international goods.
transit cargo. Naryan-Mar is seen as a point of vertical west-to-east transport corridor (Fig. 2).

The purpose of this study is to investigate transport and economic options for the development of the road transport network in the Barents region, the Arkhangelsk - Naryan-Mar transport route.

The research objectives are:
- to analyse regional transport network of Nenets Autonomous District;
- to develop versions of Arkhangelsk - Naryan-Mar transport routes;
- to estimate transport and economic characteristics and choose a variant of motor transport route.

2 Methods

2.1. Analysis of the regional transport network in the Nenets Autonomous District

The object of the study is the existing transport network of the Nenets Autonomous District and its integration with the network of the Arkhangelsk Oblast and the Barents region creating the Vartius - Onega - Arkhangelsk - Naryan-Mar road route.

The regional transport network study for the Nenets Autonomous District [15] examined the following issues:
- existing transport infrastructure of the study region and gravitation zones (infrastructure of road transport, railway transport, air transport, sea transport, river transport);
- assessment of year-round road transport accessibility;
- assessment of transport accessibility of settlements in the immediate catchment area of the Arkhangelsk - Naryan-Mar road route (year-round traffic, traffic in the "summer" period, traffic in the "winter" period).

As part of the analysis of the connection of the settlements located in the attraction zone of the planned route with regional and district centres, the transport accessibility of the settlements by various modes of transport port in different periods of the year was assessed.

2.2 Route design of the lay of line

Routing options for the direct road route Arkhangelsk - Naryan-Mar have been considered, taking into account continuous year-round operation. Two options for the Arkhangelsk - Naryan-Mar road route were considered.

Both options involve the connection of two regional roads that are currently isolated from the rest of the road network in the Nenets Autonomous Area. The first option runs mostly through unpopulated areas of the District and provides a maximum distance between settlements, which makes it a shorter option. The second variant provides year-round transport-port connection of settlements of the Nenets Autonomous Area both between themselves and with the regional and district capitals.

The road route includes both projected sections and maximum use of existing routes, including:
- Road of regional importance in the Arkhangelsk Oblast
  11 OP RZ 11A-004 "Arkhangelsk - Belogorsky - Pinega - Kimzha - Mezen" - road of IV category, length 371.781 km with asphalt concrete and gravel surface, in the section Pinega - Kimzha unpaved sections are reconstructed with gravel surface.
2.3 Assessment of transport and economic characteristics and selection of a road transport route option

2.3.1 Estimate of traffic demand for the projected facility

Forecast of traffic intensity at the projected site is made on the basis of available data on traffic volumes, analysis of demographic development trends, taking into account economic development plans of the pulling zone regions, in particular, the industrial complex.

The estimation of perspective intensity is made on the basis of the following hypothesis: with the construction of the considered motorway there will be an intermodal redistribution of passenger and freight flows, from air and water transport to motor transport [13,14]. In addition, due to increased accessibility (reduction of time and monetary costs), the intensity of transport communication in the direction of the largest settlements of the gravity zone (Mezen, Nes, Oma), which are local centres of social and community orientation, will increase.

2.3.2 Forecast of project costs

This section provides a preliminary, aggregated budget estimate for the implementation of the Arkhangelsk-Naryan-Mar road route creation and operation project.

The projected costs are determined in 2021 prices on the basis of aggregate estimates of the costs required to implement measures to create and maintain facilities along the Arkhangelsk - Naryan-Mar route in question. The aggregated costs required for the implementation of all the proposed measures are calculated for the following two items:
- capital investments;
- operating (maintenance) costs.

3 Results

Analysis of the transport network. Currently, the territory of the NAO is characterised by low transport accessibility (Fig. 3). There is no year-round connection by land transport (road and rail) with other regions of the Russian Federation. A peculiarity of the transport system is the insignificant coverage by the road network. The density of roads in the region is very low - 2 km of track per 1 000 km2 of territory - the lowest value of this index among all regions of the North-West Federal District.

In the winter season, connections between settlements of the district, with the centre of the region as well as with neighbouring regions (the Arkhangelsk region and the Komi Republic) are provided by "winter roads" using snowmobiles and all-terrain vehicles. Access is provided exclusively by air transport. A description of the NAD transport network is presented in Table 1.
Table 1. Overview of the Nenets Autonomous District transport system.

<table>
<thead>
<tr>
<th>Type of transport</th>
<th>Key elements of the transport network</th>
<th>Feature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aerial</td>
<td>Airports: Naryan-Mar, Amdema, Varandey; network of airfields, heliports and landing sites in populated areas</td>
<td>The only year-round transport provides inter-regional and domestic air services; with a number of localities it is seasonal and ceases to operate from July to September</td>
</tr>
<tr>
<td>Railway</td>
<td>-</td>
<td>Not available</td>
</tr>
<tr>
<td>Maritime</td>
<td>Naryan-Mar (including Amdema terminal), Varandey</td>
<td>Navigation from June to November. Main cargo types: fuels and lubricants, construction materials, containers</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Navigational period from June to January. The main destination of the port is oil export.</td>
</tr>
<tr>
<td>River</td>
<td>Naryan-Mar port</td>
<td>The navigation stops from July to September. The main types of cargo are products of local food farms</td>
</tr>
<tr>
<td>Automobile</td>
<td>Federal road A-381 Naryan-Mar - Naryan-Mar airport 4 km long; Provincial road Naryan-Mar - Usinsk, length 167 km (of which 54.8 km are not year-round, operated as &quot;winter road&quot;) Main roads of local importance: Verkhnyaya Piosha - Volokovsky village, 22.9 km long and Nizhnyaya Piosha - Volokovsky village, 19.9 km long. Lower Piosha - Verkhnyaya Piosha village, 19.9 km long.</td>
<td>Federal network of the region 4 km. with improved asphalt-concrete pavement; The regional network consists of 275.2 km of Category III-V paved and transitional roads</td>
</tr>
<tr>
<td></td>
<td></td>
<td>The local network of 111.2 km consists of Category V roads</td>
</tr>
</tbody>
</table>

The following conclusions can be drawn from the analysis of the transport network in the region:

- For many areas of the region, air transport is the only or main means of year-round communication;
- rail transport is absent;
- sea and river transport is seasonal and operates during the short summer navigation period;
- The road network is underdeveloped and has low technical characteristics: in winter time on the most part of the territory the road transport is carried out only on "winter roads", including the use of snowmobiles and cross-country vehicles.

Development of options for the development of road transport corridors. Route options for the direct road route Arkhangelsk - Naryan-Mar were considered in view of continuous year-round operation. Two alignment options were considered (Figure 4) and divided into sections (Table 2.). The first alignment has a total length of 887 km and runs within the Nenets Autonomous District through sparsely populated areas. This option is shorter by 53 km. The second route has a total length of 940 km and runs within Nenets Autonomous
District to the north, through 10 settlements. Both variants envisage the connection of two regional roads (Mezen - Nes, Toshviska - Naryan-Mar), currently isolated from the rest of the road network of Nenets Autonomous District. The technical parameters are presented in Table 3.

**Fig. 4.** Basic technical data of the Arkhangelsk - Naryan-Mar automobile route.

**Table 2.** Distances of sections of the planned road route according to options.

<table>
<thead>
<tr>
<th>Section:</th>
<th>Arkhangelsk Dorogorskoe</th>
<th>Dorogorskoe</th>
<th>Volkovaya</th>
<th>Volkovaya Kotkino</th>
<th>Kotkino Toshviska</th>
<th>Toshviska Naryan-Mar</th>
<th><strong>TOTAL, km</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Option 1</strong></td>
<td>340.919</td>
<td>222.249</td>
<td>171.647</td>
<td>63.933</td>
<td>88.438</td>
<td></td>
<td><strong>887.186</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Section:</th>
<th>Arkhangelsk Mezen</th>
<th>Mezen – Nes</th>
<th>Nes-Nizhnyaya pyoshya</th>
<th>Nizhnyaya pyoshya-Kotkino</th>
<th>Kotkino-Toshviska</th>
<th>Toshviska Naryan-Mar</th>
<th><strong>TOTAL, km</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Option 2</strong></td>
<td>371.781</td>
<td>91.425</td>
<td>147.383</td>
<td>176.984</td>
<td>63.933</td>
<td>88.438</td>
<td><strong>939.944</strong></td>
</tr>
</tbody>
</table>

**Table 3.** Main technical parameters of the road design according to the options.

<table>
<thead>
<tr>
<th>Indicators</th>
<th>Unit of measure</th>
<th><strong>Option 1</strong></th>
<th><strong>Option 2</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>km</td>
<td>457.83</td>
<td>388.3</td>
</tr>
<tr>
<td>Number of artificial structures (bridges)</td>
<td>unit</td>
<td>105</td>
<td>124</td>
</tr>
<tr>
<td>Category of road</td>
<td>category</td>
<td>IV</td>
<td></td>
</tr>
<tr>
<td>Estimated travel speed</td>
<td>km/h</td>
<td>80</td>
<td></td>
</tr>
<tr>
<td>Road width</td>
<td>m</td>
<td>1.5+0.5+3+3+0.5+1.5 = 10</td>
<td></td>
</tr>
<tr>
<td>Number of traffic lanes</td>
<td>unit</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Type of pavement design</td>
<td>type</td>
<td>transitional</td>
<td></td>
</tr>
<tr>
<td>Design load group</td>
<td>–</td>
<td>AK-10</td>
<td></td>
</tr>
<tr>
<td>Type of coating</td>
<td>type</td>
<td>hard crushed rock</td>
<td></td>
</tr>
<tr>
<td>Maximum longitudinal gradient</td>
<td>%</td>
<td>60</td>
<td></td>
</tr>
<tr>
<td>Smallest radius of curves in the plan</td>
<td>m</td>
<td>300</td>
<td></td>
</tr>
<tr>
<td>Smallest curve radius in the longitudinal profile</td>
<td>m</td>
<td>5000 (convex), 2000 m (concave)</td>
<td></td>
</tr>
<tr>
<td>Shortest visibility distance</td>
<td>m</td>
<td>150 (for stopping), 250 m (for an oncoming vehicle)</td>
<td></td>
</tr>
<tr>
<td>Cross slope of the roadway</td>
<td>%</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>Cross slope of the kerb</td>
<td>%</td>
<td>60</td>
<td></td>
</tr>
<tr>
<td>Value of axial standard load</td>
<td>kN</td>
<td>100</td>
<td></td>
</tr>
</tbody>
</table>

Assessment and selection of road corridor options *Forecast of traffic flows along the projected route.* Construction of Mezen-Ness' and Naryan-Mar-Toshvilksa-Kotkino road sections is planned by 2028. Completion of the "Arkhangelsk - Naryan-Mar" transport communication - by 2030 with the construction of "Kotkino - Volokovaya - Dorogorskoe"
(Version 1 of the planning solution) or "Kotkino - Nizhnyaya Pyosha - Nes", as stipulated by Option 2 of the planning solution.

The intensity of traffic flows is evaluated for three scenarios (Fig. 5.):

- The actual intensity is assessed with respect to the distribution of demand along the traffic centres and with respect to vehicle occupancy, under two scenarios of traffic demand generation.

- The realistic scenario assumes that transport demand will remain at current levels and that there will be a moderate increase in motorisation.

- The optimistic scenario assumes achievement of parameters of socio-economic development, provided by existing documents of territorial and town-planning, the corresponding increase in the level of motorization of the population.

Provided the current demographic tendencies are preserved as well as there are no large-scale transport and industrial projects in the gravity zone of the projected object, the projected average annual daily intensity of traffic flows of a highway route in 2030 will be

- on Option 1 - up to 50 vehicles/day,
- on Option 2 - up to 270 vehicles/day and will considerably differ in sections.

Fig. 5. Traffic demand assessment, forecast annual average daily traffic (AADT).

Enlarged budget estimation of the project implementation. The capital costs of the Arkhangelsk - Naryan-Mar road project by sections of the route and by route alternatives are presented in the aggregate prices of 2021. Arkhangelsk - Belogorsky - Pinega - Kimzha - Mezen for 2029 - 2050 by route alternatives are presented in Table 5. For the period from the start of operation in 2029 to 2050 inclusive, 2 repairs and 1 capital repair over the whole length of the route as well as 1 additional capital repair on the sections of the route to be put into operation first in 2029 are to be implemented on this road. The total aggregated costs of the Arkhangelsk - Naryan-Mar road route development and operation project are presented in Table 4.
Table 4. Consolidated costs of the Arkhangelsk - Naryan-Mar automobile route according to the options and sections.

<table>
<thead>
<tr>
<th>Arkhangelsk - Naryan-Mar road</th>
<th>Total aggregate capital costs of the project, million roubles at 2021 prices (including VAT)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Route option 1</td>
</tr>
<tr>
<td>Capital investments</td>
<td>119 170</td>
</tr>
<tr>
<td>Operating costs for the period 2029-2050</td>
<td>65 500</td>
</tr>
<tr>
<td>Total</td>
<td>184 600</td>
</tr>
</tbody>
</table>

4 Discussion and conclusion

Two options for the Arkhangelsk-Naryan-Mar road route were considered. The first option has a length of 887 km and runs through sparsely populated areas, through the village of Volokovaya. The second route northwards, through 10 settlements, among which there is the town of Mezen, administrative centre of Mezen district. Its length is 940 kilometres.

A more feasible route option is Route 2, which runs along the shores of the Mezen Bay of the White Sea and the Chesh Bay of the Pechora Sea. Despite the fact that this route is 77 km longer than Route 1, it would be a transport artery passing through 10 settlements, which include the town of Mezen, the administrative centre of Mezen municipal district. Currently Mezen is connected with the regional centre, Arkhangelsk, by the existing road 11 OP RZ 11A-004 "Arkhangelsk - Belogorsky - Pinega - Kimzha - Mezen", which does not provide year-round transport links, due to the fact that some natural water barriers do not have permanent artificial structures (bridges) and are only provided with pontoon bridges in the summer and ice crossings in the winter. The settlements through which Route 2 will pass are inhabited by small indigenous peoples of the Far North, who are engaged in reindeer herding and organise fishing cooperatives. Fuel and food deliveries to such settlements today depend directly on summer delivery. This route option would allow year-round transport links to these settlements. Provided the current demographic tendencies are preserved and there are no large-scale transport and industrial projects in the gravity zone of the projected route, the estimated average daily traffic intensity of the road route in 2030 will be 50 vehicles/day for Option 1 and 270 vehicles/day for Option 2 and will considerably differ in sections.

The recommended routing of the Arkhangelsk-Naryan-Mar road route and its possible integration into the Barents transport system is presented in Fig. 6.

Fig. 6. Barents link: Vartius - Arkhangelsk – Naryan-Mar route.
5 Acknowledgement

1. NORTHERN AXIS – BARENTS LINK PROJECT IMPLEMENTATION UNDER KOLARCTIC 2014-2020 CBC PROGRAMME

2. JSC Institute Stroyproekt involved in the feasibility study for the construction of a road in the Arkhangelsk region and the Nenets Autonomous District.

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