Algorithm for regional clustering of road freight transport in the Russian Federation

N G Gavrilenko¹
¹Omsk Academy of the Humanities, Omsk, Russia
E-mail: gng1978@mail.ru

Abstract. The road transport system of the Russian Federation is a system for managing road freight transport, which includes three levels: the macro-level is the federal level of management, the meso-level is the regional level of management, and the micro-level is the level of a motor transport enterprise (transport subdivision). According to the Transport Strategy of the Russian Federation, the system of road freight transport is faced with the tasks of increasing competitiveness, improving quality indicators, safety and environmental friendliness of transportation. Within the framework of this paper, the meso-level of management is considered, and the solution of the indicated tasks is seen through the formation of clusters. The study was based on a review of scientific literature, study of data from the Federal State Statistics Service, the use of expert and logical methods, methods of description and analogy, as well as correlation analysis and mathematical optimization. The presented clustering algorithm made it possible to distinguish two groups of regions. The first group is a group of innovators, regions with the greatest opportunities for the implementation and dissemination of innovations. The regions of this group are the cores of clusters. The second group is a group of imitators, regions with less innovative potential. The regions were grouped around the cores according to geography and the dominant mode of transportation. As a result, seven regional clusters were obtained. Optimization measures are aimed at increasing the efficiency of management in the field of road freight transport and enhancing the development and dissemination of innovations at the meso-level.

1. Introduction
The road transport system is a multilevel control system. So, the authors of [1-4] hold that any economic system, including the transportation management system, like any complex one, must be considered at three levels: at the macro-level, meso-level and micro-level.

The macro-level of the road transport system reflects the features of management and development at the level of the road transport industry as a whole, the micro-level is described by individual enterprises that directly transport goods by road vehicles, or individual entrepreneurs operating in transport, as well as transport divisions of enterprises in other industries (intra-industrial transport).

Within the framework of this study, the meso-level of road freight transport in the Russian Federation is represented by regional road transport systems. The need to consider the development of the road transport system in the regional context is caused by the geographical factor, differences in the structure and volumes of trade between regions associated with the territorial division of labor and taking into account differences in the requirements imposed by production on transport in the process of modernization [Federal target program “Modernization of the transport system of Russia”], various
control systems of the region, where the dependence on the characteristics of the regional leaders is quite high [5].

A controlled meso-level system refers to enterprises, divisions and individuals (micro-level) of the region that carry out road freight transport. The governing system is represented by the executive body, the ministry responsible for the work of transport and road facilities, as well as other ministries of the region that influence the system of road transport in the region. Also, the Governor as the head of the region and the Legislative Assembly as the legislature are included in the system of governance.

Today, the system of freight road transport is faced with the tasks of increasing the volume of transport work, competitiveness, improving quality, safety and environmental friendliness [Transport strategy for the period up to 2030]. The solution of these problems at the meso-level is seen through the formation of regional clusters.

As foreign and domestic practice shows, clusters are a mechanism for increasing the efficiency of sectoral economic development [6-12], and also facilitate the development and implementation of innovations, including the introduction of digital technologies into management systems [13-15].

In 1998, M. Porter defined a cluster as “a group of geographically adjacent interconnected companies and related organizations operating in a specific area, characterized by common activities and complementary to each other” [16].

Considering the large number of approaches and definitions that clarify the concept of a cluster, which are described in domestic and foreign literature, we highlight the following criteria that characterize the cluster:

- regional binding;
- a mixed composition of participants, including commercial and non-commercial structures
- combination of different forms of coordination of interaction between participants.
- focus on innovations.

Within the framework of our study, a cluster is a group of road transport enterprises, enterprises that provide the formation of road transport infrastructure and public authorities in neighboring regions. The purpose of forming a cluster is to increase the effectiveness of strategic management at the regional level, including through the joint development and implementation of organizational and technological innovations. Regional clustering is aimed at obtaining the following positive economic effects:

1. Development of infrastructure in accordance with the needs of carriers.
2. Strengthening the “business-power” connection aimed at the formation and implementation of strategic documents within the cluster.
3. Development and dissemination of innovations from the core of the cluster (the region with the greatest resource potential).

2. Methods
Regional road transport systems are subsystems of the road transport system and represent its elements. A significant increase in the efficiency of its functioning is possible provided that the bifurcation point in the development of the system is reached, i.e. the implementation of a certain phase transition from the phase of less active functioning to the phase of more active functioning. Here we can trace an analogy with the theory of active collisions, within which the following three conditions are essential:

1. Elements must interact.
2. Elements must have the necessary energy (activation energy), therefore, the activation of all elements is desired (focus on the activation of inactive elements).
3. Effective interaction is possible only between active elements, also due to the synergy effect.
4. Elements must be correctly oriented relative to each other.

The solution to the problem of increasing the efficiency of the road transport system at the meso-level is seen by combining into clusters that include active and inactive elements (requiring activation due to the participation of the subject of macro-level control and active elements of the system) (Fig. 1).

![Diagram](image_url)

**Figure 1.** Activation of inactive system elements (AE - activation energy).

The first stage of our study requires the identification of active regional road transport systems, for which we will assess the dependence of the performance indicators of road freight transport in the regions on other characteristics of the regions. For the research period 2016-2018, the following relationships were obtained, taking into account the correlation coefficients of the analyzed data (Table 3).
The factor of transport proximity, a mathematical study was assigned a rating from 1 to 79. Of the 25 considered indicators, only 14 have the greatest impact on the activity of road freight transport, such as the population, the employed population, the value of the gross regional product, the cost of fixed assets in the economy, financial results, investments in fixed assets, the volume of work performed, services provided in different areas. Based on the selected indicators, each region in the study was assigned a rating from 1 to 79.

Taking into account the high dependence of the activity of road freight transport on infrastructure - the factor of transport proximity, a mathematical model of the problem with the input data was built:

\[ n - \text{total number of regions}; \]

\[ a_i - \text{key indicator of the innovativeness of the region } i \text{ (rating)}; \]

\[ c_{ij} - \text{indicator of transport proximity (the nearest distance by road) of regions } i \text{ and } j \text{ - the main indicator of cluster formation}; \]

\[ \text{Correlation coefficient between the indicator and the volume of transported cargo} \]

| No | Indicator                                                                 | Correlation coefficient between indicator and value of cargo turnover | Correlation coefficient between the indicator and the volume of transported cargo |
|----|---------------------------------------------------------------------------|-----------------------------------------------------------------------|--------------------------------------------------------------------------------|
| 1  | Territory area, thousand km'                                              | 0.348                                                                | 0.517                                                                         |
| 2  | Population as of January 1, 2017, thousand people                         | 0.946                                                                | 0.834                                                                         |
| 3  | Average annual number of employed, thousand people                       | 0.933                                                                | 0.820                                                                         |
| 4  | Average per capita cash income, rubles/month                              | 0.129                                                                | 0.161                                                                         |
| 5  | Average consumer spending per capita, rubles/month                        | 0.270                                                                | 0.285                                                                         |
| 6  | Average monthly nominal accrued wages of employees of organizations, rubles/month | 0.099                                                                | 0.178                                                                         |
| 7  | Gross regional product, million rubles                                   | 0.867                                                                | 0.810                                                                         |
| 8  | Fixed assets in the economy (at full book value; at the end of the year), million rubles | 0.858                                                                | 0.840                                                                         |
| 9  | Fixed capital investments, million rubles                                | 0.911                                                                | 0.919                                                                         |
| 10 | The volume of transported goods of own production, works and services performed on their own by type of activity: mining, million rubles | 0.656                                                                | 0.775                                                                         |
| 11 | The volume of transported goods of own production, works and services performed on their own by type of activity: manufacturing, million rubles | 0.909                                                                | 0.788                                                                         |
| 12 | The volume of transported goods of own production, works and services performed on their own by type of activity: production and distribution of electricity, gas and water, million rubles | 0.923                                                                | 0.854                                                                         |
| 13 | Agricultural production, million rubles                                  | 0.894                                                                | 0.762                                                                         |
| 14 | Retail trade turnover, million rubles                                    | 0.901                                                                | 0.778                                                                         |
| 15 | Balanced financial result of activities of organizations in the region, million rubles | 0.718                                                                | 0.649                                                                         |
| 16 | Scope of work by type of economic activity: construction, million rubles  | 0.927                                                                | 0.859                                                                         |
| 17 | Foreign trade with non-CIS countries (export), million USD                | 0.657                                                                | 0.579                                                                         |
| 18 | Foreign trade with non-CIS countries (import), million USD                | 0.620                                                                | 0.496                                                                         |
| 19 | Foreign trade with CIS countries (export), million USD                    | 0.768                                                                | 0.633                                                                         |
| 20 | Foreign trade with the CIS countries (import), million USD                | 0.697                                                                | 0.559                                                                         |
| 21 | Revenues of the consolidated budgets of the constituent entities of the Russian Federation, million rubles | 0.867                                                                | 0.796                                                                         |
| 22 | Share of unprofitable organizations,% of the total number of organizations | -0.214                                                               | -0.203                                                                        |
| 23 | Balanced financial result of transport organizations, million rubles     | 0.675                                                                | 0.579                                                                         |
| 24 | Number of road accidents, units per 100 thousand people                  | -0.076                                                               | -0.039                                                                        |
| 25 | Density of public roads with hard surface, km of tracks per 1000 km² of territory | -0.006                                                               | -0.095                                                                        |
m – number of selected additional production indicators, which are used to assess the proximity of regions to each other.

Analysis of the structure of the gross regional product and the correlation coefficients of the characteristics of the region with the values of cargo turnover and the volume of transported cargo in the regions made it possible to identify six key directions of transportation by type of activity: manufacturing, mining, agriculture, construction, retail trade; production and distribution of electricity, gas and water. Indicators of products in the designated areas determine the dominant types of transportation in the region. The calculations used arithmetic averages for the period 2016-2018. The share of the production indicator by type of activity \( p = 1,2,\ldots,m \) in the sum of indicators for six types of activity is denoted in the region \( i = 1,2,\ldots,n \) through \( b_{ip} \). In the model under consideration, \( m = 6 \), \( n = 79 \).

Output data:
- \( k \) – optimal number of clusters;
- \( J_1, J_2,\ldots,J_k \) – clusters;
- \( x_i \) – the number of the cluster that the region \( i \) belongs to.

Let us describe the general scheme of the algorithm. Let’s sort the regions in non-increasing order of the key indicator \( a_i \). Let us fix the number of clusters \( k \) and choose the first \( k \) regions with the largest values of \( a_i \) as the cores of the clusters \( J_1, J_2,\ldots,J_k \).

For each of the region \( i \), which is not a core, we find such a core \( j \) so that the index \( c_{ij} \) would be the largest, which means the greatest transport connectivity between \( i \) and \( j \). If for some region \( i \) this indicator turned out to be close for several cores, then we leave all options for further optimization. The proximity is determined by a certain threshold value of the difference between the two values (in this case, 10%).

Most of the clusters will now be tied to the cores, and a number of border regions will need to be additionally fixed. If the region is the core or entered into some cluster, then the variable \( x_i \) is assigned a fixed value \( x_i^* \). The rest of the \( x_i \) remain variable.

Further optimization is carried out according to the proximity of the regional parameters \( b_{ip} \) to the general indicators of the cluster. The set of indicators \( (b_{i1}, b_{i2},\ldots,b_{im}) \) is already normalized, since \( b_{ip} \) sets the share of the indicator \( p \) in region \( i \), and therefore \( \sum_{p=1}^{m} b_{ip} = 1 \) for all \( i = 1,2,\ldots,n \). For example, \( (b_{i1}, b_{i2},\ldots,b_{im}) \) for the Omsk region looks like \((0.003; 0.584; 0.044; 0.078; 0.240; 0.051)\). This vector was obtained on the basis of the following information: the production indicator in the area of mining is 3414 million rubles or 0.003 of the amount for six types of activities (1,215366 million rubles); in the area: manufacturing - 709347 million rubles (0.584); in the area: production and distribution of electricity, gas and water - 53,764 million rubles (0.044); in the area: agriculture - 94,311 million rubles (0.078); in the area: retail trade - 291,862 million rubles (0.240); in the area: construction - 62668 million rubles (0.051).

The proximity of regions \( i \) and \( j \) will be determined in rectangular metric:

\[
\sum_{p=1}^{m} |b_{ip} - b_{jp}|.
\]

This metric allows, first of all, taking into account the similarity of the largest coefficients \( b_{ip} \). The general objective function of the proximity of regions is as follows:

\[
\sum_{l=1}^{k} \sum_{i,j \in J_l} \sum_{p=1}^{m} |b_{ip} - b_{jp}|,
\]

where the average summation is carried out over all pairs of regions included in the cluster \( J_l \). It is necessary to find the minimum value of this function, which will characterize the total proximity of
regions across all clusters. After that, for each previously unassigned region \(i\), the number of the cluster \(x_i\) was specified, which includes this region.

Here it should be borne in mind that most of the regions are already tied to clusters and optimization is carried out only for free regions, while for non-tied regions, the choice is limited to several options (most often two). This allows the use of directed enumeration methods to find the minimum of the objective function. Such a minimization must be carried out for each \(k\) in a certain reasonable range and, comparing the objective functions for different values of \(k\), choose the optimal number of clusters. Target-specific search was performed based on the number of regions with the highest rating.

3. Results.
As a result of the calculations, the first group was obtained - a group of regions-innovators (according to Schumpeter). The first group should include 9% of the studied regions of the Russian Federation, in which 38% of the volume of transported goods and 34% of freight turnover are formed. These regions have maximum economic opportunities for the development and distribution of innovations. The regions of this group include the Moscow Region, the Sverdlovsk Region, the Krasnoyarsk Territory, the Leningrad Region, the Republic of Tatarstan, the Tyumen Region, and the Krasnodar Territory (Table 2).

| Group number | Number of regions | Share in the total volume of transported cargo, % | Share in freight turnover, % |
|--------------|-------------------|-----------------------------------------------|----------------------------|
| 1            | 7                 | 38                                            | 34                         |
| 2            | 72                | 62                                            | 66                         |

The second group - regions-imitators. The second group includes 91% of the regions, 62% of the volume of transported goods and 66% of freight turnover are formed in it.
Seven clusters were obtained, including road transport enterprises, enterprises providing the formation of road transport infrastructure and public authorities of neighboring regions (Table 3).

| Cluster number | Innovation region | Other regions |
|----------------|-------------------|---------------|
| 1              | Krasnoyarsk Region| Republic of Tyva, Jewish Autonomous Region, Republic of Altai, Irkutsk Region, Republic of Sakha (Yakutia), Chukotka Autonomous District, Kamchatka Territory, Primorsky Territory, Khabarovsk Territory, Sakhalin Region, Amur Region, Republic of Buryatia, Trans-Baikal Territory, Magadan Region, Republic of Khakassia |
| 2              | Tyumen Region     | Omsk Region, Kemerovo Region, Altai Territory, Tomsk Region, Novosibirsk Region |
| 3              | Sverdlovsk Region | Orenburg Region, Kurgan Region, Komi Republic, Perm Region, Chelyabinsk Region, Republic of Bashkortostan |
| 4              | Republic of Tatarstan | Mari El Republic, Udmurt Republic, Penza Region, Kirov Region, Ulyanovsk Region, Chuvash Republic, Samara Region |
| 5              | Moscow Region, including Moscow | Smolensk Region, Tver Region, Vladimir Region, Kaluga Region, Bryansk Region, Ivanovo Region, Tula Region, Kostroma Region, Lipetsk Region, Kursk Region, Volgoda Region, Yaroslavl Region, Ryazan Region, Novgorod Region, Oryol Region, Republic of Mordovia, Nizhny Novgorod Region |
| 6              | Leningrad Region, including St. Petersburg | Arkhangelsk region, Murmansk region, Kaliningrad region, Republic of Karelia, Pskov region |
| 7              | Krasnodar Region  | Chechen Republic, Republic of Dagestan, Stavropol Territory, Astrakhan Region, Republic of Crimea, Republic of Ingushetia, Republic of Adygea, Kabardino-Balkarian Republic, Karachay-Cherkess Republic, Republic of North Ossetia, Alania, Rostov Region, Voronezh Region, Belgorod Region, Volgograd Region, Saratov Region, Astrakhan Region, Tambov Region, Republic of Kalmykia |
4. Conclusions
The increase in the efficiency of management of road freight transport at the meso-level is ensured by the formation of seven clusters. At the core of each cluster, there is a region with the greatest opportunities for the development and implementation of innovations. This region coordinates the actions of neighboring regions in the areas of development indicated by the Transport Strategy. Coordination is carried out through joint activities to improve road infrastructure, holding conferences, developing and implementing digital technologies: creating an electronic order base and a digital system for monitoring the implementation of strategic targets set for the industry, etc. Control and motivation of the cluster core to achieve the established Transport Strategy indicators are carried out by the subject of macro-level control. The positive effect of this event is confirmed by the results of an expert survey of control subjects at the meso- and micro-levels.

References
[1] Shastitko A E 2019 Problems of economics No 5 P 5-25 https://doi.org/10.32609/0042-8736-2019-5-5-25
[2] Mann S 2011 Sectors matter! Exploring mesoeconomics New York; Springer
[3] Menard C 2017 Meso-institutions: The variety of regulatory arrangements in the water sector Utilities Policy. Vol 49, pp 6-19
[4] Menard C, Jimenez A, Tropp H 2018 Addressing the policy-implementation gaps in water services: The key role of meso-institutions Water Internaional, Vol 43, No 1, pp 13–33
[5] Borodulina S A, Gavrilenko N G 2020 Science of man: humanitarian research No 1 P 217-226 DOI 10.17238/issn1998-5320.2020.39217
[6] Duranton G 2011 California dreaming: The feeble case for cluster policies// Review of Economic Analysis P 3-45
[7] Vivian Xu 2019 Journal of Retailing https://doi.org/10.1016/j.jretai.2019.11.004
[8] Mo C, Yang L 2020 Structural characteristics of industrial clusters and regional innovation Elsevier March https://doi.org/10.1016/j.econlet.2020.109003
[9] Felzenszttein C, Deans R 2018 Coopetition in regional clusters: Keep calm and expect unexpected changes // Industrial Marketing Management/ Elsevier Vol 69, February, Pages 116-124 https://doi.org/10.1016/j.indmarman.2018.0.1.013
[10] Grillitsch M, Rekers J V 2019 When drivers of clusters shift scale from local towards global: What remains for regional innovation policy?// Geoforum/ Elsevier Volume 102, June, Pages 57-68 https://doi.org/10.1016/j.geoforum.2019.03.010
[11] S Thomas S Ng, Frank N G 2018 Necessities and challenges to strengthen the regional infrastructure resilience within city clusters// Procedia Engineering/ Elsevier Vol 212, Pages 198-205 https://doi.org/10.1016/j.proeng.2018.01.026
[12] Babkin A V 2017 Trends in the development of the economy and industry in the context of digitalization -658 p – doi:10.18720/IEP/2017.6.
[13] Charykova O G, Markova E S 2019 Regional clustering in the digital economy // Economy of the region –V 15, No 2 – P 409-419 doi 10.17059/2019-2-8
[14] Risin I E, Treshchevsky Yu I 2016 Regional cluster policy Conceptual, methodological and instrumental support 165 pp - doi: 10.15216 / 978-5-4365-0439-1.
[15] Babkin A V 2017 Digital transformation of the economy and industry Problems and prospects 807 pp – doi: 10.18720/IEP/2017.4.
[16] Porter M E 1998 On Competition (Harvard Business School Press: Boston)
[17] Gorokhova T, Pushkareva L, Pushkarev M 2020 E3S Web of Conferences 164 09034 doi:10.1051/e3sconf/202016409034