Perspective directions of development of oil refining industry in the regions of Russia

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Abstract. Russia is a key player in the global liquid fuel market and acts as one of the world leaders in the extraction and refining of crude oil, as well as in the export of petroleum products. But for a long period of time, the Russian oil industry specialized in production, and only in early 2010 the problem of the development of the oil refining sector received due attention. However, the refining industry is still lagging behind in terms of efficiency, which is reflected in several key quality parameters: the Nelson complexity index; the share of straight-run fuel in the production of oil refineries; production of high-quality fuel per ton of refined raw materials. In this study, the authors conducted a comprehensive analysis of the current state and structure of the oil refining industry in Russia. Also, on the basis of the clustering method, oil refineries were grouped in terms of maximum similarity of indicator values. In the course of the study, the authors conducted a comprehensive analysis of the current state and structure of the oil refining industry in Russia. The purpose of the study was in conducting a comprehensive analysis of the current state and structure of the oil refining industry.

1. Introduction

Russia is a key player in the global liquid fuel market and acts as one of the world leaders in the extraction and refining of crude oil, as well as in the export of petroleum products. But for a long period of time, the Russian oil industry specialized in production, and only in early 2010 the problem of the development of the oil refining sector received due attention. However, the refining industry is still lagging behind in terms of efficiency, which is reflected in several key quality parameters: the Nelson complexity index; the share of straight-run fuel in the production of oil refineries; production of high-quality fuel per ton of refined raw materials [1].

The subsequent development of the oil refining sector is one of the priority areas for the development of the industry, established by the Energy Strategy of Russia until 2035. The directions of development and operation of oil refining in Russia are determined by the structural and technological changes that have occurred in connection with the modernization of the industry. In addition, annually tightens the requirements and standards for the quality of raw materials and processed products. The oil refining industry of Russia is also undergoing certain changes in the field of organizational and regional structure, the redistribution of the role of the main market participants. Despite the high degree of concentration and centralization of production and capital in the oil refining
industry in Russia, in recent years there has been a steady upward trend in the role of independent oil refiners, while at the same time reducing the share of vertically integrated oil companies. Despite the high degree of concentration and centralization of production and capital in the oil refining industry in Russia, in recent years there has been a steady upward trend in the role of independent processors, while at the same time reducing the share of vertically integrated oil companies. This is due to the growth of refining capacity in the regions where, until recently, there was no own oil refining, as well as parts in the regions from which oil products are exported abroad.

The primary oil refining in Russia in 2017 remained at the level of the previous year and amounted to 279.5 million tons, the level of loading of primary oil refining facilities increased slightly: from 86.4% to 86.7% (figure 1). The decline in oil refining in Russia occurred in 2014–2016. All changes in the industry in recent years were largely related to legislative decisions in the field of taxation, limiting the export of dark, low-quality petroleum products (fuel oil and partly diesel fuel), used abroad as raw materials.

![Figure 1. Dynamics of primary oil refining in the Russian Federation in 2005-2017.](source)

In this article, the authors identified the key problems facing the Russian oil refining sector: the problem of increasing refining depth and, as a result, increasing the output of gasoline and diesel fuel, reducing fuel oil; the issue of upgrading refineries for the production of environmentally friendly fuels of EURO standards; transfer of the tax burden from the external market to the domestic market (tax maneuver). This problem and its solutions through a long-term forecast of the main industry and economic indicators of the industry have already been raised and described using the SCANER model complex developed at the institute IEI RAS [2]. This approach demonstrated its feasibility during the development of global and Russian energy forecasts of IEI RAS [3] and was adopted for the analysis of key technical and economic parameters of oil refining by several authors. The forecast allowed them to assess changes in the sector, the dynamics of the internal fuel balance and export potential.

However, this issue requires further study in view of its relevance and timeliness; improvement of legislation and government management in the field of oil refining is also expected, which in turn requires sound calculations and forecasts through more sophisticated forecasting and modeling methods. To solve these problems requires more complex tools. As such a tool, we took a cluster analysis, which has already been successfully used in the work on forecasting the demand for oil and oil products [4].

Thus, the main objective of the study was to conduct a comprehensive analysis of the current state and structure of the oil refining industry in Russia. Based on the clustering method, oil refineries of Russia were grouped in terms of maximum similarity of indicators values.
2. Methods of research
In the course of the study, the authors conducted a comprehensive analysis of the current state and structure of the oil refining industry in Russia. Also, based on the clustering method, Russian refineries were grouped by the indicators of maximum similarity of indicators. In the general case, cluster analysis is designed to combine objects into clusters in such a way that the most similar objects fall into one cluster, while objects of different classes are the most different from each other. The main steps of the created algorithm are described below:

**Stage 1. Preparation.**
- Compiling a database of indicators for factories:
  The database was a table in which 24 factories are placed vertically, and 6 main indicators are located horizontally, with the help of which the measure of similarity or difference of the objects of analysis will be determined.
- Justification of the choice of indicators:
  6 indicators were selected that are essential for evaluating the activities of the refinery (table 1).

| Variable | Variable description                   |
|----------|---------------------------------------|
| X1       | Production of motor gasoline, thousand tons |
| X2       | Diesel fuel production, thousand tons  |
| X3       | Gross fuel oil, thousand tons          |
| X4       | Primary oil refining, thousand tons    |
| X5       | Depth of oil refining, %               |
| X6       | Load of facilities for primary oil refining, % |

**Stage 2. Conversion of data to comparable form.**
In view of the fact that the data selected for analysis have a different measurement scale, it was advisable to bring them to a comparable form, which can be used to calculate the measure of the difference between factories. For this, the maximum value for each indicator was assigned to one, and the values of other factories were normalized relative to the maximum value.

**Stage 3. Finding a measure of the difference between the analyzed objects.**
To begin the distribution of factories to clusters, it was necessary to choose a measure for which it would be determined whether factories are objects with similar values and at what level they are defined in one cluster. As such a measure was used Euclidean distance.

**Stage 4. Clustering objects.**
- Finding the minimum difference between factories and combining them into one cluster;
- Creating a new table with distance measures with plants united in one cluster. When forming the matrix of distances, choose the smallest value from the values of the combined objects;
- Finding a new minimum value, combining objects into one cluster, drawing up a new distance matrix;
- Continue the process until two clusters remain.

Thus, when conducting cluster analysis on the basis of the “close neighbor” principle, we managed to obtain two clusters that are the most distant from each other.

**Stage 5. Presentation of results by dendrograms.**
To visualize the clustering process, it is necessary to build a graph used to present the results of hierarchical clustering. The dendrogram shows the degree of closeness of individual objects and clusters, and also graphically demonstrates the sequence of their combination or separation. The number of levels of the dendrogram corresponds to the number of steps to merge or divide clusters.

**Stage 6. Cluster’s description**
The cluster’s description contains general information about each plant included in this cluster, as well as some general parameters and data confirming the uniformity of the groups. To describe
specific clusters, it is necessary to choose the level that will determine these clusters (chose the number of described clusters). When the distance between the merged clusters increases significantly, the dendrogram shows a significant difference between the distances at which the clusters begin to merge, which meaningfully means entering a cluster of significantly inhomogeneous objects.

The following sources became an information base for processing and using statistical information: the Federal State Statistics Service, the Federal Tax Service, the Ministry of Economic Development of Russia, the State Balance of Russia, reference, statistical information and publications on the results of the development of the fuel and energy complex of Russia.

3. Results and discussion

According to the described clustering algorithm of oil refineries, the following process was carried out: at stage 1, the initial database for 2017 was compiled for 24 factories with consideration of 6 indicators (table 2).

Table 2. Source database with indicators for factories, 2017.

| Refinery Name                  | Production of automobile gasoline, ths. tons | Production of diesel fuel, ths. tons | Gross fuel oil, ths. tons | Primary oil refining, ths. tons | Depth of oil refining, % | Load of facilities for primary oil refining, % |
|-------------------------------|----------------------------------------------|-------------------------------------|--------------------------|--------------------------------|--------------------------|-----------------------------------------------|
| Angarskaya NCC                | 1368.4                                       | 2695.9                              | 820.1                    | 9627.0                         | 91.5                     | 94.5                                          |
| Achinsky                      | 976.3                                        | 1938.6                              | 1592.8                   | 6323.2                         | 74.8                     | 84.3                                          |
| Komsomolsky                   | 547.8                                        | 1855.5                              | 160.2                    | 6438.5                         | 97.5                     | 80.5                                          |
| Kuibyshevsky                  | 789.3                                        | 1609.6                              | 1753.6                   | 5195.3                         | 66.3                     | 74.3                                          |
| Novokuibyshevsky              | 1397.0                                       | 2213.5                              | 2037.0                   | 8050.2                         | 74.7                     | 84.6                                          |
| Ryazanskaya                   | 3033.0                                       | 3057.0                              | 3822.4                   | 13335.2                        | 71.3                     | 77.8                                          |
| Saratovsky                    | 943.3                                        | 1761.2                              | 1115.3                   | 5770.9                         | 80.7                     | 82.4                                          |
| Syzransky                     | 1080.9                                       | 1955.3                              | 921.4                    | 5941.4                         | 84.4                     | 69.9                                          |
| Volgogradnepetropererabotka   | 1894.0                                       | 6141.4                              | 994.4                    | 14094.9                        | 92.9                     | 89.8                                          |
| Nizhegorodnepetroorgsintez    | 4139.8                                       | 3894.6                              | 3512.9                   | 14215.1                        | 75.2                     | 83.6                                          |
| Permnefteorgsintez            | 1665.6                                       | 5076.4                              | 367.2                    | 12598.9                        | 97.1                     | 96.2                                          |
| Ukhtanepetropererabotka       | 432.4                                        | 752.8                               | 576.5                    | 2310.4                         | 75.1                     | 58.1                                          |
| Khabarovsky                   | 623.9                                        | 912.1                               | 110.7                    | 4669.0                         | 97.6                     | 93.4                                          |
| Moscowsky                     | 1964.5                                       | 1723.7                              | 1806.2                   | 9371.3                         | 80.7                     | 77.1                                          |
| Omsky                         | 4826.8                                       | 6210.7                              | 1510.7                   | 19576.9                        | 92.3                     | 88.1                                          |
| Kirishinefteorgsintez         | 2549.5                                       | 6535.5                              | 7109.3                   | 18187.2                        | 60.9                     | 90.5                                          |
| Yaroslavnepetroorgsintez      | 2590.1                                       | 4221.7                              | 5052.0                   | 15479.3                        | 67.4                     | 103.2                                         |
| Gazprom mining Astrakhan’     | 927.3                                        | 661.0                               | 328.7                    | 2047.4                         | 83.9                     | 61.9                                          |
| Bashneft-Novoil               | 865.8                                        | 1685.4                              | 957.5                    | 6873.4                         | 86.1                     | 97.1                                          |
| Bashneft-UNPZ                 | 1546.1                                       | 2625.9                              | 1744.0                   | 5057.2                         | 65.5                     | 76.6                                          |
| Bashneft-Ufanneftekhim Gazprom| 1354.7                                       | 2414.1                              | 506.2                    | 6990.2                         | 92.8                     | 73.6                                          |
| NeftekhimSalavat              | 916.2                                        | 1512.8                              | 578.8                    | 6476.5                         | 91.1                     | 64.8                                          |
| Orsknefteorgsintez            | 744.4                                        | 911.5                               | 698.6                    | 4743.8                         | 85.3                     | 82.4                                          |
| TAIF-NK                       | 479.1                                        | 2227.7                              | 2034.3                   | 8175.4                         | 75.1                     | 98.0                                          |

Source: compiled by the author on the materials of the oil and gas magazine “Info-Tech”
Further clustering of refineries was carried out and clusters were selected, each of which contains refineries whose values are homogeneous.

At stage 5, a dendrogram was built (figure 2), which most vividly characterizes the degree of closeness of object values relative to each other.

Moving from top to bottom, refineries have more uniform indicators, combine and form clusters. Each node in the diagram above represents a union of two or more clusters; the position of the nodes on the vertical axis determines the distance at which the respective clusters were combined.

In the first cluster, the Omsk Oil Refinery is one of the largest oil refineries in Russia. It is owned by the company Gazprom Neft. It is one of the most modern oil refineries in Russia and one of the largest in the world; therefore, its characteristics differ significantly from other refineries presented for analysis.

The second cluster includes the largest number of factories in Russia. All enterprises represented in this cluster are leading refineries with an average primary oil refining of 6121 thousand tons, a refining depth of 82.5% and a workload of 79.6%.

The third cluster included two refineries of the Lukoil Company: Volgograd refining and Permnefteorgsintez, which exceed the average refineries, and show some of the highest processing results and plant utilization compared to many other refineries in Russia.

The fourth cluster consists of just one plant, Yaroslavnefteorgsintez, one of the largest oil refineries in Russia, owned by Slavneft.

The fifth cluster united 2 factories: the Ryazanskaya Refinery of the company Rosneft’ and Nizhegorodnefteorgsintez Lukoil. The enterprises are characterized by large volumes of primary oil refining and the largest production volumes of motor gasoline (after the Omsky Refinery). Ryazanskaya Refinery is the largest refining enterprise of the company Rosneft’ with primary oil refining in the amount of 13335 thousand tons and the production of motor gasoline - 3033 thousand tons. Nizhegorodnefteorgsintez is an enterprise of the fuel-oil profile in the Nizhny Novgorod region.
The sixth cluster included one oil refinery of the company Surgutneftegaz (Kirishinefteorgsintez), which is the only refinery in the North-West of Russia and is among the five largest refineries in the country. The company produces 2549 thousand tons of motor gasoline and 6535 thousand tons of diesel fuel per year.

4. Conclusion
In the history of the development of the oil refining industry in Russia since 1945, eleven stages can be distinguished. The most important stages can be considered the periods of 1998-2002 and 2011-2014, which are characterized by rapid development and active modernization of installations [5-9].

An analysis of the current state of the oil refining industry in Russia has shown that at present there has been a slight decrease in refining volumes and a drop in the level of loads due to the decline in world oil prices and, accordingly, the oil refining industry has adapted to the new conditions. In general, the following situation is observed:

1. In terms of refining capacity, the Russian oil refining industry ranks third among all countries, after United States and China;
2. The depth of oil refining has increased significantly over the past 10 years and in 2017 reached 81.6% on average in Russia;
3. The production of motor gasoline and diesel fuel does not change, while over the past 2 years, the production of fuel oil has decreased by more than 20 million tons;
4. Vertically integrated companies dominate among Russian oil companies. The share of these companies is 70% of Russia's primary processing;
5. The leader in primary refining among Russian companies is Rosneft, whose volume in 2017 amounted to 73.7 million tons (more than a quarter of the processing of all Russian companies). The second place is occupied by Lukoil, with a 15% share of the total oil refining in Russia.

Each cluster identified using the described algorithm included those refineries that are homogeneous in their parameters of primary processing, production of basic petroleum products, the depth of oil refining and the loading of primary processing equipment. Each of the selected clusters was analyzed:

1. One of the clusters includes the absolute majority of the oil refineries under consideration, which is due to their high similarity and average indicators in Russia;
2. Three clusters include just one plant each: Omsky Refinery, Kirishinefteorgsintez and Yaroslavnefteorgsintez, which are the largest factories in Russia and in the world and also they have primary processing volumes of over 15000 thousand tons per year;
3. Two clusters included two factories each, having not the highest rates, but higher than the average in Russia.

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