Improving snow removal efficiency in Arctic cities

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Abstract. The Arctic zone of the Russian Federation is quite urbanized. However, due to climatic conditions, the population of Arctic cities has recently declined. The task of the State is to change this trend. One of measures is creation of the comfortable urban environment which consists in modernization and improvement of quality of living conditions. It would seem that this task should be solved at the level of the city municipality [1], but if there are identical climatic restrictions for all cities, it is necessary to develop a single effective regional mechanism to overcome them. It is about snow removal in Arctic cities, where winter lasts more than six months, and the amount of precipitation sometimes exceeds the average values several times. And it is impossible to be prepared for this, because in such cases the issue of road safety and comfort of the urban environment for local residents and guests of the city is acute. The winter of this year in the Murmansk region showed that the existing snow removal system needs to be modernized. To this end, the author studied the Russian and foreign experience of snow removal in northern cities and developed recommendations to increase its efficiency.

1. Introduction
According to studies [2] in 2017 the population of the Arctic zone of the Russian Federation was 2,371,655 people, of whom 89.3% lived in cities. And it would seem that living in cities should be more comfortable than in small settlements away from transport highways, but in winter the concept of "transport accessibility" becomes rather blurred due to heavy snowfalls.

And it seems that all northern regions are ready for the onset of a long winter, but it happens that unpredictable elements take utilities by surprise and there is a "snow collapse." And this winter is a good confirmation of that.

In 2019, winter in the Murmansk region came smoothly and snow removal, since October, took place in the planned mode. However, since January 2020 there has been a record amount of precipitation for the region, for which neither utilities, nor city authorities, nor guests of the region were clearly ready.

And the problem is not even the amount of snow falling, but rather the insolvency and unmanageability of the process of removing it:

First, there is no clear mechanism for snow removal and snow removal, from informing citizens about the forthcoming removal of yard areas to distributing snow-clearing equipment throughout the city.

Second, the lack of responsibility of citizens for undelivered transport makes snow removal in yards much more difficult.

Third, snow removal is not established due to lack or shortage of storage places.
All these factors negatively influence the formation of public opinion about the work of management companies and municipal services and contribute to the increase of social tension among the local population.

2. Foreign snow removal experience

In Iceland, the main source of heat and electricity is geothermal sources: they heat residential buildings and offices. In addition, water is also used to fight snow: pipes through which hot water enters houses are laid under roads along the streets. This allows not to use reagents, sand and even snow-clearing machines: ice and snow simply melt. Thus, the provision of energy to homes, as well as snow removal in Iceland, occur in an environmentally friendly and natural way.

In some cities in Japan, such as Sapporo, about five meters of snow may fall in winter at a time, three times more than in Moscow. To cope quickly with clearing the city, carriageway and sidewalks in major cities are fueled by batteries installed under the road surface. However, in parts of the city where such a system is not installed, people move around the ice: the use of reagents is prohibited in the country. Salt, sodium chloride, is only allowed on high-speed motorways to avoid accidents, because studded rubber is also prohibited in Japan.

In areas where several meters of snow fall overnight, the tracks may be completely asleep. In such cases, the heating system is inefficient, and another approach is used: the drilling machine breaks the way for the rest of the equipment, and then excavators pour snow on the shoulders and level the «snow walls». Narrow snow tunnels with a two-story house and above are formed along the roads.

In the Nordic countries, the authorities refused to use the reagent because of its environmental damage. Here utilities do not clean snow to asphalt, but leave a layer of several centimeters. It is rolled with special machinery and sprinkled with granite crumb or gravel. This method does not eliminate the ice, but improves the grip on the road. Materials are used many times: in spring granite and gravel are collected by special vacuum cleaners, washed and taken to warehouses where they are stored until the next winter.

In Sweden, sand mixed with hot water is sprayed on the ground snow. This allows you to maintain a good grip on the road for longer, up to seven days. However, such a mixture cannot be reused. In Finland, in times of heavy snowfalls, when snow-clearing services fail on their own, residents are also attracted to clearing cities. After short training, they receive equipment and clean small areas of urban territory themselves.

In the northern states of America, the responsibility for snow removal is divided into three levels: public utilities clean only the main streets and major highways, roads and smaller streets are cleaned by private companies, and space at private houses is obliged to clean their residents. If the citizens have not cleared their territory within 24 hours, they are issued a fine. Such a system makes cleaning more rapid: all major urban areas are cleared within three hours of the beginning of the snowfall.

As in Russia, the US uses a reagent that damages both the environment, motorists, and citizens. But the snow mixed with the reagent in America is not discounted on the shoulders of the streets, but quickly removed and then disposed of [3].

3. Improving Snow Removal Efficiency in Russia

In Russia there is experience in renouncing reagents. In St. Petersburg, for the second year, sand mixture and granite crumb have been used to clean the roadway, and snow is removed from sidewalks on the shoulders, and then removed and disposed of. Citizens walk around the clean city with beautiful white snow and in whole shoes. The number of complaints about paw burns in animals, according to the Veterinary Hospital, decreased in the city this year to zero. The easiest alternative for Moscow may be the experience of the Nordic countries and St. Petersburg: the use of granite crumb, gravel or sand instead of reagent, as well as the involvement of private companies in the cleaning of the city.

However, the issue of snow removal is most acute in the northern part of our country, in its Arctic zone.
For example, in 17 days of January 118.3 mm of precipitation fell in Kirovsk, Murmansk region. This is almost 2.7 times more than in neighboring Apatity and 4.1 times more than in Monchegorsk. In the Murmansk region it is in these cities in winter according to many years of observations the largest amount of snow falls.

In Kirovsk, for 17 days of January, the average monthly rainfall rate has already been exceeded by 1.7 times. According to observations for 30 years, 71.4 mm of snow fell on average in January (figure 1) [4].

![Figure 1. Total amount of precipitation in the cities of Murmansk region in the beginning of 2020. Source: [4]](image)

In this regard, the model of increasing the efficiency of snow removal will be considered on the example of the city of Kirovsk, Murmansk region, in which this year an unpredictable snow winter was issued.

In addition, one of the features of the city of Kirovsk is that the city is positioned as a ski resort. Therefore, the comfort of the urban environment should be felt not only by the locals, who are used to the harsh winter of their native region, but also by the guests of the city.

To this end, the author has developed a project to increase the efficiency of snow removal in northern cities, based on the model of solid municipal waste management. The analogy is that it is up to the regional operator to coordinate snow removal in the Arctic.

In addition, snow collected from city streets has been repeatedly equated with waste [5], [6], [7]. Therefore, it is necessary to approach the removal of such snow with responsibility.

So, suppose that snow removal in Arctic cities is carried out by a regional operator - an organization that removes, exports and stores snow and snow on specially equipped polygons.

At the same time, it is important to note that the regional operator is not a management company. I believe that managing companies in northern cities already face the difficult task of keeping the housing stock in good condition. Therefore, when they throw all forces to remove snow from near-house areas, tenants of apartment buildings suffer from the leakage of melted waters from the roofs of houses and with other problems related to the maintenance of common property.

Polygons within the framework of this project should be understood as equipped sites with drainage system located on land plots owned by the region or municipality, provided to the regional operator for free use for the whole duration of the agreement.
The agreement with the regional operator, in turn, should be concluded for a period of 5 to 10 years following the results of the competitive selection.

In order to organize the activities of the regional operator, it is necessary to develop a regulatory framework, including:
- Federal law regulating snow handling in the Arctic zone of the Russian Federation;
- Normative and legal acts regulating the development of regulations and tariffs for snow collection and export in the constituent entities of the Russian Federation.

Prices for snow removal and snow removal should be set on the basis of tariffs. Tariff regulation will allow to accumulate annually a certain amount of income, part of which should form a reserve fund. The Fund's funds can be used both for snow-clearing equipment servicing and for overtime work during periods of excessive precipitation.

A uniform tariff should be established for a specific region and charged to citizens in a similar way to the fee for solid municipal waste management services, reducing by this amount the fee for maintenance and repair of housing. Such a system will allow the redistribution of funds in accordance with the real need among cities, where different numbers accumulate different amounts of funds for the maintenance of the yard territory: For example, in Kirovsk the population is half that of Apatite, and precipitation on the contrary falls more, so it is necessary to find more funds for cleaning, while funds for snow removal in Apatite settle in the budget of management companies.

Responsibility for timely cleaning should also be shared:
- The city authorities are responsible for the timely submission of applications to the regional operator for the cleaning of public city roads and inter-quarter passes;
- Organizations and entrepreneurs - for submitting applications for cleaning owned or rented territory,
  - Management companies - for submitting applications for cleaning of the yard area,
  - Local residents - for the removal of motor vehicles from the territory requiring snow removal,
  - Regional operator - for timely execution of applications with provision of feedback.

Applications should be accepted 24 hours a day online through a specially designed website and mobile application. With the help of a specially designed software application, applications will be accepted automatically, analyzed and grouped by type of work:
- Cleaning of the yard area,
- Removal of collected snow.

Grouping of applications by street name and house number will avoid their duplication and will form the optimal cleaning route for working personnel and equipment.

As the application is executed, feedback will also be provided via the website and mobile application in the form of application execution notices.

At the same time, a system of fines for individuals and legal entities should be developed. For example, a fine for an undelivered vehicle from a yard area that prevents it from being cleaned may be about 500 rubles, and similar to other fines, it may be repaid within 20 days with a discount of 50%. For the same owners of vehicles who leave their vehicles on the territory of socially important facilities, fines can be increased.

The order of snow removal remains unchanged:
I stage - federal routes and roads, as well as long-distance communication,
II stage - central streets of the city and roads to socially important objects,
III stage - yard areas.

In order to inform individuals and legal entities about the forthcoming cleaning, it is necessary to synchronize the website of the regional operator, as well as the mobile application with the Unified identification and authentication system State Services, as well as to develop an interactive map of the city, which can be available online on the official website of the regional operator and in the mobile application. An example of an interactive map, which can be based, for example, on the service Yandex.Maps, is shown in figure 2.
Figure 2. Interactive map of snow removal in the city of Kirovsk, Murmansk region.
Source: it is developed by the author. Symbols:
- the snow-removing works are completed
- snow-removing works are conducted
- impassable section of the road

- snow fill ready for removal
- travel is temporarily restricted due to snow-clearing equipment operation

Thanks to this service drivers will be able to assess the situation on roads and in yards in advance.
In addition, the digitalization of snow removal is in line with the Strategy for the Development of the Information Society in the Russian Federation [8].

Organization and maintenance of snow collection grounds should be carried out on free land plots provided to the regional operator for free use for the duration of the agreement.

At the same time, the landfill should be organized in such a way that melted waters do not enter local water bodies, and gravel crumb can be collected and stored in summer time, that is, the landfill should be organized on a solid asphalt (concrete) surface with a drainage system.

With several polygons at its disposal throughout the region, the regional operator will be able to analyze their occupancy rate and distribute the collected snow to the nearest free polygon, as the local one is filled.

The environmental friendliness of this project consists in the replacement of reagents and sand with granite crumb, the deposits of which are so rich in the Murmansk region. The experience of the Nordic countries in snow removal shows the effectiveness of this method of snow control, which consists in the possibility of repeated use of granite crumb and absence of negative impact on the environment.

However, in order to introduce granite crumb, it is necessary to revise a number of regulatory documents, including the Resolution of the State Committee for Construction of the Russian Federation of 27.09.2003 № 170 «About the approval of Rules and norms of technical operation of housing stock» [9].

At the same time, before the transition from sand and reagents to granite crumb, as well as with timely snow removal from the streets of the city, there will be no need to classify snow as a waste. At present, however, it would be relevant to store such snow on solid municipal waste landfills, transferring it to the relevant regional operator for further disposal.

Snow removal and snow removal can also be monitored online through website statistics or in a mobile application.

In addition, the implementation of this project implies the creation of new jobs for the population of northern cities, which is especially relevant for single towns of AZRF [10].
Thus, the presented project to increase the efficiency of snow removal in the cities of AZRF is intended to solve the following tasks:

- To optimize the process of snow removal due to the possibility to redistribute equipment between the cities of the region depending on the amount of precipitation in them;
- Visualize the snow removal process during the implementation of the interactive map;
- Organize online acceptance of applications with feedback by means of the introduction of an automatic information system;
- To increase the level of responsibility of drivers for timely cleaning of vehicles from yard areas by introducing a system of administrative fines;
- Make the process of snow removal more environmentally friendly by replacing reagents and sand with granite crumb and transferring contaminated snow for disposal to the regional operator for solid household waste management.

4. Conclusion
In conclusion, I would like to note that the topic of snow removal in the AZRF will always be relevant, so it is so important to make this process uninterrupted and effective. In addition, timely and high-quality snow removal creates all conditions for comfortable accommodation in the territory of AZRF both local residents and guests of the city, ensures road safety and unhindered operation of emergency services.

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