Determination of the period of operation of winter forest road using climate data statistics

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Abstract. Improving the technology of logging is one of the main directions of increasing the efficiency of logging. The logging industry is highly dependent on climatic conditions in the logging areas, which are very diverse. Since logging is most often carried out in areas with poor transport development, and timber is transported mainly by winter roads, they are subject to seasonality of work. It is necessary to plan the construction of winter roads beforehand to increase the efficiency of the logging process. Within the framework of these studies, using probabilistic approach, a methodology that determines the duration of winter logging roads in the Yenisei region of the Krasnoyarsk Territory has been developed. This technique allows to plan the dates of timber removal from the cutting area during the harvesting season, improve the quality and service life of the road. It helps to organize the logging process of the enterprise more rationally, significantly reducing the cost of additional investments in the construction of the winter road and its maintenance. This methodology and web application can be used to solve other problems in industries that depend on climatic conditions.

1. Introduction
In recent years an intensive search for the development of the timber industry in Russia and a way of overcoming the crisis phenomena in this sphere has been carried out. One of the main directions for increasing the efficiency of logging by most enterprises is the improvement of technology for logging. There are no other industries depending on climatic conditions as the logging industry does. Logging is carried out in vast territories, occupying almost half of the country, and in this regard, the climatic conditions in which loggers operate are extremely diverse. In particular, the duration of steady frosts and the number of days with very low temperatures are important for logging operations. Logging of harvested forest products also depends on climatic factors, since logging is most often carried out in areas with poor transport development and 80% of logging is carried out in winter roads. Krasnoyarsk Territory is no exception. The issue of planning the dates of certain logging operations, and especially planning the dates of the construction of winter roads, is directly related to weather conditions. Very often, the construction and operation of winter roads is carried out only on the basis of subjective experience, and recommendations based on scientific methods are not taken into account. As a result, the volume of harvesting may not correspond to the possibility of timber transportation (road capacity). This affects the efficiency of the entire logging process. For the correct planning of the dates of forestry operations, and also the planning of the construction and operation of winter roads, it is necessary to forecast the possibility of establishing these dates, based on reliable analysis of weather conditions for
the same periods of past years. Such planning will inevitably lead to increased efficiency of logging operations and lower costs of both material and labor. The aim of the study is to create a web application to determine the life of a winter forest road and test it using the example of the Yenisei district of the Krasnoyarsk Territory. In the field of studying the carrying capacity of forest roads a number of scientific studies have been carried out, the most remarkable ones were made by prof. B.A. Ilyin and prof. B.I. Kuvaldin [1]. In addition, to assess the impact of climate on the construction, operation and maintenance of timber winter roads, the works of E.V. Goryaeva, A.P. Mokhirev were studied. In these works the authors describe the creation of a geographical information resource necessary for planning and modeling the production activities of forest enterprises [2]. The work of researchers A.P. Kalashnikov, A.A. Romanov, N.N. Filatov, in which a description of the climate is presented, and climate maps are formed [3, 4, 5] were also studied. The capacity of roads is most noticeably reduced during periods of adverse weather and climate factors: rains, snowfalls, ice, fogs and others. It is well known that climatic factors significantly affect the condition and transport qualities of the road. There are a sufficient number of scientific papers and practical recommendations on this subject [6, 7]. Climatic conditions are characterized by rainfall, temperature differences, air humidity, wind direction and strength, duration and height of snow cover. All these factors have a significant impact on the safety and duration of pavement, the stability of the base and other road structures [8]. However, all climatic factors can vary over time, both during the day and during the calendar year, as well as vary by year, i.e. the nature of the manifestation of each climatic factor is probabilistic. It is difficult to predict when this or that temperature will be established this year, or what the precipitation depth will be in December this year. The issue of planning the dates of certain logging operations, and even more so planning the dates of the construction of winter roads is directly related to weather conditions.

2. Materials and research methods
The methodology presented by Shegelman, V. M. Lukashevich and L.V. Dandy [9, 10, 11] from Petrozavodsk State University was used as the basis of the web application. The methodology is based on the analysis of statistical climatic data that affects the beginning and closing of operation of winter forest roads. These are:

- data on daily mean temperatures in the region for the period starting with the first negative temperatures (the start of the winter season), and for the period when the first positive temperatures are observed (the end of the winter season);
- data on the height of snow cover in the region for the period when the first negative temperatures are observed in the region (the start of the winter season).

Data must be collected for at least the last 10 years.

To create a web application in the framework of these studies, an algorithm has been created for calculating the operating time of forest roads in winter for a given region, which includes the following actions (figure 1):

- Collection of data for at least 10 recent years on daily mean temperatures and snow-cover height in a given region for the winter period from the time of the first negative daily mean temperatures (the beginning of the winter season) to the time of the first positive daily mean temperatures (the end of the winter season). Data is collected in weather archives.
- Determining the start date for the construction of the winter road for different types of pavement.
- The closing date of the winter road is determined according to statistical weather data.
Validation of indicators is determined by assessing the probability distribution of the duration of the winter road and making an empirical distribution function of values. To collect the necessary source data, the weather viewing resource rp5.ru was used, since it has the ability to generate a convenient CSV file with a detailed daily history by id number or station name. All the data obtained was described using the object-oriented programming language PHP. To display the data, the AdminLTE-3 template based on the Bootstrap 4 framework was used.

3. Results
The functional test of the created web application was carried out to calculate the duration of operation of winter forest roads in the Yenisei region of the Krasnoyarsk Territory [13]. Logging is actively carried out in this territory having a pronounced seasonal character.

1. Data were collected on daily mean temperatures in October - May for the time period from 2005 to 2019 (a period of 14 years). After downloading the data, a time series of daily temperatures over 14 years was built, which contains an almost insignificant linear trend. For one year, the temperature in the period under study increased by about 0.04 °C. The rest of the additive series model includes a pronounced seasonal component and a random component representing white noise. For each decade of...
each month estimates of the mathematical expectation and variance of the daily mean temperatures were constructed (table 1, figure 2).

**Table 1.** Estimation of expectation and variance of temperatures.

| Month   | Decade | Average temperature | Min temperature | Max temperature | Variance | Average deviation |
|---------|--------|---------------------|-----------------|-----------------|----------|-------------------|
| October 1 | 1      | 3.58                | -2.4            | 6.8             | 2.49     | 1.58              |
| October 2 | 2      | 0.75                | -3.8            | 4.93            | 2.5      | 1.58              |
| October 3 | 3      | -2.24               | -7.21           | 2.29            | 3.01     | 1.73              |
| November 1 | 1      | -4.94               | -18.21          | 1.14            | 3.1      | 1.76              |
| November 2 | 2      | -9.71               | -19.21          | -2.36           | 4.73     | 2.18              |
| November 3 | 3      | -11.31              | -22.71          | -3.29           | 4.39     | 2.1               |
| December 1 | 1      | -13.31              | -22.36          | -5.29           | 6.77     | 2.6               |
| December 2 | 2      | -14.28              | -23.21          | -7.79           | 6.43     | 2.54              |
| December 3 | 3      | -15.15              | -25.43          | -6.43           | 6.73     | 2.59              |
| January 1 | 1      | -17.63              | -31.29          | -8.79           | 6.22     | 2.49              |
| January 2 | 2      | -19.69              | -31.14          | -9.29           | 7.54     | 2.75              |
| January 3 | 3      | -20.67              | -33.21          | -9.57           | 7.06     | 2.66              |
| February 1 | 1      | -19.09              | -26.43          | -2             | 9.69     | 3.11              |
| February 2 | 2      | -16.75              | -25.53          | -2.07           | 6.23     | 2.5               |
| February 3 | 3      | -12.54              | -20.33          | -1.13           | 5.11     | 2.26              |
| March 1   | 1      | -9.69               | -16.6           | -0.53           | 3.59     | 1.9               |
| March 2   | 2      | -6.08               | -12.4           | 0.13            | 3.38     | 1.84              |
| March 3   | 3      | -1.64               | -7.07           | 3               | 1.94     | 1.39              |
| April 1   | 1      | -0.52               | -4.47           | 8.6             | 3.35     | 1.83              |
| April 2   | 2      | 1.38                | -2.67           | 8.4             | 2.5      | 1.58              |
| April 3   | 3      | 4.32                | 0.33            | 10.87           | 1.81     | 1.34              |

**Figure 2.** Change in average temperatures and their variance for the period of 2005-2019 Russia, Krasnoyarsk Territory, Yenisei District.
The central curve with markers corresponds to the daily mean temperature over a decade. The solid curves above and below it mark the borders of the standard deviation from the mean, and the dashed curves represent the 95% range in which the temperature values are:

2. Data on the snow-cover height in October – May for the time interval from 2005 to 2019 were collected. For each decade of each month estimates of the mathematical expectation and variance of snow depth are constructed. The results are presented in table 2 and in figure 3.

Table 2. Estimation of expectation and variance of snow-cover height.

| Month   | Decade | Average temperature | Min temperature | Max temperature | Variance | Average deviation |
|---------|--------|---------------------|----------------|----------------|----------|-------------------|
| October | 1      | 0.27                | 0              | 3.93           | 0.77     | 0.88              |
| October | 2      | 1.33                | 0              | 4.13           | 1.74     | 1.32              |
| October | 3      | 3                   | 0              | 8.71           | 3.02     | 1.74              |
| November| 1      | 5.36                | 0              | 25.79          | 5.37     | 2.32              |
| November| 2      | 8.07                | 0              | 27.14          | 5.39     | 2.32              |
| November| 3      | 13.57               | 0              | 32.57          | 6.98     | 2.64              |
| December| 1      | 14.93               | 1.57           | 38.64          | 6.67     | 2.58              |
| December| 2      | 20.57               | 0              | 41.14          | 7.82     | 2.8               |
| December| 3      | 21.43               | 0              | 42.36          | 13.88    | 3.73              |
| January | 1      | 21.07               | 0              | 49.5           | 14.63    | 3.82              |
| January | 2      | 24.43               | 0              | 57.5           | 15.64    | 3.95              |
| January | 3      | 27.36               | 0              | 60.29          | 18.55    | 4.31              |
| February| 1      | 22.29               | 0              | 65.29          | 10.35    | 3.22              |
| February| 2      | 28.87               | 0              | 64.73          | 24.93    | 4.99              |
| February| 3      | 29.93               | 0              | 67.8           | 14.46    | 3.8               |
| March   | 1      | 29                  | 0              | 65             | 11.24    | 3.35              |
| March   | 2      | 30.67               | 0              | 63.4           | 11.45    | 3.38              |
| March   | 3      | 23.73               | 0              | 56             | 13.88    | 3.73              |
| April   | 1      | 11.53               | 0              | 28.27          | 15.14    | 3.89              |
| April   | 2      | 4.27                | 0              | 11.73          | 9        | 3                 |
| April   | 3      | 0.4                 | 0              | 3.27           | 1.25     | 1.12              |

According to [12], the construction of the road can be started at a negative temperature and in the presence of snow cover of 10 cm high. Figure 4 combines data on daily mean temperatures and snow-cover height. The dashed line shows the average snow-cover height, and the line with markers shows the average temperature.
Figure 3. Change in the average snow-cover height and its variance for the period 2005 - 2019 in the Yenisei region of the Krasnoyarsk Territory.

Figure 4. Graphic definition of the start and closing of operation of a winter forest road.

Road construction can be started if there is a certain temperature and enough height of snow. Based on the analysis of these data of the Yenisei region, the construction of winter roads can start at the beginning of the second decade of October. Operation of the winter road is possible until the third decade of March. Accordingly, the preliminary term of operation of the road in the Yenisei region will be 136 days. The obtained data can be used to plan the dates of the work on the removal of harvested wood.
from harvesting sites. Using the capabilities of the developed resource located at http://u96760nn.beget.tech/index.php to calculate the carrying capacity of the forest road, one need to fill out the form and then he automatically receives the result.

![Figure 5. Form for calculating the capacity of a forest road.](image)

4. **Discussion**
The obtained data on the beginning and closing of operation of forest roads are consistent with the actual periods of road operation for a given region. When comparing the obtained values with the calculations of L. V. Shchegoleva [13], the probability values are consistent, however, the obtained dates of the start and closing of road operation are different. This is due to the differing climatic conditions of the studied regions. An example of solving this problem showed the efficiency of the methodology and the created web application in determining the period of operation of the road and the carrying capacity of a winter logging road.

5. **Conclusion**
We have developed a methodology that determines, using probabilistic methods, the duration of winter logging roads in the Yenisei region of the Krasnoyarsk Territory. This technique allows to plan the dates of timber removal from the cutting area during the harvesting season, improve the quality and service life of the road and organize the logging process of the enterprises more rationally, significantly reducing the cost of additional investments in the construction of the winter road and its maintenance. This methodology and web application can also be used to solve other problems in industries that depend on climatic conditions.

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