Analysis of the Distribution of Movement Speed from Time of Day

E V Goryaeva¹, A P Mokhirev², S O Medvedev², N A Bragina²

¹Siberian Federal University, Krasnoyarsk, Russia
²Lesosibirsk Branch of Reshetnev Siberian State University of Science and Technology, Lesosibirsk, Russia

Abstract. Logging is carried out in difficult natural and climatic conditions, being often unprofitable for large industrial enterprises. However, it is the provision of forest resources that allows all other enterprises of the timber industry to carry out their activities. Transportation of forest products is most interesting from the point of view of setting and solving problems to improve the efficiency of the production process. Indeed, when delivering goods from the forest, there are many possible problems that need to be solved and ultimately affect its overall efficiency: the choice of route, traffic schedule, equipment, removal period, etc. At the same time, even when selecting optimal parameters, there are always factors that affect the work of equipment and personnel when removing wood in specific conditions. One of these factors is the time of day. The purpose of this study is to identify the nature of the dependence of the speed of movement of logging equipment on the time of day.

1. Introduction
In the context of the tendency of the forest and logging industry to constantly improve efficiency, the search for ways to increase productivity, production speed and volumes, transportation and distribution are the most important goals of scientific and applied research. Logging is carried out in difficult natural and climatic conditions and is often unprofitable for large industrial enterprises [1,2]. However, it is the provision of forest resources that allows all other timber enterprises to carry out their activities. Thus, achieving high efficiency of logging processes is an important task that is solved at different levels of management. Meanwhile, providing enterprises with timber can include three main processes - directly harvesting, storage (warehousing) and transportation. The last of them is the most interesting from the point of view and solving problems to improve its efficiency. Indeed, there are many different tasks that need to be solved during the timber carting out, which ultimately influence its overall effectiveness: the choice of route, traffic schedule, equipment, carting out period, and others. [3]. At the same time, there are always factors that influence the work of equipment and personnel when forest carting out in specific conditions, even when selecting optimal parameters [4,5]. One of these factors is the time of day. The goal of any enterprise and almost all economic and mathematical models is a constant speed of movement of logging trucks and execution of all technological operations. This allows you to calculate the parameters of all production processes, and control them [6,7]. However, in practice, such constant speed and stability is almost impossible to achieve.
The purpose of this study is to identify the nature of the dependence of the speed of movement of logging trucks on the time of day.

2. Methods and materials
For the research, the reports of the movement of the KAMAZ logging truck, generated by GLONASS from March 1 to March 30 (in the Excel format) were used. The population universe is represented by 43442 observations.

Two samples of volumes n and m were extracted from the population universe, and their sample averages were found. The samples are formed by the time of day, based on the time of sunrise and sunset at the place where logging equipment is moving: from 6 AM to 19 PM – daytime, from 19 PM to 6 AM - night time.

The results of statistical processing of samples are presented in table 1 and figures 1 and 2. Calculations have shown that the distributions under consideration are close to normal.

Table 1. Statistical analysis of samples.

| Descriptive statistics | Population universe | Sample “night” | Sample “day” |
|------------------------|---------------------|----------------|--------------|
| Average                | 31,98               | 31,14          | 32,28397     |
| Standard error         | 0,0584              | 0,1043         | 0,068781     |
| Median                 | 31,6225             | 30,7866        | 31,89579     |
| Standard deviation     | 12,1764             | 11,9506        | 12,1624      |
| Dispersion             | 148,2649            | 142,8182       | 147,924      |
| Kurtosis               | 2,1616              | 1,9729         | 2,26978      |
| Skewness               | 0,5219              | 0,3852         | 0,57292      |
| Range                  | 140,3641            | 140,26803      | 140,3641     |
| Minimum                | 0                   | 0              | 0            |
| Maximum                | 140,3641            | 140,2680       | 140,3641     |
| Sum                    | 1389579             | 408663,5608    | 1009455      |
| Number                 | 43441               | 13120          | 31268        |
| Confidence level (95,0%) | 0,114506           | 0,2045         | 0,1348       |
The movement of logging trucks is recorded as the geographical coordinates of the start and end points of each trip. Data on the movement of logging trucks is shown in figure 2.
Figure 3. Area movement of logging trucks.

Figure 3 shows the fixation of the position of the end points of movement of logging trucks. The cartographic interpretation shows that the logging truck was traveling on a single highway in the GLONASS file under consideration. This excludes the influence of such factors as the type of logging transport route (highway, moustache, portage), the type of road surface and terrain.

3. Results
It was necessary to test two competing hypotheses at the significance level $\alpha=0.05\%$ : population universe are equal and not equal.

To test the hypothesis, a two-sample F-test was performed for variances. The results of the calculations are shown in table 2.

| Descriptive statistics | Sample “night” | Sample “day” |
|------------------------|----------------|--------------|
| Average                | 32,28397       | 31,14814     |
| Dispersion             | 147,924        | 142,8182     |
| Number                 | 31268          | 13120        |
| df                     | 31267          | 13119        |
| F                      | 1.03575        | -            |
| P($F\leq f$) one-tailed| 0.008657       | -            |
| F critical one-tailed  | 1.024565       | -            |

The calculations show that $F \geq F_{cr}$. This means that the sample variances differ, but since the difference is small, additional statistical calculations are required.
Thus, the z test was calculated to check whether the average speeds of the two samples differ statistically. For this purpose, a two-tailed critical area is constructed. The critical value of the Zcr is determined from the condition:

$$F(Z_{cr}) = \frac{1 - \alpha}{2},$$

where $F(z)$ is the Laplace function.

$Z_{cr}$ is determined after calculating $F(z_{cr})$ from the Laplace Transform Table. The results of the calculations are shown in table 3.

### Table 3. Two-Sample Z-test for averages.

| Descriptive statistics | Sample “night” | Sample “day” |
|------------------------|----------------|--------------|
| Average                | 32.28397       | 31.14814     |
| Population mean (known variance) | 147,924       | 142,8182     |
| Number                 | 31268          | 13120        |
| Hypothetical definition| 0.38818        | -            |
| $z$                    | 5.982856       | -            |
| $P(Z<=z)$ one-tailed   | 1.1E-09        | -            |
| $z$ critical one-tailed| 1.644854       | -            |
| $P(Z<=z)$ two-tailed   | 2.19E-09       | -            |
| $z$ critical two-tailed| 1,959964       | -            |

The calculations show that $Z > Z_{cr}$, so the hypothesis of equality of averages is not confirmed. This means that the sample averages are statistically different from each other, meaning that the average speed during the day differs from the average speed at night.

For subsequent research, it was decided to analyze the change in the speed of logging trucks during the day. For this purpose, samples were formed for each hour of the day and statistical indicators of these samples were found. The data is presented in table 4. All samples have more than 30 observations, so they are considered representative. The results show that average speeds differ at different times of the day. The maximum range of the average values is more than 16.17 km/h.

### Table 4. Descriptive statistics of samples by hours of the day with a confidence level of 95 %.

| Time of day, lh:mm | Number | Standard error | Average, km/h |
|--------------------|--------|----------------|---------------|
| 00:00 - 00:59      | 45     | 1.1120         | 25.15±2.24    |
| 01:00 - 01:59      | 1676   | 0.2419         | 31.34±0.47    |
| 02:00 - 02:59      | 749    | 0.4017         | 32.97±0.78    |
| 03:00 - 03:59      | 230    | 0.8168         | 30.95±1.61    |
| 04:00 - 04:59      | 513    | 0.4073         | 21.77±0.80    |
| 05:00 - 05:59      | 1004   | 0.2474         | 26.55±0.48    |
| 06:00 - 06:59      | 1178   | 0.3062         | 27.45±0.60    |
| 07:00 - 07:59      | 998    | 0.4605         | 27.38±0.90    |
| 08:00 - 08:59      | 1722   | 0.1818         | 27.07±0.35    |
| 09:00 - 09:59      | 2140   | 0.2853         | 30.95±0.55    |
| 10:00 - 10:59      | 2717   | 0.2982         | 35.16±0.58    |
| 11:00 - 11:59      | 3272   | 0.2294         | 36.26±0.44    |
| 12:00 - 12:59      | 3838   | 0.1785         | 34.12±0.35    |
| 13:00 - 13:59      | 3691   | 0.1902         | 31.74±0.37    |
Table 4. Average traffic speeds in the cargo and empty directions

| Time of day, h   | Cargo Direction | Empty Direction | Average per Day |
|-----------------|-----------------|-----------------|----------------|
| 00:00 - 00:59   | 3470            | 2598            | 42569          |
| 01:00 - 01:59   | 2769            | 2133            |                |
| 02:00 - 02:59   | 1970            | 1605            |                |
| 03:00 - 03:59   | 1190            | 747             |                |
| 04:00 - 04:59   | 3243±0,31       | 29,18±0,34      |                |
| 05:00 - 05:59   | 30,85±0,41      | 32,64±0,50      |                |
| 06:00 - 06:59   | 32,43±0,31      | 30,85±0,41      |                |
| 07:00 - 07:59   | 32,64±0,50      | 30,85±0,41      |                |
| 08:00 - 08:59   | 30,85±0,41      | 30,85±0,41      |                |
| 09:00 - 09:59   | 30,85±0,41      | 30,85±0,41      |                |
| 10:00 - 10:59   | 30,85±0,41      | 30,85±0,41      |                |
| 11:00 - 11:59   | 30,85±0,41      | 30,85±0,41      |                |
| 12:00 - 12:59   | 30,85±0,41      | 30,85±0,41      |                |
| 13:00 - 13:59   | 30,85±0,41      | 30,85±0,41      |                |
| 14:00 - 14:59   | 30,85±0,41      | 30,85±0,41      |                |
| 15:00 - 15:59   | 30,85±0,41      | 30,85±0,41      |                |
| 16:00 - 16:59   | 30,85±0,41      | 30,85±0,41      |                |
| 17:00 - 17:59   | 30,85±0,41      | 30,85±0,41      |                |
| 18:00 - 18:59   | 30,85±0,41      | 30,85±0,41      |                |
| 19:00 - 19:59   | 30,85±0,41      | 30,85±0,41      |                |
| 20:00 - 20:59   | 30,85±0,41      | 30,85±0,41      |                |
| 21:00 - 21:59   | 30,85±0,41      | 30,85±0,41      |                |
| 22:00 - 22:59   | 30,85±0,41      | 30,85±0,41      |                |
| 23:00 - 23:59   | 30,85±0,41      | 30,85±0,41      |                |

Figure 4 shows a graph of the dependence of the average speed of logging trucks on the time of day.

The graph shows that the lowest speed is observed in the period from 4 to 5 AM, and the highest from 20 to 21 PM. There are three distinct peaks: from 2 to 3 AM, from 11 to 12 AM and from 20 to 21 PM. Two characteristic declines from 4 to 5 AM in the morning and from 0 to 1 AM show that after all, the lowest speed is observed at night.

Many factors affect the speed of logging trucks (terrain, surface characteristics and type of road, time of year and day, technical characteristics of the car, the degree of its load, etc.) [8,9,10]. For subsequent research of the studied dependence, it is necessary to divide each sample into two more samples that characterize the movement of cars in the cargo and empty direction. The results of sample processing are shown in Table 5. The average values of traffic speeds in the cargo and empty directions are very close. It should be noted that the average speed in the "Night" sample is higher than the average speed in the "Day" sample, regardless of the cargo or empty direction.

Figure 4. Average speed of logging trucks during the day.
Table 5. Statistical processing of the results of observations of the speed of movement of logging trucks in the cargo and empty direction at different times of the day.

| Descriptive statistics  | Sample “night” Cargo   | Sample “night” Empty | Sample “day” Cargo   | Sample “day” Empty |
|-------------------------|-------------------------|----------------------|----------------------|-------------------|
| Average                 | 32,20052                | 32,42711994          | 31,39719             | 30,71211          |
| Standard error          | 0,092499                | 0,104353097          | 0,132351             | 0,167204          |
| Median                  | 31,83944                | 32,043397            | 30,49189             | 31,06207          |
| Standard deviation      | 11,99461                | 12,3503114           | 11,66342             | 12,06883          |
| Dispersion              | 143,8706                | 152,5301916          | 136,0353             | 145,6566          |
| Kurtosis                | 2,307158                | 2,4434977            | 2,81539              | 0,653372          |
| Skewness                | 0,551617                | 0,6023467            | 0,57287              | 0,084155          |
| Range                   | 126,8759                | 140,364072           | 140,268              | 93,0367           |
| Minimum                 | 0                       | 0                    | 0                    | 0                 |
| Maximum                 | 126,8759                | 140,364072           | 140,268              | 93,0367           |
| Sum                     | 541451,7                | 454206,669           | 243830,6             | 160010,1          |
| Number                  | 16815                   | 14007                | 7766                 | 5210              |

The test of the null hypothesis about the equality of the average values of traffic speeds in the cargo and empty direction is presented in table 6.

Table 6. Two-Sample z-test for averages values.

| Descriptive statistics | Sample “night” | Sample “day” |
|------------------------|----------------|--------------|
| z                      | 0,190771916    | -6,42527     |
| P(Z<=z) one-tailed      | 0,424352146    | 6,58E-11     |
| z critical one-tailed   | 1,644853627    | 1,644854     |
| P(Z<=z) two-tailed      | 0,848704293    | 1,32E-10     |
| z critical two-tailed   | 1,959963985    | 1,959964     |

According to the Z-test, in the daytime and at night, Z < Zcr consequently, the hypothesis of equality of average speeds is confirmed.

4. Discussion

The nature of the dependence is easily explained when logging trucks work in three shifts during the day. In this case, the peaks are in the pre-afternoon. This can be caused by a subjective factor-the desire to finish work faster and start a rest period (break). At the same time declines are near the end of the shift and can be explained to driver fatigue. Thus, the change in the speed of movement of cars is caused by subjective factors, namely, it depends on the drivers. The driver cannot be replaced with an automatic machine - only a person can drive a logging truck at the moment when transporting wood on the forest territory. In this regard, it is possible to minimize the influence of the subjective factor (if necessary) only by changing the modes and schedules of the staff. However, the necessity for this is rather debatable. Reduced speed at night caused by driver fatigue can be eliminated, for example, by starting a shift (replacing the driver of a logging truck) at night (from 23 PM to 2 AM). Of course, this will achieve some speed increase. Do not forget that traffic can be slower at night, as visibility is reduced in the dark. At the same time, changing work schedules, logistics of delivery of personnel (drivers), organization of the process of changing one driver to another, and a number of additional processes at night are somewhat more difficult than in the traditional way of work. Thus, from the organizational and economic side, the transition to changes in the work schedule of drivers is extremely doubtful.
5. Conclusion
As a result of the research, it was found that the lowest speed of movement is observed in the period from 4 to 5 AM, and the highest from 20 to 21 PM. It is also shown that three distinct peaks are observed on the studied objects: from 2 to 3 AM, from 11 to 12 AM and from 20 to 21 PM.

The results were obtained as a result of statistical data processing and were subjected to validation and significance tests. The role of the human factor in changing the speed of logging trucks indicated in the research requires additional research, which is partially performed by the authors and will be continued in the course of further scientific research. The results obtained are consistent with earlier research in this direction, but they expand and supplement them in terms of changes in the speed of movement of equipment in the daytime and at night.

6. References
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