# Improving the efficiency of the underground vehicle`s brake-release mode

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**Abstract.** Nowadays electric power supplement and energy efficiency are the most important and urgency questions. This article is about present-day technical condition of the Novosibirsk subway as a big consumer which most of high power consumption for traction. A series of experiments was carried out to check the actual subway train motion condition. Statistical analysis was made for processing obtained experimental data and matched leveling function. As a result all main reasons of high energy consumption in the everyday operations of the subways are defined.

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**Keywords:** the Underground, energy efficiency, random value, a rolling stock, the optimal mode of motion

## Introduction

In modern conditions of life of the megalopolis, underground is an important type of public transport. The safe and reliable operation of the equipment is largely dependent on stable work of power supply devices. One of the exploitations' problems of the underground is high power consumption for traction, which amount is 51% of all vehicle consumed energy[1].

Obsolete vehicles series 81-717.5M, 714.5M, which require full modernization, now are used at the Novosibirsk Underground. However, despite the full technical repairs and partial updates, indicators of energy consumption for traction needs continue to grow [2].

Therefore, power-saving for traction needs of vehicles and increasing of the energy efficiency are important issues for the underground.

Smooth and stable operation of underground mainly depends on the availability of the vehicles and the efficiency of its usage [3,4]. Energy efficiency of the transport traction is defined by the optimality of its handling. Thus, optimizing the mode of movement can achieve significant energy savings. To confirm this hypothesis, a number of experiments were organized and carried out to test the real traction time of the underground vehicles.

The experiment was carried out on the underground track 1.27 km long between Marks Square and Student stations. The first experiment included measurements of the traction time between stations. For a time dimension an electronic stopwatch was used, which was switched on at the moment when vehicles started to move and switched off after the vehicle's arrival at the station.

More than one hundred dimensions were made in both directions. For the purity of the experiment tests were carried out at certain times of the day, strictly according to the schedule. Data obtained at the track, is presented at the Figure 1.

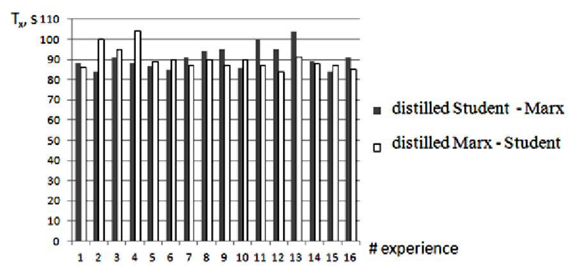


**Figure 1. Vehicle traction time in both directions**

The received data shows that there is a time difference. Real time may be determined by the acceleration and traction time while vehicle is energized [5].

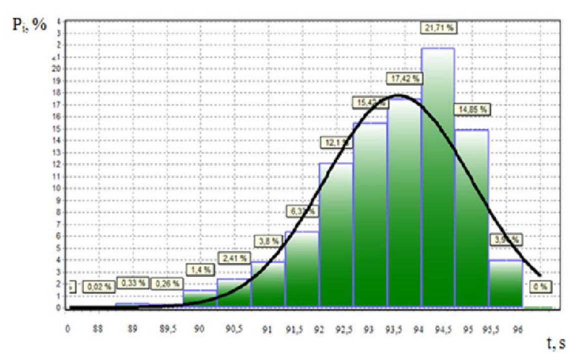


**Figure 2. Shapes of histogram and density distribution of time**

To find out reasons cause the time differences among traction time values, statistical analysis of experimental data was carried out. The values of the random variables of time ($T_x$) are grouped in ordered statistic array with numbers of ranks equal to R = 20. Shapes of histogram and density distribution of time are shown at the Figure 2.

Selection of gain functions convergence was evaluated by Pearson criteria [$ch^2$] was made. As a result, it was found that incomplete gamma function the most fully describes the time allocation.

The probability density function and gamma distribution function for relative units system could be described by the following expressions [6]:

$$P_i = \frac{r^2}{\Gamma(r)} \cdot e^{-(r \cdot t)} \cdot t^{(r-t)}, \qquad (1)$$

$$F_i = \frac{r^2}{\Gamma(r)} \cdot \int_0^t t^{(r-t)} \cdot e^{-r \cdot t} \cdot dt. \qquad (2)$$

*Γ(r)* – parameter gamma function;
*r* – parameter of the distribution.

The estimation of statistics of the gain function equivalents performed by Pearson's criteria:

$$\chi^2 = m \cdot \sum_{i=2}^{k} \frac{(P_{*i} - P_i)^2}{P_i} \qquad (3)$$

$m$ – number of experiments;
$P_{*i}$ – experimental value of probability;
$P_i$ – theoretical value of probability.

In the next phase of the work was performed by measurement of real start-up acceleration of the vehicle. It was the goal for the second experiment. Acceleration values data were obtained by means of the accelerometer, which was fixed on special metal platform. The platform with sensor was located on the floor so that the accelerometer's horizontal axis X coincides with the axis of the vehicle. Analysis and statistical data processing were carried out in the same way. Histogram and density distribution of the average starting acceleration are represented in Figure 3.

As a result, it was found that incomplete gamma function the most fully describes the traction time and acceleration.

Based on the experiments one can conclude that low energy efficiency of vehicle traction is caused by a variety of reasons, including technical ones: maintenance of outdated vehicles, non-standard work of traction equipment. Furthermore, human factor has a great influence too. Often drivers try to reach the station earlier than they are to do according to the schedule. External factors have the significant influence on the rated traction mode [7,8,9]. This research helps to identify further direction for efficiency improving of the Underground, and firstly it's connected with control of vehicle technological elements which determinate the acceleration [10].

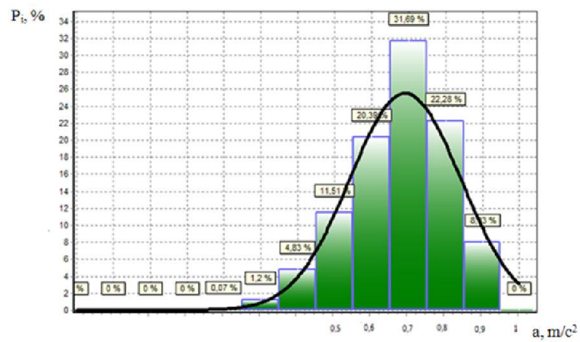


**Figure 3. Histogram and density distribution of the average starting acceleration**

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