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Method of Optimizing Placement of Mobile Car Service Stations in Sparsely Populated Areas

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Abstract

The article considers the development of a method of optimizing placement of mobile car maintenance stations (MMSs) in sparsely populated areas. The method includes the analysis of the territorial location of settlements, number of vehicles in those settlements, calculation of the MCSS travel time between settlements, determination of the optimum base site for MMS by a series of criteria.

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Keywords: optimizing; territorial placement; mobile station; maintenance; state technical inspection; vehicles

1. Introduction

The necessity of the development of a method of optimizing placement of mobile car maintenance stations (MMSs) is caused by undercoverage of cars in sparsely populated areas with technical services, therefore, the number of road traffic accidents (RTAs) increases due to faulty condition of vehicles. One of the main measures to ensure operability of vehicles is carrying out scheduled maintenance including obligatory state maintenance [Repin et al. (2012)]. In the Russian Federation, there are many sparsely populated areas, for example, the Komi Republic (KR) in which creation of a sufficient number of stationary maintenance points is economically inexpedient.

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Therefore, creation of mobile maintenance stations (MMSs) makes sense, temporary base sites of which will be in direct proximity to the territorial placement of vehicles.

2. Main text

The territorial placement of MMS base sites is defined by three factors:

- demand of the population for maintenance in mobile stations;
- territorial dispersion of settlements where vehicles are situated;
- technical capabilities of rendering this service by means of MMS.

When solving tasks of choice of the optimum territorial placement of service facilities, geoinformational technologies [Developer, Movable Type Scripts, Stackoverflow, Semico (el. resources)] and linear mathematical programming methods [Stackoverflow, Osanich and Lisnyak (2009)] are applied.

Let us assume that according to the administrative territorial division, there are *N* districts in the region. Each district is the location of consumers — owners of vehicles, living in *n* settlements. Let us denote the time of accessibility to MMS base site *j* for inhabitants of settlement *i* through t_{ij}. The total time expenditures for movement to MMS site *j* and back for settlement *i* will make:

$$T_{ij} = 2 \cdot t_{ij} \cdot K_i \cdot \delta_i \qquad (1)$$

where K_i — number of vehicles in settlement *i*; δ_i — some weighting coefficient.

Choice of a place for territorial placement of MMS

The optimum placement of MMS can be characterized by the minimum value of the regional accessibility function [Stackoverflow (el. resource), Osanich and Lisnyak (2009)]

$$T_j = \sum_{i=1}^{n} 2 \cdot t_{ij} \cdot K_i \cdot \delta_i \rightarrow \min \qquad (2)$$

Let us consider a region with unconditioned placement of *n* settlements with coordinates latitude–longitude X_i and Y_j and with the number of inhabitants I_i. To calculate distance $L_{i,j}$ between points on the earth's surface, the formula known in spherical geometry and geodesy is used [Developer, Movable Type Scripts (el. resources), Repin et al. (2016)]:

$$L_{i,j} = if(i = j, 0, ka \cdot \mathrm{Re} \cdot \mathrm{acos}(\sin Y_i \cdot \sin Y_j + \cos Y_i \cdot \cos Y_j \cdot \cos(X_j - X_i))) \qquad (3)$$

where Y and X — latitude and longitude (for the northern latitude and eastern longitude with a plus sign, for the southern latitude and western longitude with a minus sign), degrees. Re — Earth's radius, km; ka — access coefficient which takes into account the unstraightness of roads between settlements (the average value for the district under consideration is 1.4); if — logical operator "if"; i, j — counters of point numbers horizontally and vertically, respectively.

The calculation of the latitude and longitude of a settlement in Excel environment is given in Fig. 1.