TEKA. COMMISSION OF MOTORIZATION AND ENERGETICS IN AGRICULTURE – 2013, Vol. 13, No.3, 235-238

Operation of the road transport network in the presence of various options of freight shipping by automobile transport

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Received June 03.2013: accepted July 03.2013

S u m m a r y. In the paper the features of the road transport network functioning in the presence of alternative variants of freight delivery to the consumer are reviewed. The regularities of changes in the state of the system in the long term perspective are specified, and the need of periodic restoration of the road surface in order to reduce operating costs across the entire transport system is shown.
K e y w o r d s. automobile, transport network, route, freight, information, probability.

INTRODUCTION

Freight delivery by road to costumers is widely practiced due to its advantages such as efficiency, flexibility, opportunity to strategically change the route and to provide the required delivery time [1, 2]. However, the process of operating motor vehicles is accompanied by their failures, and the need to carry out repair work, to restore their functionality [3-20]. The existing road networks allow to perform the freight delivery by different routes, the choice of which is made according to the road conditions in the presence of appropriate information. At the same time durability and operability of the road transport is associated with the state of the road surface and the conditions of its operation [21, 22].

Thus, while choosing the route of delivery the information component is extremely important, but in the technical literature there is no data on how on its basis to chose and evaluate the option of freight transportation and how such decisions affect the overall condition of the transport network in the medium and long term perspective.

OBJECT OF RESEARCH

The purpose of this paper is to analyze the characteristics of the road transport network operation in the presence of information about its current state, in the conditions of a possible choice of freight delivery route to the customers.

RESEARCH RESULTS

To solve the set problem, we consider the designed scheme shown on fig. 1. We suppose that from point C to point B the regular freight delivery by road is performed, with the traffic volumes Q [t / d].

Transportation of freight in the section between points A and B is possible in two ways. In this case, option 1 is characterized by the route length L_1 = 100 [km], and option 2, respectively, by the length L_2 = 310 [km] (fig. 1).

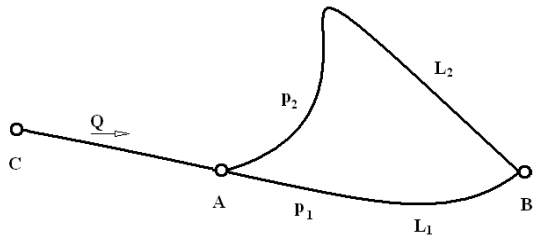

Fig. 1. Scheme of the possible routes of freight delivery

We assume that drivers have full information on the state of the routes and, basing on this data they make a choice of movement options. In this case option 1 will be selected with a probability p_1, and option 2 with a probability p_2. Obviously, the condition $p_1 + p_2 = 1$ is considered for the designed scheme.

Besides, we assume that the probability of choosing a particular route is proportional to the quality level of the roadway, and inversely proportional to the length of the route.

Then:

$$p_i = k\frac{A_i}{L_i} \quad (i=1, 2). \qquad (1)$$

where: the proportionality coefficient k:

$$k = \frac{1}{\sum_{i=1}^{2}\frac{A_i}{L_i}}.$$

In general, the indicator of the selected transport route roadbed can be defined as:

$$A = e^{-\alpha\mu},$$

where: α - the coefficient of proportionality;

μ - the number of damaged sections of the road for one kilometer length of the route, the presence of which leads to the need to brake and change the car speed limit [pc / km].

If $\mu = 0$, then A = 1 and the state of the selected route is considered to be the best. We suppose that μ_x - it's a coefficient of number of damaged areas on a kilometer length of the route, which reduces the possibility of its use in half, comparing with the best conditions.

After completing the necessary transformations, we obtain:

$$A = e^{\frac{\ln 0,5}{\mu_x}\cdot\mu}.$$

The fact that the road surface condition degrades over time, it influences the route selection and consequently the possibility of its use should also be considered.

Thus, analyzing the condition of the transport system, the possibility to change the value of μ over time should be considered.

We assume that the value of $\mu(t)$ in the result of the impact load flow q influence increases linearly with time. We assume that through the period t_x the value of $\mu(t)$ increases on $\Delta\mu$ relatively to the starting level μ_H.

Then:

$$\mu(t) = \mu_H + \beta\cdot t\cdot q.$$

Or:

$$\mu(t) = \mu_H + \frac{\Delta\mu}{t_x q_x}\cdot t\cdot q.$$

where: q - the quantity of actually observed freight flow on the route under consideration [t / d];

q_x - conditional freight flow on the route [t / d], leading to increase of road surface damage in time t_x for the amount of $\Delta\mu$.

Then for the analyzed i-th route:

$$\mu_i(t) = \mu_{Hi} + \frac{\Delta\mu}{t_x q_x}Q\cdot p_i\cdot t.$$

The system of nonlinear equations (1) in this case will be:

$$p_i = \frac{\exp\{\frac{\ln(0,5)}{\mu_x}\cdot[\mu_{Hi} + \frac{\Delta\mu}{t_x\cdot q_x}Q\cdot p_i\cdot t]\}}{L_i\cdot\sum_{i=1}^{2}\frac{\exp\{\frac{\ln(0,5)}{\mu_x}\cdot[\mu_{Hi} + \frac{\Delta\mu}{t_x\cdot q_x}Q\cdot p_i\cdot t]\}}{L_i}} \quad (i=1, 2). \qquad (2)$$

To identify the patterns of change in the state of the analyzed road network the equations system (2) was solved with the use of calculating system MathCAD for the assumed values of the parameters:

$\mu_{H1} = \mu_{H2} = \mu_{H3} = 0$ [km^{-1}]; $\mu_x = 20$ [km^{-1}]; $\Delta\mu = 2$ [km^{-1}]; t_x =1000 [d], q_x = 18 [т/d]; Q = 13000 [т/d]. A fragment of calculating program is shown on fig. 2.

The results of solving the system of equations is presented in graphic form on fig. 3, and allows us to conclude the following.

At the initial stage of the system operation the first route is the most attractive, and it accounts over 75% of choices. However, due to the large freight flow the condition of the roadbed on this route gradually deteriorates and its attractiveness decreases. At the same time, with the time increases attractiveness (and therefore the selection probability) of the alternative route.

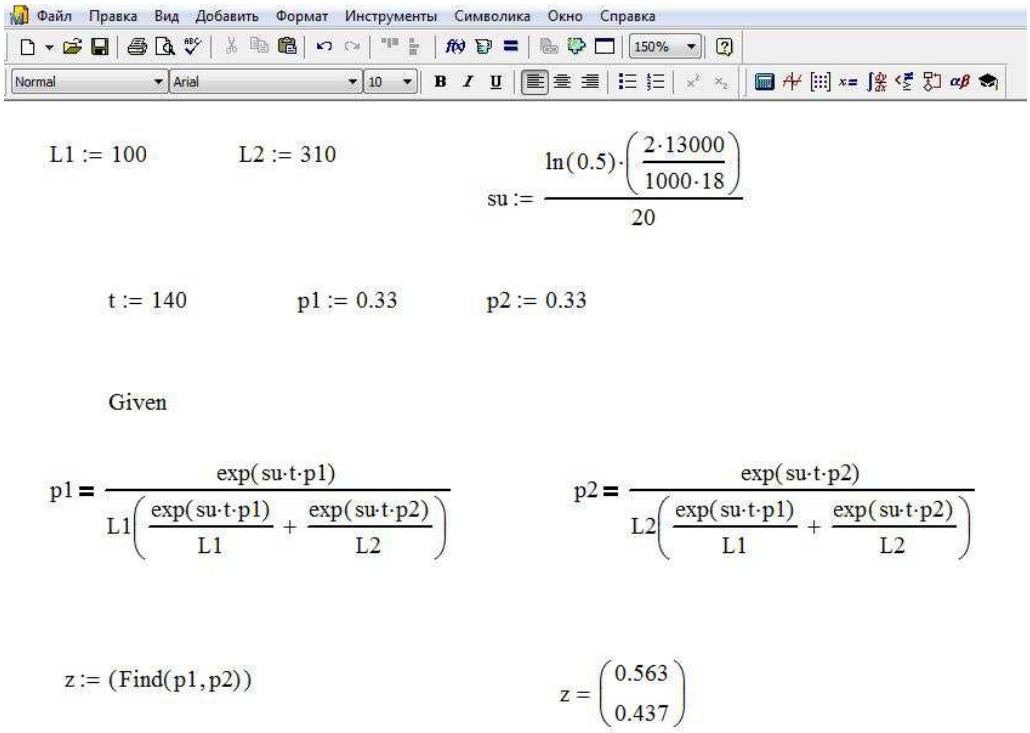

Fig. 2. A fragment of the calculating program to determine the probability

For this reason, the dependence of $p_1(t)$ c is reduced continuously over time, and the dependance $p_2(t)$ increases, lining to a level $p_1(t) = p_2(t) = 0{,}5$.

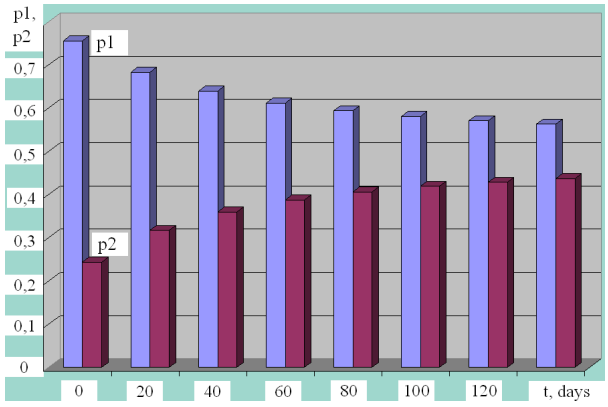

Fig. 3. Changing of the route usage probability in the analyzed transport system

Thus, in the extreme case, when the condition of the road surface for each of the possible routes is critically low, the appeal of all the options (and the probability of their usage) becomes even.

CONCLUSIONS

1. At the initial stage of the road transport system operation the shortest route is the most attractive. However, the state of the road surface on this route deteriorates over time due to the large cargo flow, and the probability of its use gradually reduces. This is accompanied by increase of the alternative route attractiveness and increase of the probability of its use.

2. The increase of the freight traffic volume on the detour route leads to an overall increase of operating costs in the scale of the analyzed transport system and can be seen as an objective factor which determines the need to perform repair work and restoration of the road surface.

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ФУНКЦИОНИРОВАНИЕ ДОРОЖНОЙ ТРАНСПОРТНОЙ СЕТИ ПРИ НАЛИЧИИ РАЗЛИЧНЫХ ВАРИАНТОВ ДОСТАВКИ ГРУЗОВ АВТОМОБИЛЬНЫМ ТРАНСПОРТОМ

Игорь Тарарычкин, Григорий Нечаев, Максим Слободянюк.

Аннотация. Рассмотрены особенности функционирования автодорожной транспортной сети при наличии альтернативных вариантов доставки грузов потребителю. Установлены закономерности изменения состояния системы в долгосрочной перспективе и показана необходимость периодического восстановления состояния дорожного покрытия для снижения эксплуатационных затрат в масштабе всей транспортной системы.

Ключевые слова: автомобиль, транспортная сеть, маршрут, грузы, информация, вероятность.