

## Ways of improvement of the city road network functioning

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**Abstract:** According to analysis of the diagram an hour-long traffic vehicles intensity determined the directions of improvement functioning of the road network of the city, by redistribution of traffic streams on sections of the road network by optimization traffic light cycles. Traffic lights cycles proposed to distribute by analyzing the distribution laws of traffic streams at crossroads during the day. By analyzing of statistical data for characteristics determination of distribution proposed to use a small sample theory that provides to get a reliable data in a short period of time. Evaluation of the effectiveness of implementation proposed measures is realizing by Student and Fisher criterions.

**Keywords:** hour-long traffic intensity, vehicles, road network, crossroads, statistical analysis.

## 1. Introduction

European court approved of the decision posting the time spent for commuting must be considered as a part of a working day. Every day employees who have to commute in cities spend from 1 to 2 hours and more to travel to their places of work and get home from work. The employees may spend up to 40 hours per month for commuting purposes. Besides, commuting involves not only wasting time but it's also a large source of financial charges. In small Ukrainian towns fuel costs for cars may vary from 20 to 40 of minimum wages. The problem is getting worse due to the fact that time of commuting is mostly the same for all dwellers.

Thus, the problem of street-road network efficient functioning is really urgent as its solving would provide less traffic jams and would cut the time spent on commuting.

## 2. The latest research and publications overview

Transportation system of Ukraine badly needs a considerable renewal (Vovk, 2015), as it was designed and built in 70-80s of the previous century and doesn't meet the requirements of modern society. Nowadays more and more highly developed countries in the world are using information technologies to improve street-road networks functioning. So in Melbourne 6 private and state companies under leadership of University of



Melbourne School of Engineering and PTV Group, started preparation for the unique project implementation on creating “alive transportation laboratory” (Melbourne, 2016).

A lively Melbourne district in Australia was chosen as a proof ground where a large number of passenger and cargo transportation routes are located. In the centre of the above-mentioned territory more than 1000 measuring elements will be set up to collect and join data on the “behavior” inside the “laboratory” about the vehicles, bicycles, pedestrians and the whole transport infrastructure. The project goal is to reduce by these smart devices the economic consequences dealing with traffic network, namely: traffic jams, road accidents, environmental pollution etc.

It’s practically impossible in Ukraine to improve the street-road network (SRN) functioning so that it will be adaptable to transport flows by means of expensive equipment. So we should more actively seek new inexpensive ways to improve the street-road network functioning.

### 3. Purpose

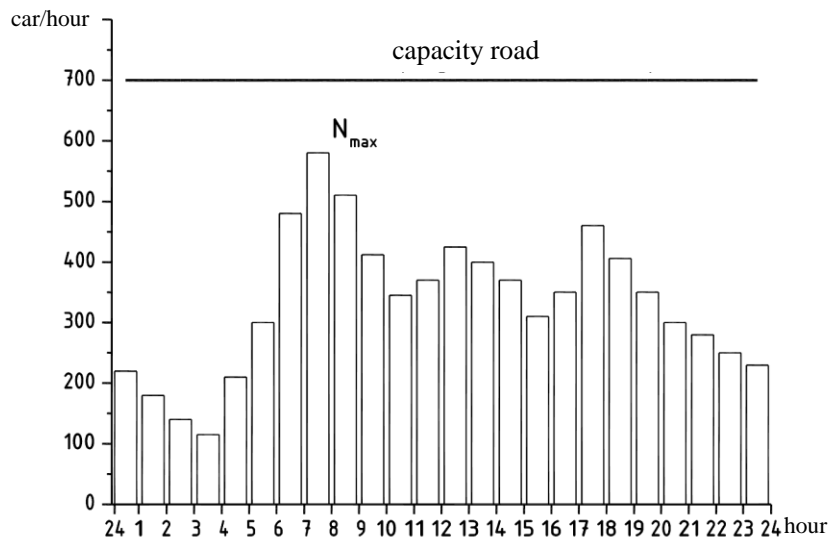
To seek the ways to improve the street-road network functioning by mathematical statistics methods use.

### 4. Main material and methods

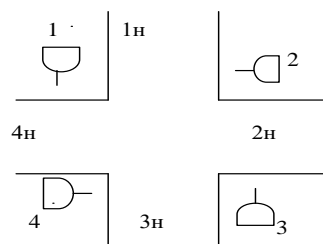
Under current housing development conditions the city problem on how to rise of street-road network traffic capacity is quite urgent. It’s resulted in considerable material costs dealing with city streets and roads traffic way widening and in certain cases this process is completely impossible. Meanwhile, the increasing number of individual vehicles, their general availability for the population makes this problem to be solved immediately.

In should be noted that there are several ways to improve the street-road network functioning. The most important of them are: to reduce the number of vehicles (here i.e. to decrease the vehicle intensity on all road network sections) and to shift traffic flows (here the vehicle intensity can be the same or it will increase).

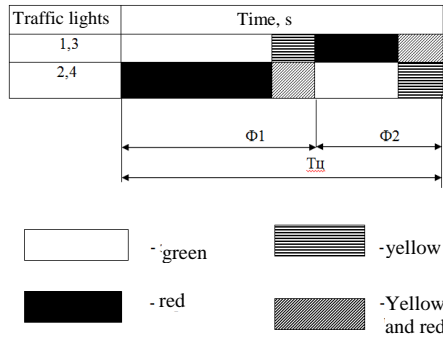
Dependency diagram of hourly traffic flow intensity on main roads of SRN connecting residential areas with the city center is shown on Fig. 1. Having analyzed the diagram it can be seen that maximum value of intensity per hour  $N_{max}$  in rush hours doesn’t exceed the traffic capacity of the road. The factor limiting vehicle intensity increase is traffic signalization.



**Fig 1. Diagram of hourly traffic distribution on the main road of the cross-road under consideration**



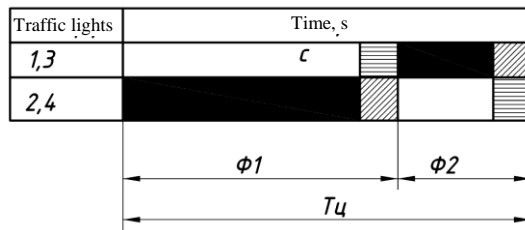
**Fig 2. Traffic lights scheme**



**Fig 3. Typical diagram of 2-phase traffic lights cycle**

The aim of the suggested measures is to increase vehicle intensity on the cross-road adjoining streets.

For this purpose statistical series of vehicle intensity values  $N_{hi}$  per hour are modeled on week days on the cross-road adjoining streets. Here  $i$  is a certain daytime ( $i=1..24$ ). For the small sample collection one needs to get not less than 10 values of hourly vehicle intensity at the same daytime  $N_{hij}$ , where  $j$  is a serial number of hourly vehicle intensity at certain daytime ( $j=1..10$ ). In this case the data selection will involve 240 values of  $N_{hij}$ .



**Fig 4. Corrected diagram of 2-phase traffic lights cycle at rush hours according to the law of hourly traffic distribution**

By Grubbs, Irvine or Romanovsky test (Kolker, 1976) they are tested on homogeneity. Values heterogeneity of statistical series may be influenced by random factors of occasional and nonrepeating nature. For instance, one of the city main roads was closed because of road accident and considerable hourly traffic increase was observed in this road section. When quite different values are found they are omitted and additionally they input the value  $N_{hij+1}$ , obtained at additional measuring and check statistical series on homogeneity once again.

Having obtained homogeneous statistical series of hourly traffic values and having applied the improved by small sample (Gaskarov & Shapovalov, 1978) iteration method (Kryvyi *et al.*, 2014) of the dependence for mathematical expectation  $M(N_{hij})$  finding, which is approximately equal to the average value  $\bar{N}_{hij}$ , i.e.  $M(N_{hij}) \approx \bar{N}_{hij}$  and dispersions  $D(N_{hij})$ .

$$M(N_h) \approx \bar{N}_h = \frac{a_1 + b_1}{2} \prod_{k=1}^n c_{ak} + \sum_{k=1}^n \prod_{k=1}^n c_{ak} \left\{ \frac{\sigma_a}{\sqrt{2\pi}} \left( e^{-\frac{z_{1k}^2}{2}} - e^{-\frac{z_{2k}^2}{2}} \right) + r_k [\Phi(z_{2k}) - \Phi(z_{1k})] \right\}, \quad (1)$$

$[a_1; b_1]$  - varying the value  $N_h$  known and considered such,  $a_1 = n_{K_{min}}$ ,  $b_1 = n_{K_{max}}$  ;

$n_{K_{min}}$  and  $n_{K_{max}}$  - according minimum and maximum value of hour-long traffic intensity  $n_k (k = 1, \bar{m})$  experimental data of a random value  $N_h$ ;

$C_{ak} (k = 1, \bar{n})$  - constant, what can be found according to the formula

$$C_{ak} = \frac{1}{1 + \Phi\left(\frac{b_1 - t_{1k}}{\sigma_a}\right) - \Phi\left(\frac{a_1 - t_{1k}}{\sigma_a}\right)};$$

$\sigma_a = \frac{b_1 - a_1}{6}$  - standard deviation random value  $N_{hij}$ ;

$z_{1k} = \frac{a_1 - n_{hk}}{\sigma_a}$  and  $z_{2k} = \frac{b_1 - n_{hk}}{\sigma_a}$  - limits of integration for random value  $N_{hij}$ ;

$\Phi(z_{1k}), \Phi(z_{2k})$  - Laplace function for random value  $N_{hij}$ .

The determined mathematical expectation of hourly traffic allows the distribution law of the given value to be established within small limits during 24 hours. After hourly traffic determination traffic lights cycles are adjusted so that green color cycle lasts longer in those periods when vehicle intensity increase was found by distribution law.

The exact time of traffic lights can be calculated analytically by hourly traffic values obtained after either observation or computer simulation.

Those traffic lights where traffic lights cycles' time changes are recommended to equip with digital time indicator of green light signal (Bakulich, Dziuba, Yeresov, 2014).

After suggested measures taking their efficiency is estimated by Student' criterion  $t_k$  and Fisher' ratio test  $F$  by the method described in (Kolker, 1976). To perform this an hourly traffic  $i_h$  is determined during 24 hours by the earlier described procedure method and form the sample. Sample characteristics  $\bar{N}_{hij}$  i  $D(\bar{N}_{hij})$  are determined.

Student' criterion is used (Kolker, 1976)

$$t_{k_{Ra}} = \frac{|\bar{R}_{a_{i+1}} - \bar{R}_{a_i}|}{\sqrt{n[D(R_{a_{i+1}}) + D(R_{a_i})]}} \cdot \sqrt{n(n-1)},$$

and on its basis the probability  $P(t_k)$  is determined, according to which the considerable difference is found [3] among average values  $\bar{R}_{a_i}$  obtained at different entries  $s$  values.

By Fisher' ratio test

$$F_{N_n} = \frac{D(\bar{N}_{h+li})}{D(\bar{N}_{hi})},$$

where  $D(\bar{N}_{h+li}) > D(\bar{N}_{hi})$  determine the value  $F_{N_n}$ , compare it with table value  $F_{TN_n}$  and, according to significance level  $q_0 = 0,05$ , and value  $k = n - 1$  they find the considerable difference between values  $N_{hij}$  dispersions obtained at different values  $h$  and they admit that traffic lights cycles changing greatly influences or doesn't influence the dispersion of scattering of roughness parameters values.

The above mentioned measures should be taken only on the troubled cross roads of street-road network. In most cases these are the main streets where traffic is queuing from suburbs to the city center in the morning and in the opposite direction in the evening.

To collect statistical data on one cross road it takes 10-14 days depending on the formed statistical series homogeneity.

## 5. Conclusions

Some measures to increase vehicle intensity on the cross-road adjoining streets by traffic flows redistribution are suggested. Traffic flows are suggested to be redistributed by means of traffic lights cycles' time changing based on hourly traffic diagram analysis being obtained by statistical analysis and small sample theory.

## Appendix A. Supplementary material

Supplementary data associated with this article can be found, in the online version, at <http://jsdtl.sciview.net>

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