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RESEARCH OF AN INFLUENCE OF A TRAFFIC FLOW MOVEMENT INTENSITY CHANGE ON THE POSSIBILITY OF NONSTOP PASSAGE OF THE TRAFFIC LIGHTS OBJECTS

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There were examined the problems of passage of the regulated parts of a road. There were investigated the changes of a traffic movement intensity in Lutsk (Ukraine) during the spread of Covid-19 pandemic. The graphic dependences of the drivers' actions estimation while passing the traffic lights objects on a chosen movement route at the beginning of quarantine measures, during the least movement intensity and at the increasing of movement intensity, were obtained. A method of increasing of a possibility of the traffic lights objects nonstop passage was offered.

Keywords: traffic lights, data exchange, vehicle, traffic flow, Covid-19, nonstop pas-sage, movement intensity

1. Introduction

The research of traffic flows is always quite a difficult task, as it leads to the need to solve a multi-criteria problem, because during the movement of vehicles there are a large number of external factors that in one way or another affect traffic, thereby complicating the task of rapid response. There are rapid and significant changes in traffic flows, to which it is necessary to respond quickly and make changes in the organization of traffic. This is difficult to predict for traffic flows, which is associated not only with changes in vehicle design, with changes in the behaviour of road users, but also the development of settlements. The proposed research topics can be considered relevant not only now but also for the future.

Intensity of the vehicles movement in a city is a determinant indicator for many different calculations and models, such as a setup of the road traffic regulation systems, a model of an environment condition, and also give a possibility to determine the critically problem parts of streets and roads net, that enables in future to make the effective decisions about the reorganization of a traffic movement and to decrease a number of traffic jams in cities.

The aim of the research is to study the impact of changes in traffic intensity on the possibility of uninterrupted passage of traffic lights during a pandemic Covid-19. The introduction of quarantine during the Covid-19 pandemic facilitated research, as sharp fluctuations in the intensity of traffic flows allowed the use of stress methods to conduct research. After reviewing the literature, the relevance of the topic and identified the main areas of work. Based on the results of experimental research, a method for evaluating the operation of traffic lights and a system for displaying the recommended mode of movement of the vehicle has been identified and proposed. This approach, together with the use of an automated control system, allows not only to choose the most rational mode of operation of the traffic light object, depending on the real traffic situation, but also to help the driver choose the optimal traffic mode.

2. Literature review

A question of transport movement intensity in localities is rather often examined by the leading scientists for different purposes. There were made many researches connected with the examination and modelling of the vehicles movement intensity on the streets and roads net of different cities (Bartuška *et al*., 2015; Cools *et al*., 2010; Dzyura, 2016).

A question of the traffic jams decreasing on the city streets is rather of current interest and its importance increases constantly together with the increasing of number of the vehicles on the streets and roads

net of a city. Scientific approach to the research of the means and methods of the traffic jams decreasing always changes, though it is necessary to have still a lot of time to solve this problem. Solving of a traffic jams problem is shown in papers (Nguyen-Phuoc *et al*., 2020; Anderson, 2013; Ben-Dor *et al*., 2018; Chandra and Kumar, 2003; Falcocchio and Levinson, 2015; Lindley, 1987; Pavkova *et al*., 2016; Metz, 2018).

In a research work by Lu *et al*. (2020) is investigated an influence of the autonomous vehicles on a movement intensity and there was made a corresponding modelling of a road traffic that proves the increasing of streets and roads net carrying capacity with the implementation of pilotless vehicles. That is why the solving of a problem of traffic jams decreasing in cities needs constant attention.

One of the methods of fuel economy is the use of methods of economic driving, which depend on the condition of the road and the organization of traffic lights (Mintsis *et al*., 2021).

The research of the algorithm for planning the optimal speed of the vehicle to increase the efficiency of the vehicle is quite extensive. As a result, Mahler and Vahidi (2012) conducted a simulation that shows that it is possible to increase the efficiency of the passage of regulated intersections by using the probabilistic time and the obtained data on the phases of traffic lights.

In such researches, it is important to take into account the human factor (Johansson and Rumar, 1971). Not all recommendations can be followed by the driver on time and in accordance with the tasks, so it is necessary to enter additional coefficient during such researches.

Research is also conducted in the areas of the optimal control formula and the choice of the trajectory of the vehicle in areas with traffic light control, which takes into account both the queue at the site and the algorithm of the traffic light (He *at al*., 2015).

When considering macromodelling of traffic among transport planners, we can note that it is quite effective, because it allows to make traffic safe in advance and to assess the dynamic and complex effects of the traffic system (Archer, 2005). This makes it possible to economy additional fuel.

Researches are conducted with the optimization of traffic and the entire traffic flow, the so-called green wave, by using a given speed mode and automated vehicles (Jiang *et al*., 2017).

In paper by Török and Kertész (1996), the research was carried out on a computer model of a green wave was performed, extrapolating to an infinite size of the system, which indicates the transition of nonzero density from free flow to the overloaded state.

Special attention should be paid to researches (Jiang *et al*., 2021), during which the behaviour of drivers is taken into account, and the results obtained allow to regulate the flow of traffic.

The paper by Zhang *et al*. (2020) presents an extended integrated method of green wave control to solve the problem of coordinated control, which takes into account the limitation of green time to ensure the required time of vehicles on branched roads and pedestrian crossings at intersections.

Problems of traffic flow, in particular the possibility of creating a green corridor for ambulances are considered in the work (Rajak *et al*., 2020).

Thorough research on the synchronization of traffic lights, taking into account the fluctuations of traffic flows on individual streets and intersections using automated traffic data in real time conducted by the authors (Guadamuz *et al*., 2021).

It is also worth noting the work (Mintsis *et al*., 2021; Zhang *et al*., 2021), which also addresses the problems of traffic organization on individual elements, as well as the possibility of using various sensors and auxiliary devices to facilitate the actions of drivers.

In ordinary conditions an intensity of vehicles movement in a city is almost constant, but it can slowly vary depending on the day of the week, the season and on the before holiday, holiday and after holiday days. In a case of the unpredictable conditions this index can vary unexpectedly, that rather complicates a possibility to promptly control the vehicles road traffic. Besides that a determination of the factors that cause some events, gives a possibility in future to minimize an influence on the traffic jams on the carrying capacity of the streets and roads net of a city. A determination on an influence of stress factors on the traffic jams is described in the research works (Nguyen-Phuoc *et al*., 2018a, 2018b; Pnevmatikou *et al.,* 2015; Rubin and Mansour, 2013).

3. Experiments and results

After the quarantine implementation on 12 March 2020 and its intensification on 19 March 2020, in Ukraine, and especially in Lutsk, there was stopped an activity of:

- educational establishments;
- urban, suburban, interurban public transport (buses, trolleybuses);
- public catering establishments;
- markets, shops.

Along with that nearly 40% of the enterprises continued they activity partially in a distant, and partially in a normal mode.

These factors caused an intense change of traffic flow intensity on the streets of a city (Figure 1).

The biggest change of a transport flow movement had place at the weekends – Saturday and Sunday, and also during an implementation of the additional quarantine events introduced from the 11 April 2020.

Then an intensity of a movement decreased to a graduation mark <30% comparing with the received data before a quarantine.

Exploring the further development of Covid-19 pandemic and the changes of intensity of transport movement, there was obtained the next graphic dependence (Figure 2).

Beginning at 12 May 2020 the traffic flow movement in Lutsk started growing up and reached the indices that were typical before the quarantine implementation. Beginning at 17 May 2020, when the most of enterprises started to open, the transport movement intensity grew up from 10 to 30%.

To choose how the movement intensity during the Covid-19 pandemic influences a possibility of traffic lights objects nonstop passage, there were made the additional monitoring on a route from one part on Lutsk to another (Figure 3).

The monitoring was made in a time period from 07:00–08:00, 10:00–12:00, 14:00–16:00, 19:00–20:00.

From 12 March 2020 to 18 March 2020 a movement intensity was high (Figure 4), and an operating mode of the traffic lights objects stayed fixed. Where: “green scale” shows a “real possibility” – it’s a percentage of cases that allow to a vehicle to pass a traffic lights object without stop (here there are included the real speeds and a time of passage to the traffic lights); “red scale” shows a “nonstop passage” – it’s a percentage of the vehicles that crossed the traffic lights without stop; “yellow scale” shows a “possibility application” – it’s a correspondence of a nonstop passage to a real possibility to cross the traffic lights.

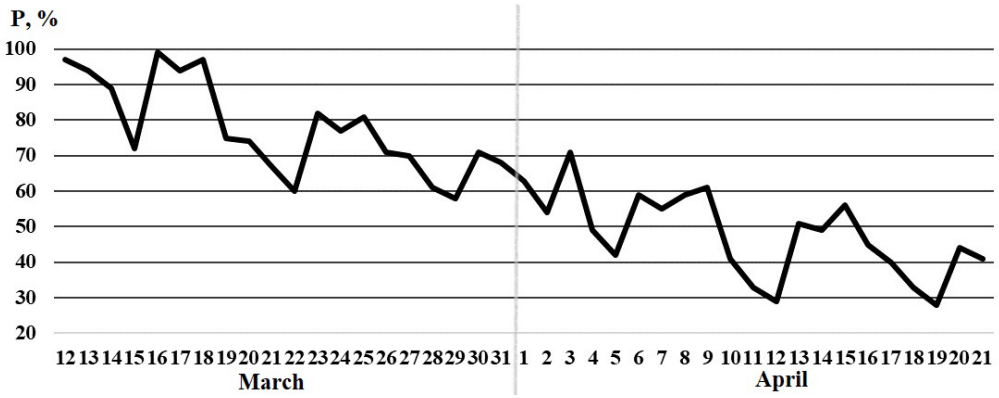


Figure 1. Intensity of a transport movement in Lutsk from 12 March 2020 to 21 April 2020 during the pandemic of Covid-19

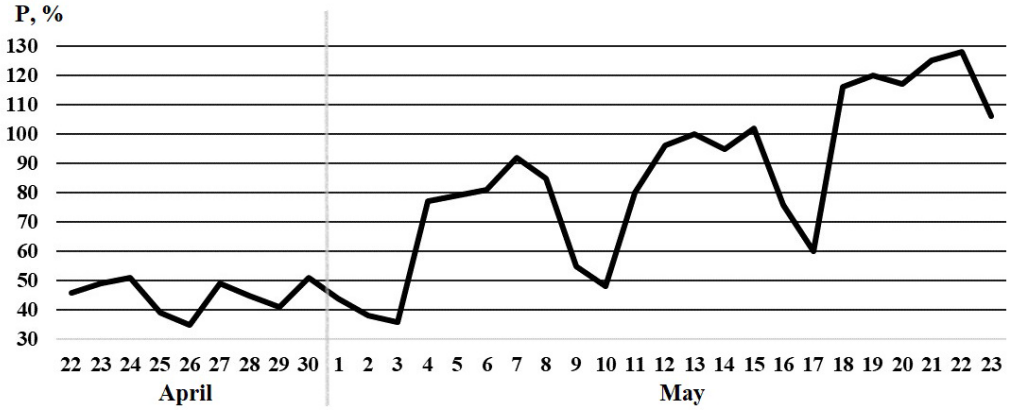


Figure 2. Transport movement intensity in Lutsk from 22 April 2020 to 23 May 2020 during the pandemic of Covid-19

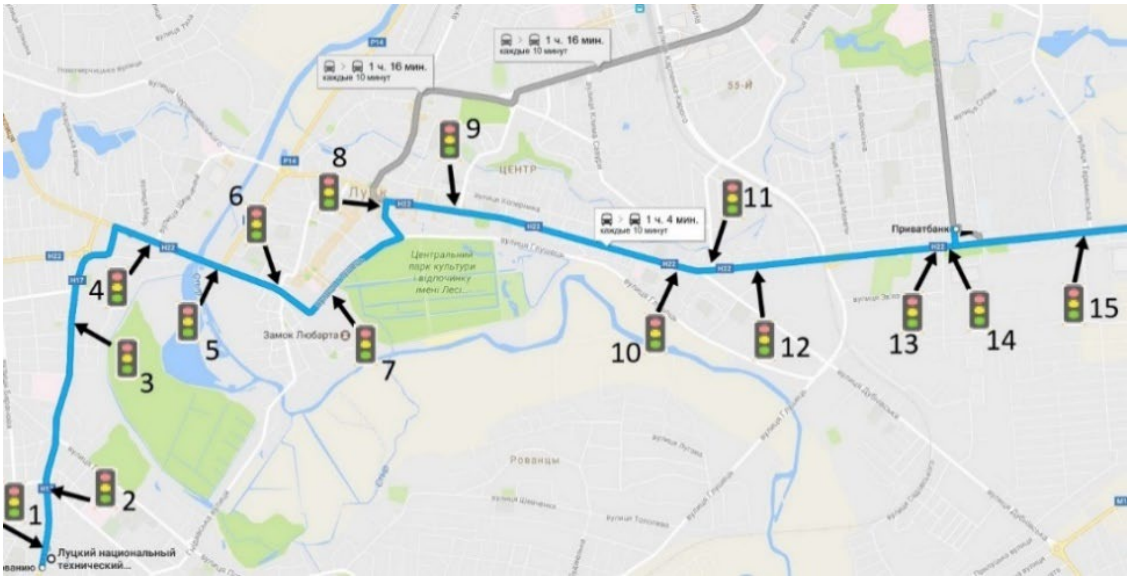
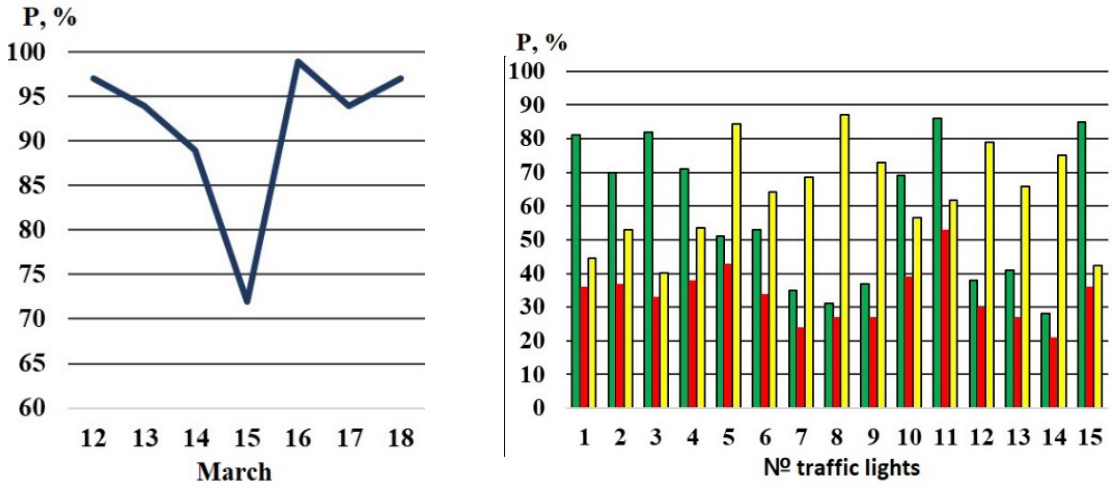


Figure 3. Arrangement of the traffic lights in Lutsk on a route Lutsk National Technical University – Modern-Expo



a) b)

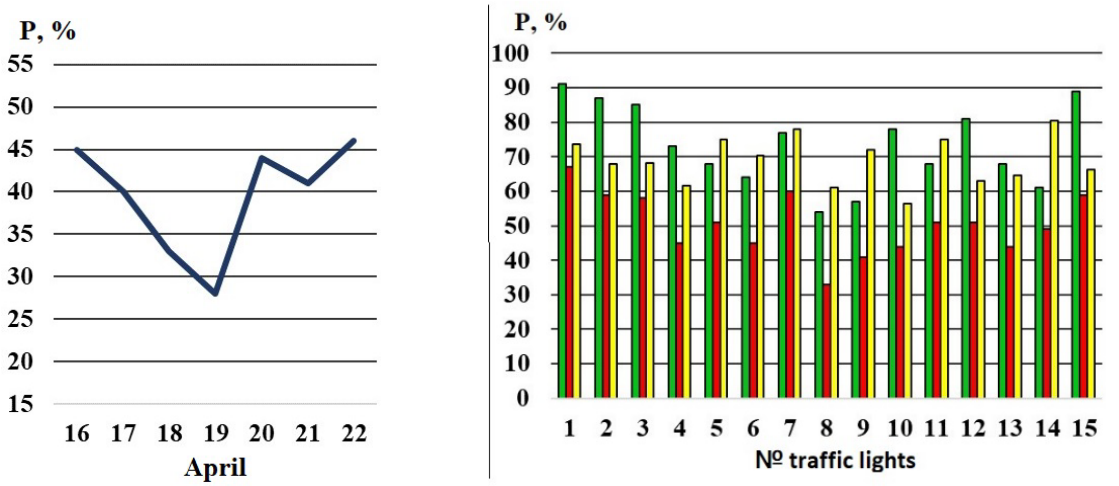
Figure 4. Graphic dependence of the transport movement intensity at the beginning of a quarantine from 12 March 2020 to 18 March 2020: a – transport movement intensity; b – researches results and evaluation of drivers' actions when passing the traffic lights objects on a given route

According to the calculations results there was found that the efficiency of actions after the passage of traffic lights objects is from 42% to 87 %, depending on a complexity of a regulated road part.

Based on a statistic of "possibility application" of a nonstop passage of the traffic lights, it can be noticed that the drivers use a traffic lights passage non-efficiently.

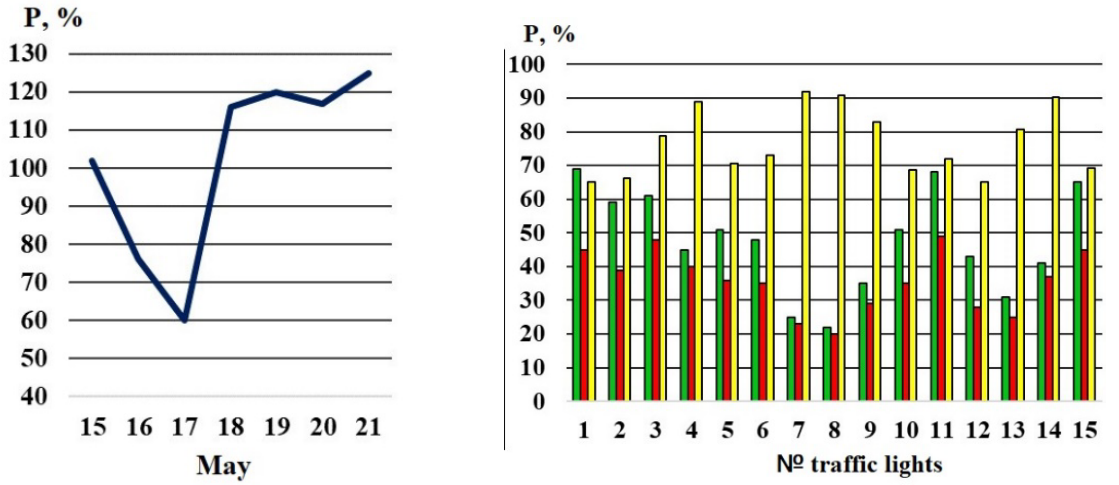
Similarly, there were built the graphs from 16 April 2020 to 22 April 2020 when the vehicles movement intensity was the lowest (Figure 5). An operating mode of the traffic lights objects was changed at the same time, a public transport was absent and a movement intensity decreased for more than 50%. Based on the calculations, a possibility of traffic lights objects passage grew up. A percentage of the drivers, who used this possibility, was from 56% to 81%.

From 15 May 2020 to 21 May 2020 vehicles movement intensity increased, but not all the traffic lights objects changes their operating mode according to this movement intensity (Figure 6). Public transport at given period didn't work, and a possibility to pass the traffic lights without stop decreased and was an average 51%.



a) b)

Figure 5. Graphic dependence of the lowest transport movement intensity during a quarantine from 16 April 2020 to 22 April 2020: a – transport movement intensity; b – researches results and evaluation of drivers' actions when passing the traffic lights objects on a given route



a) b)

Figure 6. Graphic dependence at increasing of a transport movement intensity during a quarantine from 15 May 2020 to 21 May 2020: a – transport movement intensity; b – researches results and evaluation of the drivers' actions when passing the traffic lights objects on a given route

Results of the analysis of the before mentioned graphs allowed to find the reasons of decreasing of the traffic lights passage possibility. In such a way there was ascertained that during a decreasing of movement intensity and a corresponding regulation of the traffic lights, it is noticed a decreasing of possibility of the traffic lights nonstop passage, at the same time a real possibility of passage increases, that completely corresponds to the main statements of a theory of a road traffic regulation. Along with that a real possibility of the traffic lights nonstop passage decreased during an increasing of a movement intensity and an absence of changes in a traffic lights operation. This fact affirms that such an index as "real possibility" of passage R can be used with an aim to evaluate the traffic lights operation. Increasing of this index to a level of 100 % gives evidence of right cycles of a traffic lights operation:

$$R \to 100\,\%, \tag{1}$$

where R – real possibility passage.

Besides that, an analysis of a work of the traffic lights situation points and of the road traffic schemes demonstrates that, with account of a possibility of the traffic lights object passage by all the participants of a road traffic, the next condition is necessary:

$$\sum R_i \to 100\,\%. \tag{2}$$

where $\sum R_i$ – total possibility of a passage of the traffic lights object from every direction.

That is:

$$\sum R_i = R_1 + R_2 + ... + R_n, \tag{3}$$

where n – number of movement directions, or number of switchings of a traffic lights signal.

In fact a part of a movement intensity that accounts for every movement direction $i_{ri} = R_i$, that is why:

$$\sum i_{ri} = 100\,\%. \tag{4}$$

In a case of a similar intensity of a traffic flow, a real possibility of a traffic lights object passage can be found by a dependence:

$$\sum R_i = \frac{\sum i_r}{n}, \tag{5}$$

in other case it is necessary to investigate a given intensity of the flows by every direction, and a dependence will look like:

$$\sum R_i = \sum_{k=1}^{n} i_{rk} \to 100\,\%. \tag{6}$$

It is worth mentioning that the offered scheme was developed in a case of meeting of a condition of a traffic lights object passage by all the vehicles, that is a chosen traffic lane after the traffic lights passage is expected to be limitlessly free.

An index of a “possibility application” of the traffic lights object nonstop passage is correlated with an index “real possibility” of the traffic lights passage, and correspondingly decreases to 0 provided that $\sum R_i \to 100$.

The offered method of evaluation of a traffic lights operation can be effectively used to promptly operate the traffic lights objects using the automated control systems. Such approach will give a possibility to exactly evaluate a traffic lights operating mode and to choose the most rational, depending on real road situation, especially of a movement intensity.

4. Results application

To increase the indices that are marked yellow colour of “possibility application”, it is possible to use an additional system (Sitovsky and Mazyliuk, 2018; Mazyliuk, 2018, 2019) that reflects to drivers a prompt about the actions necessary to do in order to pass the traffic lights objects without stop when there is a “real possibility” of it (Figure 7).

Given system of reflection of a recommended movement mode works in such a way.

When a vehicle 1 enters a zone of input device operation 5, there happens a data exchange between a transfer device 3, that transfers to a vehicle an information about the operating mode of the traffic lights 4. An input device 5 transfers received information to a controller 6, that also receives data from the devices of a vehicle 1, after that the received information is used to calculate a recommended deceleration or acceleration of a vehicle with a next reflect of it on a scale 8 of an indicator 7. At the same time a scale 9 reflects a real deceleration or acceleration of a vehicle movement.

A driver, when slowing down or speeding up according to the indices of a scale 8, should maximally approximate a real deceleration or acceleration of the indices of scale 9 up to the recommended one. The more these indices would coincide, the more would be a possibility of nonstop passage of a regulated road part.

A system of reflection of a recommended vehicle movement mode recommends to a driver a necessary deceleration or acceleration of a vehicle and at the same time shows its real value, that allows passing a regulated road part safely and without stop.

Respectively a using of a system should take place together with a created software (Sitovsky *et al*., 2018). The studies and the results obtained are of scientific and practical importance and are important in the training of transport specialists (Shramenko *et al*., 2020).

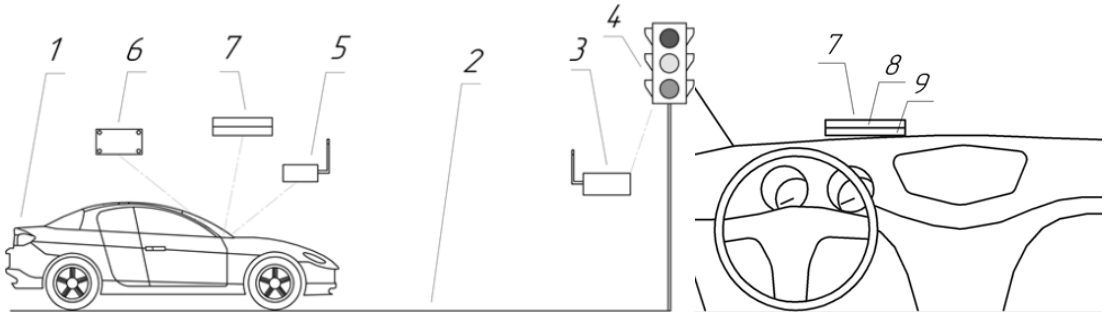


Figure 7. System of reflection of a recommended movement mode: a – system scheme; b – situation of a data exchange indicator

5. Conclusions

The results of the made researches demonstrate a possibility of application of the stress research methods. The essence of these researches consists in a forced decreasing of a traffic flow that moves from some directions or vehicles of some type. Along with that, while handling by a change of cycles of a traffic lights operation, it is possible to make an effective modelling of a traffic flows movement by a streets and roads net of a city and to reach by this an increasing of real possibility of a road part passage. This modelling is worth do be made using a software *PTV Visum*. Therefore, if a single traffic light object is considered, it is advisable to use *PTV Vissim*, but in the conditions of the settlement, it is necessary to carry out modelling, taking into account all significant influences, so it would be appropriate to use *PTV Visum* software.

Certainly in real conditions of movement there can occur some problems with an optimization of movement on some parts that are connected with an impossibility to realize an offered scheme in all the directions at the same time, that is why in this case it is necessary to make a synthesis of the methods of passage of a streets and roads part with a traffic lights subject when on one direction there is met a condition of application of a real passage possibility, and on the other direction there is assured an application of a possibility of nonstop passage of this road part. In order to maximally apply a method of nonstop passage of a streets and roads net part with a lights regulation of movement, it was offered to integrate an offered model in a system of reflection of an offered mode of a vehicle movement that was developed on a Department of the Automobiles and Transport Technologies of Lutsk National Technical University (Ukraine).

In future the mentioned researches results give a possibility to make a modelling of road traffic on a streets and roads net with a traffic lights regulation more effectively and using a synthesis of different methods to gain a significant decreasing of traffic jams on the city roads, especially using the data exchange be-tween a vehicle and the traffic lights.

It is worth mentioning that the given research results concern only a single traffic lights object, when investigating a row of such objects on a vehicle movement route, it would be necessary to make the additional researches taking into consideration a number of factors of a model.

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