Innovative Approaches in the Organization of Traffic on the Road Network and Their Applicability in the Practice of Urban Planning

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Abstract. This article discusses the most advanced solutions of the organization of transport and pedestrian communication networks used in Europe since the end of the twentieth century. The possibility of their use in the Russian realities is analyzed the conclusion about the need for innovations in the design activity based on statistical and analytical research methods is made. By mathematical operations, the formula of calculation of the probability of road accidents intended for the analysis of the existing situation and justification of the adoption of measures of further development of safe transport infrastructure is deduced. A conceptual model of the intersection, taking into account some performance indicators of the road network, which is not emphasized in the design in Russia, as well as reflecting the fundamental European methods of safety and comfort for all social groups of road users.

1. Road network in urban environment

The concept of sustainable development of territories involves the interrelation of three aspects: economic, sociological and environmental[1]. According to these aspects, there is a need to renovate approaches in urban planning, taking into account the revision of the priorities of the underlying design parameters, in order to achieve a balance of the developing situation.

Also, one of the important factors of economic efficiency not only of the state but also of any socio-territorial object is rational and expedient planning of transit communications between enterprises that create the skeleton of the economy and provide the market with new resources. Thus, the road transport network creates an opportunity for the development and productivity of the economy and carries the beginning of the establishment of the entire life support system of citizens.

Organizing the environment of settlements not only according to the needs of industry, but also the needs of the population, architectural and aesthetic trends, laid the Foundation for a comfortable urban space that satisfies the modern requirements of urbanism[2], which creates a favourable psychological background that increases sociological efficiency and the overall level of comfort.

Simultaneously, all human actions must correspond to the requirements of environmental and technosphere safety, minimizing the impact on the natural ecosphere and violation of its integrity[3]. One of the tendencies of modern urbanism is the principle of the relationship between people and the environment as a symbiosis, which is the essence of biosphere compatibility[4]. Based on these
aspects, sustainable development and complex improvement of all spheres of human activity are achieved.

One of the planning tasks in the design of the road network is to ensure the rationality of communications between the districts of the city, taking into account the needs of all groups of the population and the correlation of the development of the road transport skeleton with the level of motorization. In many ways, this factor depends on the planning structure of the city, the existing buildings, the level of development of public spaces and the functional purpose of the settlement. Also, with the rapid development of transport infrastructure, there is a discrepancy between the level of motorization and spatial solutions of the urban environment. There is no universal paradigm of complex solutions in this issue, only examples already implemented in practice, with positive and negative consequences, but the main thesis is the same for all: ensuring the continuity of movement for all participants[5].

In the urban environment formed the situational organization of functional areas, the relationship between which is provided by communication routes and urban planning solutions of their placement. On the rationality of this system depends not only the growth of the city in the economic and social spheres but also its very existence. For this reason, road network planning is the highest priority in achieving sustainable urban development[6].

2. Aspects of the road network
The design of pedestrian and transport communications is based on the aspects of safety, expediency, accessibility, and comfort, which allows all users of the road network to move around the city with maximum efficiency (accessibility, the rationality of routes, simplicity, comfort, and speed of movement). Moreover, all aspects should interact in an integrated manner to ensure the effectiveness of pedestrian and transport links.

2.1. Safety assessment of the road network
Assessment of the level of road safety in Russia is regulated by the branch document [7]. The calculated indicators include the smoothness and uniformity of the route, the consistency of design decisions, the degree of compensation for errors of the driver by the road and the level of consumer properties of the road. Western researches and statistics show that traffic safety is more influenced by the maximum speed of vehicles, visibility and the presence of blind spots, which are reflected only indirectly in the Russian document. At the same time, the death rate per one hundred thousand people in road accidents in Russia is four and a half times higher than in Europe[8].

According to the traffic rules in force in the territory of the Russian Federation, the speed within the city limits to sixty kilometres per hour, which in practice can reach seventy-nine, while creating circumstances of increased probability of an accident with serious consequences, when the driver "did not notice" or did not have time to respond to a sudden obstacle in the form of another car or pedestrian. This does not consider the effect of tunnel vision that occurs when driving at high speed, which reduces the visibility of pedestrians and increases the reaction time of the driver[9].

In European cities, the maximum speed limit of cars in some areas is twenty kilometres per hour. There is also a separate standard [10] for calculating the visibility of each group of road users. The main principle underlying the design of a safe road network: "everyone should be visible to all." This creates the possibility for a full assessment of the situation, provides the necessary reaction time, and in some cases the establishment of visual contact between road users.

In addition, the technological parameters of the road network, it is necessary to consider the psychology of the pedestrian and the driver[11], as some social groups have certain characteristics of behaviour that impede the movement of other traffic participants (schoolchildren, elderly people, disabled people). Their specific behaviours are presented in table 1, which in turn can significantly increase the probability of an emergency. Therefore, it is necessary to consider the fact of their appearance and design transport and pedestrian communication networks, ensuring minimization of
their occurrence through physical restrictions, elimination of blind spots, ensuring visibility and safe speed limits[12].

Table 1. Characteristic indicators of behaviour on the road of some social groups (schoolchildren, the elderly, the disabled).

| Terminal indicators        | Instrumental indicators |
|----------------------------|-------------------------|
| Incorrect assessment of the situation | Insufficient awareness |
| Low attention coefficient  | Narrow visual sector    |
| Difficulties of mutual understanding | Difficulties in making decisions |

2.2. The dependence of the accident on the parameters of interaction of road users

Taking into consideration the characteristics of the behaviour of pedestrians and drivers can display a function of the probability of accidents (formula 1), reflecting an inverse relationship between the incorrect assessment of about the pedestrian \((W_P(I_P))\), which arises due to insufficient awareness \((I_P)\), and a correction factor \((A)\), showing the compensation of errors of the pedestrian by the driver, considering weather conditions and road factors \((N)\).

\[
Z = \frac{W_P(I_P)}{A} \cdot N
\]  

This dependency represents the situation in the form of the polynomial equation, the estimated value of which lies in the interval from zero to unity \((0 \leq Z \leq 1)\). At the extreme values of the interval, two states are reached: critical \((Z=1)\) and ideal \((Z=0)\). The characteristics of the states are presented in table 2. According to the obtained values, it is possible to analyse about an accident, predict its evolution in the positive and negative aspects, as well as to assess the progress of decisions and measures to ensure the safety and comfort of the road.

Table 2. Characteristics of critical, ideal and intermediate states.

| State          | The index of the estimated expression |
|----------------|---------------------------------------|
|                | \(W_P(I_P)\) | \(A\) | \(N\) | \(Z\) |
| Ideal          | \(\rightarrow 0\) | \(\rightarrow \infty\) | \(\rightarrow 0\) | 0 |
| Critical       | \(\rightarrow \infty\) | \(\rightarrow 0\) | \(\rightarrow \infty\) | 1 |
| Intermediate   | \(\infty \); 1) | \(\infty \); 1) | \(\infty \); 1) | \(\infty \); 1) |

2.3. European approach to design of the road network

In European countries, where historically there was a close urban development with narrow streets, there is a lack of areas, as well as a significant indicator of population density, it is possible to identify a number of measures to address the organization of the street and road network[13]:

- Mass Cycling of the population and providing the necessary infrastructure: the creation of a network of Bicycle paths, promotion of healthy lifestyles, a system of incentives for the use of two-wheeled transport.
- The displacement of road transport outside the historic centres of the city to preserve the integrity of architectural monuments.
- Ensuring comfortable movement of pedestrians in urban space, both in terms of organization and rationality of movement, and in terms of the visual component.

These strategies of urban policy amortize environmental problems, reducing harmful emissions from transport, increasing the rate of social interaction of citizens, as well as significant financial resources, are spent on more priority tasks, which solves the economic issue. Thus, the sustainable development of the city is ensured.

2.4. The Russian approach to the design of the road network

In the Russian realities actually do not apply methods of control of car use[14], as a result of which there are problems caused by a significant difference between the level of motorization and
development of road network. Relatively recently, the use of Western developments in the field of private transport control has begun, but the activities are carried out point-by-point with the huge differences in the representation of a properly organized road transport network of Russian citizens and Europeans.

Road users in all cities of the world are represented by different composition, size, and capabilities of social groups. And everyone should be provided with access to the use of road network, both at the physical level (providing ramps, designing convenient longitudinal and transverse slopes, the possibility of passage or passage), and at the level of understanding of the organization of traffic (providing visible road signs, information boards, sound and visual designation system).

The level of use of road transport infrastructure is also provided by its comfort. The overwhelming hedonistic psychology of man [15] dictates the vectors of development of the urban environment, which must be taken into account, and either embody (the organization of the pedestrian network on the trodden paths) or reorient in another direction (public transport instead of a personal car).

3. Efficiency evaluation of the road network

Thus, safety, expediency, availability and comfort, with a rational system of their interrelation, provide a quality road transport infrastructure, the effectiveness of which is measured by the indicators of the road network assessment presented in table 3, more fully revealing its essence, allowing to identifying not only the vectors of further development, but also to set certain technical characteristics of the projected space. In this regard, there is a need to revise the domestic approaches to the design of the road network, not covering the full range of factors affecting its effectiveness. Modern Russian standards require the recalculation of norms in accordance with modern conditions of construction and the rapid modernization of technologies [16].

| An aspect of the organization of the road network | Indicator of the efficiency of the road network |
|--------------------------------------------------|------------------------------------------------|
| Road safety                                       | Criminal risks                                  |
|                                                   | The presence of conflict points                 |
|                                                   | Blind spots and "traps"                         |
| The rationality of traffic management            | Area and density of the planning structure of the settlement |
|                                                   | Connectivity and rationality of transit communications |
|                                                   | Throughput and transportation capacity          |
|                                                   | Traffic intensity                               |
|                                                   | Level of motorization                           |
|                                                   | Satisfaction ecological requirements            |
|                                                   | The energy efficiency of transport infrastructure |
| Availability of use of the road network           | Level of service of road structures and various types of transport (personal, public, bicycle, pedestrian) |
|                                                   | Financial resources of the municipality and the population |
| Comfort of movement                               | Compliance with modern technologies of construction and design |
|                                                   | Accounting of climatic features                 |

4. Conceptual model of the intersection

A number of these proposals are presented graphically on the conceptual model of street crossing. Figure 1 shows an example of crossing two-lane streets of equal importance, a distinctive feature of which is its primary focus on the pedestrian and cyclist. Each pedestrian crossing is equipped with an island of safety, which carries not only physical safety for a person but also psychological[17],
delimiting the zones of movement of drivers and pedestrians, while reducing the distance of a person in the "dangerous" zone and significantly reducing the risk of an accident. On the side of the roadway is equipped with a buffer zone in the form of tile paving, warning drivers from traffic in dangerous proximity to the sidewalk, which also serves to improve the safety of cyclists and pedestrians. A separate dedicated network of Cycling harmoniously correlates with car and pedestrian, is provided with refuge protect cyclists from turning cars. The organization of two-wheeled transport provides all the possibilities of the direction of movement, without depriving the convenience. It is taken into account that the cyclist is a hybrid of vehicle and pedestrian, and as a consequence, having related rights. Therefore, the lane of two-wheeled transport is pushed aside towards the roadway but is separated from it by a buffer zone, while the passage through the roadway is carried out by the cyclist together with the pedestrian. Such an organizational system is based on the thesis of the speed of movement of cyclists, much higher than the speed of a pedestrian, but also their vulnerability to cars, equal to the vulnerability of pedestrians.

Convention:

– The direction of possible movement of pedestrians;
– The direction of movement of the drivers;
– The direction of possible movement of cyclists.

Figure 1. Conceptual model of the intersection.

In the many cases, a person is aware of the danger of the road, as a result, he understands that the danger must be overcome as soon as possible. Therefore, there is a fact of running across roadway a pedestrian, for of reducing time spent in "dangerous" zone, this greatly increases the probability of accidents, because of the suddenness, of the falsity and recklessness of the actions of a pedestrian and insufficient reaction time of the driver.

The approach of reducing the time spent on the roadway is not correct, which is confirmed by statistics. The design of the road network should consider the aspect of reducing the distance that a pedestrian passes through the roadway, which is achieved by narrowing lanes, the presence of islands of safety, the distinction between traffic and pedestrian flows, while not limiting the rights and opportunities of each of the participants in the movement. Creating a comfortable and well-furnished...
Urban space is a complex design and philosophical task, which includes engineering calculations and knowledge of the psychology of the behaviour of masses and individuals.

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