

Abstract

The work is dedicated to improving the principles of roads' beautification elements placing. Is improved the classification of roads' beautification elements. Are detected the factors that affect the visual perception of road environment by driver and passengers. Are improved the principles of roads' beautification elements placing by developing new - the principle of simulation the spatial corridor. Are structured roads' beautification elements according to hierarchical levels. Is constructed the structural model of the spatial corridor of highway and street with distribution in sub corridors to deploy beautification elements. The spatial corridor and subcorridors are characterized by width, height and length and are proposed the formulas for their determination. For automation the determination of parameters the first time is developed a computer program ROAD BEAUTIFICATION. Is improved the methodology of designing comprehensive roads beautification according to the proposed principle.

Keywords

roads' beautification elements, perception, road environment, spatial corridor, design principle, 4D-modeling

1 Introduction

There is a steady trend of increasing economic, social and cultural impact of road transport on life in the country (Vankov, 2015).

Highways and streets are the place of employment (for drivers, workers of the road system and the state traffic police), movement and rest (for passengers, tourists), a visual and information channel for a large number of people. Their esthetic solution directly affect the living conditions of roadside areas inhabitants.

2 Defining the problem

The current deployment of beautification elements was investigated on Ukrainian roads of I-V-th category and city streets.

At inspection *the international highways of national importance of I category* identified the following main disadvantages: there are areas of roads that pass through the town; pedestrian crossings are often located in the same level with the road; on sections of roads that pass through the town and upon approaching the bridge greatly increases the number of beautification elements, including: billboards (majority established contrary to most applicable standards), nonstandard traffic information (located in the area of placing road signs); service facilities located unevenly: in some areas on average after 8 - 10 km, in other areas after 200 - 400 m. *Regional state highways of II category* are characterized by periodic alternation of open (a road runs through the field) and closed space (a road limited by two-way greenery) that has a positive effect on the human perceiving system. Lateral planting indicates the contiguity and turns. But there are road signs that are situated on the background of of billboards. The regional state highways of III category are characterized by closely planted roadside landscaping, tree crowns are hangs over the road and can create an emergency situation. Planting of poplar trees along roads creates a shimmering effect in sunny weather while driving. *Regional and district roads of local importance of IV and V category* differ by small number of beautification elements. Many public transit stops decorated with colorful ornaments. Along the road there are wells, chapels, churches, signs refer

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to land use business. Parts of roads passing through settlements often used by local inhabitants as a sidewalk because they have no special walkways. There are houses located at a distance of 3-4 meters from the road without fence. Urban planning composition of streets is characterized by glut of visual information, the most significant of which is advertisement. Large number of billboards placed against the norms and distract the driver from driving situation.

In the study of roads' beautification elements placing along highways in foreign countries found that service facilities are located on the same intervals along the road (USA - after 10 km; Germany - after 7 km), necessarily have bilateral placement with the organization the wide dividing strip or placed in various levels with road and road intersection. The distance from the edge of the road to the objects of service and the width of the territory they occupy in foreign countries is much greater (on average 86 m and 134 m respectively) than in the Ukraine (on average 15 m and 62 m respectively).

So placing of beautification elements along highways and streets in Ukraine today is not perfect. Part of the road environment of Ukraine is extremely saturated by separate elements of improvement, architectural placement of which is disordered. As a result, there is information overload and psychological stress of the driver. Other part is not enough ensured by elements of improvement that causes sensory deprivation of subjects of movement, perceiving system of which becomes insensitive. Also not always taken into account the relative positions of beautification elements of different groups. As a result, there are cases when one object interferes the perception of the other. These deficiencies can lead to traffic accidents and affect the aesthetic perception of the road in general. Therefore, the question of placing elements of improvement and creating comfortable spaces of communication is one of the important problems of road sector.

In many countries are performed scientific works devoted to beautification of roads and streets (Havard and Willis,

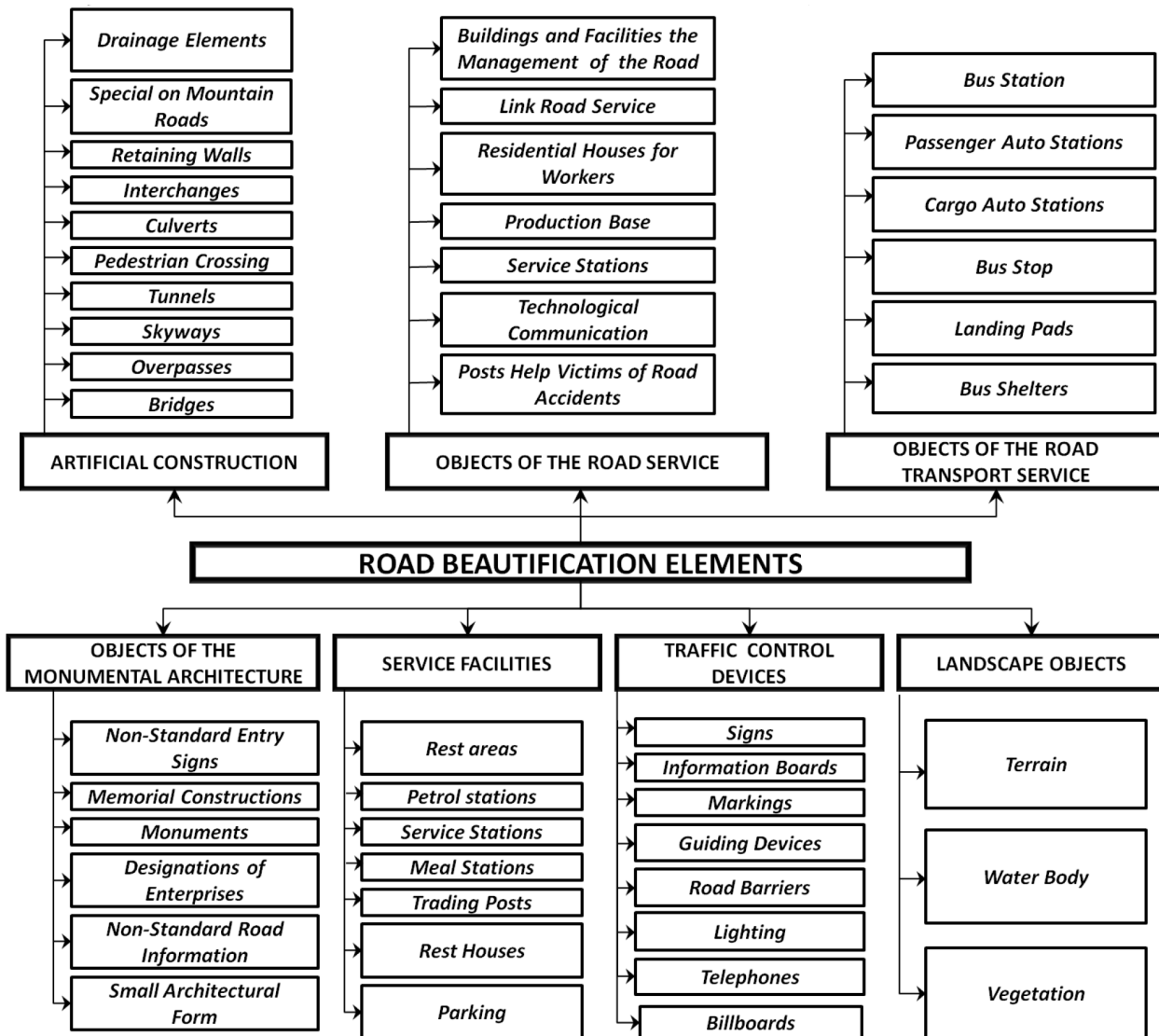


Fig. 1 Classification of road beautification elements

2012; Pellegrino, 2012; Parmet et al., 2014; Jou et al., 2013). However, existing theoretical studies are uncoordinated, fragmented, covering only the placement of individual beautification elements, without considering their complex arrangement, in conjunction with other elements. That's why it is necessary to improve the principles of placing beautification elements of roads and streets.

3 The conceptual approach to modeling the spatial corridor

After research and analysis of improvement of roads and streets, for convenient orientation in multiplicity of roads' beautification elements, was perfected their classification (Fig. 1).

On the basis of processed scientific works devoted to the visual perception of the environment (Bella, 2013; Blumentrath and Tveit, 2014; Borowsky et al., 2012; Bosurgi et al., 2013) identified the following factors that influence on the perception of road composition by drivers and passengers (Fig. 2).

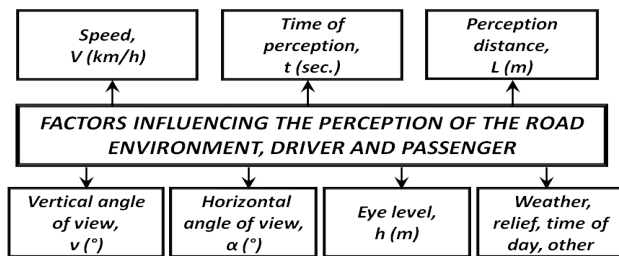


Fig. 2 Factor analysis of the perception of road environment by subjects of movement

Identified existing principles of roads' beautification elements placing: morphological structuring, composition principle, economic, genetic, landscape and environmental perception, visual perception (Sardarov, 2001; Jou et al., 2013; Li H. et al., 2011; Li Z. et al., 2011; Zhong et al., 2012).

It is proposed to improve them through the development of the new principle - modeling spatial corridor of highway, street (Fig. 3).

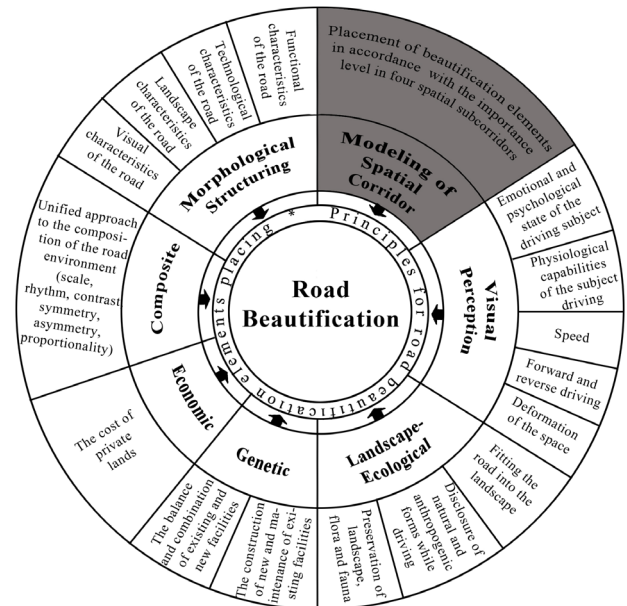


Fig. 3 Principles of road beautification elements placing:

- – the existing principles;
- – the principle proposed by the authors

In accordance with appointment, elements of roads improvement are distributed by level of importance into four groups. This is consistent with the Law of Ukraine „About automobile roads”, which clearly and in a hierarchical order defines the basic functions of roads: 1 - providing continuous movement, 2 - providing safe movement and 3 - providing convenient movement.

Beautification elements that provide first function - *continuous movement* - proposed to include to the **I level** of importance, the second function – *safe movement* - to the **II level** of importance, third function - *easy movement*, which depends on the satisfaction of physiological and psychological needs of movement - to the **III level** of importance. The environment in which road passes, it is proposed to include to the **IV level** of importance (Fig. 4.1, 4.2).

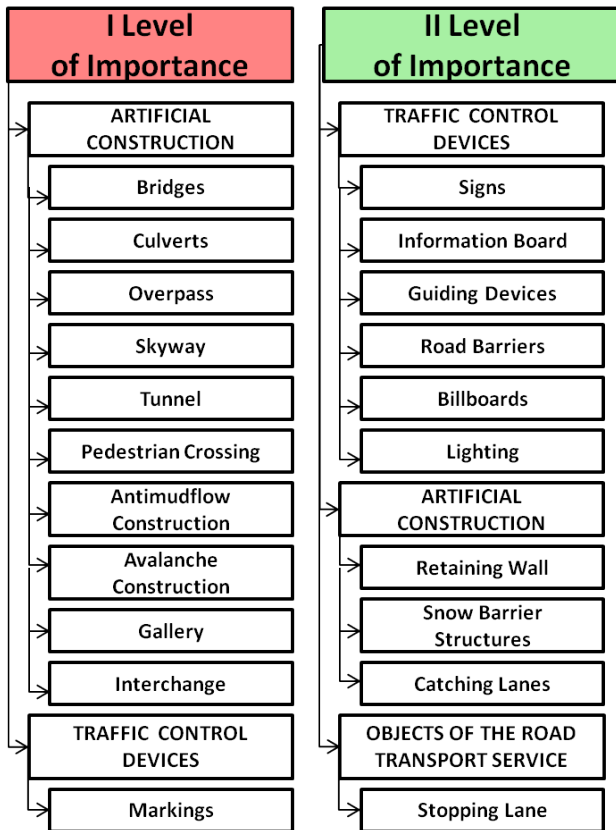


Fig. 4.1 Hierarchical I, II-levels structuring of beautification elements

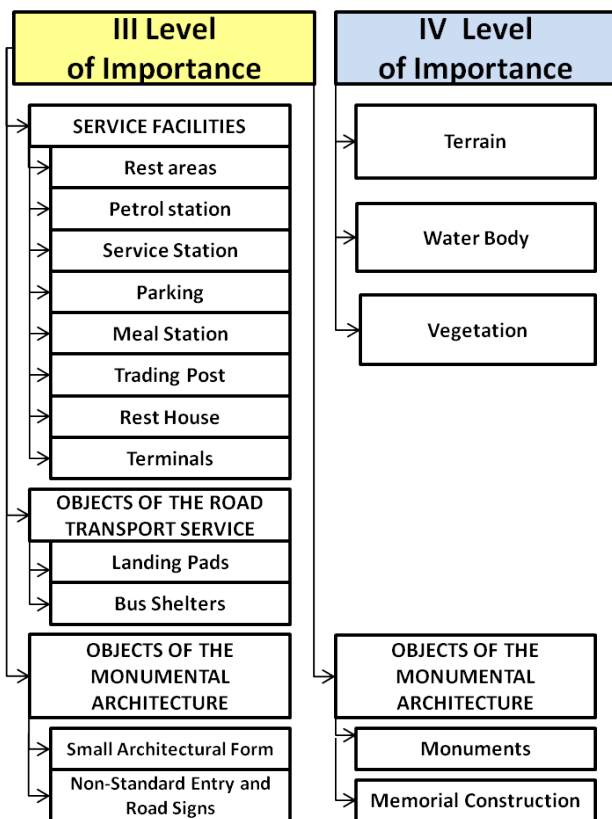


Fig. 4.2 Hierarchical III-IV-levels structuring of beautification elements

On the basis of aforementioned structuring is constructed structural model of the spatial corridor of road and street, which is divided into four subcorridors for placing beautification elements of appropriate level of importance (Fig. 5).

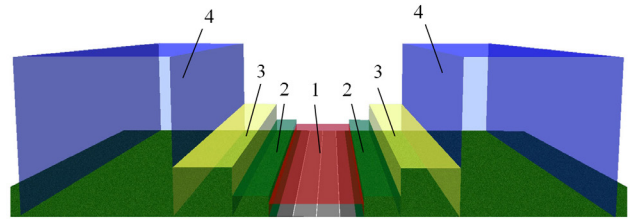


Fig. 5 The structural model of the spatial corridor of road and street: 1, 2, 3, 4 – first, second, third and fourth spatial subcorridors

Spatial corridor is characterized by the following parameters: B_{cor} , H_{cor} , L_{cor} – width, height and length of spatial corridor in accordance; B_I , H_I , L_I ; B_{II} , H_{II} , L_{II} ; B_{III} , H_{III} , L_{III} ; B_{IV} , H_{IV} , L_{IV} – width, height and length of spatial subcorridors in accordance (Fig. 6).

The next stage of work was finding the formulas for calculating parameters of spatial corridor and subcorridors.

4 The calculation of parameters of spatial corridor

Width of the spatial corridor. The minimum width of the spatial corridor of highway or street and width of spatial subcorridors of different levels of importance from the standpoint of optimal human perception offered to be determined by the formulas (1–5):

$$B_I = b \times 1; \quad (1)$$

$$B_{II} = b \times 0.382; \quad (2)$$

$$B_{III} = b \times 0.618; \quad (3)$$

$$B_{IV} = b \times 1.618; \quad (4)$$

$$B_{cor} = B_I + 2(B_{II} + B_{III} + B_{IV}); \quad (5)$$

where B_I ; B_{II} ; B_{III} ; B_{IV} – the width of first, second, third and fourth spatial subcorridors in accordance; B_{cor} – the width of road or street spatial corridor; 0,382; 0,618; 1; 1,618 – the coefficients of the „Golden section”; b – the width of street roadway highway subgrade in accordance to the standard road category.

Height of the spatial corridor. Distance of observation and related vertical angles of view related to appearing into human sense of closure. Depending on the height of buildings there is gradation from the complete closure to the complete lack of closure. The height of spatial subcorridors is proposed to determine, using vertical angles of perception, established by scientists empirically. For each of the spatial subcorridor assigned vertical angles of perception:

$$v_{bemp}^I = 14^\circ, v_{bemp}^{II} = 18^\circ, v_{bemp}^{III} = 30^\circ, v_{bemp}^{IV} = 45^\circ.$$

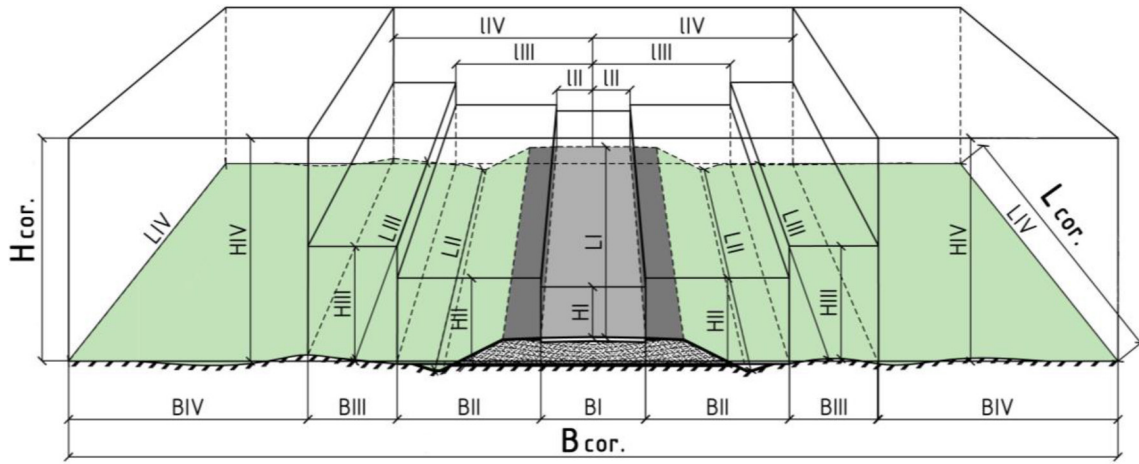


Fig. 6 Parameters of the spatial corridor of roads and streets

The distance of beautification elements perception of appropriate level of importance and the height of the spatial subcorridors is proposed to determine, using the formulas (6–10):

$$l_I = \frac{B_I}{2n} + c \quad (6)$$

$$l_{II} = l_I + \frac{B_{II}}{2} \quad (7)$$

$$l_{III} = l_{II} + \frac{B_{III}}{2} \quad (8)$$

$$l_{IV} = l_{III} + \frac{B_{IV}}{2} \quad (9)$$

$$H_i = tgv \times l_i + h \quad (10)$$

where l_i – the distance from the subject of perception to the middle of the i -th spatial subcorridor (m); n – the number of lanes (pieces); $c = 0,45$ m – the distance from the axis of the car to the axis of the driver eye; H_i – the height of i -th spatial subcorridor; $h = 0,95$ m – the average driver's eyes level.

The length of the spatial corridor. When determining the rhythm of placing elements of improvement along highways and streets must remember that frequent vertical elements, that have the ability to hold a driver's view, creating a shimmering effect in motion. Therefore the rhythm placing elements of improvement should be not too small, not too frequent – in both cases perceiving system becomes insensitive. The time of perception in motion is governed by speed, therefore the proportions of corridors should be appointed from the conditions of clear construction. To images perceived as separate, not merged and there were no shimmering effect, a pause between stimuli should be less than 1 s.

The lengths of spatial subcorridors is proposed to determine, using the formulas:

$$L_I = L_{\min} = \frac{V \times t}{3,6} \quad (11)$$

$$L_{II} = \frac{L_I \times l_{II}}{l_I} \quad (12)$$

$$L_{III} = \frac{L_{II} \times l_{III}}{l_{II}} \quad (13)$$

$$L_{IV} = L_{cor} = \frac{L_{III} \times l_{IV}}{l_{III}} \quad (14)$$

where V – design speed (km/h); t – the pause between stimuli that prevents shimmering effect ($t = 1$ sec); l_i – the distance from the subject of perception to the middle of the i -th spatial subcorridor (m); $L_I, L_{II}, L_{III}, L_{IV}$ – the lengths of the first to fourth spatial subcorridors (m); L_{cor} – the length of spatial corridor of the road (m).

The turn of beautification elements in space. Those elements that should not distract the driver's attention should be placed along the long side of the visual ray (of driver or passenger). Those elements that should attract the driver's attention should be placed perpendicularly to the visual ray (of driver's or passenger's).

5 The method of roads' beautification designing on the basis of modeling of the spatial corridor

The next stage of work become the development of the method of roads' improvement designing on the basis of modeling of the spatial corridor. It consists of three steps: there are selection of the source data, calculation of parameters of spatial corridor and subcorridors, 4D-modeling of road or street with the placement of beautification elements in four subcorridors (Fig. 7).

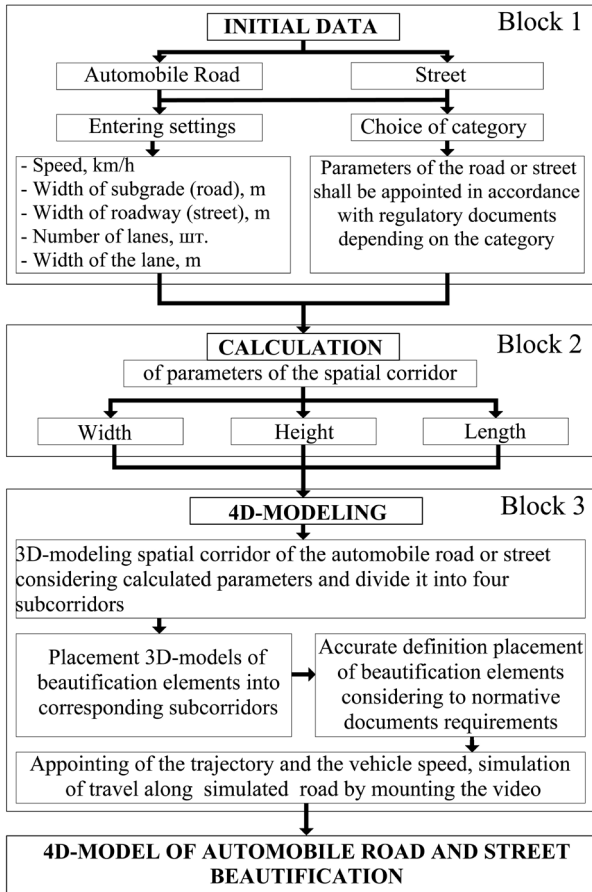


Fig. 7 The method of designing comprehensive roads and streets beautification

The fourth dimension is achieved by simulating movement of a vehicle along the modeled corridor with calculated speed.

Based on the proposed algorithm for calculating the parameters of the spatial corridor and subcorridors of roads and streets is developed applied computer program ROAD BEAUTIFICATION for the automation of calculations.

The program interface is created in HTML hypertext markup language, the algorithm is implemented in the programming language JavaScript using the library open source jQuery. An important feature of the program is that it is cross-platform, what means it can be running on any operating system where the browser is installed.

Using the program accelerates and simplifies the design of complex roads and street beautification with the spatial corridor modeling principle.

6 Conclusions

The paper presents the theoretical basis and the solution of a scientific problem, which consists in introducing a new spatial corridor modeling principle and the improvement of the methods of designing an integrated road and street beautification.

1. After analyzing the status of theoretical and practical development work on the problem of roads improvement, found that the majority of placement options of individual beautification elements are identified. But not enough attention is paid to complex locating of beautification

elements considering the mutual influence of some elements to others and their perception into motion. There is a need for a synthesis of existing researches and improving the comprehensive principles of placement elements of improvement of roads.

2. It is proved the irregularly placement of road beautification elements by full-scale survey of roads and streets of Ukraine. Part of Ukraine road environment is characterized by insignificant providing of beautification elements (0.1 service object at 1 km of road). The other part is overly saturated by separate beautification elements (5.1 service object at 1 km of road). Identified the factors that affect visual perception of the road environment, there are: speed ($0 \div 150$ km/h), time of perception ($0,1 \div 1$ sec), horizontal angle of view ($120^\circ \div 5^\circ$), vertical angle of view ($-45^\circ \div +45^\circ$), perception distance ($0 \div 2000$ m), eye level ($0,8 \div 3,8$ m), weather, relief, time of day, other (distracting; subjective: psychological, intellectual, emotional).
3. The classification of elements of roads beautification was improved and presented in a schematic form.
4. Principles of placing road beautification elements were advanced through synthesis of existing and designing a new one – spatial corridor modeling, which is based on a comprehensive and four-dimensional approach. A structural spatial corridor model of road and street was built and divided into subcorridors to deploy beautification elements. Spatial corridor and subcorridors were described with B, H, L – width, height and length characteristics of spatial corridor in accordance; $B_I, H_I, L_I; B_{II}, H_{II}, L_{II}; B_{III}, H_{III}, L_{III}; B_{IV}, H_{IV}, L_{IV}$ – width, height and length characteristics of spatial subcorridors in accordance and formulas for their determination were proposed. For automatization the parameters determination for the first time was designed computer software ROAD BEAUTIFICATION.
5. The methods of designing an integrated road and street beautification was improved in accordance with the principle of spatial corridor modeling, which consists of three stages: selection the initial data, calculation of parameters of the spatial corridor and subcorridors, 4D-modeling of road or street with placement of beautification elements in four subcorridors.
6. Benefits of an improved method compared to existing: design of comprehensive beautification, that is the placement of all the elements in one model that allows you to check their relative position; uniform arrangement of the beautification elements; the ability to verify the quality of static and dynamic (in motion) perception.

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