DETERMINATION OF HIGHWAY'S EFFECTIVE FUNCTIONING PERIOD

ВИЗНАЧЕННЯ ТЕРМІНУ ЕФЕКТИВНОГО ФУНКЦІОНУВАННЯ АВТОМОБІЛЬНОЇ ДОРОГИ

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Summary. The article considers the question of determining the functioning of the motorway during the life cycle from the beginning of construction to its reconstruction. The life cycle is to ensure the safe and economical use of road transport on the road or in its area, characterized by maximum traffic intensity without changing the speed of traffic in these road conditions. The paper proposes the determination of the bandwidth of the lane, the throughput of the highway, the practical bandwidth of the lane, the throughput of crossings and adjacencies, the maximum intensity of the lane and the maximum intensity of traffic by the section of the highway. At the maximum values of the traffic intensity of the road section, the necessity of partial or complete reconstruction of the road is determined. Partial reconstruction involves increasing the maximum intensity of the race on the course of changing the parameters of intersections and adjacencies.

In case changing the parameters of crossings and adjoining does not increase the maximum intensity of traffic on races - the issue of transfer to the higher category of road or increase in the number of lanes is considered.

Keywords: bandwidth, reconstruction, maximum intensity, lane, racing.

Introduction. As a result of an increase in traffic intensity on Ukrainian highways, there was a need for an analysis of the traffic conditions, the development of measures for their improvement and the definition of the functioning of the motorway during the life cycle from the beginning of construction to its reconstruction.

The most perfect method for solving these problems is to assess the conditions of movement and ensure maximum traffic intensity on the sections of the highway. Since the traffic of cars takes place in different road conditions, the maximum intensity of traffic is used for estimation in the current road conditions. The maximum intensity of movement is characterized by a practical throughput ability of the lane and the throughput of crossings and adjacencies. On the basis of this data, the issue of partial or complete reconstruction of the road is solved. Existing methods for determining the practical bandwidth of the lane, the maximum intensity of traffic on the section of the highway give ambiguous results that need improvement.

When justifying the need for road reconstruction, the development of a project or the scheme of traffic organization, the calculation of traffic flow control, automated systems for traffic management, analysis of the condition of highways, the value of maximum intensity of motion is used. The maximum intensity of the motorway should be considered in conjunction with the practical bandwidth of the traffic lanes and the

throughput of crossings and adjacencies. This approach will help to decide on the full or partial reconstruction of the highway, including and changing the parameters of crossings and adjacencies.

Purpose and methods. The main purpose of the work is to determine the maximum intensity of traffic by road. The road is divided into fields. The road section is chosen between major intersections and adjacencies. Large crossings and adjacencies are those where traffic flows are redistributed.

To accomplish the task, the theoretical substantiation of the method of calculating the practical bandwidth of the lane, the maximum intensity of traffic on the section of the highway and the throughput of interconnections and adjacencies in one level of different types must be provided.

On the basis of the maximum traffic intensity of the road section, measures are being developed to increase it and the period of effective functioning of the highway is determined.

The period of effective functioning of the road is the period of the life cycle of the road from construction to reconstruction, for which the intensity of traffic on the highway reaches the value of maximum intensity of movement.

Results and explanation. The traffic flow on the motorway can vary from free to column-type at any speed, that is, for each value of the speed of movement, different modes of motion of the cars may correspond. With increasing intensity and constant speed of motion, the motion mode can vary from free to column.

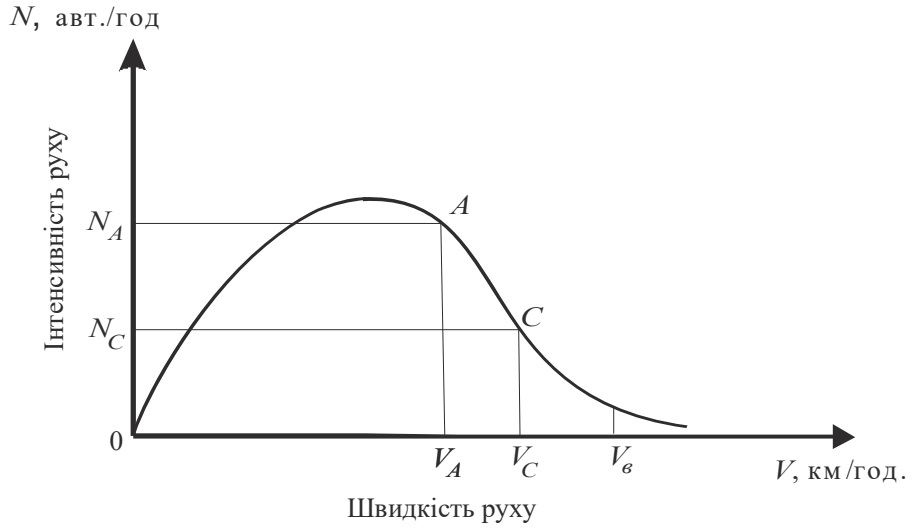


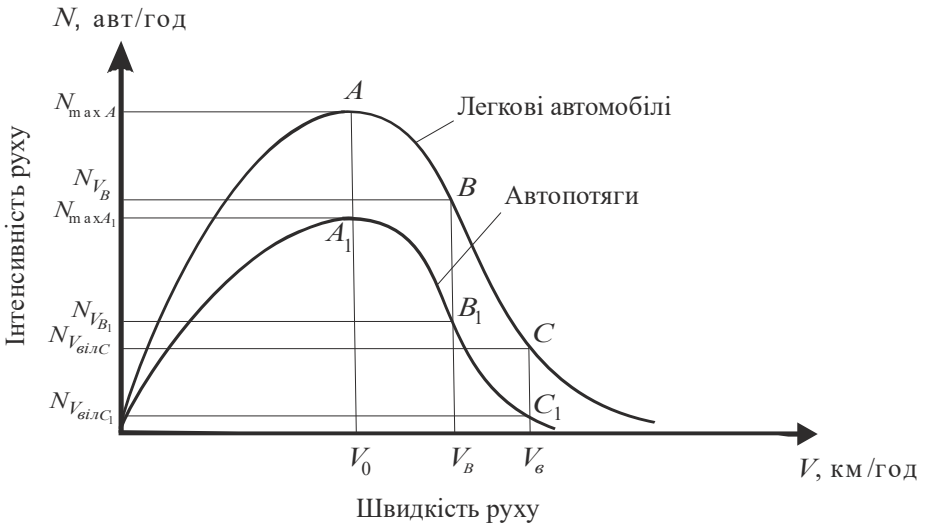
Figure 1 – Dependence "intensity - speed" [1]
Рисунок 1 – Залежність "інтенсивність - швидкість" [1]

Out of schedule (fig. 1) It can be seen that each value of the velocity corresponds to a certain value of maximum intensity of motion. For example, at the point A, the maximum intensity of the motion of the N_A corresponds to the velocity V_A, and at the point C, the maximum intensity of the motion N_c, which will be less than N_A.

The maximum intensity of traffic on the road is calculated on the basis of the maximum intensity of the traffic lane of the highway, which is reduced due to crossings and adjacencies on the same level that are on this road.

The intensity of the movement may vary from a minimum to a maximum value with a defined composition of the traffic flow. The minimum value of the traffic intensity corresponds to the column traffic of vehicles at an average free-speed. The maximum value of the intensity of the movement corresponds to the intensity of motion at a minimum interval (optimal speed). Fig. 2 shows a graph of changes in maximum traffic intensity, depending on the speed of traffic flow.

The ABC line and the A1B1C1 line describe the change in the maximum intensity of traffic for cars of the minimum and maximum lengths and the change in the maximum traffic intensity from the minimum to the maximum value for a given composition of the traffic flow. The dependencies for the different composition of the traffic flow will be located between the lines ABC and A1B1C1 in the zone, which is limited by these lines and the values of the minimum and maximum values.



V_0 – average speed corresponding to bandwidth;

$V_в$ – average free-movement speed;

V_B – average speed at the point B & B_1;

N_{maxA} – maximum traffic intensity corresponding to passenger car capacity;

N_{maxA1} – maximum traffic intensity corresponding to the capacity for motor trains;

$N_{VвілC}$ – maximum traffic intensity at passenger speed for passenger cars;

$N_{VвілC1}$ – maximum intensity of movement at the speed of free movement for car trains.

Figure 2 – Chart of the maximum intensity variation depending on the speed of the traffic and the composition of the traffic flow

Рисунок 2 – Діаграма зміни максимальної інтенсивності залежно від швидкості руху та складу транспортного потоку

To study the influence of the dynamic size on the maximum intensity of motion, one can consider different variants of the movement of cars in the group band of the highway.

1. To study the effect of the dynamic dimension on the maximum intensity of motion, one can consider different variants of car movement on the highway. (Fig. 3 a)

In the first case, there is no free space between the dynamic dimensions ($\Delta L_i=0$):

$$\Delta L_i = (d_i + l_i) - D_i = 0, \quad (1)$$

where d_i – distance between cars;

l_i – length of the i-th car, m

D_i – dynamic factor of the i-th car

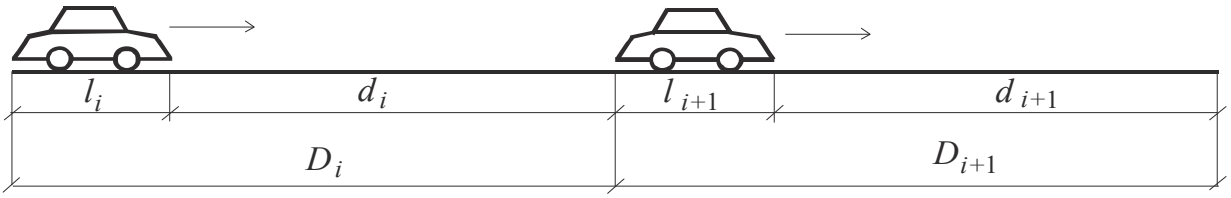
In the second case, there is free space between two adjacent dynamic dimensions ($\Delta L_i > 0$):

$$\Delta L_i = (d_i + l_i) - D_i. \quad (2)$$

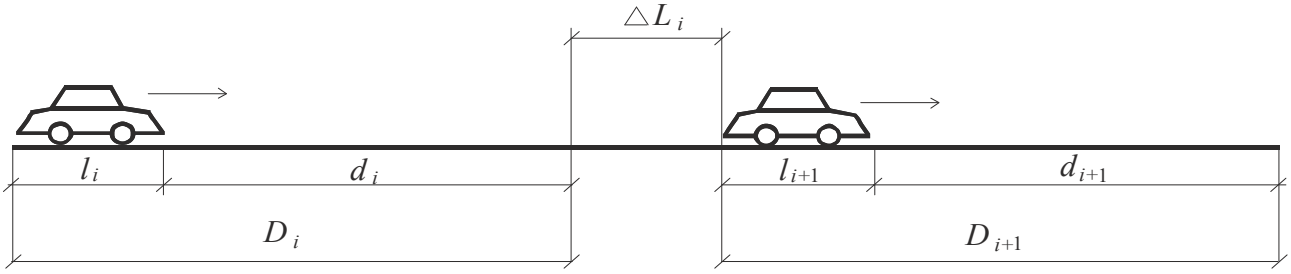
In the third case there is an overlay of dynamic dimensions, when the rear car reduces the distance ($\Delta L_i < 0$):

$$\Delta L_i = D_i - (d_i + l_i). \quad (3)$$

The variation of the intensity of motion at different values of dynamic dimensions is shown in the Fig. 4.



2. The driver, at the same speed, can withstand a greater distance. As a result, the intensity of the movement decreases (Fig. 3 b).



3. The driver, at the same speed, can withstand a smaller distance. As a result, the traffic intensity increases, but the danger of the car's movement increases and the movement is carried out in the risk zone. (Fig.3 c).

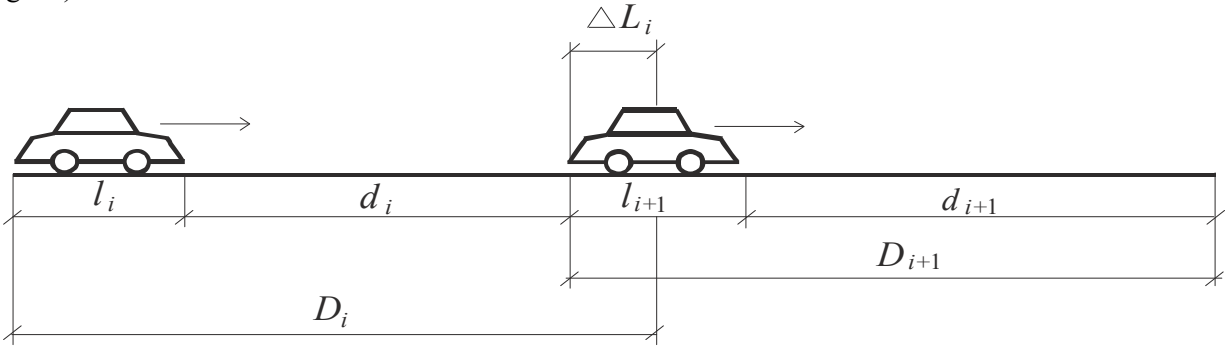


Figure 3 – Possible variants of dynamic dimensions in the traffic flow at the column movement of cars.
Рисунок 3 – Можливі варіанти динамічних відстаней в транспортному потоці при колонному русі

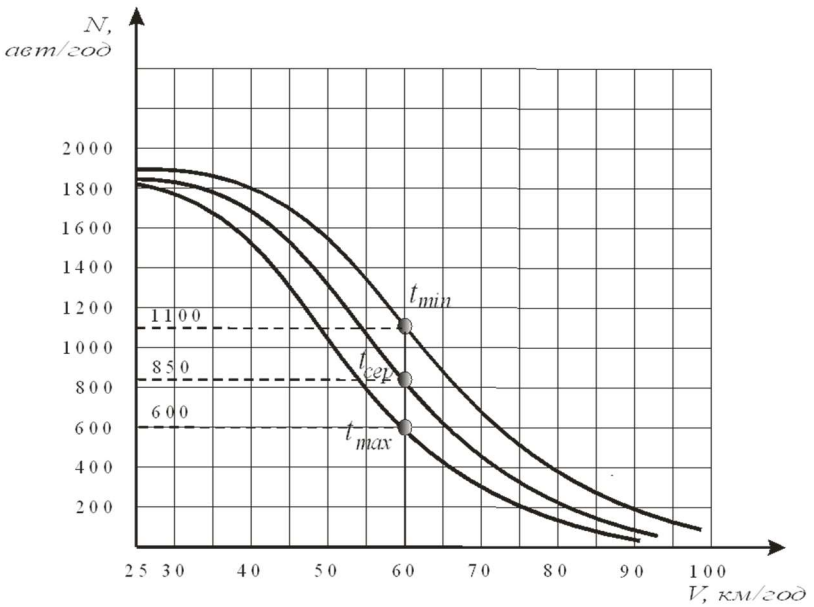


Figure 4 – Dependence of the intensity of movement on dynamic dimensions at a given speed
Рисунок 4 – Залежність інтенсивності руху від динамічних відстаней при заданій швидкості

As can be seen from the graph, at a speed of 60 km / h, the intensity can be 600, 850 or 1100 car / h, depending on the size of the dynamic size. Accordingly, the interval between cars moving at a speed of 60 km / h can be 6, 4.2 or 3.3 s. At maximum interval between cars it is possible to increase the intensity of traffic to the intensity of motion, which corresponds to the average interval. And with a minimum interval of traffic between cars, the flow of traffic occurs in the risk zone. Consequently, in studies it is necessary to determine the average value of the interval between cars, which characterizes the safe traffic flow and corresponds to the maximum intensity of the traffic lane of the highway.

Consequently, the maximum intensity of the traffic in the road strip varies from the minimum to the maximum value depending on the composition of the traffic flow, which in turn depends on the average length of the car in the group. And also, the maximum traffic intensity of the road changes from the minimum to the maximum for a certain composition of the traffic flow. Consequently, the "intensity-speed" dependencies will be in the defined zone and will have limitations on the speed and average length of the car.

The main factors that are taken into account in determining the intensity of traffic are the average speed of the traffic flow and the average length of the car in it.

The "intensity-speed" dependence will have the form:

$$P = f(V, d, l_a) = f(V, D) \cdot \tag{4}$$

where V – average speed of traffic flow;

d – distance between cars;

l_a – average length of the car in the traffic flow;

D – dynamic size.

On the basis of the processing of experimental data, the "intensity-speed" dependence is obtained as a polynomial line of the second degree. The equation describing the dependence of "intensity-speed" has the form:

$$N = Ax^2 + Bx + C, \tag{5}$$

where A, B, C – coefficients depending on the average length of the car.

Coefficients A, B, C characterize the average length of the car in the traffic flow and are represented by the following dependencies:

$$A = -0{,}0026 \cdot l_a^2 + 0{,}0538 \cdot l_a - 0{,}4678, \tag{6}$$

$$B = 0{,}0277 \cdot l_a^2 - 0{,}1752 \cdot l_a + 10{,}182, \tag{7}$$

$$C = 18{,}362 \cdot l_a^2 - 438{,}84 \cdot l_a + 3069. \tag{8}$$

As a result of data processing observations, the dependence of "intensity-speed" was obtained taking into account the composition of the transport stream in the form:

$$N = (0{,}0026 l_a^2 + 0{,}0538 l_a - 0{,}4678) V^2 + (0{,}0277 l_a^2 - 0{,}1752 l_a + 10{,}182) V + \\ + (18{,}362 l_a^2 - 438{,}84 l_a + 3069), \tag{9}$$

where l_a – car length, m;

V – average speed, km/hour.

Crossing and adjoining in one level determine the maximum intensity of movement as a separate section of the road, as well as the whole road in general. The capacity of crossings and interconnections in one level depends on the category of intersecting or adjacent roads, the composition of traffic flows, average speeds, car maneuvers, weather conditions and the percentage of left-turning vehicles.

The basic element of calculating the practical capacity of crossings and adjacencies is the time required to perform a maneuver with a car considering the safety of motion.

Analysing the maneuvers of cars at simple intersections and couplings:

- turn right from the secondary road to the main road;

- turn left from the secondary road to the main one;
- turn to the right of the main road to the secondary;
- turn to the left of the main road to the secondary;
- crossing the main road.

The mathematical dependences for calculating the interval on the main road and the time to perform maneuvers in determining the throughput of crossings and adjoints are given in Table. 1.1.

The example of calculating the capacity of crossing the highways Kyiv - Sumy and Ichnia - Priluki and maximum traffic intensity on the road section

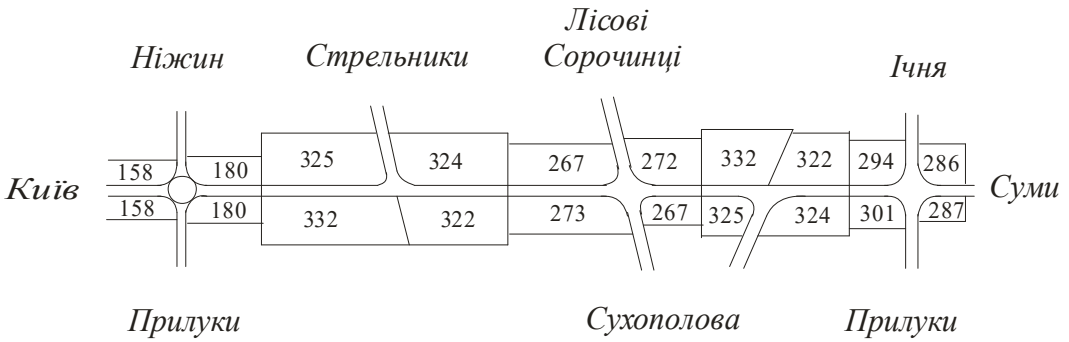


Figure 5 – The general scheme of maximum intensity of the section of the highway Kiev - Sumy taking into account crossings and adjacencies
Рисунок 5 – Загальна схема максимальної інтенсивності руху ділянки автомобільної дороги Київ - Суми з урахуванням пересічень та примикань

Table 1 – Distance on the main road and time to perform maneuvers in determining the maximum intensity of traffic at crossings and adjacencies

Таблиця 1 – Відстань на головній дорозі та час виконання маневрів при визначенні максимальної інтенсивності руху на пересіченнях та примиканнях

№	Car maneuver	Time for maneuver (interval)	Interval on the main road
1	2	3	4
Crossing without transition-high-speed bands			
1	Rotate to the right of the main road	$t_{гал} = \frac{V_p - V_з}{\bar{a}}$	$T = t_{\min}$
2	Rotate to the left of the main road	$t_{гал} = \frac{V_p - V_з}{\bar{a}}$	$T = t_{\min}$
3	Turn to the right of the secondary road	$t_p = \frac{V_p}{\bar{a}}$	$T = t_p + t_{\min}$
4	Turn to the left of the secondary road	$t_p = \frac{V_p}{\bar{a}}$	$T = t_p + t_{\min}$

1	2	3	4
5	Intersection of the main road	$t_{пер} = \frac{\sqrt{2(B + l_a)a}}{a}$	$T = t_{\min}$
Cross-speed transitions with high-speed bands			
1	Rotate to the right of the main road	$t_{зс} = \frac{2\sqrt{Rb}}{V_p}$	$T = t_{\min}$
2	Rotate to the left of the main road	$t_{зс} = \frac{2\sqrt{Rb}}{V_p}$	$T = t_{\min}$
3	Turn to the right of the secondary road	$t_{зс} = \frac{2\sqrt{Rb}}{V_p}$	$T = 2t_{\min}$
4	Turn to the left of the secondary road	$t_{зс} = \frac{2\sqrt{Rb}}{V_p}$	$T = 2t_{\min}$
5	Intersection of the main road	$t_{пер} = \frac{\sqrt{2(B + l_a)a}}{a}$	$T = t_{\min}$
Note: V_p – the estimated speed of the traffic lane of the highway, m/sec; $V_з$ – speed at the congress during maneuvering, m/sec; a – average acceleration value, m/sec^2; B – width of the roadway, m; R – radius of the congress, m; b – width of the road lane, m; $t_{\min}$ – average safe interval in the column movement of cars for this average speed, sec; $t_р$ – time is necessary for acceleration to the calculated speed of movement V_p on the road, sec.			

Table 2 – Measures to increase the maximum intensity of traffic on the road
Таблиця 2 – Заходи щодо збільшення максимальної інтенсивності руху на дорозі

Intensity of traffic on the main road	Measures to increase the maximum intensity of motion on the adjacency	Load factor of the system K_a	The coefficient of increasing the maximum intensity of movement K_N
1	2	3	4
Direct direction			
$N < \frac{3600 \cdot 2}{t_p + t_{\min}}$	No measures are foreseen	< 0,5	1,0
$\frac{3600 \cdot 2}{t_p + t_{\min}} \le N \le \frac{3600}{t_{\min}}$	1. Arrangement of the PSP for the turn to the right of the secondary road to the main; 2. Arrangement of the PSP for the turn to the right of the main road to the secondary (on condition, what $t_{головне} > t_{\min}$)	0,5 – 0,9	1,2 – 1,4
$N > \frac{3600}{t_{\min}}$	Arrangement of solutions at different levels	0,9 – 0,95	1,4– 1,6
$N > \frac{3600}{t_{\min}}$	Transfer the road to the highest category	> 0,95	> 1,6

1	2	3	4
Reverse direction			
$N < \frac{3600 \cdot 2}{t_p + t_{\min}}$	No measures are foreseen	< 0,5	1,0
$\frac{3600 \cdot 2}{t_p + t_{\min}} \le N < \frac{3600}{t_{\min}}$	Arrangement of the PSP for the turn to the left of the secondary road	0,5 – 0,9	1,2 – 1,4
$N = \frac{3600}{t_{\min}}$	Arrangement of the auxiliary belt to perform a turn to the left of the main road to the secondary	0,9 – 0,95	1,4 – 1,6
$N > \frac{3600}{t_{\min}}$	Arrangement of solutions at different levels	0,95	1,4– 1,6
$N > \frac{3600}{t_{\min}}$	Transfer the road to the highest category	> 0,95	> 1,6

Table 3 – Measures to increase the maximum intensity of traffic of the considered section of the highway Kyiv – Sumy

Таблиця 3 – Заходи щодо збільшення максимальної інтенсивності руху ділянки автомобільної дороги Київ - Суми

№	Crossing and adjoining on the section of the Kyiv-Sumy highway	Measures with increasing traffic intensity		
		to 3100 cars/day	3100-6000 cars/day	від 6000 cars/day
1	Junction with higway Nizhyn - Pryluky	The activities are not overlooked	Arrangement of an additional strip on the ring	Arrangement of solutions at different levels
2	Adjoining the road from the village Strel′nyky	The activities are not overlooked	The activities are not overlooked	Arrangement of transition high-speed bands
3	Junction with higway Lisovi Sorochyntsi - Sukhopolova	The activities are not overlooked	The activities are not overlooked	Arrangement of transition high-speed bands
4	Adjoining the road from the village Sukhopolova	The activities are not overlooked	The activities are not overlooked	Arrangement of transition high-speed bands
5	Junction with higway Ichnya-Pryluky	The activities are not overlooked	The activities are not overlooked	Arrangement of solutions at different levels

Conclusion

1. The method of determining the effective functioning of the motorway or its area on the basis of determining the maximum intensity of traffic, taking into account the composition of the traffic flow and the throughput of crossings and adjacencies is presented in the work.

2. On the basis of the calculated data, measures are being developed to increase the maximum intensity of traffic and to determine the period of effective functioning of the highway or its area.

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ВИЗНАЧЕННЯ ТЕРМІНУ ЕФЕКТИВНОГО ФУНКЦІОНУВАННЯ АВТОМОБІЛЬНОЇ ДОРОГИ

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Анотація. В роботі розглянуто питання визначення функціонування автомобільної дороги протягом життєвого циклу від початку будівництва до її реконструкції. Під життєвим циклом розуміється забезпечення безпечного та економічно вигідного руху автомобільного транспорту по дорозі або її ділянці, що характеризується максимальною інтенсивністю руху без зміни швидкості руху у даних дорожніх умовах. У роботі запропоновано визначення пропускної здатності смуги руху, пропускної здатності автомобільної дороги, практичної пропускної здатності смуги руху, пропускної здатності перехрещень та примикань, максимальної інтенсивності смуги руху та максимальної інтенсивності руху ділянкою автомобільної дороги. При максимальних значеннях інтенсивності руху ділянкою автомобільної дороги визначається необхідність проведення часткової або повної реконструкції дороги. Часткова реконструкція передбачає збільшення максимальної інтенсивності руху на перегонах за рахунок зміни параметрів перехрещень та примикань. У випадку коли змінення параметрів перехрещень та примикань не підвищує максимальну інтенсивність руху на перегонах – розглядається питання переведення у вищу категорію дороги або збільшення кількості смуг руху.

Ключові слова: пропускна здатність, реконструкція, максимальна інтенсивність, смуга руху, перегони.

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