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ROAD VISIBILITY STUDY FOR DRIVERS DEPENDING ON THEIR AGE

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ABSTRACT

The article is devoted to the issues of visibility of highways, taking into account the age factor of drivers. The optimization possibilities of Adrian's theory of visibility, as applied to highways, are investigated. Using the theory of variation analysis, it is shown that visibility on highways for drivers according to Adrian can be increased by choosing the time of observation of critically dangerous small objects on the roads during a time interval proportional to the square root of a specially introduced age factor that functionally depends on the age of the driver.

Keywords: highway, visibility, optimization, age factor, optimization, variational method

INTRODUCTION

As noted in [1], even if the illumination levels are higher than the recommended value for normal illumination of night roads, visibility conditions may be unsuitable. Therefore, new criteria should be adopted to create effective and safe road lighting conditions. According to [2], the visibility level of the critical size of an object located on the road surface is defined as

$$VL = \Delta L_{actual}/\Delta L_e \quad (1)$$

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where VL is the level of visibility; ΔL_actual is the difference between the illumination of the target and its background for real road conditions; ΔL_e is the difference in illumination of the target having a certain angular size and its background required to ensure minimum visibility.

In [3], it is noted that to calculate the visibility level, first of all, it is necessary to define such a concept as a "critical object". The critical size of such an object should correspond to the size of the clearance (empty gap) between the road surface and the body structure of normal vehicles. In [1], the size of such an object was chosen as 20×20 cm as the minimum size object that could pose a threat to the safety of a normal-sized car. In the same work, the reflection coefficient of such an object was chosen to be 25%. In many studies (see [4,5,6]), it was assumed that the visibility level on the roads should be greater than 7. The level of visibility quantifies the observer's ability to see an object without difficulty. At the same time, contrast is an important indicator that affects the visibility of objects. This refers to the contrast ΔL between the object and the background. Visibility is also affected by the visual ability of the observer, the level of illumination, the time of observation, as well as the angular size of the object

. The actual difference between the illumination of the object and the background is defined as

$$\Delta L_{actual} = L_f - L_b \quad (2)$$

where L_f-is the illumination of the object (cd/m2); $L_b$is the illumination of the background (cd/m2).

According to [2], the threshold value $\Delta L_{e\_}$ is determined by the following equation

$$\Delta L_e = k\left(\frac{\sqrt{\Phi}}{\alpha} + \sqrt{L}\right)^2 \frac{a(\alpha, L_b) + t_g}{t_g} F_{cp} AF = k\left(\frac{\sqrt{\Phi}}{\alpha} + \sqrt{L}\right)^2 \left(\frac{a(\alpha, L_b)}{t_g} + 1\right) F_{cp} AF \quad (3)$$

where k is the coefficient characterizing the probability of perception, where for 100% probability k=2.6; Φ is a function of luminous flux (lm);

L is a function of brightness (cd/m2); F_{cp} is the contrast polarity coefficient; AF is the coefficient (factor) of old age $a(\alpha, L_b)$ is a parameter depends on the size of the target (object) (α) and background brightness (L_b); ;

t_g- is the observation time (sec.).

The light photon function (Φ) and the brightness function (L) are calculated experimentally, the values of these indicators vary depending on the background brightness [7]. F_cp-the coefficient that takes into account the contrast polarity must be taken into account even if there is a negative contrast between the object and the background; with, $F_{cp} = 1$ the contrast is considered positive.

As noted in [7], the driver's eye sensitivity decreases with age, according to this rule, the age factor (AF) is included in formula (2), defined as:

$$AF = \frac{(age - 19)^2}{2160} + 0{,}99; AT\ 23 < age < 64 \quad (4)$$

$$AF = \frac{(age - 56{,}6)^2}{116{,}3} + 1{,}43; at\ 64 < age < 75 \quad (5)$$

, The purpose of this study is to calculate the optimal dependence $t_g = \psi$ (age) at which ΔL_ein formula (1) and determined by formula (2) reaches a minimum on average, and therefore the VL (visibility) indicator according to formula (1) will reach a maximum.

Materials and methods

Formula (2) is generally represented as

$$\Delta L_e = C_1\left(\frac{C_2}{t_g} + 1\right) AF \tag{6}$$

Where

$$C_1 = \left(\frac{\sqrt{\Phi}}{\alpha} + \sqrt{L}\right)^2 F_{cp} \tag{7}$$

$$C_2 = a(\alpha_1, L_b) \tag{8}$$

Assume that when condition (4) is fulfilled, the AF index changes within $b_1 \div b_2$, and when condition (5) is fulfilled, it changes within. $b_3 \div b_4$.

Let's introduce the function for consideration

$$t_g = \psi_1(AF) \tag{9}$$

Let us make up the following target functionals on the basis of formulas(6), (8), (9):

$$F_1 = \frac{1}{b_1 - b_2}\int_{b_1}^{b_2} C_1\left(\frac{C_2}{\psi_1(AF)} + 1\right) AF\, d(AF) \tag{10}$$

$$F_2 = \frac{1}{b_4 - b_3}\int_{b_3}^{b_4} C_1\left(\frac{C_2}{\psi_1(AF)} + 1\right) AF\, d(AF) \tag{11}$$

As it can be seen from expressions (10) and (11), the above target functionals

(11)

are almost identical and differ only in the integration boundaries. For this reason, we will perform the optimization procedure for one of them, namelyF_1.. To calculate the optimal function *ψ(AF),* we impose on this function a certain restrictive condition that characterizes the limitation of the total time interval allocated for observing objects:

$$\int_{b_1}^{b_2} \psi_1(AF)\, d(AF) = C_3;\ C_3 = const \qquad (12$$

Taking into account expressions (10) and (12), we form the following target functional of unconditional variational optimization

$$F_3 = \frac{1}{b_1 - b_2} \int_{b_1}^{b_2} C_1 \left(\frac{C_2}{\psi_1(AF)} + 1 \right) AF\, d(AF) + \lambda \left[\int_{b_1}^{b_2} \psi_1(AF)\, d(AF) - C_3 \right] \qquad (13\}$$

where λ is the Lagrange multiplier; λ=const.

The solution of problem (13) according to theory of Euler satisfies the condition:

$$\frac{d\left\{C_1\left(\frac{C_2}{\psi_1(AF)}+1\right)AF+\lambda\psi(AF)\right\}}{d\psi_1(AF)} = 0 \qquad (14)$$

From condition (14) we obtain:

$$-\frac{C_1 C_2 AF}{\psi^2(AF)} + \lambda = 0 \qquad (15)$$

From expression (15) we obtain

$$\psi_1(AF) = \sqrt{\frac{C_1 C_2 AF}{\lambda}} \qquad (16)$$

It can be shown that when solving (16), F_3 reaches a minimum value. To do this, we use the Lagrange sign and calculate the second derivative of the under integral expression in (13). We have

$$\beta = \frac{d^2\left\{C_1\left(\frac{C_2}{\psi_1(AF)}+1\right)AF+\lambda\psi_1(AF)\right\}}{d\psi_1(AF)} \tag{17}$$

It is easy to see that β is always a positive quantity. Therefore, when solving (16), the VL (visibility) indicator determined by formula (1) will reach a maximum. To determine λ, we use expressions (12) and (16). We have:

$$\sqrt{\frac{C_1C_2}{\lambda}}\int_{b_1}^{b_2}(AF)^{\frac{1}{2}}\,d(AF) = C_3 \tag{18}$$

From expression (18) we get

$$\frac{2}{3}\sqrt{\frac{C_1C_2}{\lambda}}\left(b_2^{\frac{2}{3}} - b_1^{\frac{2}{3}}\right) = C_3 \tag{19}$$

From expression (19) we get

$$,\frac{4C_1C_2}{9C_3^2}\left(b_2^{\frac{2}{3}} - b_1^{\frac{2}{3}}\right)^2 = \lambda \tag{20}$$

taking into account expressions (16) and (20), we obtain

$$\psi_1(AF) = \sqrt{\frac{AF}{\frac{4}{9}C_3^2\left(b_2^{\frac{2}{3}}-b_1^{\frac{2}{3}}\right)^2}} = \frac{3}{2}\frac{C_3\sqrt{AF}}{\left(b_2^{\frac{2}{3}}-b_1^{\frac{2}{3}}\right)} \tag{21}$$

Due to the similarity of the functionals F_1 and F_2 for the functional. F_2 we have solutions

$$\psi_2(AF) = \frac{3}{2}\frac{C_4\sqrt{AF}}{\left(b_4^{\frac{2}{3}} - b_3^{\frac{2}{3}}\right)} \quad (22)$$

where C_4 is defined by similarity to formula (12) as

$$C_4 = \int_{b_1}^{b_2} \psi_2(AF)\, d(AF) = C_4$$

Discussion

Taking into account the constancy of the value C_3 and $\left(b_2^{\frac{2}{3}} - b_1^{\frac{2}{3}}\right)$ with respect to the functional F_1 and value C_4 and $\left(b_4^{\frac{2}{3}} - b_3^{\frac{2}{3}}\right)$ and the values F_1 and value C_4 and $\left(b_4^{\frac{2}{3}} - b_3^{\frac{2}{3}}\right)$ with respect to F_2, based on formulas (22) and (23), it can be concluded that the optimal observation of objects proportional to the square root of the *AF* factor. In this case, when calculating the *AF* factor, formulas (4) for $k\psi_1(AF)$ and (5) for $k\psi_2(AF)$should be used. Therefore, the *AF* factor is not an indicator directly proportional to the age of the driver, but functionally depends on age. With solutions (22) and (23), the functionals F_1 and F_2, are minimized, and therefore ΔL_e is also minimized which leads to an increase in the visibility of VL according to formula (1).

Conclusion

The optimization possibilities of Adrian's theory of visibility, as applied to highways, are analyzed. It is shown that visibility on Adrian's roads can be increased by choosing the time of observation of small objects on the roads during a time interval proportional to the square root of a specially introduced age factor that functionally depends on the age of the driver.

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