Studies on Visibility Embarrassment due to Traffic from the Opposite Direction

THIERHEIMER ALEXANDRU, ALEXANDRU CĂTĂLIN, SIFFT MICHAEL, CRAUCIUC DANIEL, THIERHEIMER WALTER WILHELM
EMFT Department
Transilvania University of Brasov
Brasov, ROMANIA
thierheimer@unitbv.ro

Abstract: The natural and artificial lighting is the essential element of the road traffic in whose absence the participants' motion could not be possible. When natural lighting lacks, both the vehicle's artificial illumination and the external urban illumination facilitate, the maintenance of (the road traffic) the functioning of the system vehicle – road – pedestrian.
This paper offers basic information on the visual guidance, which is a quality criterion with an essential role in ensuring a fluent and safe traffic. The manifestations of disability glare are given as examples, particularly in traffic. The paper also reveals a series of data that allow the establishment of the luminance level in the road-conflict area.

Key-Words: drivers' vision, natural and artificial lighting, disability glare, urban illumination, safe traffic.

1 Introduction

Natural and artificial light are indispensable to secure road traffic. In the absence of the natural light (night light, road tunnel, and unfavorable weather), the artificial lightening supply good conditions for the participants to road traffic, even they are motor vehicles, pedestrians, or others. A safety road traffic can be accomplished only by choosing good solutions for urban enlighten. This is to reduce the road events on night time, due to the fact that the darkness is favorable to the bad events which can appear because of the inadequate toggle of the traffic participants signalized on the road or pedestrians particularly.

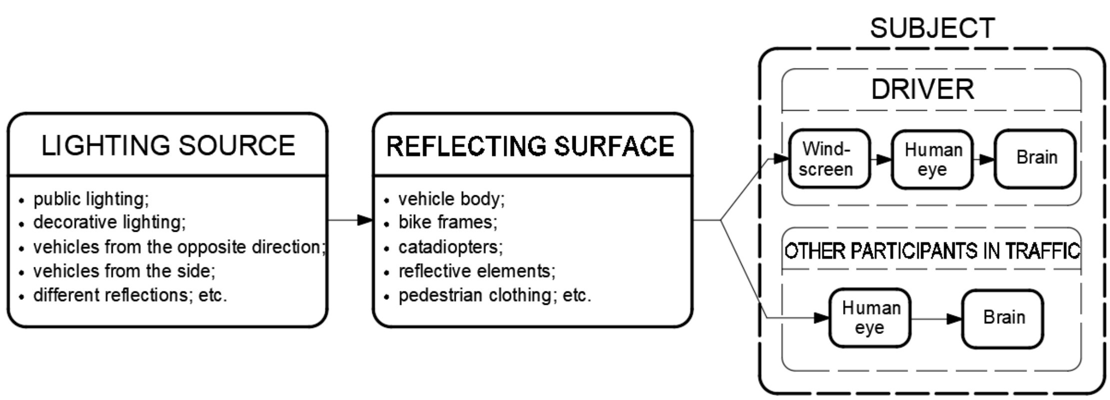

Fig.1. Basics elements for seeing process

2 The Observer- Light Link

About 85 % of the traffic information's is received by eyes participants. This is possible due to the fact that the system observer-light is a complex one, in which the brain takes over the information and processed it, figure 1. In the figure 1 are presented basics elements for seeing process in which an important role has the light source, such about 85 % of the traffic information's is received by eyes participants. This is possible due to the fact that the system observer-light is a complex one, in which the brain takes over the information and processed it, figure 1. In the figure 1 are presented basics elements for seeing process in which an important role has the light source, such as public lighting or the car system for lighting.

The second element is the surface reflection without it is not possible to observe the traffic participants. Here we mean that in the environment we see the reflex-reflector, optical reflectance elements, or the colors of the clothes. All these receive light flow from the source and reflect it to the observer eyes (the driver). A human eye is a complex system, with multiple components, each of them having a specific role.

Relative spectral luminous efficiency

Spectral luminous efficiency curves for both photopic, $V(\lambda)$ and scotopic, $V^{'}(\lambda)$ vision are shown in figure 2. For scotopic vision, the curve is shifted 50 nm to the left from the photopic curve.

This phenomenon is termed the Purkinje effect, and means qualitatively that the eye is relatively less sensitive to red and more sensitive to blue at night than during the day.

The spectral luminous efficiency curve is the screen that enables us to evaluate the visual effect of radiant energy.

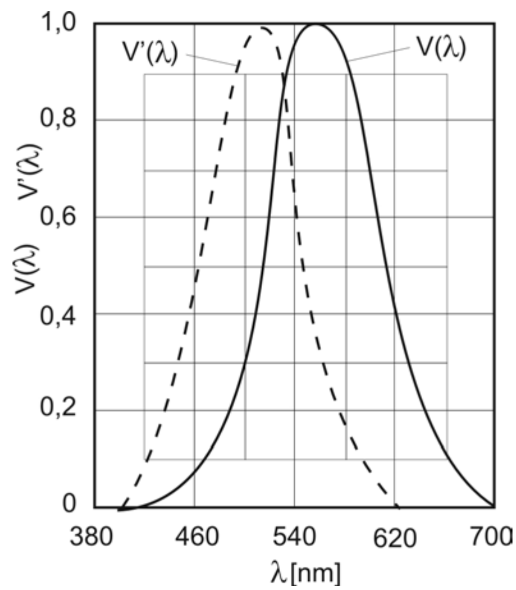

Fig.2. Spectral luminous efficiency

2.1 Human EYE CHARACTERISTICS VISUAL FIELD

The visual field is defined by the environment perceived by human eye or eyes (monocular or binocular) in an immovable position of head or sight.

It can be distinguished according to the clarity of the image:

- central vision field, a zone, in which the objects are perceived in the minor details;
- peripheral vision field, b zone, in which the objects are seized by the eye without a pertinent clarity of the details, figure 3.

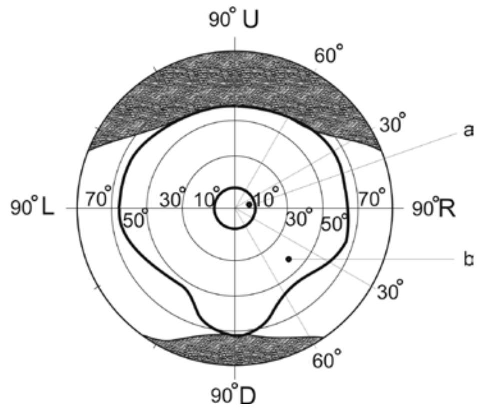

Fig. 3. Visual field's vertical- transversal plan projection

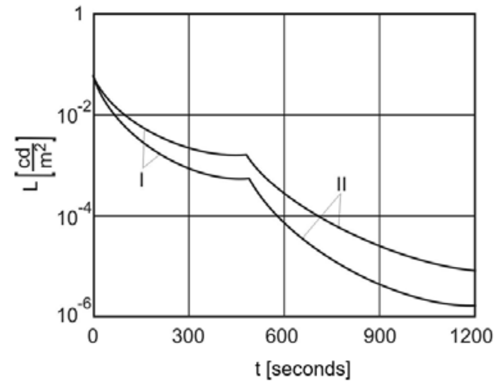

Fig. 4. Eyes adaptation at low luminance

Visual adaptation, does the property of the human eye to adapt at different luminance levels and at the luminance contrast exist in the human visual field?

The features of adaptation at the lower luminance are shown in figure 4. The level of luminance at the logarithmic scale is shown in figure 4. The I^{st} zone is a photopic one lasting maximum ten minutes, followed by the II^{nd} zone- scotopic one, much more longer in time, touching a threshold of $L = 10^{-6}$ [cd/m^2].

The adaptation is the eye's capacity to modify in an involuntary way the convergence of the crystalline in order to get the best image regardless of the distance between the eye and veiling luminance. The adaptation is disturbed by the phenomenon of glaring as well the inappropriate contrasts.

Contrast sensitivity

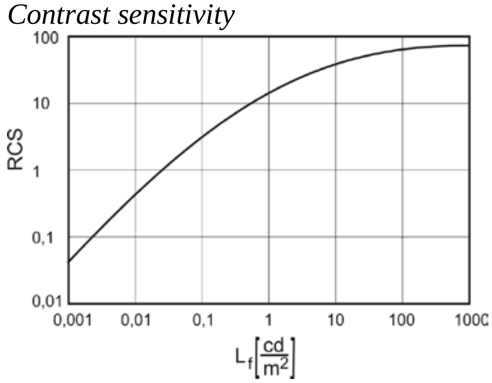

Fig.5. Contrast sensitivity versus the Background luminance

The contrast is the ratio between the difference of the background luminance L_f and the veiling luminance L_v and the background luminance. This ratio is an undimentional measure. The contrast makes possible the distinction of the fine details.

$$C = \frac{|L_f - L_v|}{L_f} \quad (1)$$

The contrast sensitivity is defined as the inverse of the contrast, it is the capacity of the eye to distinguish a detail of luminance.

$$CS = \frac{1}{C} \quad (2)$$

Figure 5 shows the way in which the variation of the contrast sensitivity depends on the background luminance.

3 The Influence of the Traffic Road Illuminance

The artificial illuminance is known to be useful, creating comfortable conditions for the traffic. Meanwhile, it can have negative effects on the driver's visibility, due to the vehicles coming from the driver's left or from a lateral side, as well as the lack of quality criteria for the luminance environment evaluation (public illuminance and/or decorative one). The uncontrolled glare phenomenon could cause a condition of discomfort.

Glare is the adversary of good visual performance. It is a sensation caused by the presence of a luminance in the visual field, different as value from the luminance at which the traffic participants' eyes are adapted (driver, pedestrian, etc.). Glare causes an embarrassing condition reducing the visual capacity of the participant in the traffic.

Depending on the variation between the values of the luminance existing in the driver's visual field, there two types of glare:

- *Disability glare* or *veiling luminance* – is caused by the presence of a luminous source striking the driver's visual field;
- *Discomfort glare* – is caused by the significant luminance contrast in the visual field and it occurs in time and space.

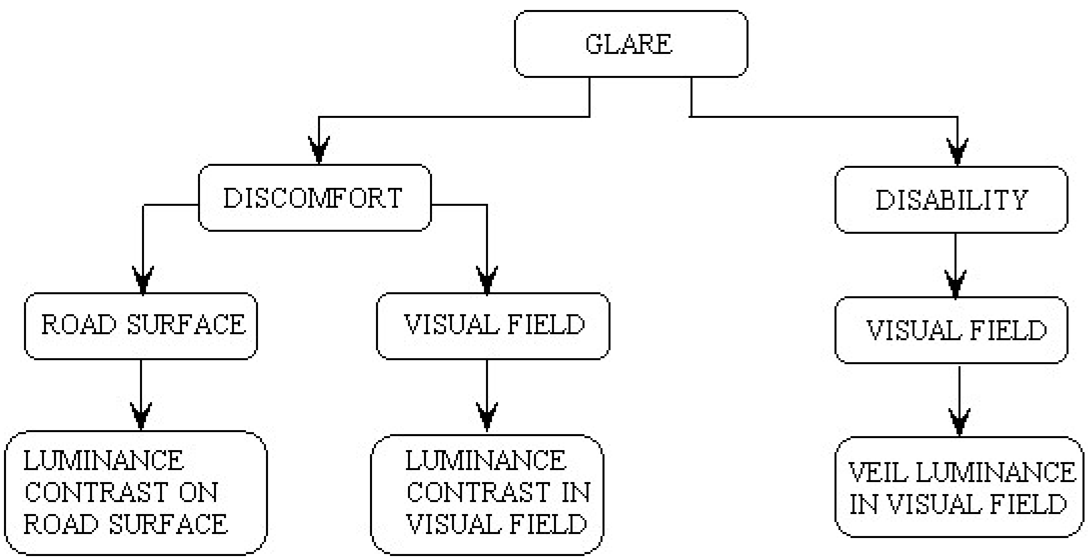

Fig. 6. The evaluation of glare in traffic road

- ***Disability Glare***, or veiling luminance, is caused by light scattered into the eye that shines on the retina and reduces the contrast of images that we would normally see clearly without the presence of glare. This affect often becomes profound with people who have a medical condition called 'low vision' or more commonly referred to as cataracts. Disability glare occurs more often with people over thirty years old because our eyes change as we age. As we get older the eye does not react as fast to rapidly changing illumination levels. Some people with perfectly healthy eyes commonly refer to the veiling luminance effect as 'night blindness'.

- ***Discomfort Glare*** may not reduce visual acuity as profoundly as disability glare does. Discomfort glare often occurs when encountering an area that has very high illumination levels. Everyone who has gone outdoors on a sunny day at noon time has experienced discomfort glare. This is why so many sunglasses get sold in the summer. When discomfort glare occurs after dark, the best cure is to reduce the illumination level, or the amount of light being cast over an area. Discomfort glare occurs at night because of high contrast levels between bight and dark areas. This problem can also be reduced by increasing the level of illumination in background areas, but

that wastes energy. The best solution is to simply reduce the basic illumination levels. This provides a safer environment and is the most economical solution.
The evaluation of the disability glare is related to the classic Stiles-Holladay disability glare formula for a point glare source:

$$L_{eqv} = \frac{kE_{glare}}{\theta^2} \quad [cd/m^2] \qquad (3)$$

with L_{eqv} the equivalent veiling background; E_{glare} the illuminance at the eye by the glare source, in lux, and θ the angular distance between the line of sight and the glare source, in degrees; k – correction coefficient that depends on the age of the traffic participant. As the person grows old, this coefficient increases, $k = 10$ at the age of 30. In case of multiple sources, the relation (3) becomes:

$$L_{v_{tot}} = \sum_{i=1}^{n} L_{v_i} \qquad (4)$$

Taking into account only the illuminance sources having a value higher than 2% out of the veil luminance. The value of the θ angle is limited at 20^o on vertical plan and 18^o on horizontal plan, values conditioned by the extremities of the windshields. When the vehicle is well positioned on the road, the view line is paralleled to the longitudinal axis of the road platform and forms an angle $\alpha = 1^o$ with the rolling surface.
The tables 1 and 2 show reference values for illuminance E and luminance L.

Table 1. Reference values for illuminance

Summer, clear sky (natural component)	100000 lx
Night, full moon (natural component)	0.25 lx
Urban public illumination (artificial component)	5 … 30 lx
Inside illuminantion in workplace (artificial component)	150 … 700 lx

Table 2. Reference values for luminance

Sun surface	2000000000 cd/m^2
Full moon surface	2500 cd/m^2
Illuminated road surface	2 cd/m^2
Fluorescent tube surface	5000 … 15000 cd/m^2

4 Corrections to Classic Stiles-Holladay Disability Glare Formula

The phenomenon of glare has been known since time immemorial but the origin of the masking light veil became the subject of scientific interest only in the early 19th century. As a starting point for further scientific research, one can best consider a paper written in 1852 by Helmholtz in which more or less casually, he mentions two possibilities: a nervous and a physical explanation. According to Helmholtz, scattering process certainly occur and only further investigations would show the role that nervous process might play. Thank to the development of the so-called equivalent background technique by Cobb, substantially experimental investigations really got started. The masking effect on the visibility of objects was compared with the masking effect on the same objects by a veiling background and hence, disability glare could be quantified. Of the many investigators who used this technique, we mention only the pioneers Holladay, Stiles, and later Stiles and Crawford. Their combined results were brought by Stiles to the 1939 CIE meeting in Scheveningen and resulted in the now almost classic Stiles-Holladay disability glare formula for a point glare source.

This formula has since been widely used, even though it was never officially adopted by the CIE. Undoubtely, it derived its success from its astonishing simplicity and transparency. Its most obvious feature is the proportionality between L_{eqv} and E_{glare}, which cannot be read other than as a clear sign that disability glare is an optical phenomenon due to the light scattering in the eye media and not a result of some neural process. After a few decades of little research interest in glare, new investigations were underway that could provide new data. The Amsterdam research group headed by Van den Berg, provided new data on three aspects: age dependence, dependence on ocular pigmentation and angular dependency in the larger glare angle domain. All these data, together with theoretical considerations on ocular scatter, provided sufficiently reliable evidence to construct an extension of the Stiles-Holladay equation over the full zero-to 100-degree angular range. Moreover, the data obtained by the Amsterdam group on the influence of age and ocular pigmentation enabled the inclusion of those effects in that extended Stiles-Holladay course.

The most general version, the CIE General Disability Glare Equation, valid in the glare angle domain $0.1^0 < \theta < 100^0$, reads:

$$\left(\frac{L_{veil}}{E_{glare}}\right)_{general} = \frac{10}{\theta^3} + \left(\frac{5}{\theta^2} + \frac{0.1p}{\theta}\right) \cdot \left(1 + \left[\frac{Age}{62.5}\right]^4\right) + 0.0025\,p \tag{5}$$

in which θ is in degree, L_{veil} in cd/m^2 and E_{glare} in lux. In relation (5) are included some features such as, the increased steepness on θ at small angles, the age dependency in the middle angular region and the dependence on ocular pigmentation, p (ranging from p=0 for black eyes to p=1.2 for very light eyes) at very large glare angles. It was left out the region less than 0.1 degrees, which is the typical point spread region and therefore highly dependent on pupil size.

For the most purposes the relation (5), is very complex so it was simplified to the CIE Small Angle Disability Glare Relation:

$$\left(\frac{L_{veil}}{E_{glare}}\right)_{small\,angle} = \frac{10}{\theta^3} + \left(\frac{5}{\theta^2}\right) \cdot \left(1 + \left[\frac{Age}{62.5}\right]^4\right) \tag{6}$$

valid in the restricted angular range $0.1^0 < \theta < 30^0$, and so it could leave out the terms with the ocular pigmentation factor p.

In the same angular range $0.1^0 < \theta < 30^0$, a third relation was established, called CIE Age-Adjusted Stiles-Holladay Disability Glare Relation:

$$\left(\frac{L_{veil}}{E_{glare}}\right)_{Age-Adjusted\,Stiles-Holladay} = \frac{k}{\theta^2} \cdot \left(1 + \left[\frac{Age}{70}\right]^4\right) \tag{7}$$

One easily recognizes the old Stiles-Holladay formula relation (3), now complemented by the age factor.

Because light scattering in the eye is predominantly due to scattering at structures that are large with respect to wavelength the glare is independent of wavelength.

5 Glare in Traffic

Glare is a phenomenon well known in traffic. We shall present two cases to show the age driver influence. For the sake of simplicity the first traffic situation is that of two approaching motorbikes. The car have two head-lights, one to the driver's left which would complicate calculations.

The light scatter veil in the eye may impede distinguishing obstacles in your own lane such as joggers or pedestrians.

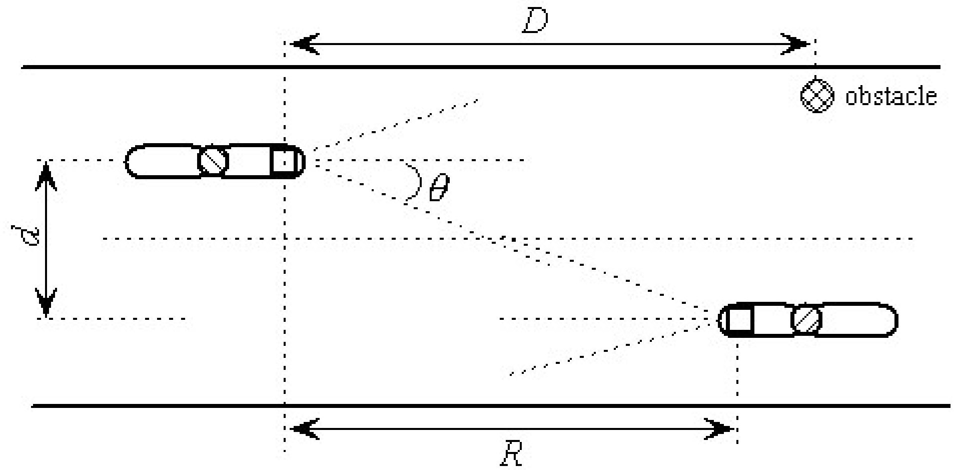

Fig. 6 Traffic situation with two motor bikes on approaching courses.

The glare angle $\theta_{rad} = d/R$, with R their mutual distance and d their lateral distance, or $\theta_{degrees} = (180/\pi)\cdot d/R$. If we have I the headlight intensity then:

$$E_{glare} = \frac{I}{R^2} \quad (8)$$

The luminance of the traffic obstacle to be seen is:

$$L_{obst} = \rho \frac{I}{D^2} \quad (9)$$

where ρ is the reflection factor for the obstacle, the pedestrian's raincoat for example.

The contrast C by which the obstacle stands out against the veiling glare luminance is:

$$C = \frac{L_{obst}}{L_{veil}} = \frac{\rho\left(\left[\frac{180}{\pi}\right]\cdot\frac{d}{D}\right)^2}{k\left[1+\left(\frac{Age}{70}\right)^4\right]} \quad (10)$$

We can note that the relation do not depend on I in a direct way.

The distance of detection the obstacle is:

$$D_{detection} = \frac{180\cdot d}{\pi}\sqrt{\frac{\rho}{k\cdot C\left(1+\left[\frac{Age}{70}\right]^4\right)}} \quad (11)$$

The atmosphere may be completely transparent and windscreen freshly cleaned and free of scratches but one should introduce a nominal allowance for scattering by the atmosphere and windscreen glass.

The second case concerns tunnel entrance lighting. When a tunnel entrance contrasts with the sky, the high sky luminance casts a glare veil over the tunnel entrance, which can easily mask preceding cars that have already entered the relatively dark tunnel. The net effect can be that the tunnel entrance even thought it is more luminous by the stray light veil, is effectively obscured (darkened) by the contrast with the bright sky and the non-visibility of objects in the tunnel. The approaching driver then views a dark wall instead of a tunnel entrance and this black wall illusion may lead to a shock reaction in panicking drivers. The remedy is to provide tunnel entrances with a light-transition zone, in which the admission of the sky light is gradually tempered and that is the way modern tunnels are usually built.

6 Conclusion

The original Stiles-Holladay relation is valid only for young adults. It was shown that it was quantified the glare handicap of the aged.

In all experiments was not found dependence between glare and wavelength of the light.

It is obvious that the aged driver will be prone to more visual problem than the young driver.

The most important sources of extra ocular light scatter are dirty or scratched windshield and the atmosphere. A survey test on realistic values for atmospheric and windshield light scatter indicated that doubling the original Stiles-Holladay coefficient k = 10 is normal.

The age-adapted version, now accepted by CIE as a standard, shows that disability glare rapidly increases beyond the age of 60 years: it doubles around 70 and triples at 83: with large individual variations.

Calculations indicate that the visual handicap due to disability glare in traffic and many other situations may be much more pronounced in the aged than in young adults.

References:

[1] L. Holladay, "*The Fundamentals of glare and visibility*," J. Opt. Soc. Am. 14, 1-15 (1927);

[2] W.S. Stiles,"*The effect of glare on the brightness difference threshold*", Proc. Roy. Soc. Lond. 1929, 104B;322-355;

[3] J.J. Vos, "*On the cause of disability glare and its dependence on glare angle, age and ocular pigmentation*" Clin. Exp. Optom 2003, 86:6:363-370;

[4] A. Roorda, "*Human visual system-image formation*", University of Houston, College of Optometry, Houston, TX;

[5] J.J. Vos and T.J.T.P. Van den Berg, *Report on disability glare CIE Research Note 135/1, Commision Internationale de L'élairage (CIE)*, 1999;

[6] Thierheimer, W., *Raport de expertiză tehnică*, Dosar penal, I.P.J. Braşov, 2003.

[7] Murdoch, J., *Ilumination Engineering from Edison's Lamp to the laser*, N.Y., 1990.

[8] CIE 146: 2002, *CIE equations for disability glare,* ISBN 3-901-906-15-0, 2002;

[9] CIE 147: 2002, *Glare from small, large and complex sources*, ISBN 3-901-906-15-0, 2002;

[10]Alexandru. C.: Modelarea legăturilor din sistemele mecanice prin utilizarea de softuri multibody**,** *8th International Conference*, Targu Jiu, mai 24-26, 2002.

[12] Danila, D.M., s.a.: Management of the potato crops for minimizing environmental and human health impacts, *Environmental Engineering and Management Journal*, Vol.9, No. 12, 2010, pp. 1685-1691.

[13] Gaceu, L., Gruia, R., Thierheimer W. - Applications of a Model Simulation Referring to the Energetic Flow Transformities in Agroecosystems, în *Proceedings of the 8th WSEAS International Conference on SYSTEM SCIENCE and SIMULATION in ENGINEERING* (ICOSSSE '09), Genova, Italy, ISSN: 1790-2769, 2009, pp. 41-46.

[14] Ola, D.C., Manescu, M.: Automatic control through computer of a volumetric screw dosing system destined for Agro-foods bulk solids, *Journal of Environmental Protection and Ecology 9*, No 1, 2008, pp. 200-210, ISSN:1311-5065.

[15] Oţăt, O. V., Dumitru N., Oţăt V., Dumitru I.: Dynamic models to analyse the influence of the seat belt in a frontal collision, *The 11th edition of The International Congress of Automotive and Road Transport Engineering, International Congress Of Automotive And Transport Engineering - Mobility Engineering And Environment* (CAR2017), IOP PUBLISHING LTD, DIRAC HOUSE, TEMPLE BACK, BRISTOL BS1 6BE, ENGLAND, 2017.

[16] Thierheimer, Al., ș.a.: Aspects regarding the experimental research of the stressors of the human pregnancy in case of road events, *IMT Oradea*-2018, ISSN 2457-8347, Vol. XVII, 2018, pp 135-138 University of Oradea Publishing House, Romania.

[17] Zamfira, S., Thierheimer, W., Ţane, N., Boldor, D. *Aspects Regarding the Influence of the Public Illumination on the Road Events*, CONAT 2004 International Automotive Congress, 20-22 octombrie 2004, Braşov, pag. 199-201, ISBN 973-635-394-X.

[18] Thierheimer, W.: *Sisteme tehnice din industria turismului*, Editura Universităţii Transilvania din Brașov, 2018.

[19] W. W. Thierheimer, N. Tane. R. Gruia, L. Gaceu, D. Thierhiemer, D. Ola, V. Cojocaru, M. Clinciu – *Risk Arising from Transport Activities*, în Environmental Engineering and Management Journal, December 2010, vol. 9, No. 12 ISSN: 1582-9596, pp. 1667-1670, Publishing House ECOZONE of the OAIMDD, Iași, Romania.