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REPORT ON:

A PROPOSED SOLUTION FOR HEADLAMP GLARE

Transmitted by the expert from Turkey

Note: The text reproduced below was prepared by the expert from Turkey upon the recommendation of GTB in accordance with the decision taken during the fifty-third GRE session (TRANS/WP.29/GRE/53, para. 66).

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## FOREWORD

The issue of achievement of adequate illumination using passing beam headlamp without glaring effect is still not solved completely. There have been numerous studies to improve low beam patterns, but, while these studies have advanced understanding of the problem, a comprehensive solution has not been attained. The purpose of these studies has been to develop a low beam pattern that provides adequate visibility, while at the same time eliminating glare for oncoming traffic and into rear view mirrors.

The purpose of this study has been to propose a solution for glaring effect of passing beam illumination by motor vehicle headlamp while providing adequate illumination. This paper, the result of long scientific efforts, established a solution for adequate illumination without glaring effect.

This report is prepared by Dr. Turhan Alçelik et al. under the coordination of the Turkish Ministry of Industry and Trade. It is intended to cause initiatives to be taken by UNECE to make appropriate amendments to UNECE Regulations applicable to passing beam illumination.

## ABSTRACT

Headlamp glare has been a great concern for both drivers and pedestrians particularly over the last decades, upon introduction of new lighting technologies. Many efforts have been made to eliminate or at least reduce glare, but all proved to be unsuccessful in eliminating the glare effect completely. This report contains a proposed solution for the glare problem providing adequate illumination distance without glare effect. The new concept passing beam illumination system has been tested for glaring effects and the results of these tests revealed a considerable decrease in glare.

## 1. Introduction

Headlamp glare issue has become an important public concern over the past decade (1). Developments in light source technologies (High Intensity Discharge (HID), Light Emitting Diode (LED), etc.) and optical design introduced headlamp systems (e.g. projection type headlamp systems) with higher efficiency, having different spectral power distributions and smaller sizes than conventional halogen headlamps.

Glaring caused by the headlamp of oncoming vehicles during nighttime driving has been a major problem affecting and disturbing both drivers and pedestrians. Contemporary illumination technologies, increase in aged population and progress in vehicle design all intensified the glare problem.

Illumination and contrast are the indispensable components of vision. Illumination is improper and the quality of vision is low if the light source is more apparent than the object it illuminates.

Before going through the details of this study, it would be useful to define some basic terms used in this report.

## 2. Definitions

- Visual acuity is the capability or feeling of the eye to distinguish the shape of object.
- Light sensation is the capability of the eye to discriminate between various contrast levels.
- Adaptation is the adjustment by the eye when shifting from dark to illuminated zone (photopic) or vice versa (scotopic).
- Retinal illuminance is the amount of photometric flux that reaches the retina of the eye; it is a function of the diameter of the pupil of the eye and the amount of light absorption within the eye.
- Accommodation is the adaptation by the optical structure of the eye to clarify the image falling on the retina.
- Glare is a bright light reflection that occurs when the luminous intensity or luminance within the visual field is greater than that to which the eyes are accustomed, a subjective sensation adversely affecting the visual function developed as a result of retinal illuminance that is higher than that which the light adaptation mechanism of the eye can tolerate.
- Contrast is the relationship between the luminance of an object being illuminated and its background. Although the visual function generally becomes easier as the contrast increases, too much contrast causes glare and makes the visual function more difficult. A bright object alone does not necessarily cause glare, but a bright object in front of a dark background, usually causes glare.

## 3. The Human Retina

Figure 1 shows the anatomic structure of the human eye and eye parts involved in this study (2). Pupilla is the space located at the center of iris, and adjusts the amount of light entering the eye. Retina is the inner layer of the eye where photoreceptor cells (rod, cone) are located. The eye contains approximately 5.5 millions of cone and 125 millions of rod. The retina consists of two parts: 1. Central retina, and 2. Peripheral retina. The central retina is called macula, and its central part is fovea. The central retina is effective in photopic vision and the peripheral retina in scotopic vision. Assuming the eye as a single optical structure, the optical axis and the visual axis of the eye are different. Optic nerve head is also the part of the optic nerve visible on the retina, and also called blind point.

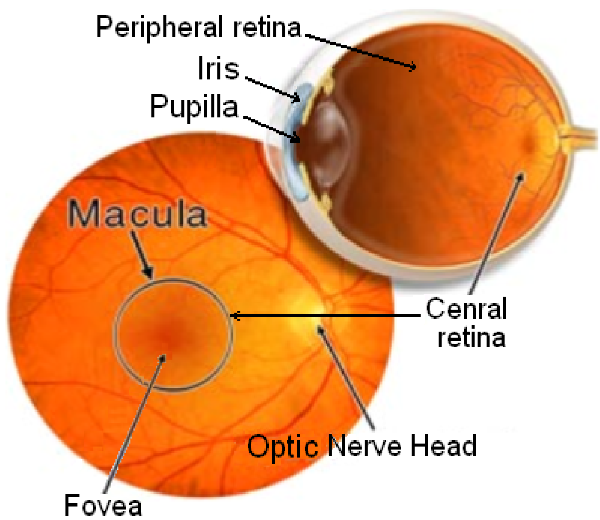


Figure 1: Anatomic structure of human eye

The amount of light that enters the eye is determined by pupil size, which is regulated by the dilation and contraction of the iris. The amount of light that enters the eye depends on both the pupil size and iris colour. The pigmented iris (dark-coloured) prevents the light from entering the retina; however the low-pigmented iris (light-coloured) is translucent.

The retina contains two types of photoreceptors, rods and cones. The rods, located in the peripheral retina are more sensitive than the cones and more effective in nighttime vision (scotopic vision). The cones, located in the central retina (in the fovea zone of macula part of the retina layer) provide the eye's color sensitivity and daytime vision (photopic vision). Mesopic vision is a combination between photopic vision and scotopic vision in low but not quite dark lighting situations. The combination of the higher total sensitivity of the rods in the eye for the blue range with the color perception through the cones results in a very strong appearance of bluish colors around dawn. The photoreceptor cells (cone, rod) may change their light sensitivity up to 1 million times maximum. The pupilla diameter varies between 1.5 and 8 mm, and the amount of light entering the eye is proportional to the square of pupilla diameter, and the pupilla can change the amount of light entering the eye up to 30 times during photopic and scotopic adaptation.

Peripheral vision is a very important issue for nighttime driving. The pupilla is large (mydriasis) during nighttime when compared to daytime, and the rods in peripheral retina are effective in nighttime vision (scotopic vision).

The first direct effect of the headlights on the oncoming traffic users' eye during nighttime driving is pupillary contraction (miosis). In case of miosis phenomenon on the eye, some rods located in the peripheral retina, which are effective in scotopic vision, pupillary miosis is disabled, thereby restricting the visual capability during nighttime. The glaring effect caused by oncoming headlights during nighttime driving causes miosis, partly disables the peripheral retina and undesirably causes the visual field to get narrower. Our proposed system minimizes such phenomena.

When the illuminance in dark zone (Zone III in UNECE photometric measurement screen) is increased, or the amount of scattered stray lights increases, glare increases and vision is worsened.

Even though many reasons have been introduced by scientific studies to explain the glare mechanism, none of them achieved a full description of such mechanism.

In many studies to examine the relationship between glare and illuminance level, even the lowest illuminance level found to have caused reduced visual distance. Generally, headlight glare is liable to increase the frequency of accidents, and discourages people to drive during nighttime (3). The purpose of this study is to eliminate glare even if the illumination level on the road surface is increased, and to remove the worries of people about nighttime driving.

In a two-way traffic, when the opposing vehicles use standard low beam, the visibility distance for both drivers decreases due to glaring effect, whereas in our system, the headlights of opposing vehicles are additive to visibility distance of both vehicles.

## 4. Headlight Glare

Glare is a subjective sensation caused by luminance in the visual field that is too bright that cannot be tolerated by the eye, as a result it is the annoyance, discomfort or loss of visual performance caused by excessive contrast or brightness. Increasing the luminous intensity of headlamps increases the glare they provide (4). Various studies show that different illuminance levels cause glare (5, 6).

Glaring effect occurs when visual field brightness is greater than the luminance to which the eyes are adapted. It can be caused by direct and indirect light sources. Some studies examined the relation between the size and intensity of glare source (7).

The history of studies on glare goes back to the 1920's. Holladay and Stiles studied the glaring effect in roadway lighting, and Holladay defined the concept of "disability glare" as the glare that decreases a driver's ability to see clearly, and assumed the reason for glare as the crosstalk in the optic nerve (8, 9). Stiles showed that glare is caused by the scattering of light in the optic media of the eye, rather than occurring in the optic nerve. In the 1930's, Crawford showed that the stray light in the eye from different sources is additive (10). In 1991, Adrian and Bhanji studied the effect of the glare source on the vertical plane of the driver's eye, and the glare angle (11). The light rays scattered in the eye causing glare disturb the retinal image. The eye reacts by suppressing the disturbed image to provide clear visibility.

There are two types of nighttime lighting concerning glare: fixed overhead lighting and vehicle headlights. Improper roadway lighting facilitates road vision, but may also increase the glaring effect. Our proposed system not only provide adequate illumination by headlights without glare, but can also be applied in fixed overhead lighting, where it provides a homogeneous lighting with minimum glare.

As far as glare is concerned, the light rays have two different optical effects on the eye:
(a) Direct Glare produced by a direct light from light sources, and
(b) Indirect Glare produced by a reflective surface.
Direct glare is caused by light sources in the field of view (such as headlights and luminaires). Indirect glare is caused by reflections from bright surfaces that reflect light toward the driver.

Glare affects night driving performance. At night, automobile headlights produce direct glare by shining into the eyes of drivers in oncoming cars, and indirect glare is experienced from rearview mirrors and vehicle interiors that reflect light from following vehicles.

The effects of glare on drivers are much higher at night, because during nighttime driving, drivers are adapted to lower levels of light and therefore require a higher difference in luminance between objects and background to see objects on the road surface. This luminance difference is reduced by stray light coming either directly from a glaring light source or indirectly from reflections of headlamps.

## 4.1 Causes of headlight glare

The dense light intensity of the headlamp surfaces acting as two different sources of glare and the light rays from that source falling on the eye at different angles as well as the excessive contrast difference with respect to zone with lower luminance suppress the image on the road surface and make the nighttime vision difficulty even cause blinding effect. The light distribution on the retina is heterogeneous. Some of the rods in the retina are disabled, causing improper vision.

The direct effect of the out-of-control spread light caused by oncoming vehicles on the eye, the contrast difference on the headlamp surface and its surrounding, the contrast between the headlamp surface, including its surrounding, and road surface, and the glaring effect on the rear view mirrors caused by the vehicles following and driving in the same direction are the main reasons of disability and discomfort. Any curvatures, turns or irregularities on the road surface cause glare from both oncoming and following vehicles. In other words, the brightness on the headlamp surface and its surrounding as well as on the road surface is one of the most important components contributing to glaring effect.

The out-of-standard or defective headlamps offered in the market for after sales services as well as dirty headlamps are also a cause of glare. The design and manufacturing and construction defects in roadway and vehicle headlamps may also contribute glaring effect. Vehicles having their headlights misaimed as well as old-aged vehicles increase the glaring problem. Long nighttime driving contributes fatigue of the eye, and thus increasing the sensitivity of eye to glare.

Ophthalmic diseases, particularly refraction disabilities (myopia, astigmatism, etc.), inadequate illumination and glaring effect are the main causes for disturbed scotopic vision. Especially the refraction disease on the eye (particularly astigmatism) is one of the factors increasing the glaring effect. Even though such defects are treated by making use of eye glasses, contact lens, or through excimer laser therapy LASIK (Laser In-Situ Keratomileusis), glaring effect may still continue. Additionally, the very small opacities in the crystalline lens or cornea may adversely contribute to glaring effect.

The people with light-colored eyes, elderly and those having cataract problem are especially sensitive to disability glare.

Illuminance from the glare source is determined by the photometric intensity distribution of the oncoming headlamps, the aiming and height of the lamps, and the distance from the glare source to the oncoming traffic users. The greater the intensity directed towards an observer, the greater the illuminance reaching the traffic users' eyes. As the traffic user gets closer to oncoming headlights, the illuminance increases and, therefore, the glaring effect increases. Whereas the Turkish system completely avoid glare irrespective of the photometric intensity distribution and distance with both halogen and xenon light sources.

The human eye physiologically and involuntarily tends to be attracted to a moving or a brighter object within the visual field. During nighttime driving, the eye tends to be attracted to the oncoming headlamps, the phenomenon called "Preferential Looking Effect", disturbing the adaptation of the eye to darkness and increasing glare. However, the eye later voluntarily tends to get far away from the glare source. Such phenomenon is more apparent with standard halogen and xenon headlamps. In this study, this phenomenon is assumed to be one of the important reasons for glare, and the proposed system minimizes glare during that phenomenon.

Glare in nighttime driving has a high angular or spatial dependence, resulting in eye movements that consistently lead to transient changes in the luminance reaching the eye and so to dark adaptation or light adaptation. As part of the adaptation process, the retina adjusts to the quantity of light. Although different parts of the retina are exposed to different quantities of light, it is generally assumed that an instantaneous state of adaptation of the fovea zone in central retina (cones), which is effective in photopic vision and light adaptation, can be described by an equivalent veiling luminance from a uniform source superimposed on the visual field. Peripheral retina (rods) is effective in scotopic vision and dark adaptation.

The stray light in the eye causes scattering, diffraction on the fringe of the pupil, and optical imperfections in the eye, all deflecting light from the retinal image. Stray light reduces the contrast between the image and background, and decreases the quality of nighttime vision. The effects of stray light increase with increasing age due to changes in the intraocular media and cornea of the ageing eye that increase scattering.

In 1963, Hopkinson examined the effect of luminance of the surrounding on glare (12). The halo forming on the luminance zone is caused by stray lights and is highly important in respect of glare. In this study, the luminance zone on the surrounding is fully controlled, thereby avoiding glare.

Glare is a subjective disturbance, and some people are very sensitive to glare. While a given illumination does not disturb some people at all, the same illumination may highly disturb some others who are sensitive to glare.

Some people are included in high-risk group in respect of nighttime glare: those with light-colored eye and the elderly. Another potential high-risk group is composed of drivers with eyeglasses and contact lenses, having refraction defects (myopia, astigmatism), particularly using scratched or damaged eyeglasses or contact lenses. Some drivers who have had vision correction surgery, such as corneal excimer laser therapy (LASIK), also complain about glare.

The level of ambient illumination along the road is an important factor in the perception of glare. Higher ambient illumination levels provided by fixed pole lighting results in higher thresholds for discomfort glare (13).

## 4.2. Types of Glare

Glare is usually classified according to its effect on the observer, and there are two types of glare; disability glare and discomfort glare.

Disability glare impairs the capability of the eye to perceive small changes in brightness, and may cause loss of vision (2,14).

Past studies showed a contradiction between glare and visibility: the higher the light intensity the higher the glaring effect. In this study, glare is completely eliminated while providing required illumination. Disability glare is very important, because it is directly related to the driver's ability to see objects and thus may result in traffic accidents.

Disability and discomfort glare apparently have quite different physiological origins. Disability glare is the reduction of visibility caused by light scattered in the eye, and the discomfort glare is the sensation of discomfort caused by a glare source in the field of vision, and related to neuronal interactions similar to such physiological functions as skin resistance or the pupillary response to light (15). These two phenomena often, but do not necessarily always, occur simultaneously.

Discomfort glare causes visual discomfort, disturbance, and fatigue. Disability glare causes loss in visual performance, which is generally defined as a reduction in the visibility distance of low contrast objects and in quality. It is always felt that discomfort glare is more important than disability glare, because the drivers complain about discomfort glare. In our opinion, however, discomfort glare and disability glare are not more important than each other, and therefore efforts should be taken to establish a system minimizing both discomfort and disability glare, which is aimed at in our study.

## 4.3. Effects of glare

### 4.3.1. Visual performance

It is almost always the case that headlamp glare reduces visual performance under driving conditions relative to the level of performance achievable without glare (16).

### 4.3.2. Fatigue

Fatigue is one of the important consequences of headlight glare. In case of bright light eye and facial muscles are stimulated eye muscles. Such muscles undergo fatigue when glare caused by bright light conditions is continuous or prolonged. One source of fatigue is the effort to keep the eyes focused on the road surface in front of the vehicle.

4.3.3. Accident frequency

A study by Hemion in 1969 reports the ratio of traffic accidents caused by headlamp glaring particularly by blinding effect to be around 1 percent (3,17). Some studies show that the traffic accidents during nighttime driving increased up to 4.4 times (18). Although most of the past studies did not establish a close relation between the traffic accidents during nighttime and glare, our study clearly shows that glare causes a significant loss in visual capability. More importantly, we suggest that, even though glare is not directly involved just at the time of accident, the additive and cumulative effect of glare on the eye and decreased visual distance, and consequently fatigue, stress and loss in concentration are extremely important and perhaps most of such accidents are caused by glare. We consider, however, that more extensive studies are required in this field. In addition, our proposed system minimizes such additive and cumulative effect of glare.

4.3.4. Driving behaviour

Depending on the glare effect, drivers usually decrease their speed, get angry, and have their concentration disturbed, thereby leading to dangerous situation in traffic. Our proposed system minimizes such problems.

5. Countermeasures against glare and the Turkish proposed solution

Many studies were carried out in the past based on different methods to solve the headlight glare problem. Some of the solutions produced by these studies are provided below (19):

5.1. Reducing the intensity or luminance of the glare source - reduce glare by reducing the luminance of the glare source or by regulating the light intensity on the road surface. Photometric Distribution is governed by standard UNECE Regulations.

5.1.1. Lowering the headlamp: Lowering the headlamp height is one of the simple ways of solving headlamp glare problem, however, lowering the headlamps may reduce glare, but cause loss of forward visibility.

5.1.2. Use of adaptive headlamps: Adaptive headlamps, provides significant improvements to visibility, particularly on curves, but its effect on glare is not certain. In the system proposed by Turkey, curve lighting can be provided without any additional mechanism.

5.1.3. Aiming of the headlamps: The tolerances in the current standard for initial aiming may cause glare against oncoming traffic users (particularly right curves for right-hand traffic and left curves for left-hand traffic) and forwarding vehicles (particularly during passing).

For example, considering a type of vehicle with a headlamp height of 100 cm, the initial aiming is set to 1 per cent in the unladen vehicle state with one person in the driver’s seat (see UNECE Regulation No. 48, paras. 6.2.6.1.1. and 6.2.6.1.2.). However, the other settings in Regulation No. 48 are extremely flexible, and permits many incorrect initial settings. Our proposal eliminates glare caused by headlamp aiming. For this purpose, the initial aiming is changed by, +/- 0.1 per cent for each 10-cm variation in headlamp height. For example, the initial aiming is set to 0.6 per cent for a vehicle with a headlamp height of 60 cm, and to 1.3 per cent for 130 cm, which means that a continuous illumination distance of 100 m shall be provided by passing beam without glaring effect. This illumination distance may be changed as required. This proposed aiming minimizes the glare problems that may be caused by mounting defects or mounting height.

5.2. Reducing the illumination reaching the driver's eyes - this countermeasure is intended to block or filter light, thereby reducing the amount of illumination reaching a driver's eye. Anti-glare mirrors, polarized lighting and night-driving glasses are some of the measures for reducing the illumination reaching the driver's eyes. Among them, polarized lighting offers the most appropriate solution for eliminating glare, but it is difficult to implement.

Among them, anti-glare side mirrors and rear-view mirrors solve glare problem during nighttime driving, but impair rearward visibility. The Turkish system, however, allows these mirrors to be used in daytime mode during nighttime driving and provides a better rearward visibility.

5.3. Increasing the glare angle – this is a method to reduce glare by using wide angles between the glare source and the road surface.

5.4. Indirectly minimizing the effects of glare – this method solves the glare problem indirectly by reducing the illumination needed for vision or raising the adaptation level of drivers. The arrangements that can be used for this purpose are ultraviolet headlights having some potential to reduce glare indirectly but difficult to implement, regular road lighting, restriction of nighttime driving especially for glare-sensitive drivers, driver corrective lenses and ophthalmic surgery (LASIK).

Glare-sensitive drivers who must drive at night should increase the following distance, and avoid looking into headlights. In our proposed system, no glare is caused even if the inside of the headlamp is looked at directly.

## 6. Methods

Three different test methods were employed in order to comparatively evaluate the photometric distribution pattern and cut-off lines of current standard passing beam (UNECE Regulations Nos. 112, 98, 48, and FMVSS 108 for the United States of America) and of the proposed prototypes in respect of glare.

### 6.1 Method 1

Glare was assessed using De Boer rating scale, and the results were comparatively analyzed using the following Boer scale (20).

| Visual response | Rating |
|---|---|

| | |
|---|---|
| Unnoticeable | 9 |
| | 8 |
| Satisfactory | 7 |
| | 6 |
| Just admissible | 5 |
| | 4 |
| Disturbing | 3 |
| | 2 |
| Unbearable | 1 |

Table 1. The De Boer rating scale for discomfort glare (1967).

In the rating evaluation using Boer scale, current standard passing beam achieved a rating of 5, whereas the proposed passing beam 8.

6.2. Method 2

Four different projection-type headlamp prototypes were used in this study. Two out of these prototypes have a standard cut-off, and other two are proposed TuRhan design headlamp prototype having proposed cut-off.

Both standard and proposed headlamp prototypes used halogen and xenon light sources. All prototypes are mounted on a table providing a proper fixation; with the headlamp focal point located 70 cm high. Care was taken to ensure that the area of headlamp surface is the same for all prototypes.

All pictures were taken on a standard roadway, behind a semi-permeable screen, by the same person, using the same camera and camera settings, at the same distance. Pictures were taken at an eye level of approximately 110 cm from ground, which is considered as the eye level for the oncoming traffic, with the semi-permeable screen located at distances of 250 cm and 625 cm from the headlamp, and the distance between the screen and the camera kept constant during all shots. Then, these pictures were comparatively evaluated, using "Pixel Profile" image analysis software.

The reasons for using the distances of 250 cm and 625 cm are to comply with standard photometric measurement distance of 25 m (1/10 for 250 cm, 1/4 for 625 cm), and to satisfy the measurement distance to measure the visual acuity with accommodation (250 cm) and without accommodation (625 cm).

The results from the halogen headlamp with standard cut-off and from TuRhan design halogen headlamp were comparatively analyzed using graphical illustrations. Similarly, the results from the xenon headlamp and from TuRhan design xenon headlamp were comparatively analyzed using graphical illustrations.

It was concluded upon comparisons that the proposed system minimizes glare caused by oncoming headlights, while providing adequate illumination distance.

The following figures show the photographs taken through a semi-translucent screen, specially prepared for this study to clearly indicate the photometric light distributions for current standard passing beam and TuRhan design passing beam, and comparative light intensity analysis on these photographs using the "PIXEL PROFILE" image analysis software.

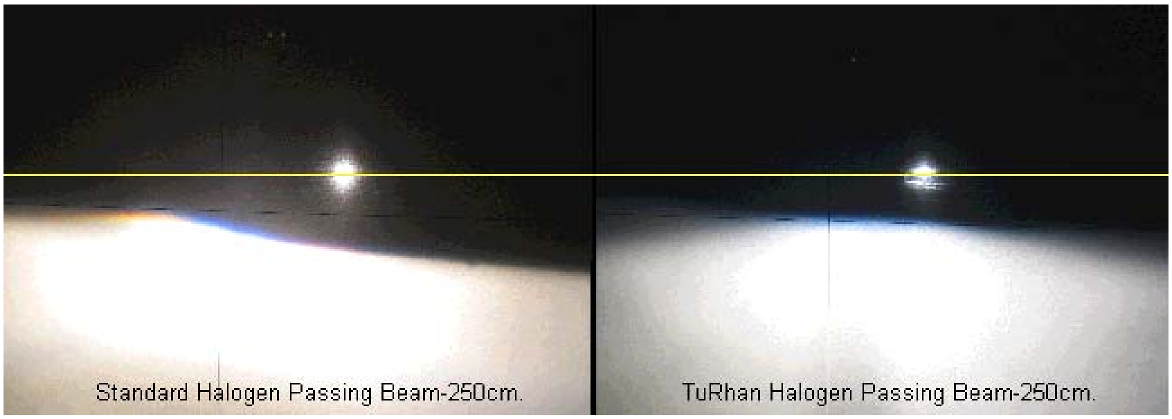


Figure 2: Standard halogen passing beam and TuRhan design halogen passing beam-250 cm.

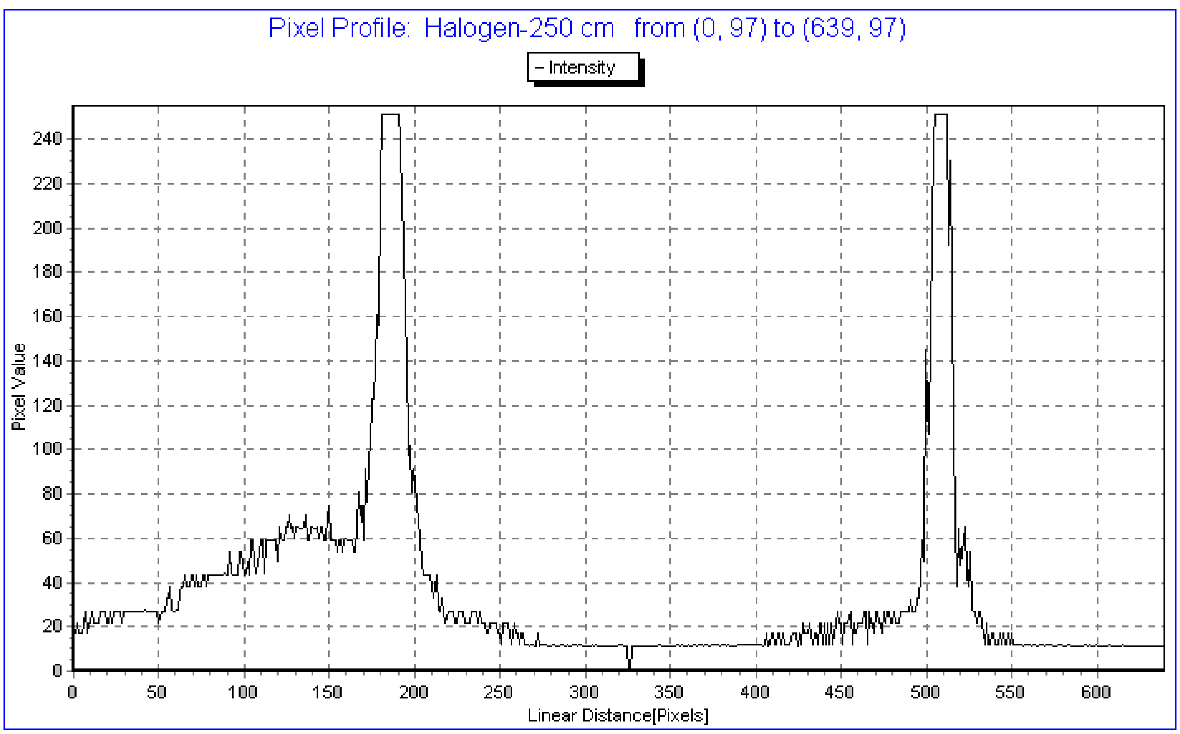

Figure 3: Plot for comparative analysis for passing beam photometric distribution patterns of standard halogen passing beam and TuRhan design halogen passing beam in Figure 2 (intensity analysis was carried out at both headlamp levels shown with yellow line).

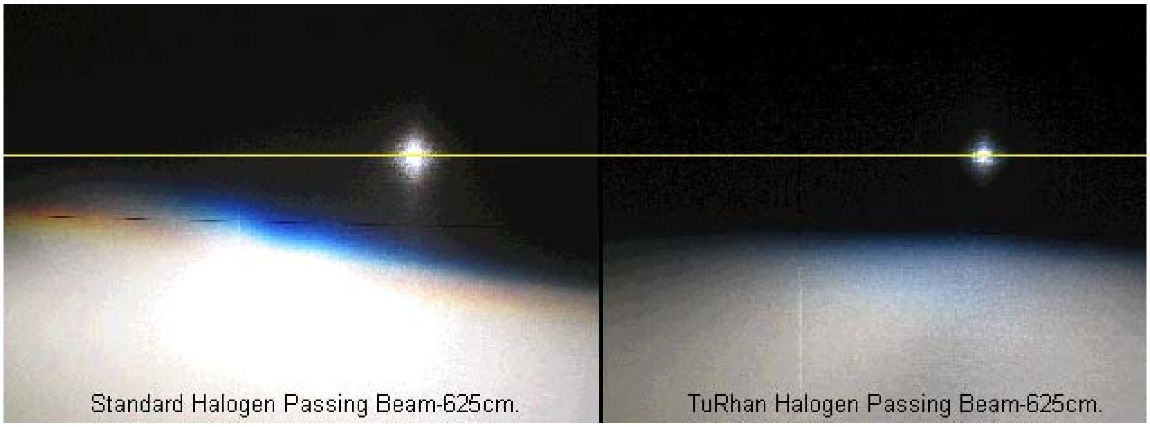


Figure 4: Standard halogen passing beam and TuRhan design halogen passing beam-625 cm.

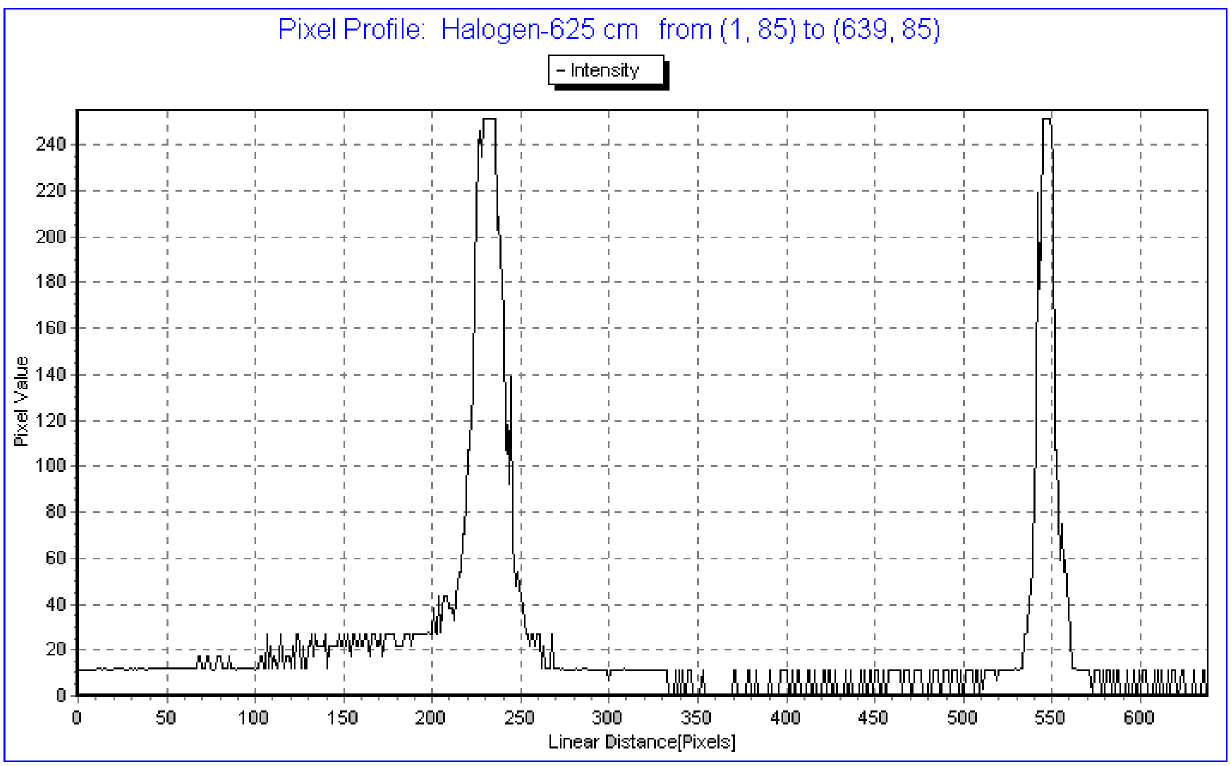

Figure 5: Plot for comparative analysis for passing beam photometric distribution patterns of standard halogen passing beam and TuRhan design halogen passing beam in Figure 4 (intensity analysis was carried out at both headlamp levels shown with yellow line).

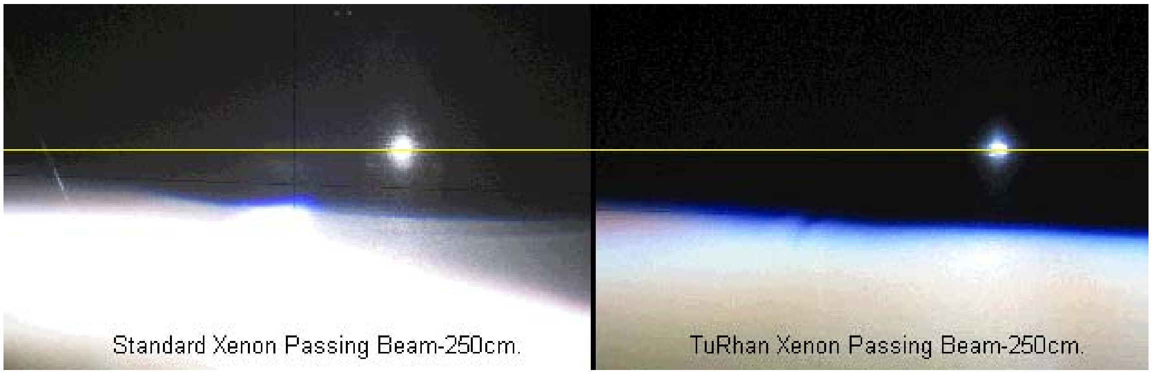


Figure 6: Standard xenon passing beam and TuRhan xenon passing beam - 250 cm.

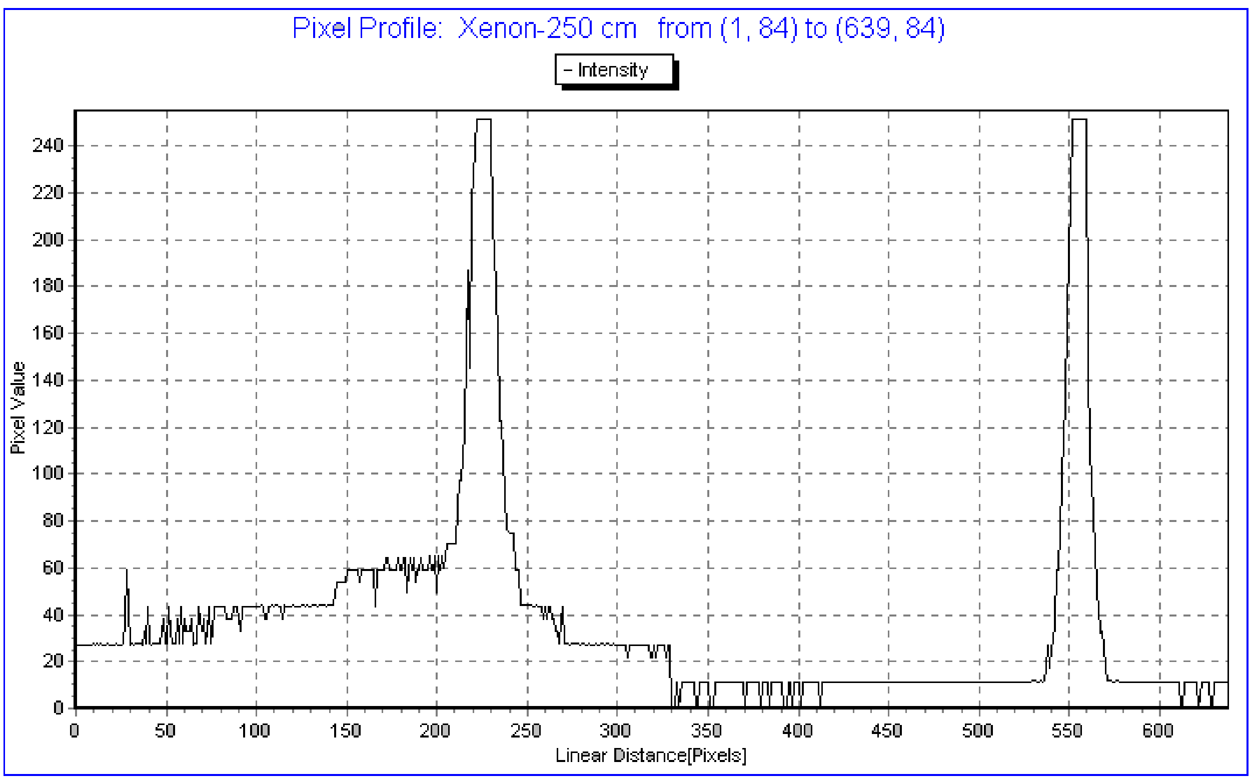


Figure 7: Plot for comparative analysis for passing beam photometric distribution patterns of standard xenon passing beam and TuRhan design xenon passing beam in Figure 6 (intensity analysis was carried out at both headlamp levels shown with yellow line).

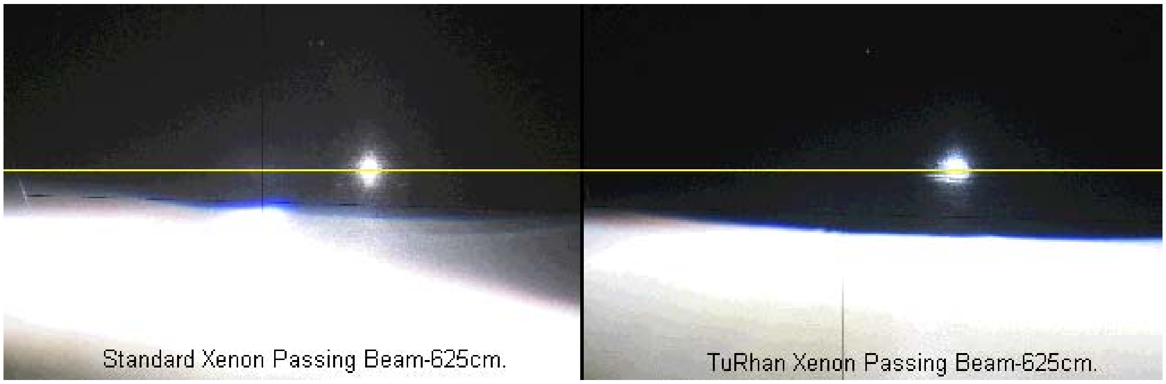


Figure 8: Standard xenon passing beam and TuRhan xenon passing beam - 625 cm.

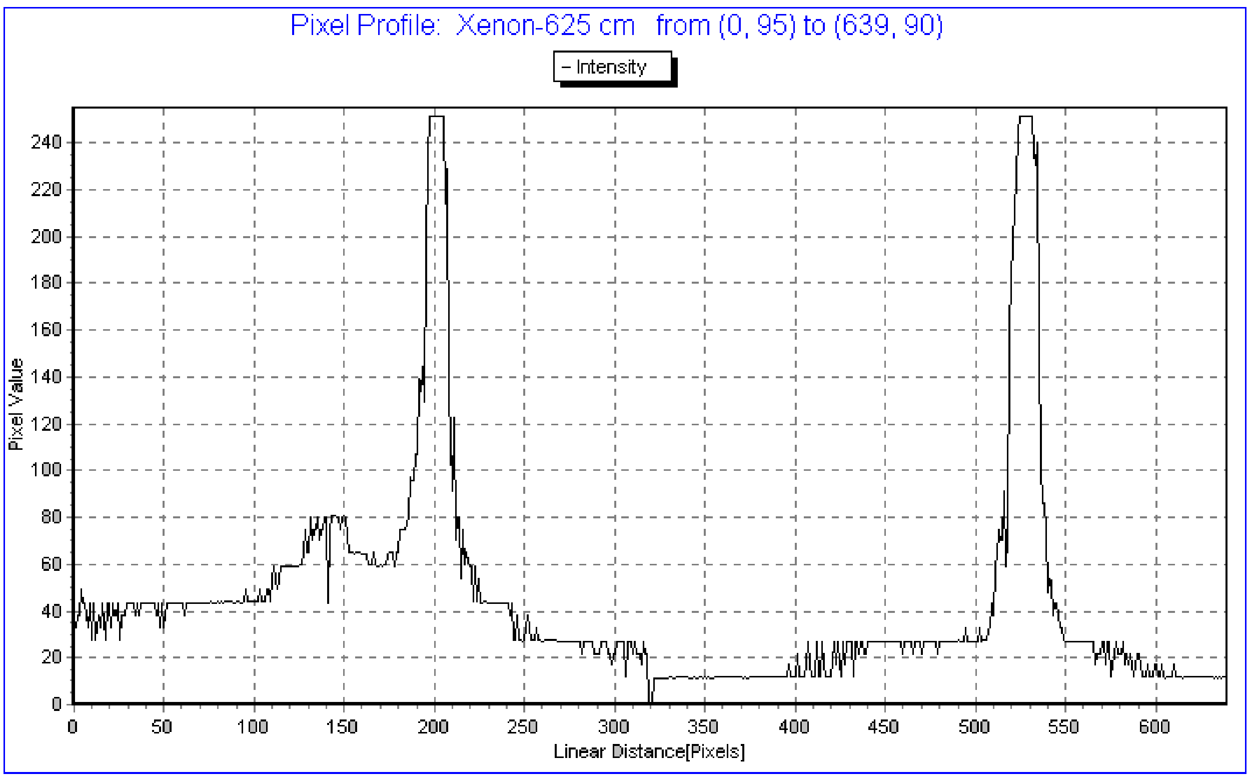


Figure 9: Plot for comparative analysis for passing beam photometric distribution patterns of standard xenon passing beam and TuRhan design xenon passing beam in Figure 8 (intensity analysis was carried out at both headlamp levels shown with yellow line).

During the measurements taken using the pixel profile software, the brightest point was assumed to be 256 pixels, and the darkest point to be 0 pixels. Measurements were taken on the same ground clearance (horizontal level) for both prototypes using different passing beam illumination systems. The reason for taking the measurements at that level is to determine the difference in the extent to which the eye is adversely affected by the bright zone formed on the headlamp surface and its surrounding as a result of preferential looking effect on the drivers tending to look at the oncoming headlights. The brightness pixel values of conventional halogen and xenon systems and of TuRhan design halogen and xenon systems were comparatively analyzed. It was concluded as a result of this evaluation that the brightest point for both systems is the center of the headlamp having a pixel value of approximately 256.

When the pixel values which are the measure of the brightness or rather the scattered light around the headlamp, which we consider the major cause of glare, are compared, such brightness reaches up to 80 pixels with conventional passing beam systems, whereas it is kept around 30 pixels with our proposed system. The difference between such values may also be interpreted as a measure of difference in glare caused by both systems. It can be clearly established that the proposed system offers a much less glare that offered by conventional system – even no ratio is given.

6.3. Method 3

Three preliminary tests were carried out under laboratory conditions. The visual acuity of all participants used in the tests was verified before testing, and all determined to have a visual acuity of 10/10. Then, the participants were subjected to glare sensitivity test, contrast sensitivity under dark room conditions, using the original test settings of the software. The participants were then required to have driver's position and look at the surface of standard headlamp positioned to have standard aiming for a few seconds, and in the second part, the participants were again required to have driver's position, but look at the surface of TuRhan design headlamp positioned to have proposed aiming for a few seconds. Dark room conditions were satisfied during all tests, and adequate time is granted for dark adaptation of the participant. Finally, the results were comparatively analyzed.

The figure aside shows a conventional headlamp with standard passing beam photometric light distribution pattern and the headlamp with TuRhan design passing beam pattern as well as the equipment required for laboratory testing. Frisen Glare Test and Tri-VA with Frisen Contrast Test software were used for this test, and the test results were analyzed by PINAR AYDIN O`DWYER, M.D., PhD.

Figure 9: Equipment for Glare Visual Acuity Test

The following tables show the visual acuity and average glare test results for the participants (Table 2) and distribution of glare and contrast test results among participants (Table 3).

| VISUAL ACUITY | BASELINE GLARE ACUITY (mean) | STANDARD GLARE ACUITY (mean) | STANDARD HEADLIGHT GLARE ACUITY (mean) | PROPOSED HEADLIGHT GLARE ACUITY (mean) |
|---|---|---|---|---|
| 10/10 | 16.9 | 26.9 | 21.9 | 17.9 |

Table 2: Results of mean glare visual acuity in 12 eyes of 6 normal cases

| Control | Control | Glare | Glare | Control | Control | Standard | Standard | TuRhan | TuRhan | Standard | Standard | TuRhan | TuRhan |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| glare | glare | glare | glare | con dB | con dB | glare | glare | glare | glare | con dB | con dB | con dB | con dB |
| right | left | right | left | right | left | right | left | right | left | right | left | right | LEFT |
| 16 | 16 | 28 | 28 | 1 | 1 | 20 | 20 | 16 | 16 | 1 | 1 | 1 | 1 |
| 16 | 16 | 28 | 28 | 1 | 1 | 19 | 19 | 16 | 16 | -1 | -1 | -1 | -1 |
| 18 | 18 | 25 | 25 | 1 | 1 | 23 | 23 | 18 | 18 | 1 | 1 | 1 | 1 |
| 16 | 16 | 24 | 24 | 1 | 1 | 22 | 22 | 18 | 18 | -1 | -1 | 1 | 1 |
| 19 | 19 | 31 | 26 | 1 | 1 | 26 | 21 | 21 | 19 | -1 | 1 | -1 | 1 |
| 16 | 17 | 28 | 28 | 1 | -1 | 24 | 24 | 20 | 19 | -2 | -2 | -1 | -1 |

Table 3: Results of mean glare and contrast value.

Test 1

Best corrected visual acuity with Snellen chart: 12 eyes of 6 normal people (1 female, 5 males, age range 29-53, mean age: 40.6) were assessed in the following tests.

Test 2

Visual acuity with Frisen Glare test (in a dark room, at a distance of 1 m). Test was carried out in 4 different positions as follows:

a. Under normal conditions,
b. Under test glare conditions,
c. Under simultaneously presented conventional headlight conditions,
d. Under simultaneously presented proposed headlight conditions.

Test 3

Contrast sensitivity with Tri-VA with Frisen Contrast Test (in a dark room, at a distance of 2m). Test was carried out in 3 different positions as follows:

a. Under normal conditions,
b. Under simultaneously presented conventional headlight conditions
c. Under simultaneously presented proposed headlight conditions

Results

1. Best corrected visual acuities in all cases were full.
2. In all cases, glare visual acuities were worse under test glare conditions and worse under conventional headlight conditions. Whereas under the proposed headlight prototype conditions, glare visual acuity was better than conventional passing beam prototype and under test glare conditions.
3. In all cases, contrast sensitivity acuities remained unchanged in all three cases.

Conclusions

European standards prefer a downward aiming of the headlamp in order to limit headlamp glare, but thereby shortening the illumination distance, whereas the U.S. standards prefer upward headlamp aiming in order to provide a longer illumination distance but thereby increasing the glare effect. Attempts to achieve both long distance illumination and low glare have not proven successful. Every effort to reduce headlamp illumination or change the beam pattern has been met with visibility problem, and every effort to increase illumination has been met with glare problem. In this report, we propose a solution in which both glare is eliminated and long illumination distance is provided. This system is very easy to implement and can be used together with existing systems without any disadvantage.

This report is a preliminary study based on our proposals for amendment to UNECE Regulations Nos. 112, 98 and 48 regarding passing beam headlamps. Further studies and tests may be conducted under different road and whether conditions (foggy and raining and snowing whether conditions, mesopic vision conditions, etc.).

The following pictures compare the proposed system with conventional system regarding illumination distance and glare effect.

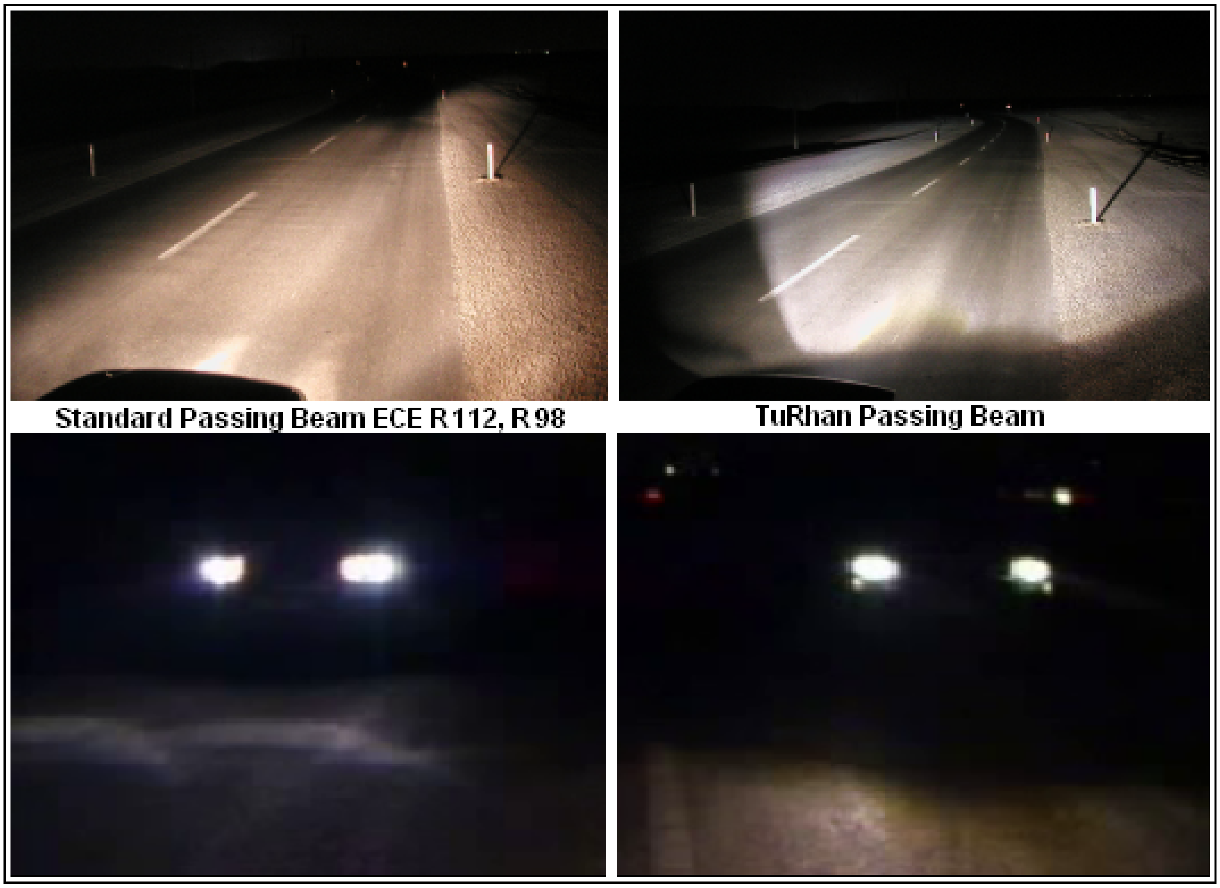


Figure 10: A comparison between standard passing beam and our proposed system for distances and opposing glare effects.

References

1. An Investigation of Headlamp Glare: Intensity, Spectrum and Size. U.S. Department of Transportation - National Highway Traffic Safety Administration, DOT HS 809 672 - October 2003

2. Arthur C. Guyton, M.D., Textbook of Medical Physiology 7. Edition - Turkish Edition Volume: 2 pp. 1005-55

3. Cadena, D. G. and Hemion, R. H. (1969). "Disability glare effects from vehicle headlights and fixed overhead street lighting." Final Report on Phase IV-B of FHWA Contract CPR 11-4126, Report No. AR-700,

4. Hare CT, Hemion RH. 1968. Headlamp Beam Usage on U.S. Highways, Report AR-666. San Antonio, TX: Southwest Research Institute.

5. Bullough JD, Fu Z, Van Derlofske J. 2002. Discomfort and disability glare from halogen and HID headlamp systems. Society of Automotive Engineers World Congress, Detroit, MI: Society of Automotive Engineers (Paper 2002-01-0010).

6. Alferdinck JWAM, Varkevisser J. 1991. Discomfort Glare From D1 Headlamps of Different Size, Report IZF 1991 C-21. Soesterberg, Netherlands: TNO Institute for Perception.

7. Manz K. 2001. The influence by size of headlamp on discomfort glare. Progress in Automobile Lighting Symposium, Darmstadt, Germany: Darmstadt University of Technology (pp. 618-634).

8. Holladay, L. L. (1926). "The fundamentals of glare and visibility." Journal of the Optical Society of America, 12, 271–319.

9. Stiles, W. S. (1928–29). "The effect of glare on the brightness difference threshold." proceedings of the Royal Society (London) B104, 322.

10. Crawford, B. H. (1936). “The integration of the effects from a number of glare sources.” Proc. Phys. Soc. London 48. p. 35.

11. Adrian, W. and Bhanji, A. (1991). "Fundamentals of disability glare. A formula to describe stray light in the eye as a function of the glare angle and age." Proceedings of the First International Symposium on Glare, Orlando, Florida, pp. 185–194.

12. Hopkinson, R. G. (1963). Architectural Physics: Lighting. Her Majesty’s Stationary Office, London, UK.

13. Schmidt-Clausen HJ, Bindels JTH. 1974. Assessment of discomfort glare in motor vehicle lighting. Lighting Research and Technology 6(2): 79-88.

14. Flannagan, M. J., Sivak, M., Traube, E. C., and Kojima, S. (1996). "Effects of overall low-beam intensity on seeing distance in the presence of glare." Report UMTRI-96-26, University of Michigan Transportation Research Institute, Ann Arbor, MI., pp. 1–26.

15. Fry, G. A. and King, V. M. (1975). "The pupillary response and discomfort glare." Journal of the Illuminating Engineering Society 4, 307.

16. Mortimer RG. 1969. Requirements for automobile exterior lighting. In Visual Factors in Transportation Systems. Washington, DC: National Academy of Sciences.

17. Hemion RH. 1969. A Preliminary Cost-Benefit Study of Headlight Glare Reduction, Report AR-683.San Antonio, TX: Southwest Research Institute.

18. National Safety Council (1999). Injury Facts, National Safety Council, Washington, DC, pg. 90.

19. Countermeasures for Reducing the Effects of Headlight Glare. The AAA Foundation for Traffic Safety. December 2001.

20. DeBoer, J. B. and Schreuder, D. A. (1967). Transportation Illuminating Engineering Society (London), 32, 117.

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