

# PASSING BEAM VISIBILITY DISTANCE - TECHNICAL POSSIBILITIES, LEGAL REQUIREMENTS AND ROAD SAFETY

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## **Abstract**

*Night-time visibility is essential for road traffic safety. It depends mostly on quantity of light falling on the objects important to be seen to avoid collision. The relatively simple and easily understood criterion for quality of passing beam is visibility distance. In fact visibility distance of driver using headlamps is a much more complicated function of many factors such as design of headlamp, light source used, mounting height, aiming, change of beam pattern inclination during change of vehicle load. From point of view of legal requirements it is important to meet all requirements concerning all mentioned factors. But the problem is that there are separate legal requirements for light sources, headlighting systems and mounting conditions on vehicle. Final visibility distance is significantly influenced by coincidence of all this performances but also by visual possibilities of driver and road conditions. The process of requirements creation is complicated. A number of experts work on them for a long time. It is influenced by technical progress, market needs, level of knowledge and experience. . In this paper author describes influence of important factors for present state of possible and real visibility distances in dependence on technical design, kind of light source used and way of creation of type approval requirements and propose improved concept for aiming and levelling.*

**Keywords:** *traffic safety, visibility, headlighting*

## **1. Introduction**

The main task of headlighting is to illuminate road and its surroundings. This task is realised by putting light in appropriate way. Presently there are in use driving beam, passing beam and also adaptive light beams based on this two. Visibility distance for driving beam is much longer than for passing beam because passing beam pattern is created in such a way that higher illumination is under the horizon line and significantly lower illumination is over it. It is result of need to restrict glaring other road users.

The result of this within UN ECE Regulations, which are basic technical requirements in Europe, is a division of the beam pattern into two parts: "light" and "shadow" separated by the cut-off line. It was introduced at the very beginning of ECE headlamp Regulations [1] coming into force, more than 50 years ago. It is important that such definition was influenced by technical possibilities of that time as well as imagination and experience of people creating Regulations. It is important that in process of Regulation creation participate many people during long period of time. It is characteristic that initiative in this process should have people competent, educated and experienced enough. Some other has only common knowledge regarding lighting as they are wider transport specialist. The first group sometimes creates requirements in the way convenient for manufacturers and some of them have closer or casual connection with industry. With years, people working with preparation of requirements change in natural way. It is reflected in Regulations but it is difficult to reconstruct clear justifications for some changes as they are the effect of work in certain stages. During the final stage of polishing requirements by international experts' team often compromises take place. Finally Regulations are sometimes not clear and coherent enough in some areas.

The European passing beam pattern is good example of such a way of thinking and work. American passing beam pattern evolved differently with different required shape and values and it is functioning for many years in parallel to European beam pattern, although serves the same purpose. Asymmetrical cut-off line is characteristic for European way of thinking (from some years cut-off is also used in USA but symmetrical) started to be important in headlamps aiming procedure. In the following years, until the present time, a significant technical progress has taken place.

Basically cut-off line position on the road could be used to determine how far light reaches the objects and the road surface because it separates high and low illumination areas. The situation became more complicated because of technical progress. Many different light sources became available and different headlamps constructions are possible. If we try and look deeper into details the visibility distance also depends on beam pattern. It is connected with light sources used and technology of headlamp design. Some passing beam headlamps illuminate much intensively objects on the right road shoulder, sometimes up to 100-200 m. Usually such headlamps because more glare in these areas, especially on the right road curves. Also because of it higher amount of light is directed just under cut-off, especially on the left side. Then far areas will be better illuminated. Nevertheless cut-off on the road can be treated as clear and simple visibility distance limit.

## **2. Restrictions of illumination**

The main restriction of visibility distance during night-time driving is the inverted square law which explains that for each doubling of distance light intensity decreases four times. Braking distance for average car and driver under good road conditions is about 20 m for the speed of 30 km/h, 50 m for 60 km/h, 100 m for 90 km/h, 140 m for 110km/h and 190 m for 130 km/h. It means that the needed visibility distance in front of vehicle is over 200 m. For 400 m the luminous flux should be greater four times than for 200 m and it could be the problem because of luminous flux needed for it.

Distances of 200-300 m are possible to be illuminated for contemporary driving beams. It is also important that driving beam is relatively narrow. It is not significant problem because the higher speeds are possible on the straight road with big radius of curvature only and narrow angle of beam is sufficient to illuminate the needed area. If passing beam is considered the most important restriction of visibility distance is the cut-off line inclination. It is also important that on the roads with curves of smaller radius driving with lower speed is required but also better side illumination is needed. Relatively new group of headlamps equipped with gas-discharge light sources allows to better illumination of side areas, because the luminous flux is 2-3 times greater than for halogen light sources and could be spread horizontally. The important issue is that passing beam is used during most of the time because of high traffic density.

## **3. Regulatory requirements**

Requirements which finally influence the road visibility and glare are divided into three groups. Each of them concerns separate components: light sources, headlamps as optical device and fixing on the vehicle including aiming. All these groups are separately regulated taking into account their cooperation. But for standardization reasons each group of requirements assumes that the other groups' requirements are met in standard conditions. For instance, during checking photometrical requirements for headlamp etalon bulb is used with decreased geometrical tolerances, nominal mounting height and nominal cut-off inclination.

First group of requirements refers to the light source and defines geometrical size and position of light emitting part in reference to the cap (reference plane, reference axis) and reference luminous flux [3, 4]. Second group includes headlamps requirements, mostly photometrical, which

define values for fixed headlamp position - 750 mm in height and 1% down in aiming [5, 7, 2]. Third group concerns mounting width and height on the vehicle coincided with initial aiming and levelling tolerance [8]. Finally possible tolerances for all these groups of Regulations allow for significant differences in road illumination and glare when comparing photometrical requirements described by second group and tested during type approval. [9, 10]

Nevertheless the biggest influence for visibility distance has the third group of Regulations which allows for significant change of the real road illumination range and glare when compared to the “theoretical” second group. Critical issue is an initial aiming and levelling tolerance.

#### 4. Illumination distance as a result of aiming tolerance

For the further analysis we assume that nominal photometrical requirements of the second group of regulations concern high nominal illumination just under cut-off. The possible mounting height according Regulation 48 [8] is between 500 mm and 1200 mm (1500 mm max). It is also required that depending on mounting height range the initial aiming and levelling tolerance in any loading conditions should be within given ranges. (Fig. 1).

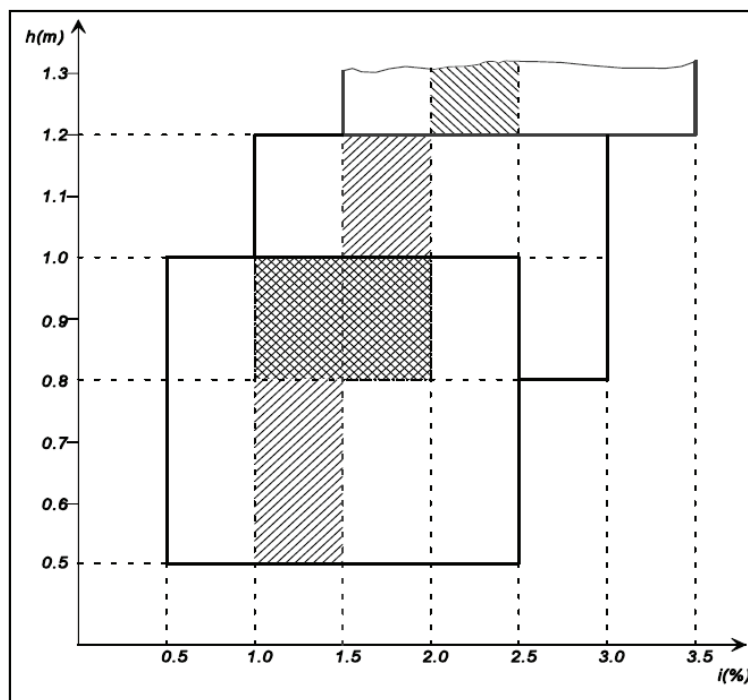


Fig. 1. Initial aiming ( $i$ ) and aiming tolerances depending on mounting height ( $h$ ) according Regulation No 48 [8]

These requirements relate to the visibility distance by distance at which cut-off cross road surface. Regulations describing requirements for headlamps relate to nominal vertical inclination of cut-off and mounting height. It means that cut-off line cross road at a distance of 75m. Similarly could be treated measuring point with highest illumination (75R) which is on the right edge of driving lane at a distance of 75 m. It means that nominal visibility distance for passing beam can be assumed as 75m. It corresponds to vehicle speed of about 80 km/h.

If we take into account initial aiming and aiming tolerances according to Regulation No. 48 (Fig. 1) visibility distance can change from 20 m to 200 m (Fig. 2).

It means that safe speed using passing beams according to Regulation No. 48 could change from about 30 km/h to about 130 km/h but there is no possibility that actual value to be known to the driver. It is real weak point of Regulation No. 48 which can thwart very good headlamp basic performance allowing for excellent road illumination in nominal condition.

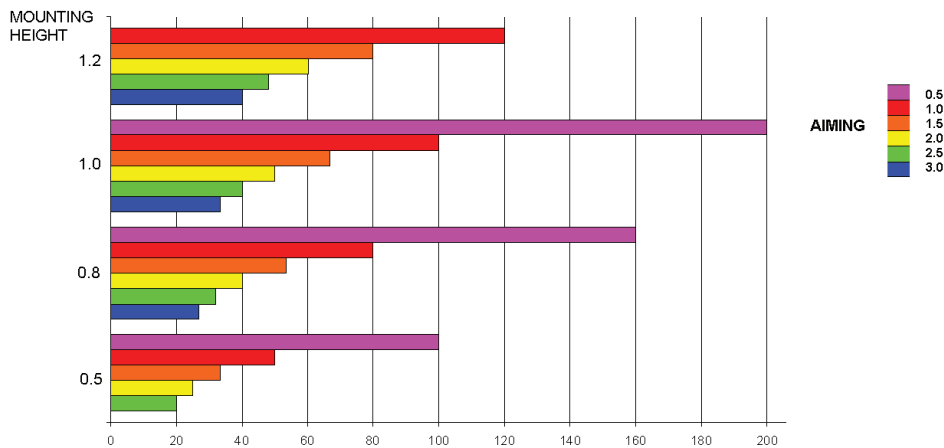


Fig. 2: Visibility distance as result of tolerances of ECE Regulation No 48 [m]

If the headlamp inclination cannot be maintained in prescribed tolerances under all loading conditions, appropriate automatic or manual levelling device is required. As the criterion for use of automatic levelling, the luminous flux of light source more than 2000 lm is used. It is an outdated artificial criterion agreed many years ago as gentleman's agreement which separated low flux halogen headlamps and high flux gas discharge light source headlamps. It was introduced basically to avoid excessive glaring by use of gas discharge light sources. It was assumed that gas-discharge headlamps glare is stronger than halogen. This criterion has very conventional, arbitrary character which very loosely reflects glaring possibility. Glare depends much more on beam pattern which can be diverse and is more the result of headlamp design than light source used.

Automatic levelling relates very strongly to visibility distance. If initial aiming allows for reasonable far illumination then use of automatic levelling maintains this value during all loading conditions. If vehicle is equipped with manual levelling device, cut-off inclination could change between minimum and maximum allowed values but only if the manual levelling device is properly used. It means that visibility distance could change significantly even more than above presented. Finally automatic or manual levelling according to the requirements of Regulation 48 guarantees passing beam to illuminate road to the maximum distance of only 20m. It is also possible that visibility distance will be longer, up to 200m but there is no guarantee based on type approval. Obviously conformity of production tolerances as well as aiming during operation could cause further visibility distance changes.

At present, there is a tendency to omit requirement of automatic levelling by using new 25 W xenon light sources with 2000 lm luminous flux. It really breaks the above mentioned gentleman's agreement without replacing artificial 2000 lm criterion with a new one, objective and reasonable. Manual levelling device is rarely understood by drivers who do not know how to use it. It is not often properly used. On the other hand new ideas appear to introduce obligatory automatic levelling for all headlamps independently of any technical solution. It is important to answer if the automatic levelling is really needed for all kind of headlamps or if there are only special situations when it should be used. It seems that obligatory use of automatic levelling could improve general situation but in some situations not by much. It is also important to decide if it should be restricted today to characteristic vehicles or headlamps. Also performance of automatic levelling needs to be more precisely defined. The intention for defining aiming and levelling requirements was to assure that road illumination and glare should be under control during all load conditions. Unfortunately the requirements were described in a design-oriented way. Because of this tolerance and precision of aiming and levelling can cause doubts. It was proposed by GRE (UN ECE) requirements to modify 2000 lm criterion - it will not be valid for new 2000 lm 25W gas discharge light sources but all LED headlamps will need to have automatic levelling independently on luminous flux. Why gas discharge light source should be privileged is not clear.

## **5. Problems and possible solutions**

Presently drivers believe that the driving speed at night is restricted only by road traffic law and eventually by special conditions as fog, snow etc. They rather have no imagination that visibility distance depends on state of headlamps and aiming. It is result of performance of human sight. People can see something but cannot assess visibility distance with satisfactory accuracy and its changes. Similarly it concerns type approval procedure. It is presumed, that vehicle meeting requirements allows for safe driving at any speed. Authorities believe that Regulation requirements guarantee the safety. On the other hand manufacturers argue that automatic levelling is not needed because Regulation in force does not require to use it for halogen headlamps. Statistics shows that percentage of time of driving with loaded trunk is relatively small, and most often cars drive with only one person and empty trunk. Also accidents with loaded trunk are not very often [1]. It could be the reason that the lights of vehicle with loaded trunk come up and road illumination is better, especially when manual levelling is in nominal position. Increased risk is connected with higher level of glare and has no reflection in accident statistics because glared driver could make an accident, not car which caused glare. It could be added that most of the time driving takes place during high density traffic, when the rear of preceding car with position lights is good visible. This is clear example that during creation and modification process of requirements during many years insufficient importance was attributed to basic performance parameters. The problem looks to be complicated because it is very difficult to obtain clear numerical measure based on physical phenomena. Assessment of situation is based rather on mixture of more or less scientific research, common sense feelings and statistics of factors not directly connected with visibility.

But if something unexpected happens during night-driving e.g. animal or people cross the road in close distance to front of the oncoming car, or there are some things like fallen branches lying on the road or there are holes in the road surface or not illuminated trailer or tractor is standing on the road, the result could be an accident because visibility distance could be not adequate to allowed speed. Presently observed tendency to simplify requirements for automatic levelling for gas-discharge light sources could cause additional danger because of increased glare possibility when incorrect aiming/levelling occurs. Important is that statistics should not be used for creating regulatory requirements which concern personal safety because responsibility rests on regulatory requirements. Statistics are of course useful for various situations like cost calculation or performance comparison and assessment. For regulatory requirements the worst case should be used.

It seems that it is possible to solve this problem in two ways. First is to improve precision of definition of requirements and require automatic levelling on each vehicle which will guarantee visibility distance longer than resulting from present law. Second it is possibility to increase the responsibility of the manufacturers and drivers. In such situation drivers should have a choice and clear information. It is possible to inform driver by a note in the car and in the user manual informing how long is visibility distance and how it depends on driver behaviour. In such situation quality of lights and used technology could be reflected in the price. Customer will have the choice e.g. automatic levelling, automatic suspension or better light source or lighting system. It should be responsibility of the manufacturer to inform precisely about visibility distance and allowed maximum speed for given vehicle type / model and the responsibility taken for precision of information.

## **6. Improved concept for aiming and levelling**

Requirements regarding initial aiming and levelling does not guarantee sufficient visibility distance remaining in range allowed by headlamps regulations. Coming to performance-based requirements is not very complicated on the base of present requirements. Initial aiming and levelling tolerance should be defined in such a way that it guarantees minimum road illumination

distance with reasonable tolerances. The base can be fixed distance for cut-off crossing the road surface independent from mounting height. Aiming tolerance should be such that this cut-off and road surface crossing distance should remain in fixed range (Fig. 3.) This modified initial aiming and levelling tolerance requirements proposal in a simple way connects visibility distance, mounting height and initial aiming with tolerances.

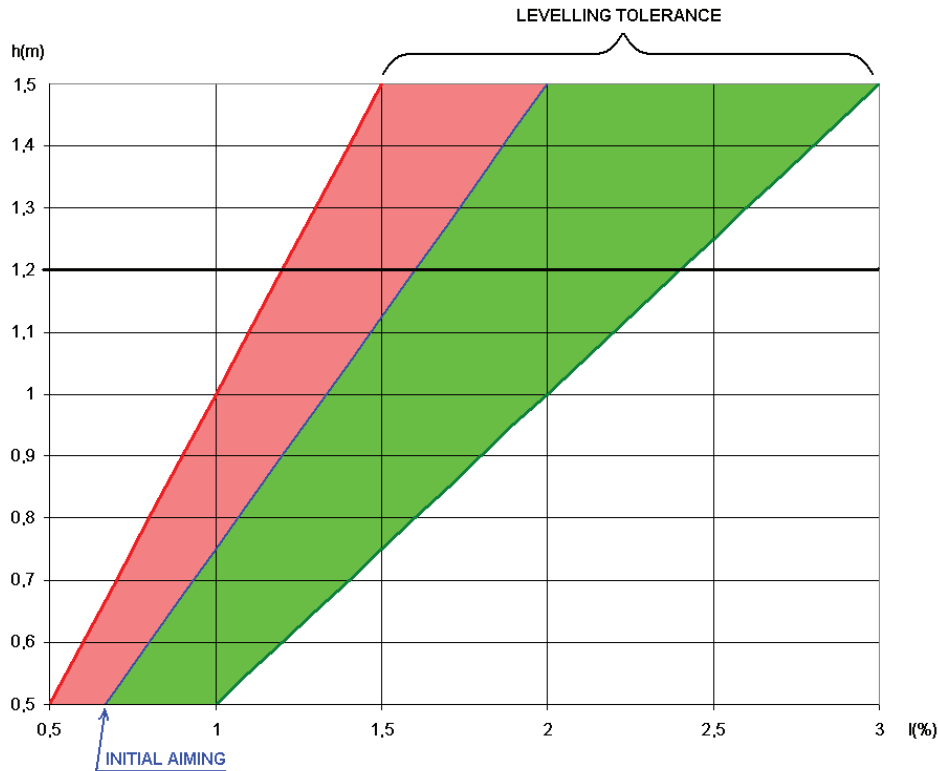


Fig. 3. Proposal of improved initial aiming and levelling tolerances description (compare with Fig. 1)

Requirements for “glare zone” over horizon are described by compulsory requirements of headlamps Regulations. It is possible to require the same values during vehicle type approval test according to Regulation No 48 because they are legal requirements in force and should be safety worst case requirements. It is possible to imagine in given situations that manual levelling could satisfy above requirements. But it will significantly depend on suspension characteristics. The real problem is how to obligate the drivers to accurately use manual levelling device with high precision to fulfil the road illumination requirements checked during type approval. It requires detailed information inside the vehicle user’s manual and teaching the drivers of its importance and how to deal with it.

## 7. Conclusions

Present situation of initial aiming and levelling tolerances as far as the requirements are concerned, is the consequence of historical reasons. It allows taking incomplete advantage of potential headlamp performance, especially in conjunction with manual levelling device. It means that very well and perhaps, expensive headlamps could illuminate road much worse than less effective ones but installed in vehicle at the appropriate mounting height/suspension design/levelling correction.

Discussions and proposals to complicate or simplify present aiming requirements by obligation to use or not use automatic levelling depending on the design features looks to be never ending story and will rather not guarantee better road illumination and glare reduction.

It is quite easily possible to change priorities and use performance based requirements with reference to headlamps photometry requirements currently in force. Criteria based on the kind of light source used, or arbitrary and artificial luminous flux borderline should no longer be used. The use of automatic levelling should be left up to the manufacturer and should only depend on fulfilling photometric requirements under all mounting and loading condition and give clear and precise information to vehicle purchaser.

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