Impact

The Journal of the Institute of Traffic Accident Investigators
Autumn 2021 Volume 29 No. 2

Preserving the Scene with Photogrammetry – Drone vs Handheld

Measuring the effects of distraction on drivers: evidence of impairment and the challenges of communicating it

Does the use of a mobile telephone have an effect on the walking speed of adult pedestrians?

Vision and Visibility – An introduction for understanding

FCIN Update - ISO/IEC 17020:2012

Impact : Autumn Edition 2021 (Vol.29 No.2)

Contents

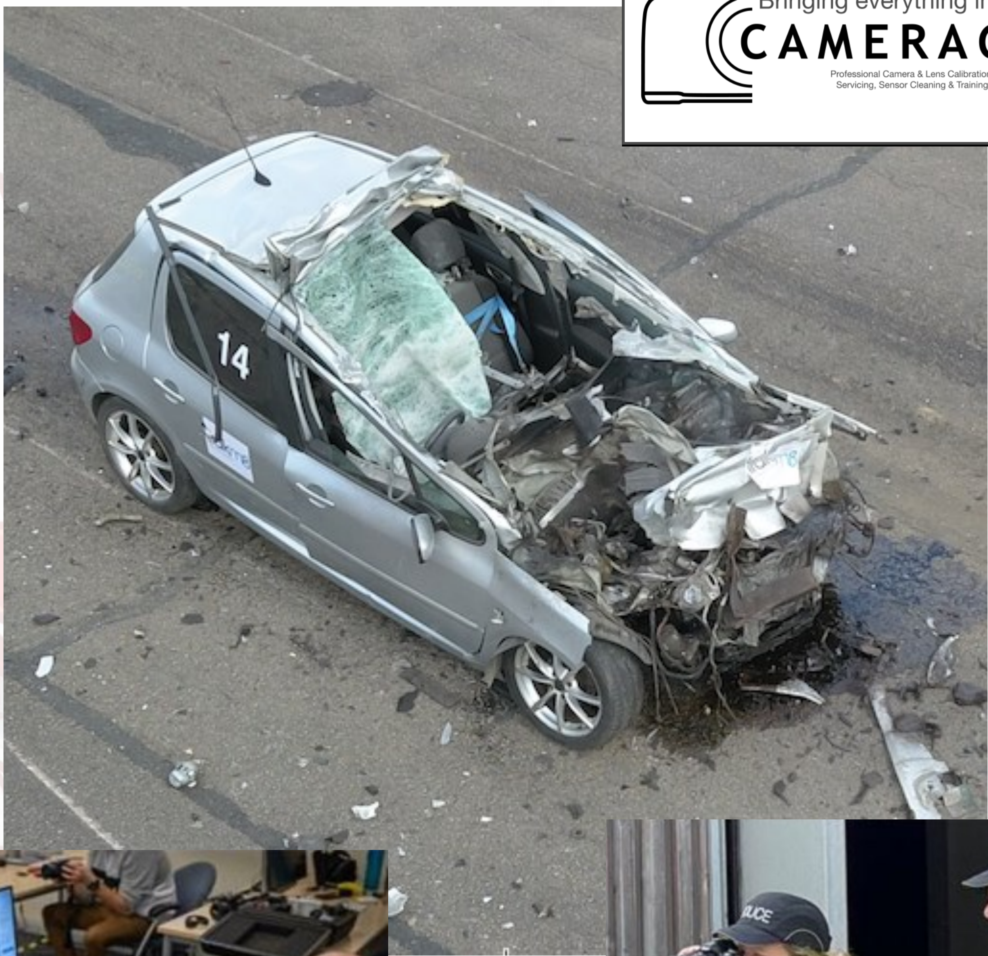
From the Editor

Dr Gemma Briggs continues her series of webinars on Wednesday 17th November 2021 when she will be discussing further her work in the field of distracted driving. This webinar is preceded by a second article in this edition of Impact.

On a comparable subject, this edition also features an interesting paper from DC Donna Hewlett, also considering the effects of mobile phone use, not on driving, but on walking speeds. Donna is one of the first of a new generation of Police Forensic Collision Investigators who have attained a BSc(Hons) degree in Forensic Road Collision Investigation from De Montfort University.

Stephen Cash

editor@itai.org



Digital Photography for forensic collision investigators

7th-11th February 2022

Cameracal, Unit 2, The Studio, Southlands Lane, West Chiltington, West Sussex RH20 2JU

Cost

Members of ITAI- £595.00 pp (inc refreshments and lunches)

Non-member of ITAI - £650.00 pp (inc refreshments and lunches)

To reserve your place, please email: **training@cameracal.uk**

Accommodation is booked by delegates direct—a list of nearby hotels can be found listed in the accompanying advert at www.itai.org/Other-Courses)

Cameracal - *www.cameracal.co.uk* ***Tel:*** *01798 306599*

The Institute of Traffic Accident Investigators

General information concerning Membership Grades,

The Institute of Traffic Accident Investigators provides a means of communication, education, representation and regulation in the field of traffic accident investigation. Its main aim is to provide a forum for spreading knowledge and enhancing experience amongst those engaged in the discipline.

Further, the Institute seeks to promote a professional approach to traffic accident investigation and, through its rules and discipline procedures, to encourage honesty and integrity.

The current membership represents a wide spectrum of professions, including police officers, researchers, lecturers in higher education, and private practitioners.

Membership of the Institute will be of assistance to anyone wishing to be informed of current developments and thinking in the discipline of traffic accident investigation, in addition to those in a career where the use and understanding of the principles of accident investigation are required.

The Institute is not a police organisation, nor is it a trade union or political pressure group.

Membership Grades

There are 5 grades of membership - (i) Student (in full time education), (ii) Affiliate, (iii) Associate, (iv) Member and (v) Retired. Membership at any level is restricted to individuals. There is no corporate membership.

Affiliate membership is open to anyone who has an interest in the field of traffic accident investigation and the Institute will accept direct membership applications to the various grades. Associate and Member status will be granted by the Grades Assessment Panel subject to the meeting of specific criteria, further details of which can be obtained from the Institute's website **www.itai.org.**

A full Member of the Institute is permitted to use the letters MITAI. Similarly, an Associate is permitted to use the letters AMITAI.

Student, Affiliate or Retired members may refer to their membership in any curriculum vitae or the like, but it must be clearly understood that those levels of membership are not to be regarded as any form of qualification.

Fees and Subscriptions

Currently there is a non-returnable registration fee of £15 on first application for grades of Affiliate, Associate and Member. Those registering as Student members are not charged a fee. There is a £60 administration and assessment fee in respect of application for full Member or Associate membership.

(i) Student annual subscription is £20
(ii) Affiliate annual subscription is £50
(iii) Associate annual subscription is £60
(iv) Full Member annual subscription is £70
(v) Retired member annual subscription is £20

The subscription payable on first application is calculated on a quarterly basis.

Impact (The Institute's journal)

'Impact' (in hard copy or electronic form) is distributed free of charge to all members three times each year. Non-members are able to subscribe by application to the Institute's Administration Department, or by making the appropriate payment at the Institute's on-line shop - (see details set out below). Back issues of *'Impact'* can also be purchased via the Institute's Administration Department or on-line shop.

Letters to the Editor are welcomed. Opinions expressed in letters and articles within *'Impact'* do not necessarily reflect those of the Editorial Board or the Institute.

Webinar

Measuring the effects of distraction on drivers: evidence of impairment and the challenges of communicating it

Wednesday 17th November 2021

The Institute will be presenting the next one hour webinar for the membership on Wednesday 17th November 2021 in which applied cognitive psychologist, Dr Gemma Briggs – a senior lecturer at the Open University – will discuss research findings on driver distraction.

Gemma has researched this area for many years, and her collaborative research has provided new explanations for both how and why phone use leads to deteriorated driving.

Following on from her first talk, which discussed research on mobile phone use by drivers, this session will look further into the measurable effects of distraction on driving performance. It will cover some of the research findings on reaction times, hazard detection rates, stopping distances and lane discipline, with the aim of giving indications of how lab-based research can meaningfully inform assessment of real-world incidents.

The webinar will also delve deeper into research findings on inattention blindness, with particular reference to the eye movements of distracted drivers, as well as the enduring effects of distraction after a phone conversation has ended. The varying and changeable nature of distraction within an individual journey makes it challenging for researchers and practitioners alike to determine at what point a driver has overloaded their attentional capabilities. This issue will be discussed and provide some applied resources which have been developed, which may be of use to those who need to convince a court of the very real consequences of inattention behind the wheel.

The Members wishing to register to take part in the webinar will find further details on the Institute website at www.itai.org

Preserving the Scene with Photogrammetry - Drone vs Handheld

Simon Brown
Director - AccuPixel Ltd.

Introduction

The speed & efficiency of capture, level of detail, geo referencing, and highly realistic digital reconstruction offered by photogrammetry can deliver extreme value to forensic collision investigation.

The outputs of photogrammetry are broadly defined as:

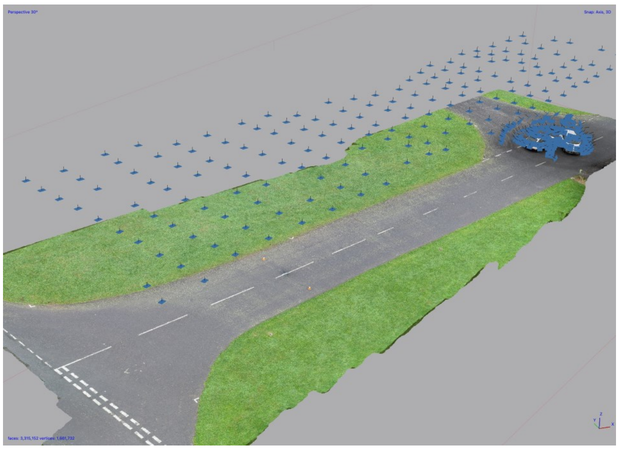
- 3D Mesh & texture – geo referenced measurement/visualisation with first person viewing in virtual reality
- Dense Point Cloud – 3D geo referenced/ scaled point cloud of scene of interest
- Ortho photo – 2D geo referenced/scaled colour rendered site plan with level of detail typically 1mm (or better) per pixel
- Digital Elevation Model – 2.5D geo referenced/scaled colour gradient display of a scene showing relative (or absolute) elevation

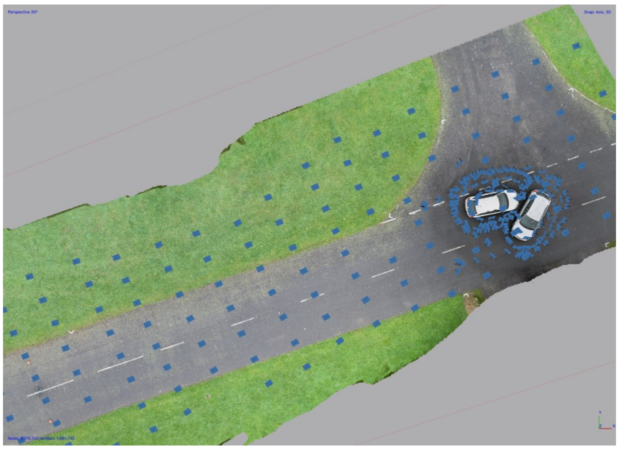
Each output delivers high value, either for analysis of events & outcomes, the presentation of analysis and conclusions, or a combination of the two. Presenting a compelling set of evidence to lay people in a format that is easy to understand and relate to eases communication and can clearly articulate the key points in a case – I use this regularly when dealing with underwater cultural resources and non-divers suddenly "get it" when they can experience for themselves what lies on the seabed.

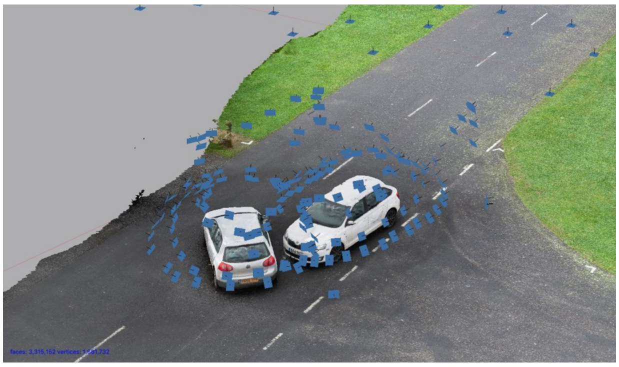
But the entire process of photogrammetry is dependent on the source images, their quality and overlap. Compromising the 3D reconstruction with unsuitable images will impact every output and the methods used to shoot the scene are critical. Broadly speaking there are two methods:

- Handheld photography – close range photogrammetry
- Drone photography – aerial photogrammetry

Both methods have their advantages and disadvantages, and this article discusses the relative merits of each.







Close Range Photogrammetry

Close range, or handheld, photogrammetry is the most widely practiced method and offers an exceptionally low entry point in terms of skills and financial outlay. Just about any camera is suitable and in a recent back-to-back test an iPhone 12 outperformed a Nikon D7100 cropped sensor DSLR. However, when conditions are less-than-ideal for photography a modern DSLR with a large sensor and inherent low noise/high ISO performance, complete with a range of high-quality dedicated lenses remains a tool of choice.

Nevertheless, in most conditions the camera at hand will deliver more than acceptable quality images for photogrammetry. What is more critical are the methods of capture and with a handheld technique the human in the process remains the weakest link (Personal experience teaches me this!).

Two critical aspects of photogrammetry must be considered when working handheld:

- Full coverage of the scene – all areas covered
- Image overlap – sufficient but not excessive

The first factor that helps guide both is the camera-to-subject distance, which in turn dictates the level of detail that can be extracted from the images…and dictates somewhat how long processing the data will take. The camera-to-subject distance will depend on the choice of lens (read on…) but is typically in the 1.5m~3m range.

The second factor that guides the working distance is the camera and lens. A long focal length lens (50mm and up) with a narrow field of view will require far more images than an extreme wide-angle lens (ranging from 28mm to 16mm fisheye) will require a lower number of images.

For close range photogrammetry wide angle lenses are preferred. Their wide coverage ensures image overlap is less critical and the volume of images results in acceptable processing times and image distortion – even extreme fisheye lenses – are catered for and corrected within Metashape during processing.

From a practical perspective the use of a wide-angle lens dictates a certain technique, one required to prevent the shoes of the photographer appearing in the frame when shooting downwards (personal experience again). For this we can use a camera pole.

The camera pole is an invaluable tool for close range photogrammetry. It can elevate the camera and increase the camera-to-subject distance, ensuring a wide-angle lens covers a larger area whilst delivering sufficient detail whilst simultaneously ensuring the photographer's shoes do not appear. Using this method, a typical road can be covered in two or three passes, and whilst coverage could be achieved in perhaps a single pass, single camera track photogrammetry can induce curvature in the camera alignment and is to be avoided.

There is a compromise with camera pole work, as the ideal sensor orientation to the road surface would be parallel and with handheld work the sensor is typically at or close to 45 degrees. The second issue is consistency of camera positions, especially when compared to a planned drone mission, as the human in the process will never maintain the same level of precise control of camera position available to a drone.

As long as image overlap is maintained the precision of image capture position is not

critical and by experience we know the sequence of "Shoot/One pace forwards/ pause/shoot/repeat" works with a wide angle lens and with practice the technique can produce consistent results.

Aerial Photogrammetry

The use of drones for aerial photogrammetry has transformed the process of aerial photogrammetry. Typically specialist and very expensive, aerial photogrammetry price points have reach a level and capability where consumer and entry level drones are capable of delivering results.

Not all drones, or rather not all drone mounted cameras, are suitable. Zoom lenses and rolling shutters – CMOS sensor chips that expose pixels line by line instead of reading every pixel value concurrently - can induce errors and distortion into the 3D scene. Both issues can be mitigated by maintaining a fixed zoom value throughout the flight (same rules for close range) and by using stop-and-capture for images during flight but both features are best avoided.

The greatest advantage of drone capture is the consistency of the image overlap and altitude of flight. Mission planning software allows the pilot to pre-set values that produce optimum overlap and control the level of detail delivered. The mission can be planned and saved days or weeks in advance and uploaded to the drone on site, having arrived knowing how long the planned duration of the flight is, the number of images to be captured and how many battery sets are required to complete.

The consistency of capture applied by drone flight software can ensure very high-quality results with maximum efficiency but the tools are not perfect. Terrain can alter the required flight plan with sloping land dictating a differing approach to ensure the camera sensor remains approximately parallel to the surface. The satellite imagery used as a backdrop for planning can be out of date and of insufficient resolution to reveal hidden hazards such as street furniture, power lines, antenna or trees, and accuracy of GPS signal can offset the position of the drone when compared to the mission view.

One of the added benefits of using a drone will be GPS position data embedded into each image. On the face of it, this appears useful but in practice unless the drone is using real time kinematics (RTK) correction during the mission the latitude, longitude and altitude values cause more issues than they fix. Photogrammetry can produce exceptionally high accuracy models but is entirely dependent on the accuracy of the source data. Relying on inaccurate GPS values for reconstruction will introduce errors and in this instance it's better to discard GPS position information in the images, using on local measurements to scale, constrain and reference the model.

For all the benefits, when compared to close range photogrammetry aerial capture comes with a greater degree of legal compliance and risk mitigation responsibilities. Flying a drone here in the UK requires strict adherence to the laws governing their use with the Civil Aviation Authority acting as governing body. Certain constraints, such as not exceeding 400'/120m above ground level, are of lesser importance to those preserving high levels of detail – such scenes typically require a max flight altitude of 30'/10m or less but this is the exception. Pilot registration and competency tests are mandatory in the UK, and an operator ID label must be attached to the drone(s) operated.

The rules around drone flights are geared around risk profile and are set by the Civil Aviation Authority (CAA). For example, flying a drone near an airport in what is known as a Flight Restriction Zone is illegal without permission from the National Air Traffic Service and, at time of flight, clearance from the local airport air traffic control. From personal experience the process of applying for what is termed a Non-Standard Flight is very straightforward and the ATC staff are always helpful – permission for take-off has never been refused or delayed. For those flying DJI drones then a second layer of protection exists, with the drone knowing it's located within a no-fly zone and preventing take off until a temporary unlock code is applied for and received.

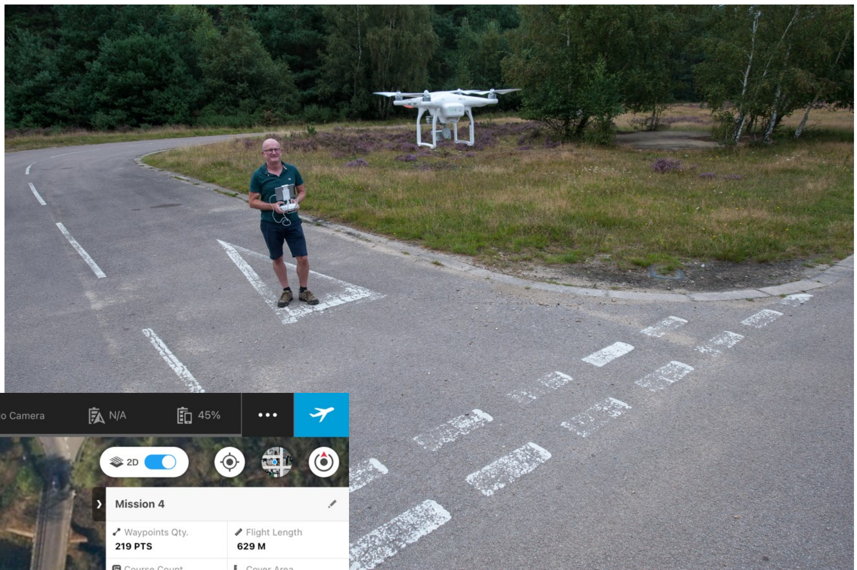
The general restrictions of drone flight are geared around public safety. The following is not an exhaustive list but the basic rules are as follows:

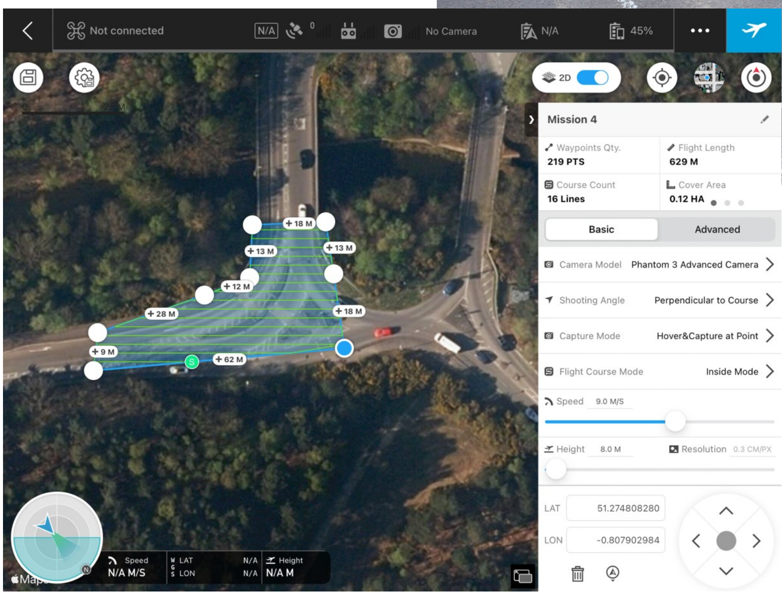
- Weigh less than 25kgs
- Maintain line of sight between drone and pilot
- Maintain a minimum distance of 50m between drone and people, buildings, cars etc
- Maintain a minimum distance of 150m between residential, commercial or recreational areas
- Do not overfly large groups of people
- Respect privacy of others

All of which is covered by what is termed the Open Category (see https://www.caa.co.uk/Consumers/Unmanned-aircraft/Recreational-drones/Flying-in-the-open-category/) and likely to be highly restrictive when applying a drone for private practice forensic collision investigation.

The route to using drones in higher risk categories is via what is termed Specific Category Operations (See https://www.caa.co.uk/Commercial-industry/Aircraft/Unmanned-aircraft/Small-drones/Flying-in-the-specific-category/) where operational authorisation is issued by the CAA and is based on evaluation of risk and mitigation thereof.

Operating under the Specific Category will require more intensive risk assessment, operator competency checks, qualifications and insurance but opens the potential for drone use at scenes that would otherwise be impossible to cover with aerial photogrammetry.





Summary – Close Range vs Drone

Both aerial and close-range photogrammetry come with a series of benefits and downsides. Firstly, close range benefits:

- Cost effective – can exploit existing investment in equipment
- Flight restrictions do not apply – few restrictions of public photography
- Speed of deployment and capture – comparable to drone flight for similar area
- Very low risk of collision with obstacles – delivers in impossible-to-fly situations
- Works well under and around overhead obstacles; roofs, bridges, tunnels etc

With the downsides:

- Human process – requires a level of skill to maintain overlap etc
- Sensor angle – not always optimum for or terrain/subject
- Prone to camera shake – blurred images

For drones the benefits can be summarised as:

- Consistency of capture – overlap and altitude maintained
- Mission planning – survey preparation ahead of site visit
- Sensor alignment – optimum for the terrain
- Excellent image stabilisation

With the downsides:

- Capital equipment costs – extra outlay for drone
- Training – drone operator skills
- Ongoing costs – liability insurance
- Specific Category Operation clearance – CAA approval required
- Subject to the weather – wind and rain

One important point to stress is that each method is not mutually exclusive – using mixed camera and image sources and even laser scans in Metashape is supported and works well when large areas requiring minimal detail can be merged with smaller areas of high refinement where fine detail are needed.

Either capture method – drone or hand held – can deliver exceptionally high quality 3D and 2D data that conveys more information in an easy-to-understand format. The ortho mosaic in this example is scaled to 1.97mm per pixel (see https://dronelab.io/map/public/viewer/930d5d2f3283469db6593cec17930f9b) and the digital elevation model (DEM) reveals tyre marks on the verge that is otherwise impossible to see when viewing RGB colour (see https://dronelab.io/map/public/viewer/369625e0e8b34a7e9049110d83703af0) . Both formats are scaled, geo referenced and can be printed or included in reports if required.

So, it will be very much down to an operational decision as to which route to take. With the ability to close a road and control a scene the law enforcement agencies are already taking the drone route, with the use of handheld techniques taught to cater for the flight impossible scenarios. For the private practitioner restrictions on drone use are likely to apply but for those willing to adopt the CAA Specific Category principles then either route – handheld/close range or drone use – remains a viable route for serious collision investigation.

Contact

Simon Brown

Director

AccuPixel Ltd.

www.accupixel.co.uk

ACCUPIXEL

Measuring the effects of distraction on drivers: evidence of impairment and the challenges of communicating it

Dr. Gemma Briggs

Head of Discipline and Senior Lecturer in Psychology

As an applied cognitive psychologist, and Senior Lecturer in psychology at The Open University, my area of research interest and expertise is driver distraction. Specifically, I am interested in how drivers allocate their attention when they try to multitask behind the wheel. Most of my work looks at mobile phone use by drivers, one of the so-called fatal 4 behaviours which the police target to improve road safety. I have worked extensively with the police, road safety charities, members of industry and policy makers to promote education and evidence-based practice in the area of distracted driving.

Research on hands-free mobile phone use has shown that drivers distracted by their phones are at an increased crash risk [1], have poorer hazard detection ability [2], show diminished situation awareness [3] and have much longer reaction times [4] and stopping distances for any hazards they do notice. As such, the cognitive distraction imposed by phone use negatively affects driving performance. Some of my work, carried out collaboratively with other colleagues, has also shown that phone-using drivers demonstrate different visual scanning strategies to undistracted drivers [5] [6]. In some of our research [5], distracted drivers were found to demonstrate what we termed 'cognitive and visual tunnelling', meaning their eye movements were focused in a highly concentrated area of the driving scene, and they often failed to look to the peripheral areas. These drivers tended to focus their visual attention directly ahead of them, just above the bonnet, compared with undistracted drivers who looked around the scene far more. In fact, distracted drivers looked at an area of the driving scene 4 times smaller than their undistracted counterparts.

Obviously, failing to look at aspects of a driving scene can be problematic, but psychological research in this area also shows that there is a clear distinction between *looking* and *seeing*. A driver who fails to orient their eyes to a child stepping off the pavement won't see them, yet a distracted driver who orients their eyes to a vehicle braking hard, directly in front of them, can *still* fail to perceive that vehicle. This phenomenon is known as 'inattention blindness', or 'looking without seeing', and it demonstrates the importance of attention for accurate visual perception. As such, a driver who attempts to share their attention between the tasks of driving and talking on the phone, may not have the cognitive resources available to them at any given moment to notice a hazard, even if it appears right before their eyes. Our study demonstrated just that: phone using drivers showed inattention blindness for hazards that occurred directly ahead of them, whilst also failing to properly observe the peripheral areas of the scene. This shows that when a driver is distracted, they can both fail to observe aspects of the scene completely and can effectively be cognitively blind to other aspects.

Some of our other work [5] has provided explanations for *why* this is the case, drawing on what psychology tells us about how we allocate different cognitive resources, and how our brains process visual and auditory information. In that study we identified that phone conversation encourages mental imagery, which draws on the same cognitive resources needed for accurate visual perception. When we create images in our heads, we use the same processes and brain areas as when we perceive a real-world visual stimulus. As such, when we complete both tasks at once, there is competition for limited attentional resources and brain areas, as both tasks have a visual component. This competition can explain why distracted drivers may experience inattention blindness while also demonstrating decreased driving performance. This research also shows why removing the hazard of physically holding a phone (the illegal form of phone use) doesn't actually improve driver performance or road safety.

Of course, demonstrating these kind of effects in the lab is more straight forward than attempting to measure distraction in real-world settings. This is often used as a challenge to research such as ours, and to the general acceptance of these kind of findings. Amongst drivers this is perhaps understandable: distracted drivers are largely unaware of how unaware they are. In the absence of any serious incident, a distracted driver is unlikely to notice or recall errors they make (such as veering out of their lane) or the actions of other road users to compensate for their behaviour. This leads to the experience of hands-free phone use being 'safe' and unproblematic. Each time a phone-using driver completes a journey seemingly without incident, this is used as additional evidence that the behaviour is appropriate and safe. I talked about some of this research in more detail in the session I ran in September [www.itai.org/event-4377773], and there are further details and resources on our project website:

https://drivingchange.webflow.io/

In my next online talk, which will take place on 17th Nov from 10am, I'll discuss some further issues related to the measurable effects of distraction on driving performance. I'll covers some of our research findings on reaction times, hazard detection rates, stopping distances and lane discipline, with the aim of giving indications of how lab-based research can meaningfully inform assessment of real-world incidents. We will also delve deeper into research findings on inattention blindness, with particular reference to the eye movements of distracted drivers, as well as the enduring effects of distraction after a phone conversation has ended. The varying and changeable nature of distraction within an individual journey makes it challenging for researchers and practitioners alike to determine at what point a driver has overloaded their attentional capabilities. We'll discuss this issue and I'll provide some applied resources which we've developed, which may be of use to those who need to convince a court of the very real consequences of inattention behind the wheel.

I look forward to seeing you on 17th November.

References

[1] Dingus, T.A., Guo, F., Lee, S., Antin, J.F., Perez, M., Buchanan-King, M. and Hankey, J. (2016). Driver crash risk factors and prevalence evaluation using naturalistic driving data. Proceedings of the National Academy of Sciences, 113 (10), pp.2636-2641.

[2] Ebadi, Y, Fisher, D. L., Roberts, S.C, (2019). Impact of Cognitive Distractions on Drivers' Hazard Anticipation Behavior in Complex Scenarios. Transportation Research Record, 2673(9), 440–451.

[3] Chandrasekaran, L., Crookes, A. & Lansdown, T. C. (2019). Driver situation awareness – Investigating the effect of passenger experience. Transportation Research Part F: Traffic Psychology and Behaviour, 61, 152-162.

[4] Chen, Y Fu, R, Xu, Q & Yuan, W (2020). Mobile Phone Use in a Car-Following Situation: Impact on Time Headway and Effectiveness of Driver's Rear-End Risk Compensation Behavior via a Driving Simulator Study. International Journal of Environmental Research and Public Health 17, 4, 1328.

[5] Briggs, G. F., Hole, G. J. & Land, M. F. (2016). Imagery-inducing distraction leads to cognitive tunnelling and deteriorated driving performance. Transportation Research Part F, 38, 106–117. https://doi.org/10.1016/j.trf.2016.01.007

[6] Briggs, G. F., Hole, G. J. & Turner, J. A. (2018). The impact of attentional set and Situation awareness on dual tasking driving performance. Transportation Research Part F, special issue on Attention and Awareness in Everyday Driving, 57, 36-47. https://doi.org/10.1016/j.trf.2017.08.007

Contact

Dr. Gemma Briggs,
The Open University
gemma.briggs@open.ac.uk

Impact

Submissions invited

Next Edition Dec./Jan. 2021

As ever, the Editor would be very pleased to hear from members, non-members or subscribers, who have produced material that they feel would be of interest to readers of *'Impact'*. Details of research projects or relevant collision investigation testing would be particularly welcome. Attracting sufficient numbers of articles for publication in the Institute's journal remains a difficulty! Whilst the Editor is delighted to receive papers from overseas contributors, a greater supply of 'home grown' material would also be very welcome.

If you have any questions regarding the publication of an article / paper, or simply wish to discuss the possibility of preparing a piece for the journal, please contact the Editor at **editor@itai.org**

Visit the Institute's website at www.itai.org

'Impact' subscription, and all other enquiries should be addressed to

The Institute of Traffic Accident Investigators
Administration Department
Column House, London Road, Shrewsbury SY2 6NN

Tel +44 (0)8456 21 20 66 : Fax +44 (0)8456 21 20 77 : email admin@itai.org

Registered Charity No. 1014784
Registered in England as a Company No.2753420 : Registered Office - Column House, London Road, Shrewsbury SY2 6NN
 ISSN 0959-4302

Printed by DPS Print (Gravesend) : Tel. 01474 533395

"Does the use of a mobile telephone have an effect on the walking speed of adult pedestrians?"

Donna Hewlett

Collision Investigation Unit, States of Jersey Police

Abstract

Pedestrian walking speeds are used worldwide in the field of collision investigation, yet the actual speed of the pedestrian involved in a collision is rarely known. Investigators often use walking speeds established though research from which to reconstruct collisions.

Mobile telephone use is prevalent in today's society and such devices are becoming increasingly used year on year.

The principle objective of this study was to assess whether the use of a mobile telephone has an effect on an adult pedestrians walking speed. In addition, it was also envisaged that the research would also provide reliable and usable adult pedestrian mean walking speeds for collision investigators regardless of any mobile telephone use.

The methodology was to covertly examine adult pedestrians in a variety of locations within St Helier, Jersey (Channel Islands) through the use of overt Closed Circuit Television Cameras (CCTV). Pedestrian speeds were calculated for pedestrians who were simply walking as well as those who were walking whilst using a mobile telephone. Mobile telephone use included those who were seen to be using the touchscreen or keypad and those who were engaged in a telephone call conversation (the phone held up to their ear).

The results of the study found that males walked approximately 4% faster than females with mean walking speeds, without the use of a mobile telephone, of 1.62ms $^{-1}$ and 1.55ms $^{-1}$ respectively. All pedestrians who were using a mobile telephone, whether by in call or screen use were found to have a reduction in mean speed of 9%.

Introduction

This research project was designed to establish whether the use of a mobile telephone has an effect on the walking speed of adult pedestrians and to report on the mean walking speeds of pedestrians when simply walking and those who were walking whilst using a mobile telephone.

Walking is a gross motor skill learned, practiced and perfected at a young age. The act of walking takes very little thought at all, whereas the use of a mobile telephone requires a thought process and working memory (cognitive load) to both operate the device and to complete the task being performed. Studies by Cabañero et al (2019, 2020) found that there are tasks performed with a mobile telephone with higher cognitive demands than others, with audio production and consumption demanding the greater cognitive load.

A study into object negotiation whilst walking and texting by Chopra et al (2018) found that texting whilst walking introduces a visual distraction which reduced the ability for healthy adults to respond to cognitively demanding object negotiation tasks. The findings of their study were not that the cognitive demand of the texting task increased the risk of accidents but rather a combination of looking at the mobile telephone in addition to making decisions in respect of events in the environment around them which increased the risk of collision.

Mobile telephone use is extremely prevalent in today's society, with 79% of adults in the UK (≥18 years) using smartphones (Ofcom, 2019). Whilst there has been a significant amount of research undertaken to determine the mean walking speed of pedestrians, from young children right through to the elderly there is less-so with the intention of establishing the average walking speeds for pedestrians whom are using a mobile telephone. Much of the research that is available has been conducted with a view to establishing the safety implications and the effect of 'in attentional blindness' of walking whilst using a mobile telephone or from an urban planning perspective.

The focus of this study was to conduct the research with collision investigators as the target audience, as such it was decided to undertake the study covertly as the advantage of observing the natural behaviour of the participants outweighed the minor disadvantages of not knowing some social demographic information and exact use of the mobile telephone.

Materials and Methods

This research used overt CCTV cameras to covertly observe pedestrians at 4 different locations. Thereafter the pedestrians' walking speed was calculated. Whilst all the CCTV cameras had pan, tilt and zoom (PTZ) capabilities, during the study all cameras were set to a default position. This allowed the author to identify fixed points within the default frame positions from which to establish a known distance walked by each participant.

Participants were timed (using the footage metadata) from the moment their leading foot crossed the first fixed point and ended when a foot crossed the second fixed point.

Four CCTV cameras were selected from which to obtain the data required for this study. Two cameras covered pedestrian precincts (West Centre and King Street), one covered a pedestrian pavement adjacent to a one-way street (Mulcaster Street) and the final covered a pedestrian crossing. Through the use of these four cameras the study sought to gather speed data for pedestrianised precincts, a

***Figure One**. Field of view of the four CCTV camera's used within this study.*

pavement and a crossing to establish any statistical difference between location types.

The default CCTV position frames for each of the selected cameras are shown in figure one. The two yellow stripes within each image depicts the two fixed points used to determine the distance travelled by each participant.

Research by Pinna & Murrau (2017, 2018), Finnis & Walton (2007) and Willis et al (2004) all considered the age of the pedestrian. Their research concluded that pedestrian speed decreases with age and found that there is a significant decrease in speed amongst 'older' pedestrians. Bohannon and Andrews (2011) undertook a meta-analysis of 41 prior studies from around the world which analysed the walking speed of over 23,000 healthy subjects. Their analysis looked at steady state walking speed of participant's ≥ 20 years old. The results were categorised by age (in decades) and gender. The results of their meta-analysis showed that males walked faster than females in all age groups and both males and females walking speed reduced from c.60 years old. Having considered these studies it was decided to only include participants which were assessed as being aged between 20 years and 60 years old. This was a subjective visual estimation of age conducted whilst reviewing the CCTV footage.

The study sought to establish the mean walking speeds of single pedestrians, as such persons walking in pairs or more were disregarded. Persons who appeared to have any mobility impairment, those who were laden with luggage and those pushing wheelchairs, pushchairs or similar such items were also deliberately omitted from this study.

All pedestrians who stopped, made an obvious change to their speed or changed course whilst crossing the area between the fixed point were also omitted from this study.

All participants used within the study were all recorded having walked through the test areas between 0700 hours and 1359 hours on Monday 20th January 2020. The weather was consistent at all four locations for the duration of the study. The weather was dry and sunny, there was no noticeable wind and the temperature was approximately 8°, which is normal for that time of year (Jersey climate January 2020, 2020). There was a total of 2,533 participants in this study.

Results

Overall mean walking Speed

The mean walking speed of all participants, at all locations was 1.55ms^{-1}. The data were normally distributed about the mean with a standard deviation of 0.1950ms^{-1}.

Analysis by gender

The results showed that males walked 4% faster than their female counterparts irrespective of the pedestrian type (simply walking, screen use, in call). Males were found to have a mean walking speed of 1.58ms^{-1} (SD = 0.1944ms^{-1}) whereas females were found to have a mean walking speed of 1.51ms^{-1} (SD = 0.1892ms^{-1}). This difference (0.7ms^{-1}) was found to be extremely significant (independent sample t-test; $p < 0.0001$).

Analysis by pedestrian type

The mean waking speed of all 'walking' pedestrians was found to be 1.58ms^{-1} with a standard deviation of 0.1805ms^{-1}. 'Screen use' pedestrians were found to have a mean walking speed of 1.44ms^{-1} with a standard deviation of 0.2033ms^{-1} and 'in call' pedestrians were found to also have a mean walking speed of 1.44ms^{-1} but with a standard deviation of 0.1959ms^{-1}.

The difference in mean walking speeds between the 'walking' and 'telephone use' pedestrians (0.14ms^{-1}) was found to be extremely statistically significant (two tailed p value of < 0.0001). There was however no statistical significant difference between the mean walking speeds of the 'screen use' and 'in call' pedestrians. The p value was equal to 0.8711.

The results showed that both males and females had a 9% reduction in walking speed whilst using a mobile telephone, during 'screen use' and 'in call'.

Analysis by location

Pedestrianised Precincts (West Centre & King Street)

The tactile paving in West Centre and King Street were used to determine the fixed points for this study.

A total of 1604 pedestrians who walked through the test areas were included in this study, 836 of which were male and 768 were female. Of these, 1158 were 'walking', 313 were 'screen use' and 133 were 'in call' pedestrian types.

The mean speed for males in the 'walking' category type was found to be $1.60ms^{-1}$. 'Screen use' and 'in call' males were found to have mean walking speeds of $1.47ms^{-1}$ and $1.46ms^{-1}$ respectively.

The mean speed for females in the 'walking' category type was found to be $1.55ms^{-1}$. 'Screen use' and 'in call' females were found to have mean walking speeds of $1.40ms^{-1}$ and $1.37ms^{-1}$ respectively.

Mulcaster Street

Physical features within the pavement were used to determine the fixed points for this study, these being a horizontal drain and a parallel join in the paving at the foot of a post, as seen in figure one.

A total of 290 pedestrians who walked through the test area were included in this study, 154 of which were male and 136 were female. Of these 236 were 'walking', 37 were 'screen use' and 17 were 'in call' pedestrians.

The mean speed of 'walking' males was found to be $1.62ms^{-1}$. The mean walking speed of 'screen use' and 'in call' males was found to be $1.50ms^{-1}$ and $1.53ms^{-1}$ respectively.

The mean speed of 'walking' females was found to be $1.51ms^{-1}$. The mean walking speed of 'screen use' and 'in call' females were found to be $1.42ms^{-1}$ and $1.46ms^{-1}$ respectively.

Gloucester Street

The width of Gloucester Street at the pedestrian crossing was used as the distance in this part of the study.

A total of 639 pedestrians who walked through the test area were included in this study, 344 of which were male and 295 were female. Of these 553 were 'walking', 58 were 'screen use' and 28 were 'in call' pedestrians.

The mean speed of 'walking' males was found to be $1.64ms^{-1}$. The mean walking speed of 'screen use' and 'in call' males was found to be $1.47ms^{-1}$ and $1.52ms^{-1}$ respectively.

The mean speed of 'walking' females was found to be $1.54ms^{-1}$. The mean walking speed of 'screen use' and 'in call' females were found to be $1.42ms^{-1}$ and $1.51ms^{-1}$ respectively.

Discussion

As with studies by Pinna & Murrau (2017, 2018), Finnis & Walton (2007) and Willis et al (2004) and Chandra & Bharti (2013) this study found that male walked faster, on average, than females.

A covert pedestrian speed study conducted at a conventional crosswalk in Canada (Alsaleh et al, 2018) found that 'walking' pedestrians had a mean walking speed of $1.66ms^{-1}$ ($\pm 0.19ms^{-1}$) whilst 'telephone use' pedestrians had a mean walking speed of $1.49ms^{-1}$ ($\pm 0.24ms^{-1}$). When comparing this to this study's data for Gloucester Street, it can be seen that the results are similar. The mean walking speed for 'walking' pedestrians crossing Gloucester Street was $1.60ms^{-1}$ and 'telephone use' pedestrians using the same crossing were found to have a mean walking speed of 1.47ms^{-1}. Of note, 86% of the participants in the study by Alsaleh et al (2018) were classified as 'young adults' which may account for the overall faster walking speeds in comparison to this study.

When considering the research of Chandra & Bharti (2013) it was anticipated that the 'all pedestrianised' category would have a slower mean walking speed and the crossing location (Gloucester Street) experienced the fastest. The results of this study supported these findings with Gloucester Street having the fastest mean walking speed (1.58ms^{-1}) and the 'all pedestrianised' category having the slowest (1.50ms^{-1}).

The cause of the reduction in mean walking speed whilst using a mobile telephone was not examined as this was outside the scope of this study. However, given that walking is a motor skill which requires minimal thought is likely that a pedestrian is not distracted from the task of walking but rather has an additional task which requires a greater cognitive load which diverts their attention. This coupled with the split in attention between the telephone task and the environment in which the pedestrian is walking in turn causes the pedestrian to subconsciously reduce their walking speed.

Conclusions

This study has shown that the use of a mobile telephone does have an effect on the walking speed of adult pedestrians. The study found that pedestrians using a mobile telephone walked slower than those who were simply walking without using such a device. There was no significant statistical difference in walking speed between those in the 'screen use' and 'in call' categories.

The results show that there is a speed reduction of approximately 9% for pedestrians, both male and female, whilst using a mobile telephone.

This study also highlighted, like many others that males walked faster than females. The results found that males (both 'walking' and 'telephone use') walked approximately 4% faster than females.

All male participants (at all locations) who were simply walking without using a mobile telephone were found to have a mean walking speed of 1.62ms^{-1}, whereas the 'telephone use' category of male pedestrians were found to have a mean walking speed of 1.47ms^{-1}.

All female participants (at all locations) who were simply walking without using a mobile telephone were found to have a mean walking speed of 1.55ms^{-1}, whereas the 'telephone use' category of female pedestrians were found to have a mean walking speed of 1.41ms^{-1}.

The study found that pedestrians crossing the carriageway at Gloucester Street were found to have the fastest mean walking speed (1.58ms^{-1}) and that pedestrians using the pedestrian precincts were found to have the slowest mean walking speed (1.50ms^{-1}). The difference in mean walking speeds at these two location categories were found to be statistically significant.

Conflicts of interest

The author declares there are no known conflicts of interests .

Acknowledgements

Whilst this research was not funded the author would like to thank the States of Jersey Police for allowing their CCTV system to be used for this research project, Detective Sergeant Rob Manners for providing support throughout this project and Craig Dawson from AiTS for his support and guidance.

References

- Alsaleh, R., Sayed, T. and Zaki, M., 2018. Assessing the Effect of Pedestrians' Use of Cell Phones on Their Walking

Behavior: A Study Based on Automated Video Analysis. Transportation Research Record: Journal of the Transportation Research Board, 2672(35), pp.46-57.

- Cabañero, L., Hervás, R., González, I., Fontecha, J., Mondéjar, T. and Bravo, J., 2019. Analysis of Cognitive Load Using EEG when Interacting with Mobile Devices. *Proceedings*, 31(1), p.70.
- Cabañero, L., Hervás, R., González, I., Fontecha, J., Mondéjar, T. and Bravo, J., 2020. Characterisation of mobile-device tasks by their associated cognitive load through EEG data processing. Future *Generation Computer Systems*, 113, pp.380-390.
- Chandra, S. and Bharti, A., 2013. Speed Distribution Curves for Pedestrians During Walking and Crossing. *Procedia - Social and Behavioral Sciences,* 104, pp.660-667.
- Chopra, P., Castelli, D. and Dingwell, J., 2018. Cognitively Demanding Object Negotiation While Walking and Texting. Scientific Reports, 8(1).
- Finnis, K. K. and Walton, D., 2007. Field observations of factors influencing walking speed. In Proceedings of the 2nd International Conference Proceedings on Sustainability Engineering and Science, Aukland, New Zealand.
- Gov.je. 2020. Jersey Climate January 2020. [online] Available at: <https://www.gov.je/weather/Pages/Jersey-Climate.aspx> [Accessed 3 August 2020].
- Ofcom, 2019. Communications Market Report 2019.
- Pinna, F. and Murrau, R., 2017. Isolated and Single Pedestrians and Pedestrian Groups on Sidewalks. Infrastructures, 2 (4), p.21.
- Pinna, F. and Murrau, R., 2018. Age Factor and Pedestrian Speed on Sidewalks. Sustainability, 10(11), p.4084.
- Willis, A., Gjersoe, N., Havard, C., Kerridge, J. and Kukla, R., 2004. Human Movement Behaviour in Urban Spaces: Implications for the Design and Modelling of Effective Pedestrian Environments. Environment and Planning B: Planning and Design, 31(6), pp.805-828.

Bibliography

- Barkley, J. and Lepp, A., 2016. Cellular telephone use during free-living walking significantly reduces average walking speed. *BMC Research Notes*, 9(1).
- Department for Transport Statistics. 2019. Reported Road Casualties Great Britain: 2018 Annual Report.
- Fritz, S. and Lusardi, M., 2009. White Paper: "Walking Speed: the Sixth Vital Sign". *Journal of Geriatric Physical Therapy,* 32(2), pp.2-5.
- Hyman, I., Boss, S., Wise, B., McKenzie, K. and Caggiano, J., 2009. Did you see the unicycling clown? Inattentional blindness while walking and talking on a cell phone. Applied Cognitive Psychology, 24(5), pp.597-607.
- Jiang, K., Ling, F., Feng, Z., Ma, C., Kumfer, W., Shao, C. and Wang, K., 2018. Effects of mobile phone distraction on pedestrians' crossing behavior and visual attention allocation at a signalized intersection: An outdoor experimental study. *Accident Analysis & Prevention*, 115, pp.170-177.
- Lamberg, E. M., and Muratori, L.M., 2012. Cell Phones Change The Way We Walk. Gait & Posture 35, pp.688-690.
- Muley, D., Alhajyaseen, W., Kharbeche, M. and Al-Salem, M., 2018. Pedestrians' Speed Analysis at Signalized Crosswalks. *Procedia Computer Science*, 130, pp.567 -574.
- Mwakalonge, J., Siuhi, S. and White, J.,

2015. Distracted walking: Examining the extent to pedestrian safety problems. *Journal of Traffic and Transportation Engineering (English Edition),* 2(5), pp.327-337.

- Piazza, A., Knowlden, A., Hibberd, E., Leeper, J., Paschal, A. and Usdan, S., 2019. Mobile device use while crossing the street: Utilizing the theory of planned behavior. Accident Analysis & Prevention, 127, pp.9-18.
- Schwebel, D., Stavrinos, D., Byington, K., Davis, T., O'Neal, E. and de Jong, D., 2012. Distraction and pedestrian safety: How talking on the phone, texting, and listening to music impact crossing the street. Accident Analysis & Prevention, 45, pp.266-271.

Contact

DC Donna Hewlett

Detective Constable

Collision Investigation Unit,

States of Jersey Police

E-mail: d.hewlett@jersey.pnn.police.uk

STATES OF JERSEY POLICE

Visit the Institute's website at www.itai.org

'Impact' subscription, and all other enquiries should be addressed to

The Institute of Traffic Accident Investigators
Administration Department
Column House, London Road, Shrewsbury SY2 6NN

Tel +44 (0)8456 21 20 66 : Fax +44 (0)8456 21 20 77 : email admin@itai.org

Registered Charity No. 1014784
Registered in England as a Company No.2753420 : Registered Office - Column House, London Road, Shrewsbury SY2 6NN

Printed by DPS Print (Gravesend) : Tel. 01474 533395

Vision and Visibility – An introduction for understanding

Eng Jan Unarski, PhD

Head of Road Traffic Analysis Dept, Krakow University 1979- 2016

Traffic safety and visual performance are highly interrelated, and despite the progress in the construction of autonomous vehicles, a driver still receives an avalanche of information simply through the organ of vision. The other senses only supplement this visual information, and this can be aggravated, both during the day and at night, by weather conditions. Information must be collected, selected and processed by the brain, so that at any time the driver can effectively control the vehicle and travel safely.

Traditionally, vision is divided by scientists into two major components: sensation and perception, separated by an attention filter. Sensation is the detection of energy and starts after light energy has reached the driver's eye photoreceptors (cones and rods) and launches the process to convert the energy of light into nerve impulses. Then, the impulses are transferred to the brain, where the image is transferred to the "visible image". The most important sensation is created not by light but by the contrast between the object and its background. There are several types of contrast (shape, colour, texture, motion) but for us the most important is the contrast of brightness, particularly when the eyes are working as a threshold detector, under extremely low illumination. Perception is a cognitive process in which the interpretation and comparison takes place, based on the delivered images from the photoreceptors and on the stored knowledge. Viewers continually compare the actual images with the images or situations stored in the brain, but because the amount of stored information is huge, their limitation is supervised by an attention filter. The mechanism of saccadic eye movements (the quick simultaneous movement of both eyes between two or more phases of fixation in the same direction) helps to combine these three components. When the object is below the detection threshold, it cannot be recognized. When the object is above the threshold limit, the object may theoretically be visible. In practice, some correction factor is necessary, to allow for recognition.

Usually, during the day objects create a sharp contrast through brightness (luminance) or other types of contrast with their background, so detecting them is not a problem. A failure to recognize an object during the day may result from a lack of sufficient attention, looking in another direction or the object may not be recognized due to some optical illusion. In this discourse daytime visibility is not discussed.

In order to understand the underlying process of vision in conditions of limited visibility (dawn, dusk, night, fog) we must briefly review the majority of the factors determining the possibility to perceive objects in such conditions.

Let us start with some comments on the nature of light and some definitions necessary to understand the problem.

Light is a portion of various electromagnetic waves traveling through space. Visible light is only a small part of all light spectrums between 380–770 Nanometres. Rays of light are propagated from a light source in all directions towards different surfaces. Each surface –except absolute black– reflects light, and that is why we can see them. In the automotive area we can find:

- diffuse reflectors which are characterized by rough texture that reflects light more or less equally in many directions (of the same brightness from different angles), e.g. road surfaces, pedestrian garments.

- specular reflectors which have a microscopically smooth surface (mirror). In a specular reflector, light is reflected at an angle equal and opposite to the angle at which it enters, e.g. shop windows, water covered road during rain.
- retroreflectors in which the light encountering a retroreflector is reflected back toward the source with minimal scatter. They are very sensitive to the entrance angle and observation angle, and can be found as retroreflectors in cars or on safety triangles, as well as the foil on road signs and the retro-reflexing elements on HiVis garments for pedestrians, and Ambulance, Fire Service and Police personnel.

In the accident reconstruction area, we can also find:

- fluorescent materials which have the capability of converting electromagnetic energy into visible wavelengths. As a result, they appear much brighter than would a surface of the same area that is not fluorescent. The fluorescent characteristics are activated by ultraviolet wavelengths. Since normally there is no ultraviolet light around in the hours of darkness, fluorescent materials are of little use during night-time (exceptions perhaps in some HiVis safety vests).
- luminous materials that have the ability to absorb electromagnetic energy and emit light in visible wavelengths after the energy source has been removed. Luminous sources do not require that a light source be directed toward them to make them appear bright. After 30-60 minutes they no longer operate (direction arrows in garages).

Some basic definitions of light parameters are graphically presented in Figure 1.

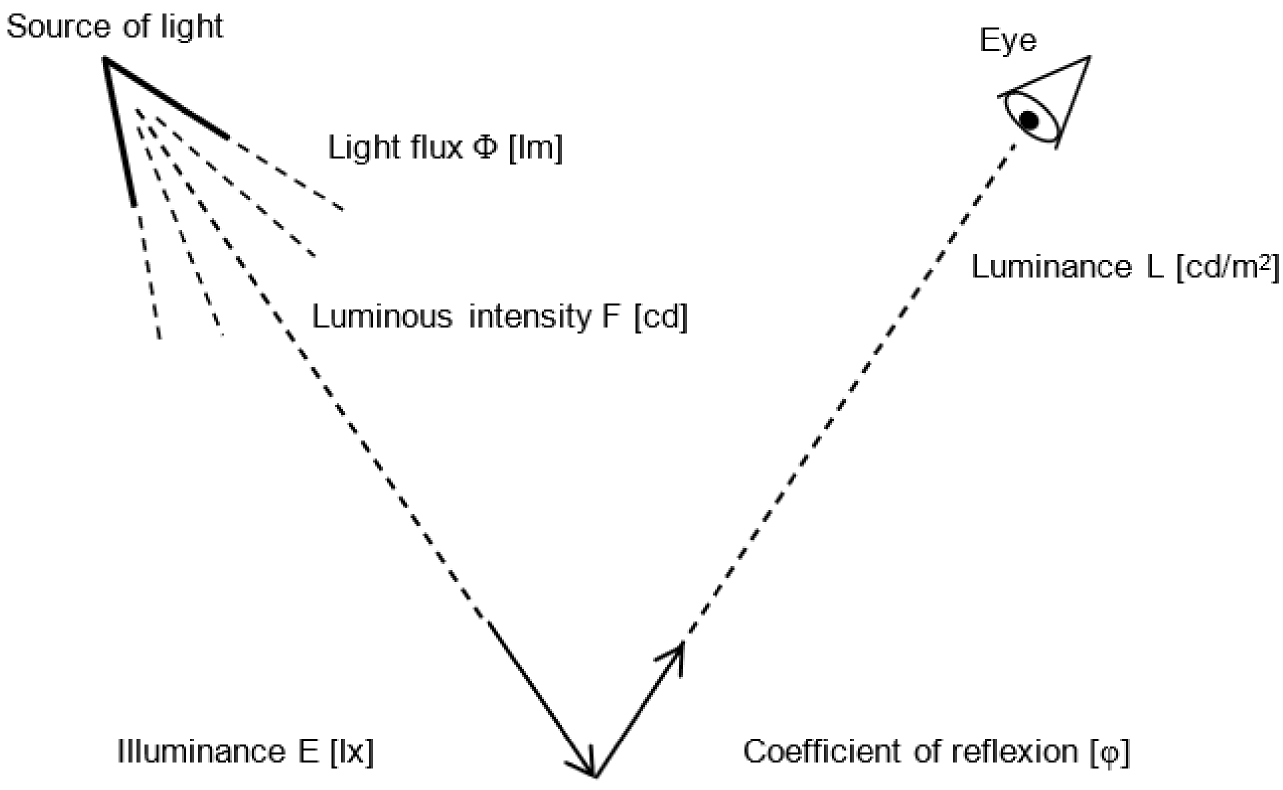
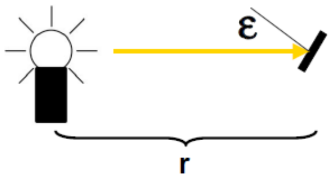


***Figure 1**. Relations between light elements.*

Luminous intensity [F] Source output	Luminous intensity is the density of luminous flux F (time rate of flow of light) in a given unit solid angle. The unit solid angle is called steradian. There are 4π steradians contained within a sphere. The uniformly radiating source has an intensity equal to $F/4\pi$. A measurement unit of total light output from a source is the lumen (lm). Alternative unit is candela (cd). A source of one candela will produce one lumen of luminous flux per steradian. Therefore, one candela source will produce 4π (12,57) lumens.	
Illuminance [E] The amount of light reaching a surface.	Illuminance is the density of luminous flux incident on a surface. It can be measured by lumens per square metre called lux (lx). The imperial equivalent of illuminance is foot candles (ft-c), which is lumens per square foot. One foot candle equals 10,76 lux, or one lux equals 0,0929-foot candles. *Illuminance is measured on the surface of the object – the sensor is directed to the front of the light source.*	Illuminance decreases as a square of the distance from the source. $$E = \frac{F}{d^2}$$ *Equation 1* E= illuminance F = source output d = distance from source to surface
Luminance [L] The amount of light reflected from a surface	Light reflected from a surface yields the sensation of brightness. The photometric term is luminance. Brightness is a subjective impression of the object depending on many factors such as background and the level of dark adaptation. Luminance is measured in candelas per metre squared (cd/m2) or in foot-Lamberts (ft-L). One cd/m^2 equals 0,292-foot Lamberts, or 1 foot Lamberts equals 3,425 cd/m^2. *Luminance is measured from the eye of observer to the surface of object.*	Luminance is sensitive to the angular position of the reflecting surface relative to the line of sight. $$L = \frac{F}{r^2} \cos \varepsilon$$ *Equation 2* 
Coefficient of reflexion [φ]	Is the portion of light reflected from a surface relative to the amount of light reaching the surface. The relationship between luminance of diffuse surface and illuminance is: $$L = \frac{E \cdot \varphi}{\pi}$$ *Equation 3* where: L – luminance E – illuminance π – 3,14 φ – coefficient of reflexion	$0 < \varphi < 1$ $\varphi = 0{,}5 \div 0{,}65$ (light garments) $\varphi = 0{,}04 \div 0{,}1$ (dark garments)

The major components of a visibility problem can be divided into four groups:

- human (age, health, adaptation to darkness, etc.),
- headlamps (kind of reflectors, headlamp beams and cleanliness, adjustment, etc.),
- background (colour of surface, unevenness, slope, external lightening, etc.),
- object (colour, dimension, position, etc.).

Let us move on to particular aspects of the problem before discussing the rules of determining distances.

Human

In Figure 2 the essential components of the **human eye are shown**. The cornea is the transparent front surface of the eye through which light enters. The cornea and the lens cooperate to bring the incoming light to a focus on the retina. The pupil diameter changes according to the intensity of light reaching the eye, but also with the age of the driver. The scope of the diameter change for a 20 year old driver is between 2.5 - 7.5 mm, but at the age of 80 only 2.5 - 4.8 mm, and therefore less light enters the eye of the older driver in night time conditions. The transparency of the pupil also degrades with age.

Inside the eye the **retina** is the light sensitive internal surface of the eye, and we find two kinds of receptors (Fig. 3). These are **cones** and **rods**. Cones - about 6 million sensors for the daytime (photopic) view, concentrate mostly in the middle of the retina. They are wavelength sensitive at higher light levels and they provide colour vision. Rods - about 120 million sensors for night-time (scotopic) vision, concentrated mostly in the outer area of the middle of the retina. They operate at low light intensity and transmit vision but only in grey scale colour. Vision using both cones and rods, called mesotopic vision, is frequent during driving at night both on lit and unlit roads.

Another aspect of the eye is the sharpness of vision which is defined by three separate areas – Foveal, Parafoveal and Peripheral Vision.

When fixating on an object there is a small cone of about 2.5° radius where the object and its surroundings are in perfect focus; this is Foveal Vision. Outside of this area there is a further cone with a 10° radius where objects are clearly visible, but not in perfect focus. This is the Parafoveal zone. Outside of this region is Peripheral Vision, which extends to a radius of around 50° and in this area the sharpness of vision gradually decreases towards the edges. The effective limits to Peripheral Vision can easily be estimated by stretching out the arms with the thumbs extended, and moving them to a point where they are just visible. The angle subtended by the arms gives an indication of the limits to vision. Figure 4 below demonstrates the three zones.

Due to the function and distribution of cones and the small area of the fovea, unexpected objects often appear in the peripheral vision,

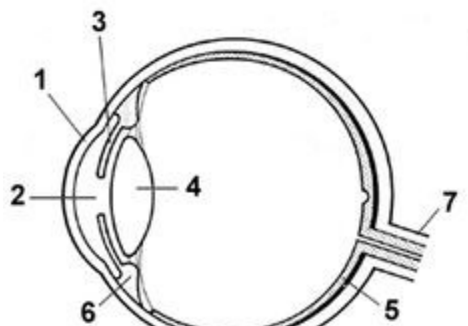


Figure 2. *Elements of the eye: 1. Cornea, 2.Pupil, 3.Iris, 4.Lens, 5.Retina, 6.Ciliary body, 7. Optic nerve.*

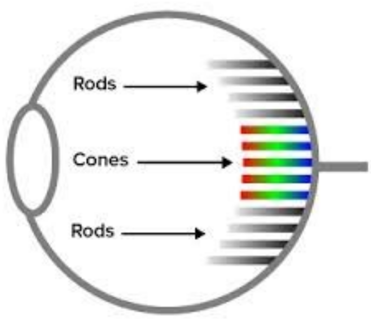


Figure. 3*. Sensors inside human eyes.*

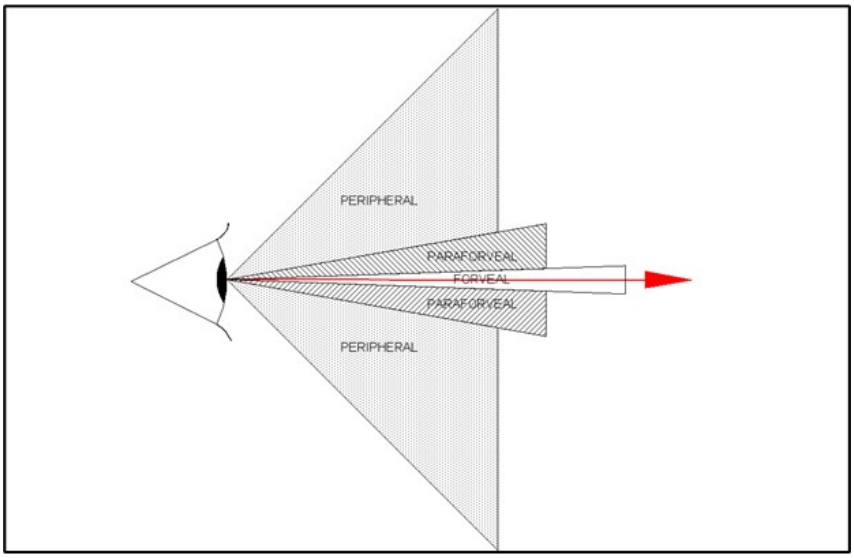


***Figure 4**. Sharpness of Vision*

and the eyes will be shifted to bring the detected object into focus in the foveal area as a part of the identification process. When detection occurs in periphery, the target object's conspicuity must be greater than if it occurred in the fovea, due to lesser quality of vision in the peripheral zone.

The perception of objects in front of the vehicle may also be impaired as a result of insufficient sharpness of vision (eye dysfunction, diabetes), not wearing glasses, badly adjusted glasses, being blinded by the sun, oncoming car beams, light reflections, weariness, being overtired, and finally by the influence of alcohol, drugs or medicine.

Headlamps

Another component of visibility is represented by **headlamps and sources of light**. Modern cars are equipped with many different types of headlamps. Headlamps are designed for a particular kind of the beam (low beam or high beam) or alternatively use a reflector system which can produce two kinds of beams from one source of light. The equipment on modern cars includes parabolic headlights, ellipsoid headlights (DE), "free form" headlights and combined headlights. Parabolic headlights usually have a mirror in the form of a paraboloid, or its parts, and the exterior glass is grooved for better distribution of light. The efficiency of these reflectors is usually the smallest at about 27 %. The source of light in them is often provided by halogen bulbs types: H4, H7, H1. Another group is ellipsoid headlights. This kind of headlight is equipped with a rotational ellipsoid mirror, lens and a shutter. Ellipsoidal headlamps produce mostly one kind of beam (low or high), or if the shutter mounted inside is rotational, they can produce two kinds of beam. They are used in H7 or D2S – xenon bulbs and their efficiency is at about 35%. Still another type of headlamps is called "free form". Inside them the multi-surface mirror provides very good distribution of the light beam, while the front glass is smooth and made from polycarbonate. Depending on the design of the mirror and the bulb used inside, these headlamps can emit two kinds of light, low or high or both. We can find these inside H4, H7 or D2R – xenon bulbs. The efficiency of light is at about 45%. The last type of headlamp is the LED light, with a matrix of LEDs, combined with small mirrors, sometimes turned facing the rear or using a combination of mirrors.

These main headlamps are supplemented by turning lights, fog lights or day lights. Most modern cars are also equipped with headlamps working in cooperation with a computer and camera system whose design allows the beam of light to adapt to the needs including the speed, kind of road, oncoming traffic, etc. They provide autonomous lighting

 Parabolic	 ellipsoid
 “free form”	 LED matrix

Figure. 5. *Four kinds of headlamps.*

systems that independently, without the driver’s intervention, decide which lights are to be switched on at that moment. They are very efficient safety-wise; however, they are not particularly helpful in establishing many facts necessary to determine the visibility distance (DynaBeam, VarioX, Adaptive headlights, etc.).

There are three main kinds of light sources:

1) Filament bulbs (Bilux or halogen H1, H3, H4, H7 …etc.),

2) HID (high energy discharge) – Xenon lights – D2S, D2R…etc.,

3) LED – lights.

Each type of bulb has different power and light temperature and, obviously, flux output. Some of them are plain, some are reinforced, and the names of some indicate extra flux or extra-long life (Osram Silverstar +50% light, Philips Premium +30% extra light, Philips Vision Plus 50% light, etc.). Also, some bulbs offer slight changes in the colour of light (Osram Cool Blue) because the eye at night tends to be more sensitive to blue colour.

Light flux values measured in lumens [lm] are:

Bulb type	Power [W]	Light flux [lm] approxi-mately
H1	55	1400
H3	55	1200 - 1400
H4 (two filaments)	60/55	1650/ 1000
H7	55	1300 - 1400
D2S	35	3200
D2R	35	2880
R2 (Bilux)	45/40	600/500
H4 reinforced	100/80	2600/1500
H4 reinforced	130/90	3550/1820

Consequently, on different car models different types of reflectors (and bulbs) will be used, and the shape of the illuminated area ahead of the car will differ on low beam and high beam lights. Low beam lights (which will be of interest to us almost exclusively) have a limited range because they are directed downward toward the road, and also because of their asymmetry – their range on the left-hand side of the vehicle is shorter than that directed to the road right shoulder for left-hand drive vehicles and the reverse for right-hand drive.

If the illumination of the field of low beam lights is measured in steps (e.g. 1, 2, 4, 8, 16, 32, 64, 128 lux), a "field of isolux" can be obtained. A sample field of low beam lights is shown in Figure 6.

It is also possible to measure the illumination in front of cars in the most interesting position e.g.: slightly on the right-hand side of a European car, where pedestrians walk along the shoulder of the road. Figure 7 shows two plots of illumination of low beam lights and high beam lights measured at 0.02 m and 0.5 m above an asphalt road.

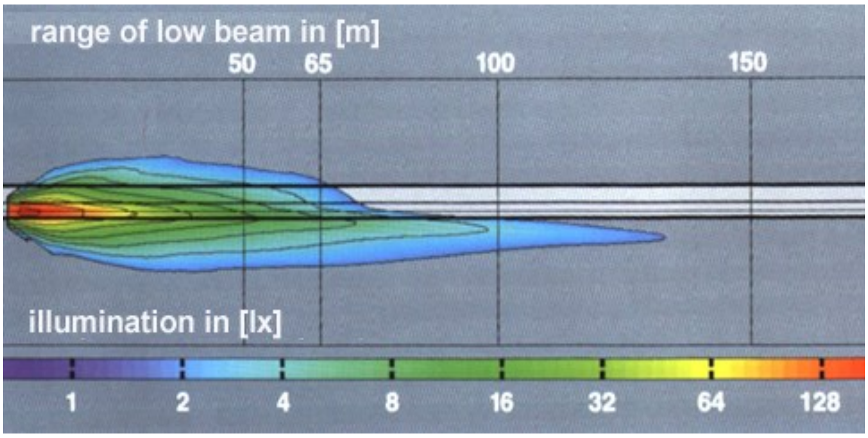


Figure 6. *Field of isolux in front of a car with low beam lights on (source: Hella advertisement materials)*

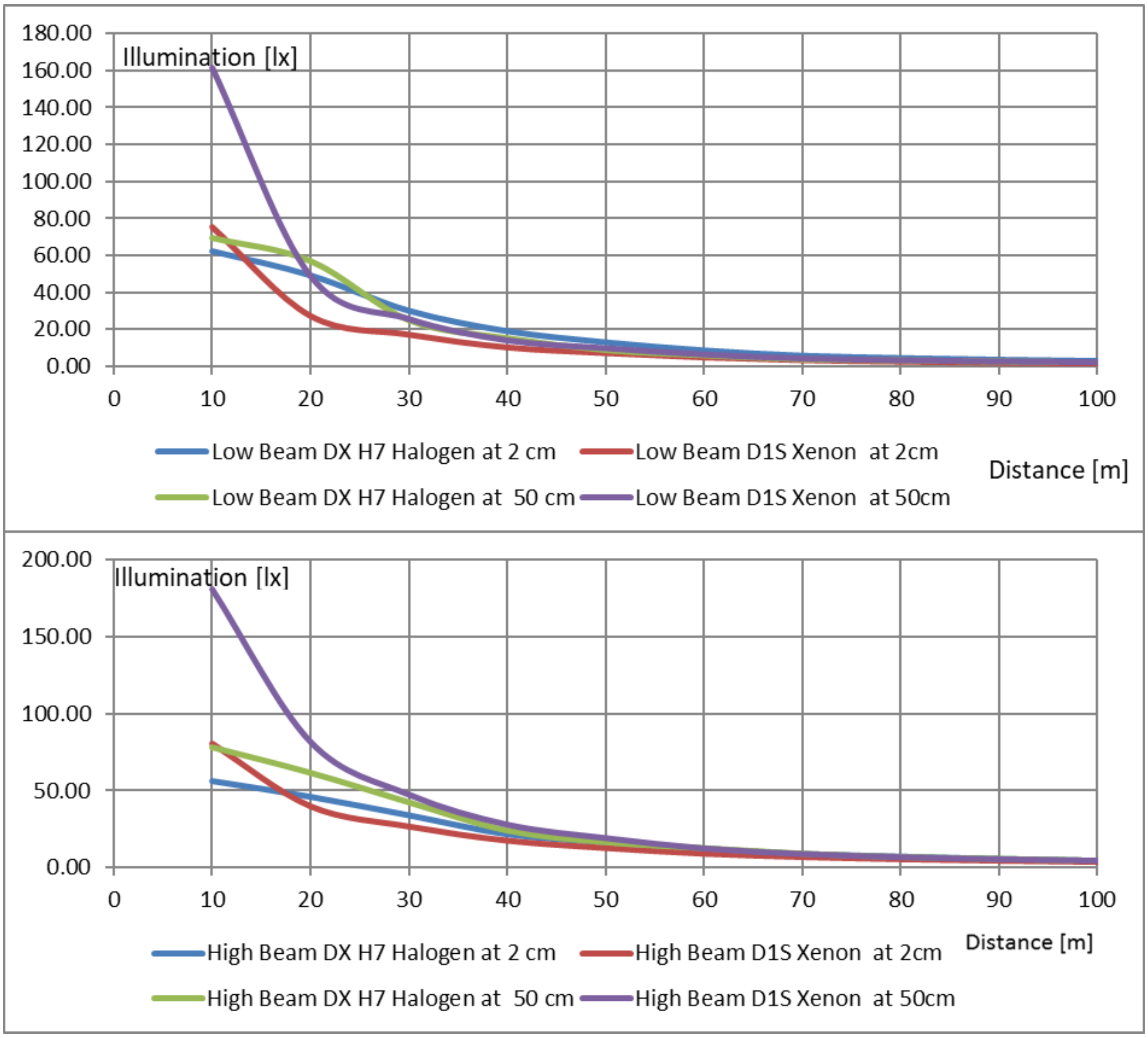


Figure 7. *Illumination in front of a car decreasing with distance in low and high beam lights [2].*

The large variety of isolux field sizes employed in modern cars makes some generalization necessary. In the collective work [3] the authors gathered all the available distribution curves of isolux for the field illuminated in front of various vehicles, equipped with various types of headlamps. They next arranged the results into groups according to types of headlights and lamps, and finally approximated, by means of polynomials, the boundary curves for isolux 3.2 lx (Fig. 8). Corresponding equations are also given.

At the end of civil twilight, the illumination of the earth surface has been considered to be 3.2 lux, with a clear sky and no other ambient light sources. It has regularly been used as a standard measurement point for contrasting different headlamps.

Background

The third element necessary to investigate visibility is the background. The roadway, the shoulders and the space above them, including walls of buildings or other vehicles, are the background against which obstacles appear. The road surface can be clear and dry, wet or water covered at any time during the year and in winter snow can be a factor. Also, with external lighting, the reflection from street lamps, will cause some surface sections to be brightly lit while others will be darker. The material from which roads are built, i.e. concrete, asphalt shellgrip etc, can also affect the road colour (Fig. 9).

Differences are particularly noticeable in wet conditions or during rainfall at night. The same road when partly illuminated will present itself differently to the driver's right and left-hand sides. In Fig 10, a hazard the same distance ahead of the car, on the left-hand side will be well lit in negative contrast, whilst to the right-hand side, without a positive contrast the object will be difficult to see.

On wet roads, full of additional lights and reflections, pedestrians are very difficult to recognize, particularly in mid-lanes (Fig. 11).

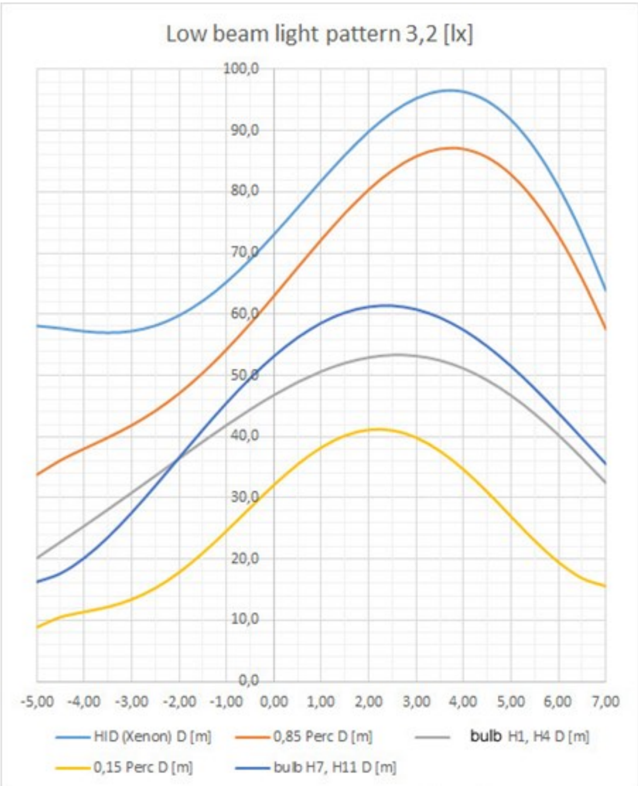


Figure 8. *Isolux 3.2 lx of various types of headlights. Position 0.00 m denotes the left side of car.*

Figure 9. *Three-lane motorway – different colours of parts of the road*

Figure 10. *Different illumination of the left and right sides of the same road*

Figure 11. *Glare from oncoming cars on a city wet street with a pedestrian in mid-lane*

Taking the above into account, there are no easy ways to determine the detection distance in many cases. The expert would need to be at the scene of the accident, with exactly the same conditions, for the experience and measurements to be credible.

Snow covered roads look very brightly lit by car beams, but it should be remembered that snow is highly reflective, and the human eye immediately reacts and adapts to the new, higher level of illumination; with the iris blocking the light. Only a smaller portion of light reflected from an object can reach the eye's sensors (Fig. 12).

Object

The last determinant regarding identify an object is the object itself (eg a pedestrian, cyclist or another non lit obstacle). The parameters of the object include:

- size – measured in [m] (0.25 x 0.25 m is most often adopted as an object in visibility studies) or angle (angular width (or height) of the object measured in minutes).
- position within the Isolux contours.

- position in reference to the visual fixation axis.
- luminance of the object - its colour or coefficient of reflection.
- movement of the object.

Depending on the luminance of the object relative to the luminance of background the value of contrast is calculated as follows - (Weber contrast):

$$K = \frac{(L_o - L_b)}{L_b}$$

Equation 4

where:

L_0 – luminance of object

L_b – luminance of background

In this way the contrast has the value of $0<C<\infty$ when the object has greater luminance than the background (positive contrast) or $-1<C<0$ when the object has lower luminance than the background (negative contrast) (Fig. 13).

Some researchers use the grey colour scale, which is easy to use during investigation and also easy to compare with the colour of a real object. The initial point at which an object starts to come into view will be in the grey scale at minimal illuminance (scotopic view). A sample grayscale with reflection coefficients for each colour used in many of the authors' researches is shown in Fig. 14.

This scale is also easy to use for comparison of the colour of the pedestrian clothing with the background, when standing at a given distance from the target object.

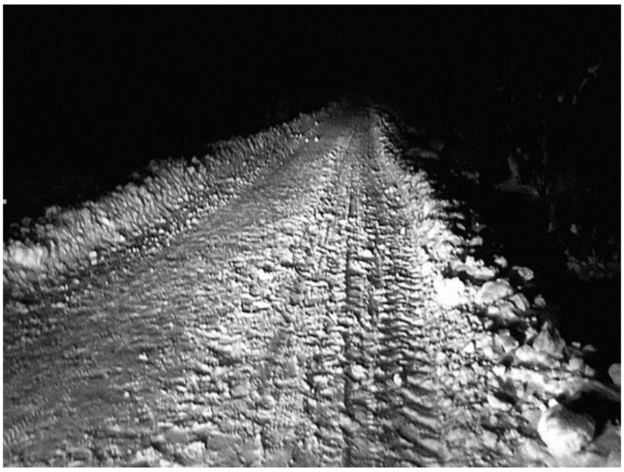


Figure 12. *Narrow, snow-covered road with snow banks*

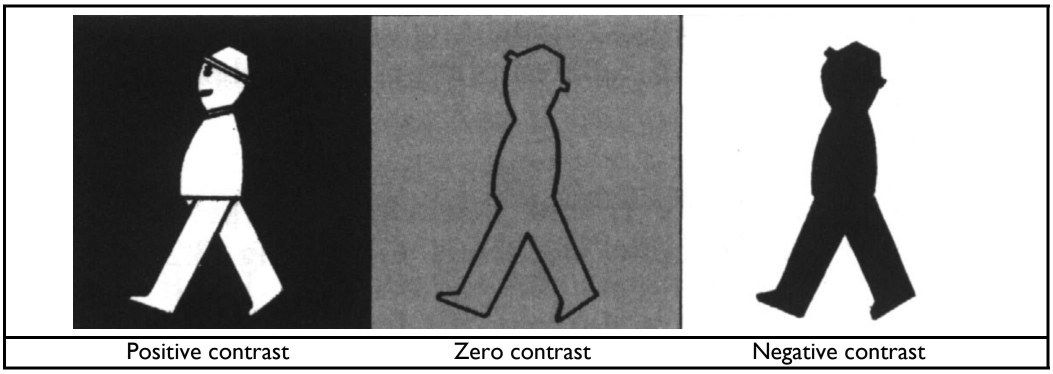


Figure 13. *Types of contrast*

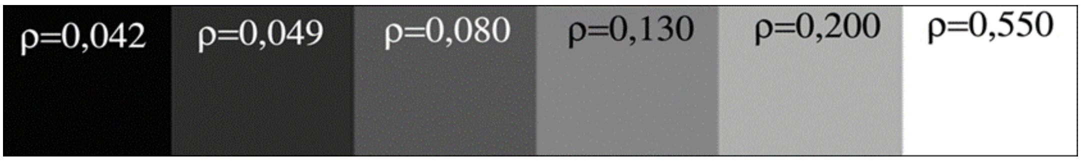


Figure 14. *Sample greyscale with coefficients of reflection*

A simple way to determine visibility distance

In their daily work accident reconstruction experts need to determine the visibility distance of objects. Depending on the circumstances of the case and the equipment available, an expert must have the ability to provide the right answer. If they do not have to deal with sources of light other than that from the vehicle, this is relatively easy. There are only three main factors to be considered: the kind of the car lights, the colour of the object and the colour of the background.

For these simple cases (without other light sources) a lot of research has been performed and therefore let us quote the ones that most often are applicable in practice, their use is simple, and the level of the 'certainty of results' is sufficient.

Visibility distance was checked by the authors [3] in road tests, with a variety of headlights, using objects in the greyscale (Fig. 14.), and the results are shown as Isolux fields. The objects were placed on the geometrical axis of cars (Fig. 15.).

Another simple method is to use the results of minimal illumination of particular colours published by Muttart [4]. He found, by tests and reference to research papers and real-life data, that the minimal illumination for the recognition of a black or very dark object is 15 – 20 lux, for grey 3–7 lux, and white or light 1–2 lux (Fig. 16).

The values for the calculation of visibility distance can be found in Fig. 7 and following the equation:

$$d_o = \sqrt{\frac{3.2 \cdot d_{3.2}^2}{E_o}}$$

Equation 5

where:

$d_{3.2}$ - distance of isolux 3.2 lx in front of vehicle,

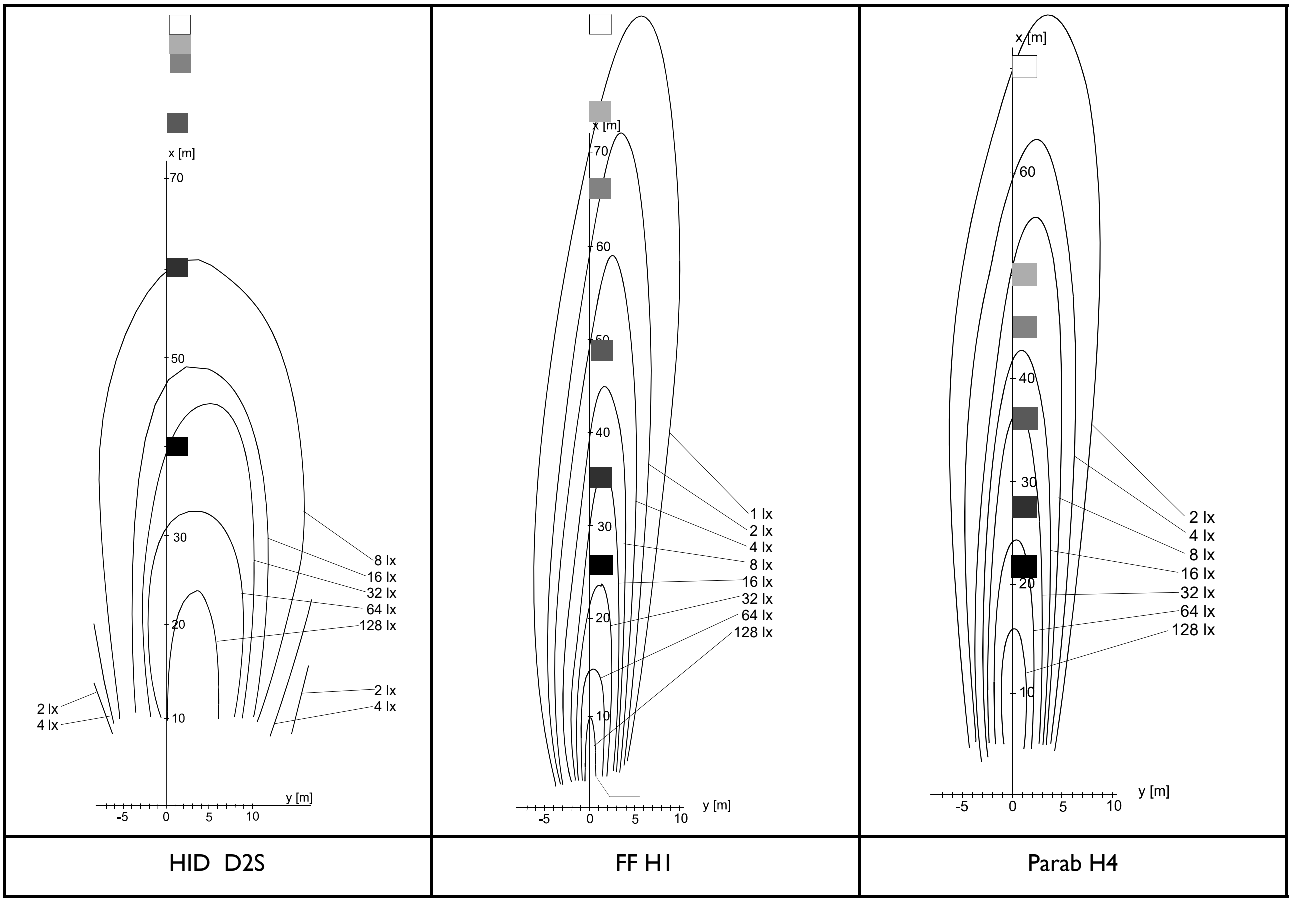


Figure 15. *Visibility distances of objects in grey colour scale in different headlights*

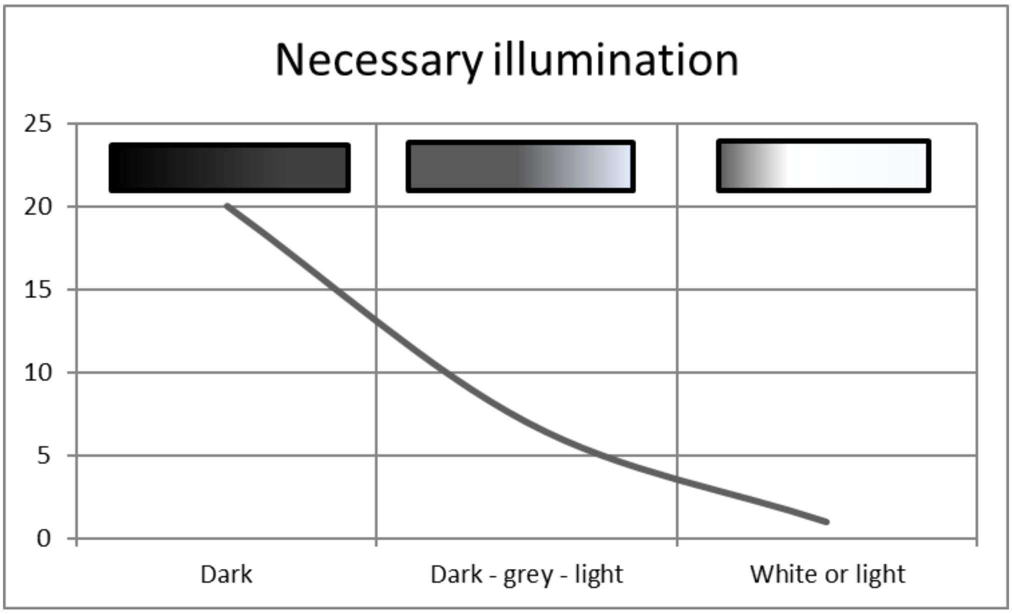


Figure 16. *Necessary illumination of objects for recognition*

E_o - expected illuminance (e.g.: 1, 5, 15, 20 lx),

d_o - distance in front of vehicle at which illuminance should appear.

Practically, a luxmeter can be used to determine the profile for the required lighting levels and the distance from the vehicle can then be recorded.

Still another simple method is to use the results presented by Olson and Sivak [5]. They compared the US light system and European system in a practical way using two types of pedestrian clothing: (1) white T-shirt, dark trousers, (2) dark T-shirt, dark jeans. The tests were performed on a very large group of people and the results were presented as a normal probability plot with respect to the seeing distance. The position defined as Right in Fig. 17 denotes a person standing in front of the car and to the right of the centerline (maximum range), whilst Left defines a person standing on the left-hand side (minimum range). As can be seen, in each option the objects are perceived over a very wide range (e.g. for dark top and jeans (Right) the range varies from 26 metres for 10 % of observers to over 80 metres for 95% of observers. For practical use the distance between the red vertical lines representing 10 -15% of observers should be used as a base level (85–90% of drivers should notice the object from a distance not shorter than 26 metres.), since most people noticed this kind of object from a distance "not shorter than 26 metres".

One of the latest data sets has been obtained from practical investigations by Kledus R. et al [6]. They used the oculography method for the determination of detection moment (distance to the object), when the driver clearly directs his gaze on the pedestrian. During their tests they confirmed that when the pedestrian wears dark clothes, the illumination intensity required to create enough contrast may be, depending on the circumstances, as much as 20 Lux, while with the pedestrian wearing light clothes, an adequate contrast can be achieved with the illumination intensity as low as 2 Lux. For the given vehicle and the headlights used, a pedestrian dressed predominantly in dark clothing will usually be noticed at a shorter distance (later) than a pedestrian wearing light clothes. In the measurements with headlights switched to low beam, what is more important is the clothing contrast in the lower part of the pedestrian's body, whereas in the measurements conducted with a high beam the clothes contrast in the upper part of the pedestrian's body is more important.

The representative distances from these tests can be shown in three ranges for both low and high beam settings, with H7 or XE lights

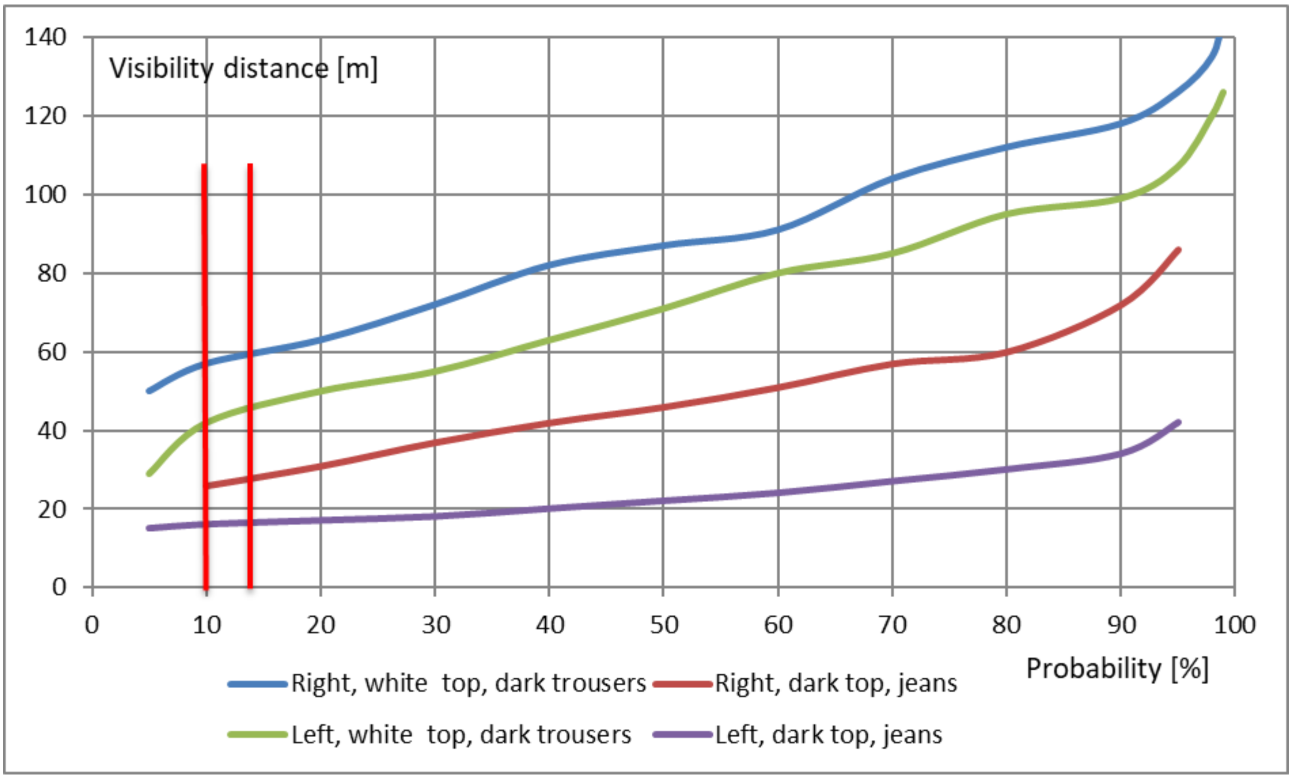


Figure 17. *Statistical results of visibility limits from Olson & Sivak's research*

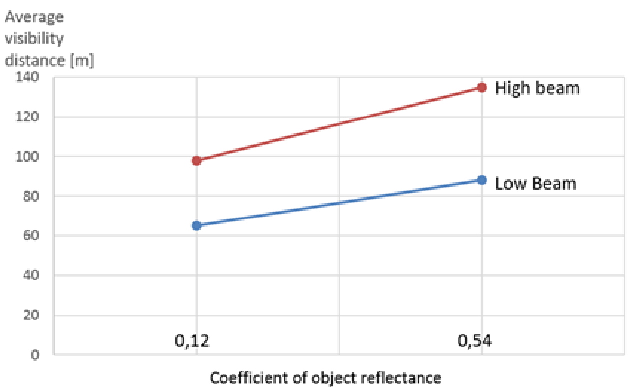
Dark colour garment	Medium grey colour garment	Light colour garment
		
Low beam = 30 – 35 m	40 - 45 m	47 - 54 m
High beam = 65 – 82 m	85 – 90 m	115 – 140 m

Figure 18. *Statistical results of visibility limits from Olson & Sivak's research*

(Fig. 18).

It can be seen that with low beam lights the visibility distance to light colour clothes is no longer than the mean range of the light-shade limit (40-55 m right of the centerline). This suggests that the driver's vision at night is directed primarily at the border of light and shade, although pedestrians in light clothes may be seen from some distance further away. This is an important factor to keep in mind, as whilst the lighting level may bring a white object into view in the distance the driver's concentration on the border between light and shade means that the object will not, according to the research, be in foveal view. The last important information can be derived from the comparison of the visibility range in low and high beam lights as described by Olson & Mortimer 1974 (Fig. 19).

As can be seen above, an increase in the object reflectance has a major effect on visibility when the lights are changed from low to high beam (φ =0,54). Inversely, bigger changes in visibility can be seen in high beam light on the left-hand side of the car, where the profile of low beam lights give a shorter visibility range to prevent glare.



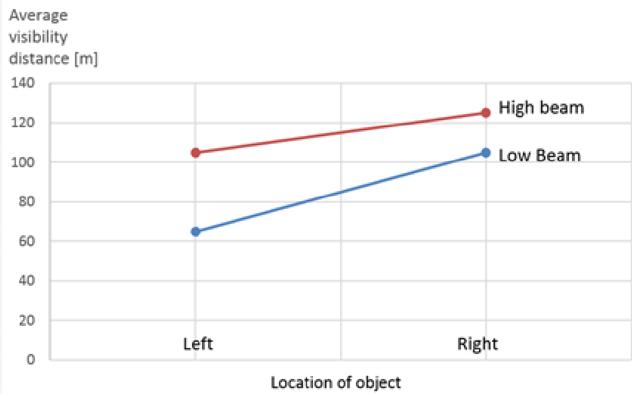


Figure 19. *Average visibility distance in low and high beam lights depending on object's reflectance and*

An expanded and more accurate model for determination of visibility distance.

Prior to the precise calculation of the visibility distance, it is necessary to measure certain values at the scene of accident. The required elements are the vehicle, the object (or its representation) and the road in the same colour conditions as at the time of the accident. With the headlamps illuminated, measurements of the luminance of the object and background should be recorded, over a range from 100 m to 10 m (in 10 m or 20 m steps). Luminance can be measured with any luminance meter (e.g. Minolta LS 110 or 100), but it is recommended to employ a photographic method (LMK from TechnoTeam Bildverarbeitung GmbH. or a calibrated camera coupled with PC-Rect 4.2 software). Figure 20 illustrates the measurement of luminance points.

Pairs of luminance (object – background) can be calculated from formula:

$$\Delta L = L_o - L_b$$

Equation 6

or,

$$K = \frac{L_o - L_b}{L_b}$$

Equation 7

where:

L_0 – luminance of object

L_b – luminance of background

However, the values of or must be compared with the threshold value of luminance (ΔL_{th} or K_{th}) and adjusted accordingly. For real accident conditions the adjusted values must be used because of the differences between the tests done in laboratory conditions and real traffic conditions.

For the background threshold the values for ΔL_{th} in the following diagram, called Berek's Curves, can be used (taken from the Norm DIN 5037 – blatt 2). Figure 21 illustrates the diagram for a certain range.

Alternatively, accident reconstruction experts could use the chart of threshold contrast depending on the luminance of background, whose general profile is shown in Fig. 22.

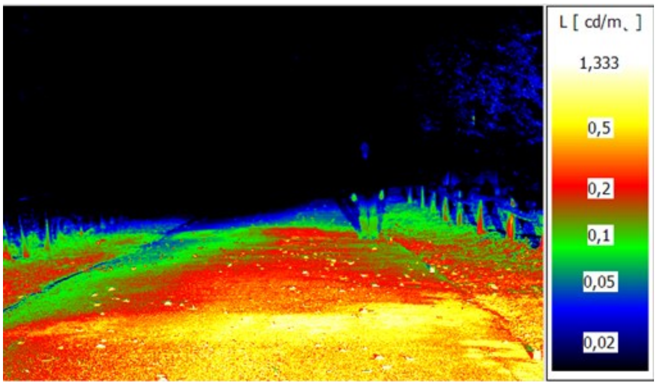


Figure 20. *Measurement of luminance for visibility distance needs*

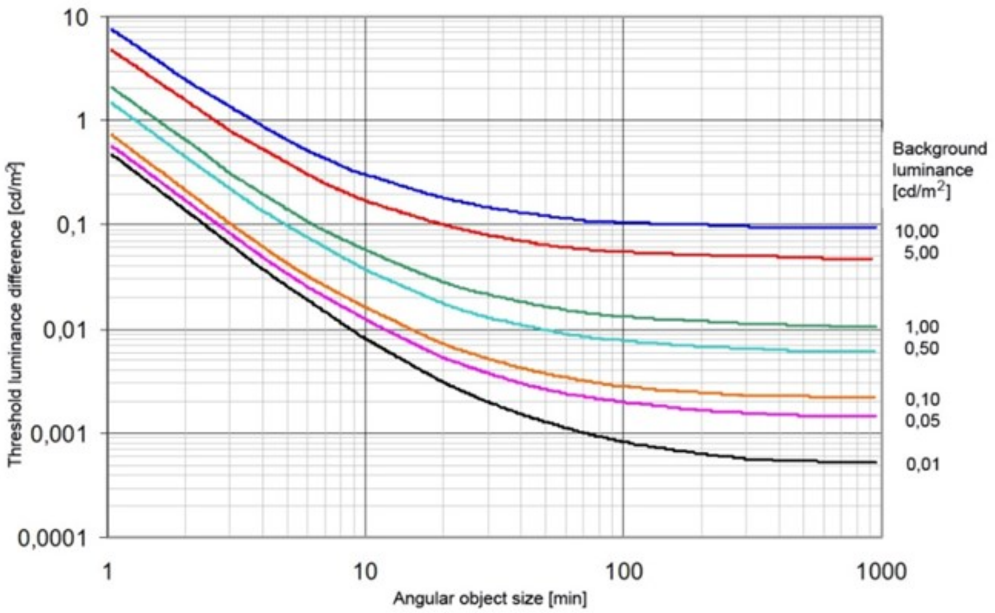


Figure 21. *Berek's curves of threshold luminance difference*

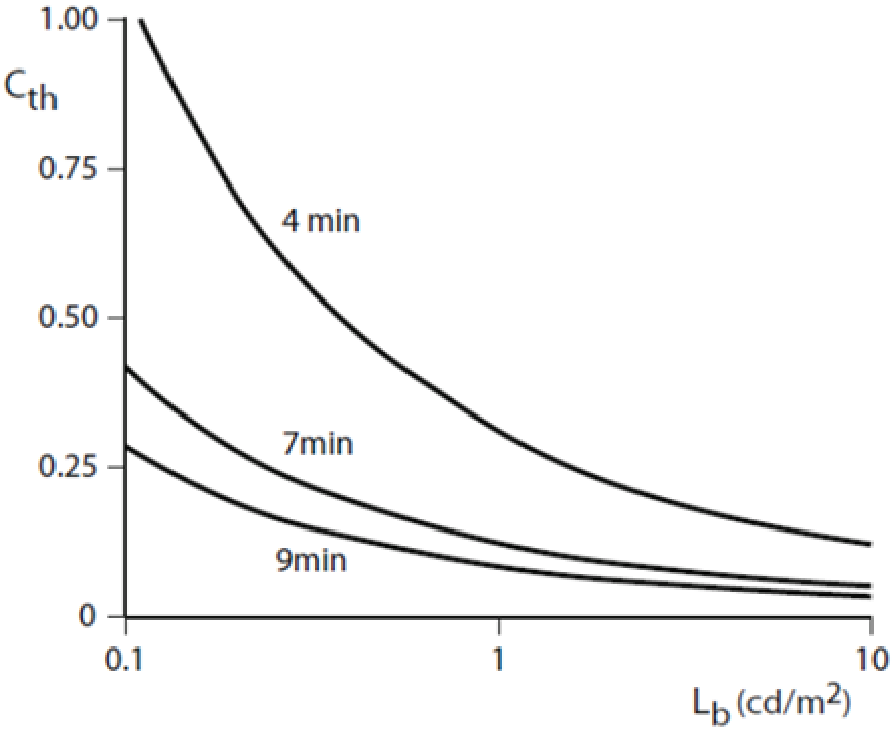


Figure 22. *The decrease in threshold contrast, C_{th} with an increase in background luminance, Lb for objects subtending an angle of 4, 7 and 9 minutes of arc. Positive contrast, observation time 0.2 seconds, observer age 30 years (Adrian 1989 – reference 17)*

Graphic method using Berek's curves

Berek's Curves are usually presented in a logarithmic system of coordinates and they indicate the luminance difference, necessary for visual perception, between the object and its background, depending on the object's angular size given in [minutes]. The curves enable graphic determination of visibility distance. For practical use the basic values of Berek's Curves will be multiplied by a correction

factor called the "Praxifactor" which is a theoretical number lying between +3 and +40. In real cases, two values of the Praxifactor (PF in Fig. 23) are used; these are 5 and 10. They will be discussed later in the chapter. Since the angular size of the object of a constant width is recalculated into the object's distance from the viewer, the X-axis (in green) at the top of the plot indicates the view distance in [m] for the given Background Luminance, Colour and Praxifactor.

A way of plotting the visibility distance for a dry road and a pedestrian wearing clothes colour 4 with coefficient of reflexion ρ=0,080 (see Fig. 14) is shown below.

The value of luminance of the background and object were read at each distance by LMK LabSoft.

Lines PF 5 and PF 10 represent the necessary minimal difference of luminance calculated according to background luminance and object's angular size, and line colour 4 represents the real luminance difference between the object and background. The intersection of these curves in projection on the distance axis (green at the of the top graph) indicates the range of object detection lies between 44 – 52 m. This method is relatively simple but burdensome.

Calculation of visibility distance proposed by U. Carraro (based on W. Adrian's research.)[7]:

The author of this method suggests that the object becomes visible when:

$$|\Delta L_A| > |\Delta L_{th}|$$

Equation 8

where:

ΔL_A – actual luminance difference [cd/m^2]

ΔL_{th} – threshold luminance [cd/m^2].

The current difference in luminance ΔL_A should be measured at each of the examined distances, whereas threshold luminance difference ΔL_{th} for each of the distances must be calculated using the following procedure.

$$\Delta L_{th} = K \cdot C \cdot \left(\frac{A}{\alpha} + B\right)^2$$

Equation 9

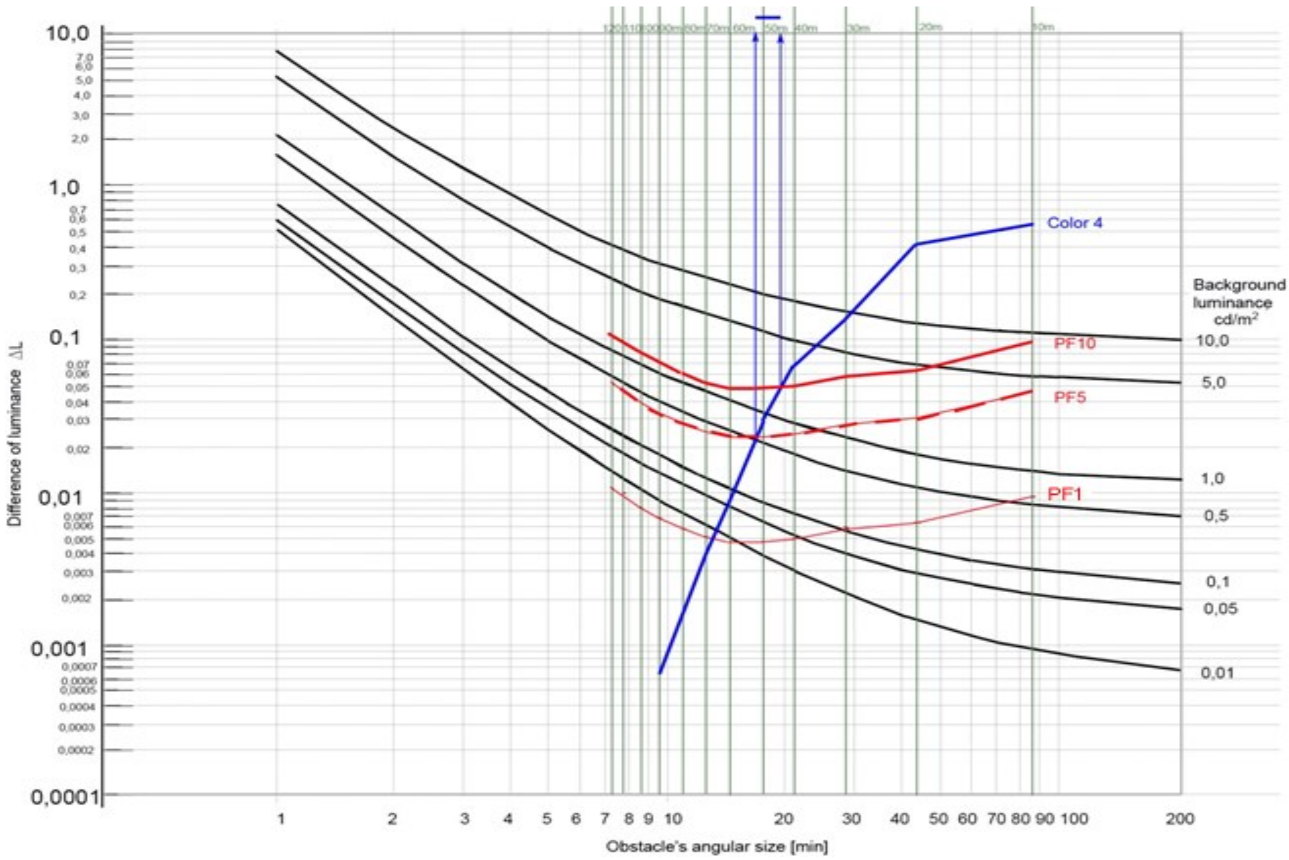


Figure 23. *The plot for the sighting of a pedestrian wearing clothes in colour 4 on a dry road (44–52 m)*

$$\lg A = -0{,}072 + 0{,}3372 \cdot \lg(L_b) + 0{,}0866 \cdot [\lg(L_b)]^2$$

Equation 10

$$\lg B = -1{,}256 + 0{,}319 \cdot \lg(L_b)$$

Equation 11

where:

α – object's angular size [min]

L_b – luminance of background [cd/m^2]

A, B – constant dependent on Lb (equation valid for: 0,0042 [cd/m^2] < Lb < 2,6 [cd/m^2])

K – constant for probability of noticing objects: K=3,1 for 100% probability

C – Praxifactor: C=10 (for unexpected objects in normal conditions).

After the calculation of all pairs of luminance (ΔL_A and ΔL_{th}) these values should be plotted as a function of distance (100m to 10m before the object) and finally read for what distance these lines intersect. It will be –of course – only be an approximate visibility distance.

There are numerous publications available on the research and theoretical calculation of object detection both in English: Kosmatka W [8], Adrian W. [10], Narisada K. [11], and in German: K. Schmedding & M. Becke [9], M. Eckert [12].

The results of these calculations for identical objects differ slightly between the authors (10 –20% of distance), which indicates the complexity of the problem.

In the authors' studies [14] the luminance for objects in grey scale colours was measured and thereafter the visibility distances using Berek's curves were calculated. The background conditions used were a dry, a snow-covered and a wet road. Two values of Praxifaktor: C=5 (recommended for cases demanding special attention such as at the intersection of roads, pedestrian crossings or other locations where hazards are to be expected) and C=10 (for cases where the conditions would mean that an object or hazard would be unexpected). The results of these tests and calculations are presented in Fig.24. Three photos for the object with the colour code 4 in the table (φ =0.095) are shown in Fig. 25; the photos were taken near the visibility range.

It can be seen from the table (Fig. 24.) that on snow covered roads the three darkest colours are noticeable almost simultaneously. Equally where the objects is bright relative to a dark background (dry road) or dark relative to a light background (snow) first visualization occurs earlier than with an average gray object. It is also interesting to note that with negative contrast (snow) the visibility of the object is at a greater distance when both lighter and darker that the average grey codes (3 and 4), whilst the distance degrades continuously from white to black with positive contrast (dry road).

Colour	1	2	3	4	5	6
φ	0.44	0.22	0.12	0.095	0.05	0.04
dry	77-69 m	68-63 m	58-52 m	55-48 m	53-46 m	42-33 m
snow	64-56 m	49-38 m	39-31 m	49-34 m	50-34 m	51-28 m

Notice: the longer distances are for C = 5 and shorter for C = 10

Figure 24. *Object detection distances for particular colours in the grey scale (calculated with Berek's curves for C = 5 and C = 10)*

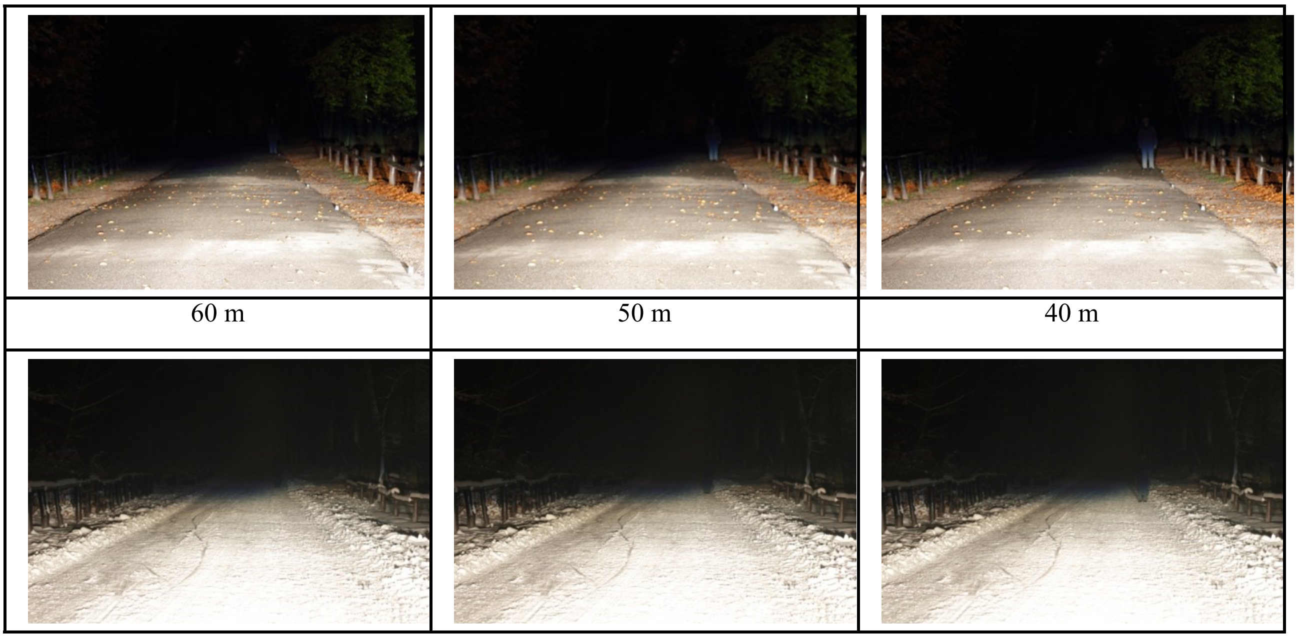


Figure 25. *Photos for the object with the colour code 4 taken near the visibility range: upper photos – dry*

Detection of objects in glare

The human eye's ability to register visual information can be disrupted by any high luminance within the field of vision. The effects on any individual person will be dependent on a variety of psychological and physiological factors. The phenomenon is called "glare".

Glare can result from car headlamps in the oncoming carriageway, street lighting and reflected lighting on wet road surfaces. The headlamps on the cars behind reflected through the mirrors, and light advertisements in towns, etc can also have an effect. The physiological mechanism by which glare affects the eye is known to be the effect of veiling luminance Lv within the eye. Veiling luminance produces discomfort that can be rated in de Boer scale.

The effect of the equivalent veiling luminance on the luminance contrast of an object can be estimated by adding it to the luminance of both the object and the immediate background and the simplified equation looks like this:

$$K_v = \frac{L_o - L_b}{L_b + L_v}$$

Equation 12

where:

L_0 – luminance of object

L_b – luminance of background

L_v – equivalent veiling luminance [cd/m^2]

The equivalent veiling luminance $\mathbf{L_v}$ in the driver's eye can be calculated if the illuminance in the driver's eye from an n-th glare source [lx] can be measured. It can be done easily if a luxmeter sensor is placed in front of the eye and the luminance value is measured in stepped distances to the oncoming car or a stationary object. Moreover, from each point of measurement the angle between the line of sight and the line to the n-th glare source must be measured (Fig. 26). The formula for equivalent veiling luminance applies to glare sources positioned between 10 and 300 from the line of sight.

The equation for equivalent veiling luminance in [cd/m^2] is:

$$L_v = \sum\left[\left(\frac{10 \cdot E_n}{\theta_n^3} + (1 + \left(\frac{A}{62{,}5}\right)^4\right) \cdot 5 \cdot \frac{E}{\theta_n^2}\right]$$

Equation 13

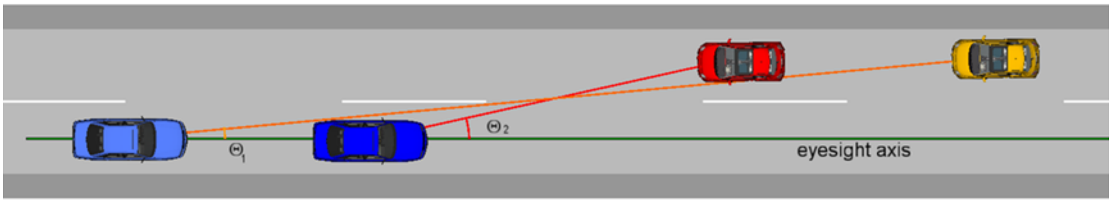


Figure 26. *Changes of angle between line of sight and line of glare source as vehicles approach each other.*

where:

L_v – equivalent veiling luminance [cd/m^2]

A – age of driver [years]

E_n – illuminance of the eye from the n-th glare source [lx]

Θ – angle of the n-th glare source from the line of sight [degrees].

This formula, developed by CIE 2002, is suitable for the angular range of 1° to 30° from the line of sight, for both young or old persons. In actual practice the formula is only suitable in the case of one oncoming car, because if there are more sources of glare, it is difficult to switch on each of them for separate measurements of illumination and angle. For one car it is quite easy, because illuminance is measured in the driver's eye from one oncoming car. For example, illuminance from one car equipped in DE low beam lights, measured at 2.5 m side distance to the left from the driver's eye to the centerline of this car is shown in figure 27.

When the luminance of objects and background are measured by the photographic method (e.g. LMK), in the photographs taken at each particular distance, all other sources of glare were visible. The procedure of measuring veiling luminance from all glare sources (surfaces in a calibrated photo) and measuring luminance of the object and background is easy. What must be done is to recalculate the veiling luminance from each source of light using a relevant equation, taking into account the size of the object, its angular location and distance from the car, and finally sum them (Fig. 28).

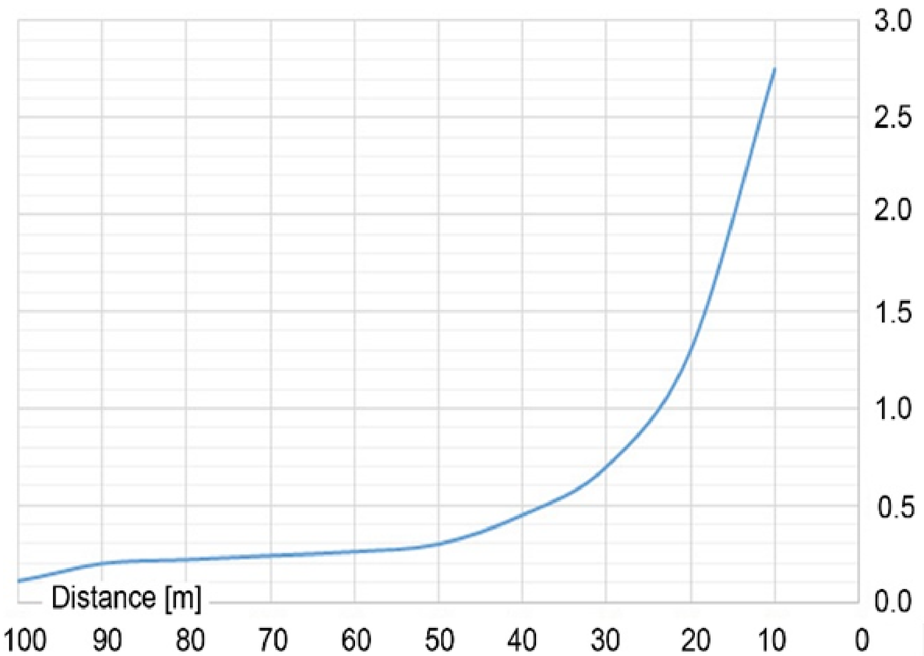


Figure 27. *Illuminance in driver's eye while passing oncoming vehicle (low beam) in [lx].*

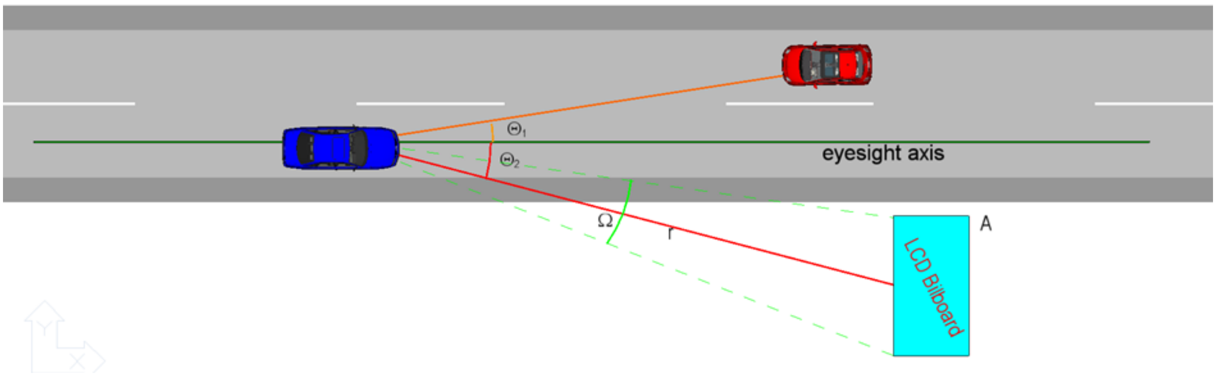


Figure 28. *Calculation of luminance of glare from different sources.*

$$L_v = 10 \cdot \sum_{i=1}^{n} \frac{L_{vi} \cdot \cos(\theta)}{\theta(\theta + 1.5)} \cdot \Omega$$

Equation 14

where:

L_{vi} – luminance of -th glare source,

θ – angle of glare source off the vision fixation axis in [°], which should lie within the 1.5°< θ < 30° range,

Ω – spherical angle $\Omega = A/r^2$, where **A** – surface of glare source [m^2], **r** – distance between the viewer and glare source [m].

If the diagram of contrast is to be used for further calculations, the previously calculated luminance of glare has to be introduced to the denominator in the Weber modified equation (Eq.12) .

If Berek's curves or luminance difference threshold are to be used, the method proposed by Carraro has to be followed [7].

Initially the Threshold Increment TI (Schwellenerhöhung) must be calculated using the equation:

$$TI = 65 \cdot \frac{L_v}{L_{bavg}^{0,8}} \quad [\%]$$

for range: L_{bavg}=0,05 .... 5 [cd/m^2]

Equation 15

$$TI = 95 \cdot \frac{L_v}{L_{bavg}^{1,05}} \quad [\%]$$

for range: L_{bavg}=5 .... 2000 [cd/m^2]

Equation 16

valid for: Illumination in driver's eye E=0,1 ... 500 [lx], θ – angle of glare source lies within 1.5°< θ < 30° range

The newly added value in the above equation is $L_{b\ avg}$. This value is defined as the average background luminance over the field of view with an opening angle ± 300 to the eyesight axis in [cd/m^2]. Some authors equate $L_{b\ avg}$ with L_b, but in our opinion it is more favourable to introduce the value of $L_{b\ avg}$ measured a little ahead of the object on the same half of the road. That is where driver's eyes are focused while driving.

Now only one step separates us from the calculation of the new value of threshold luminance for glare conditions, based on the previously calculated threshold luminance without glare condition. The equation is:

$$\Delta L_{th\ glare} = \Delta L_{th} \cdot TI / 100$$

Equation 17

The *"good practice of experts"* demands that one always compares the calculated values with the results of other studies and observations.

For practical comparison the diagram (Fig. 29) of visibility distance of an object with reflectance $\rho = 0{,}12$, published previously by Mortimer & Becker, 1973, reported in [13] is shown below.

The tests proved that visibility distance to an object decreases by about 20 – 25% on dry roads and up to 40% on water-covered roads, depending on the road width and illuminance of oncoming lights.

As can be seen graphically above, there is a period after passing an oncoming car, when the driver's perception ability does not immediately return to the previous condition. This process continues for 1–4 seconds depending on the level of glare, whilst on the approach the minimum visibility distance can be as low as 25–15 metres if looking towards the oncoming car.

Movement of an object

The analysis so far has been concerned with cases involving a stationary object (e.g. pedestrian). In general, if the pedestrian is walking along a road, this approach is correct. But if the pedestrian is moving perpendicular to the road axis and fast, the moment when entering the illuminated area must be calculated. Fig. 30 is a model of such an event, where both speeds are known, and V_c is the car speed and vp (v_{px}, v_{py}) is the speed of the pedestrian.

Calculation procedure is as follows:

1. Calculate the angle $\alpha = \arctan v_{py}/v_c$
2. Draw a line from contact point on the car at an angle α to the border of light contour (3.2 lx) and find the distance S_1

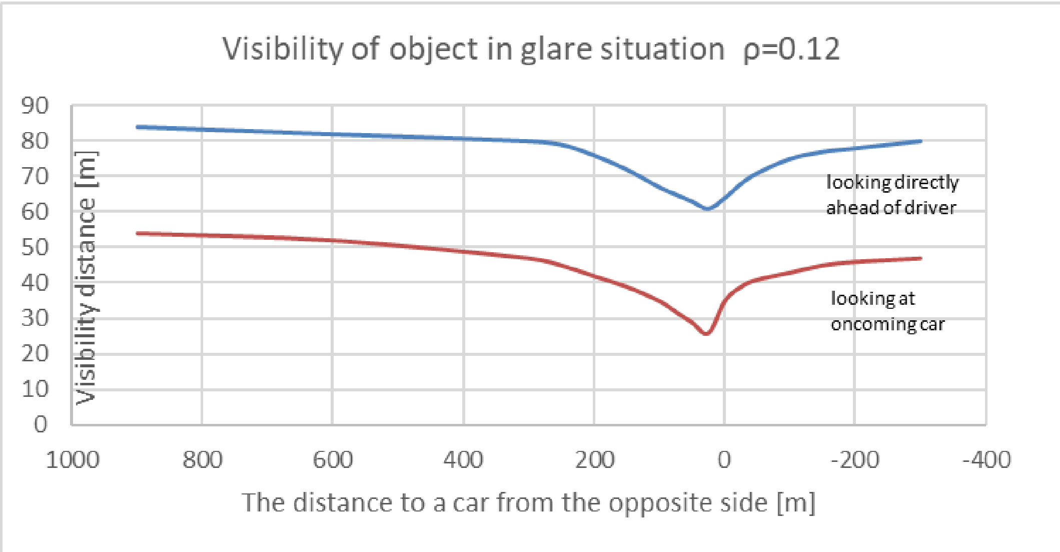


Figure 29. *Visibility distance of objects in glare from oncoming traffic.*

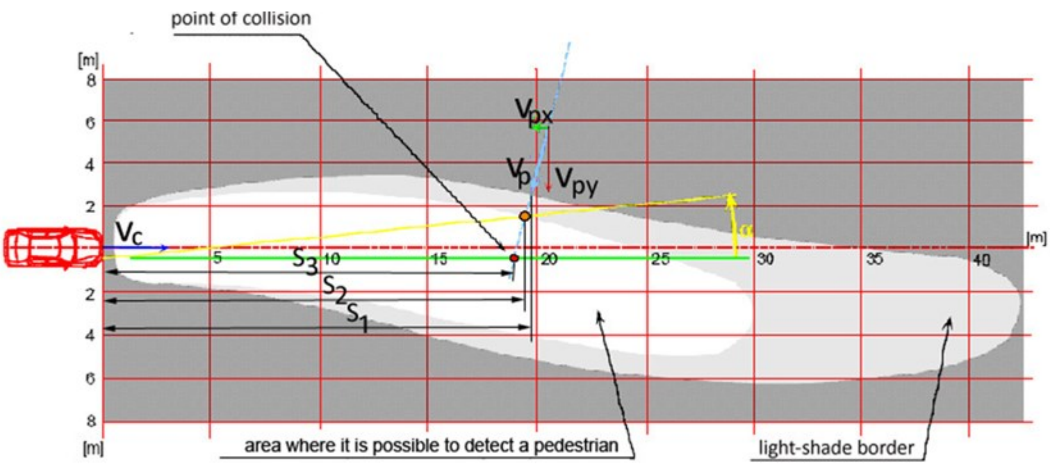


Figure 30. *Calculation of impact of pedestrian's movement on visibility distance.*

3. Calculate visibility distance (for stationary objects) S_2. This distance can be calculated as:

$$S_2 = S_1 \cdot \frac{H - h}{H}$$

Equation 18

where:

H- height of the middle of reflector (beam),

h- light beam level on object 0.25-0.3 m (as minimum for detection).

Notice: value S_2 can also be established in another way.

4. Distance for recognition of object S_3 can be calculated using the effect of pedestrian's speed

on pedestrian's approach

$$S_3 = S_2 \cdot \frac{v_c}{v_c + v_{px}}$$

Equation 19

on pedestrian's walking away

$$S_3 = S_2 \cdot \frac{v_c}{v_c - v_{px}}$$

Equation 20

Other important remarks

The analysis of the visibility process in night conditions requires a multidisciplinary approach. The literature on the subject is extensive and growing. Below, some selected information is given that may prove useful when the expert is considering the conditions applying in an accident analysis and reconstruction.

- Many modern cars have additional lights which activate automatically during cornering. In Fig. 31 differences in illuminated space in front of a car and the field of isolux of low beam light and cornering light are shown.
- The tests on visibility [15] with the same type of reflector but with different bulbs showed a wide variation. Modern halogen bulbs (H7), designed especially for night conditions like Philips Blue Vision (additional marks: BV), Osram

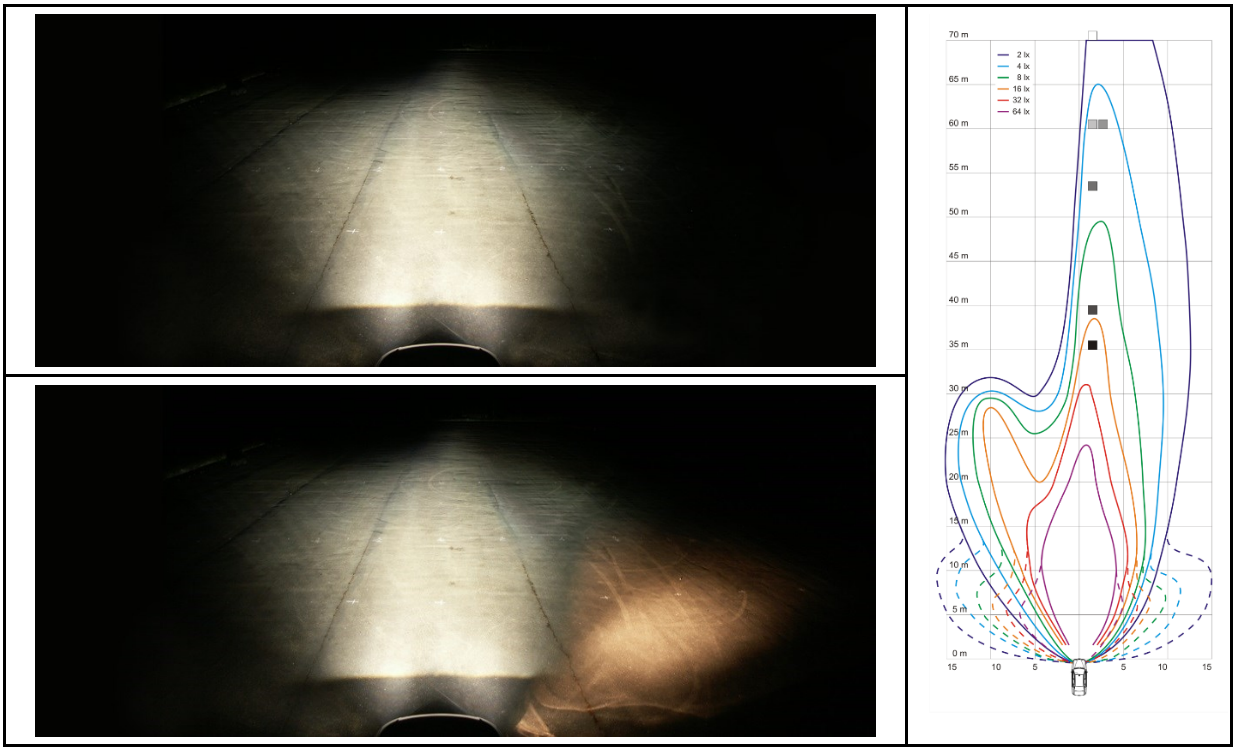


Figure 31. *Additional cornering lights from VW Passat in photos and on isolux field.*

Cool Blue (CB), Philips Vision Plus +50% (VP), Osram Silverstar +50%, proved that discernibility distance could be increases by 25–45%, however other bulbs like Philips Premium +30% and Philips Night Guide (NG) gave lower results in the region of 10-20%.

- Although it is rather infrequent for a pedestrian to be lying in the road, it does happen, especially where the person is exceedingly drunk or has been hit by a vehicle in a previous incident. The author performed tests using a lying human dummy wearing dark clothes, which did not contrast with the road. A comparison was made between the lying dummy and a figure standing at the critical distance (Fig. 32). It is clear that due to the vertical posture of the pedestrian, in a position which would normally be expected on the road, the lighter elements such as the hands and face are more identifiable. With the upper parts of torso hidden in the darker background, these elements are also in sharper contrast than would be the case if the upper torso were more visible.
- In contrast the lying person is often in an unexpected position in the centre of the road and at the border of light and shadow. It is unlikely to be a situation which has been experienced by the driver in the past and this will inevitably delay recognition. In real life, noticing an object lying in the road is unlikely to occur at more than 20–30 m, and probably significantly less.
- In the case of a person lying on the road two effects can also be observed: contrast of luminance and contrast of colour (Fig. 33). From the same distance of 30 m (particularly on partially light roads –mesotopic vision), it is easier to recognize an object in colour mode rather than in b/w, although the luminance of the object and the luminance of the background will be the same.
- If the driver is to detect a person dressed in dark clothing which includes some white elements, the location of those white elements will be significant. White shoes, even if the person is not moving, will be easier to see than a white cap. This stems mainly from the driver's line of view, which will normally be directed downwards towards the

Figure 32. *A lying pedestrian dummy versus a human wearing the same colour clothing.*

Figure 33. *A person lying on the road: colour and b/w impression.*

Figure 34. *Visibility from 40 metres: left – white shoes, right – white cap.*

road ahead, but also from loom of the headlamp profile which is angled downwards to illuminate the road surface. Objects at a higher level will be illuminated later (Fig. 34).

Strategy of night driving

Whilst the physical parameters governing the perception of objects/hazards on the road are independent of the country, the expert's assessment may sometimes vary from country to country. The jurisprudence in different countries and the associated variations in road traffic law, will have a bearing upon the levels of responsibility devolving onto both drivers and pedestrians.

The fact-based and technical knowledge in this field indicates that the lights of a passing vehicle usually have a range of approx. 50–55 m to the border of light and shade. Research proves that object detection based on colour and the type of lights varies from 30–120 m. From a comparison of these parameters, we can see that often the driver cannot stop before a hazard, even if he is driving at a safe speed (stopping distance compared with distance of light-shade border).

Each country must therefore work out a strategy of its own regarding the assessment of drivers' behavior, particularly with regard to the assessment of "safe speed", and the driver's obligation to predict the presence of unlit obstacles on the road.

Looming of objects

In practice, there are traffic events in which the driver (observer) and another vehicle are moving along tracks parallel or near parallel to each other. Often this happens when the preceding vehicle starts braking, which ends with a collision called rear-end collision or when a vehicle is turning left across an oncoming vehicle, which has priority. The main problem, in these incidents, is the ability to determine the correct distance and speed of the approaching vehicle. A classic example is the difficulty in determining the speed of an approaching train when we are waiting on the

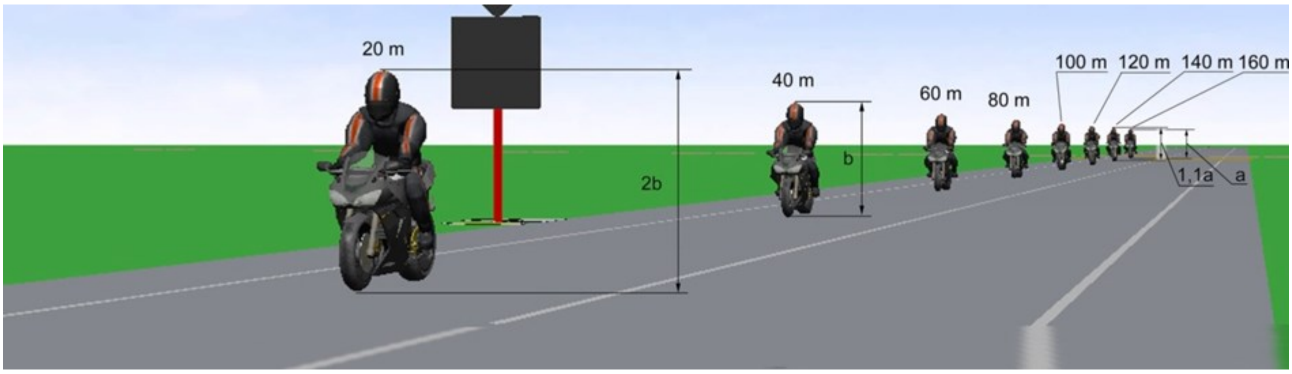


Figure 35. *Motorcyclist looming to the observer.*

platform, and the train is relatively far away.

Figure 35 shows a motorcyclist who is moving closer to the observer. If he moves twenty metres, from a distance of 160 m to 140 m, his initial size (height, width) will increase by less than 10% (from a to 1,1a). But the same motorcyclist, traveling at the same speed and moving between 40 m to 20 m away from the observer will increase his size twofold (with b to 2b).

At a greater distance, the angle at which the object edges are observed changes only slightly. At closer observation distances the object grows many times faster in the same interval of time.

Researchers [1, 5] have tried to establish the limit of distance or the speed of looming of the object from which a determination of speed can be made.

R. G. Mortimer and E. R. Hofmann found the minimal detection threshold was based on a change in the viewing angle Θ per unit time. They established the value at $\Theta = 0.003$ rad/s (0.170°/s). Other researchers have also confirmed this value, adding a standard error of 0.001 rad/s.

To determine the distance for correct speed recognition the equation was proposed:

$$S = \sqrt{\frac{w \cdot v}{(0.002 \div 0.004)}}$$

Equation 21

where:

S – distance limit for easy speed identification [m],

w – width of object [m], (e.g. 0.7 m for motorcycle, 1.8 m for car),

v – speed [m/s].

In figure 36 the estimated distance for possible identification of looming objects is presented. As an example, the motorcycle travelling at the speed of 140 km/hr is likely to be recognized from about 95 m distance. That distance would be covered in 2.4 seconds. Using the same speed, the recognition of a car's speed could be correctly estimated from a distance of 153 m. Therefore, there is a significantly higher risk of collisions with motorcycles in turn left manoeuvres than with cars.

During our research [16] we also noticed that the observers who were viewing motorcyclists in this way usually underestimate the speed. The magnitude of underestimation increased with the speed of the oncoming motorcycle. (Fig. 37).

At the end

In this short review on Vision and Visibility, the author has addressed some of the research into the problems of perceiving hazards in night time driving scenarios. The intention has been to express that research in a simple format which may be of assistance in understanding this fairly complex area of study.

The theories and equations presented here are not the only valid ones, especially as in recent

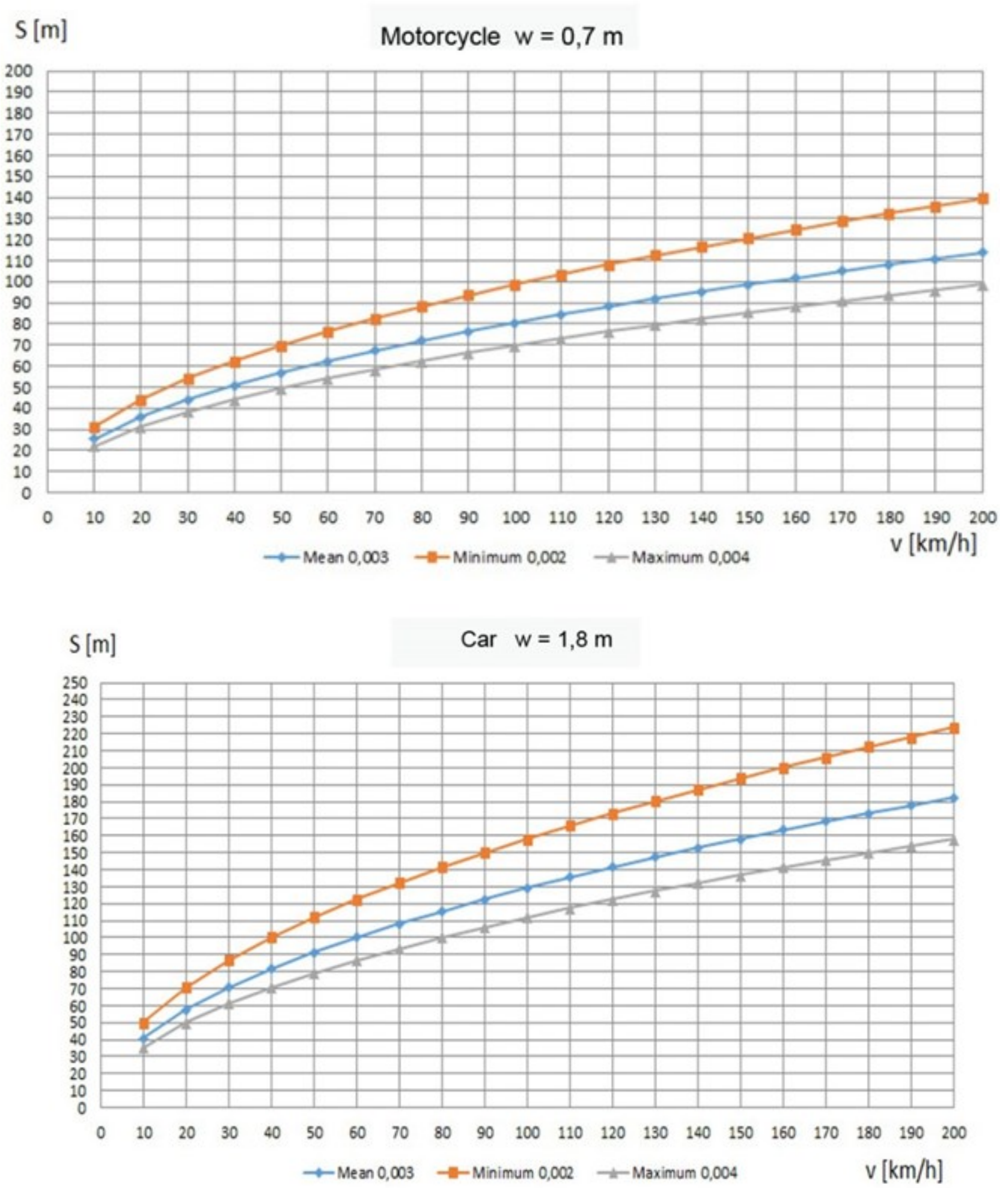


Figure 36. *The distance limit for vehicle speed identification [16].*

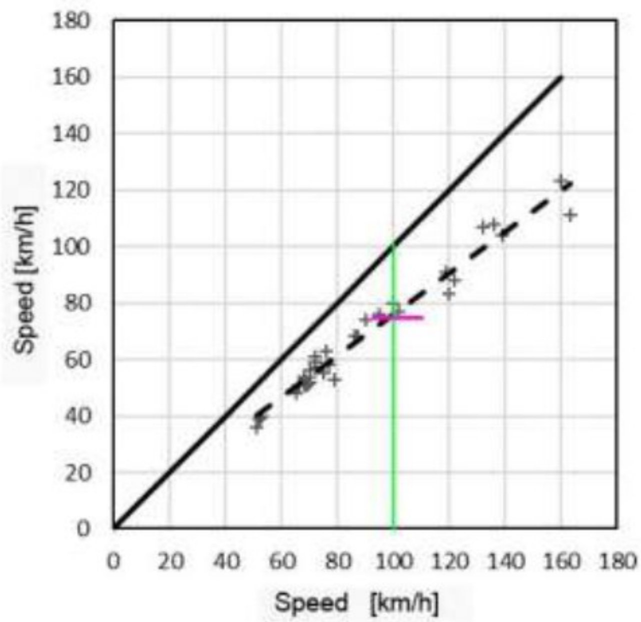


Figure 37. *Comparison of real values of the speed (continuous line) with the estimated values (points). The dotted line represents the trend line. For example, 100 km/h was estimated at 75 km/h.*

years, research in this field has progressed rapidly. One of the driving forces behind this being the introduction of autonomous lighting in vehicles, and in particular the introduction of new forms of lighting beyond the traditional dipped and main beam. Of course, the basic principles described in the article are still valid to a large extent, however it must be remembered that in cases where autonomous lighting systems are involved, the expert may not be able to determine the actual headlamp setting in the leadup to the accident. This state of affairs will continue until this data is automatically stored in the vehicle's Events Data Recorder. The author hopes that the above text on Vision and Visibility will be helpful to Road Traffic Accident Investigators and any other parties with an interest in this area of research.

NOTICE:

The author is especially grateful to Mr. Ian White and his wife for their interest in the above text, for reviewing it, inspiring comments and remarks, as well as for preparing its English-speaking content.

Bibliography

[1] Green, M., Allen, M.J., Abrams, B.S., Weintraub, L.: Forensic vision with application to highway safety, Lawyers & Judges Publishing Company, Inc. 2008, ISBN -13: 978-1-933264-54-7.

[2] Bahlerova G., Moznosti osvetleni vosidel pro zvyseni bezpecnosti silnicnovo provozu, Diploma work, USI Brno 2012.

[3] Unarski J., Wach W., Zębala J., From researches over perception objects in degraded visibility conditions, EVU Congress 1999.

[4] Muttart J.W., Kauderer Ch., Unarski J., Barlett W., Johnston G., Barshinger D., Romoser M., Determining when an object enters the headlight beam pattern of a vehicle, SAE Technical Paper No. 2013-01-0787, Warrendale PA 2013.

[5] Olson, P. L. and Sivak, M. (1983). Improved Low-Beam Photometrics. The University of Michigan Transportation Research Institute. Report No. UMTRI 83 -9.

[6] Kledus R., Bradác A., Semela M., Comparative Perception of Objects by Drivers from Stationary and Moving Vehicles in Regular Road Traffic, EVU Congress, Prague 2010.

[7] Burg H., Moser A. [ed.], Handbuch Verkehrsunfallrekonstruktion, 2. Auflage, Carraro U., C13 Dunkelheitsunfälle, pp. 875–889, Vieweg + Teubner Verlag, Wiesbaden 2009.

[8] Kosmatka W. J., UDC – Uniform Detection Characteristic for Detecting Roadway Obstacles, SAE Technical Paper Series 2006-01-0948.

[9] Schmedding K., Becke M., Das SBU-diagram und die Bestimmung von Erkennbarkeitsentfernungen mit Hilfe des SI-Diagrams, Verkehrsunfall und Fahrzeugtechnik 1/1990.

[10] Adrian W., Visibility of targets: Model for calculation, Lighting Research and Technology 1989, Vol. 31(4), 181–188.

[11] Narisada K., Role of Adaptation in Perception under Traffic Lighting Conditions, PAL 2001 Symposium, Darmstadt University of Technology.

[12] Eckert M., Lichttechnik und optische Wahrnehmungs-sicherheit in Straßenverkehr, Verlag Technik GmbH, Berlin-München 1993.

[13] Olson P., Forensic Aspects of Driver Perception and Response, Lawyers & Judges Publishing Co. 1996.

[14] Unarski J., Wach W., Ciępka P. Determining Visibility Distance Based on Measurements with LMK System EVU Congress, Florence 2013.

[15] Reza A., Ciępka P., Unarski J., Night Visibility with new Kinds of Light Bulbs, including Snow-covered Roads, EVU +

ITAI Congress, Hinckley 2009.

[16] Unarski J.,Reza A., Wach W.,Zębala J., Ciepka P., Looming effect and motorcycles, Proceedings of EVU Congress, Barcelona 2019

[17] Van Bommel W., Road Lighting , Fundamentls, Technology and Application, Springer, ISBN 978-3-319-11465-1

Contact

Eng Jan Unarski, PhD

E-mail: junarski@gmail.com

Impact

Submissions invited

Next Edition Sept./Oct. 2021

As ever, the Editor would be very pleased to hear from members, non-members or subscribers, who have produced material that they feel would be of interest to readers of *'Impact'*. Details of research projects or relevant collision investigation testing would be particularly welcome. Attracting sufficient numbers of articles for publication in the Institute's journal remains a difficulty! Whilst the Editor is delighted to receive papers from overseas contributors, a greater supply of 'home grown' material would also be very welcome.

If you have any questions regarding the publication of an article / paper, or simply wish to discuss the possibility of preparing a piece for the journal, please contact the Editor at **editor@itai.org**

Visit the Institute's website at www.itai.org

'Impact' subscription, and all other enquiries should be addressed to

The Institute of Traffic Accident Investigators
Administration Department
Column House, London Road, Shrewsbury SY2 6NN

Tel +44 (0)8456 21 20 66 : Fax +44 (0)8456 21 20 77 : email admin@itai.org

Registered Charity No. 1014784
Registered in England as a Company No.2753420 : Registered Office - Column House, London Road, Shrewsbury SY2 6NN
 ISSN 0959-4302

Printed by DPS Print (Gravesend) : Tel. 01474 533395

ISO/IEC 17020:2012—An Update

Frances Senior
Head of the Forensic Collision Investigation Network

FORENSIC COLLISION INVESTIGATION NETWORK

In November the first Forensic Collision Investigation Base (FCIB) in the network of all 43 Police Forces in England and Wales, will undergo a UKAS assessment against the ISO/IEC standard of 17020:2012 and the Forensic Science Regulators Codes of Practice and Conduct. Getting to this point has been the culmination of around 3 years work, prior to the launch of the FCIN.

ISO accreditation is not an easy journey, but it is a vital one to have the independent assurance that our quality systems are working effectively and that we have an effective continual improvement ethos, that methods are validated and competent individuals work to standard operating procedures.

Whilst we look forward to the assessment, we keep reminding ourselves that this is a 'pilot' accreditation, designed to test that we can apply it effectively. We are not expecting perfection nor should we – this is a new world for Police delivered FCI and we anticipate that areas for improvement are identified. To provide some context around that statement, it is important to realise that achieving accreditation has been hugely challenging for all Police delivered forensics. There are unlikely to have been any assessments that have not yielded 'findings' and most have not achieved accreditation on a first assessment. What we do know though is that the FCIN and the pilot base (North Wales Police) have worked exceptionally hard, collaboratively, and scientifically to prepare for the pilot.

In many ways, North Wales FCIB were already way ahead of the readiness curve for accreditation. They had processes and procedures in place and were already operating within a forensic environment, being under Scientific Support. They had invested in their staffing and training structures and provided facilities that would be compliant with the standard and the codes. The North Wales unit have been led by the head of forensics for many years and have been guided towards accreditation prior to the inception of the FCIN – in short, they were in the best place possible to be the pilot, but notwithstanding their strong foundations they have still been working relentlessly to prepare.

In addition to testing the North Wales FCIB, UKAS will be testing the FCIN – this is the first time that a networked approach has been taken with regards to accreditation, so the concept as well as the detail will be scrutinised – legally, locally, nationally, and scientifically. As I take a pause to write this article, it is easy to worry about things that might not yet be 100% where we would like them to be, but instead I want to look at what we have achieved in our readiness for this moment. Every action that we have undertaken to get to the position we are in today has been seen as an opportunity to improve and I think we can confidently say that we have

Scope 1 Science

We have now finished the validation of activities within our first scope of accreditation - this is not the end of the story though. In addition to all the other technical activities that will follow in subsequent accreditation scopes, we will have to undertake re-validation of the science in the current scope, should the need arise – for instance in the event of new technology, advancements in science, or issues that transpire along the way.

The activities within scope 1 are listed below and have taken tens of thousands of hours to research, define, test, validate, report and verify:

1. Deceleration Testing – non - ABS.
2. Photography – Terrestrial.
3. Laser Scanning.
4. Analysis of CCTV.
5. Total Station Mapping.
6. Critical Speed.
7. Recording of Collision Scenes/Scene attendance process.
8. Manual Measurements.
9. Control and Avoidance of Contamination.
10. Plan Drawing.
11. Data Acquisition and Retention/Exhibit Handling.
12. Equipment Calibration, Condition Monitoring and Control.
13. Uncertainty of Measurement.

Training and Competency Framework [TCF]

A requirement of the accreditation process is to have ensured that forensic practitioners are not just qualified but assessed and deemed competent. The FCIN have designed an extensive national training and competency framework, which includes qualification pathways, trainee workbooks and a multistage competency test that each FCI in England and Wales will be undertaking.

The witnessed competency assessment is held centrally at FCIN facilities and includes different 'stations', an online invigilated exam and a submission of outputs for scrutiny.

FCIs who do not demonstrate competency in each area will be supported with a development plan created by the FCIN to be undertaken back in the workplace prior to sign off by their supervisor and the FCIN. FCIs who do demonstrate competency sufficiently will be recorded on the FCIN register of authorised FCIs.

In addition, the TCF will also enable FCI's to access SAE International and all their journals, research and publications, another valuable tool that will enhance the ongoing learning and development of practitioners.

This robust process will ensure that all FCIs in England and Wales are tested against known outcomes, independently verified and capable of delivering activities within the scope of accreditation.

Quality Assurance Process

A very comprehensive and ISO compliant QA process has been designed and is about to be launched to the network. All FCI reports will now be completed in a phased manner, with independent QA checks carried out by FCIs in other bases. These reports will include critical findings checks, hypothesis reviews and conclusions checks at various stages of the process to ensure impartiality and reduce the impact of unconscious bias. There are mechanisms built into the QA process for mediating disputes, with each stage documented on national forms and members of the FCIN team being drawn upon to review and remediate.

This process will reap multiple benefits, it will ensure network wide consistency of approach. It will share learning and expertise between FCIs – not just in their base or region, but across England and Wales. It will minimise risk of error or oversight, it will increase impartiality and scientific rigor and ultimately – will increase the standards of reporting providing the best service possible to victims and the courts.

Facilities

The FCIN now has a physical home at Cranfield University, Bedfordshire. The facilities include a briefing room / office, asset storage, a road type test zone and access to other university resources where required. Cranfield University has a strong 'accident investigation' background across transport sectors, strong links to the motor industry and along with extensive facilities, also houses a forensic centre.

Standardised national forms and documents

We have created a vast array of FCIN forms and documents that will be utilised in each base. These will ensure that all Police FCIs will use the same documentation, procedures and reports and standardise the products produced to victims, families, the courts and third parties.

Quality Management System

The primary responsibility of the FCIN is to ensure network wide consistency and ISO accreditation for each base. The Quality Management System underpins all the activities, policies and procedures required to achieve this. We have developed processes for continual improvement that every Police FCI can utilise, non-conforming work processes, audit regimes, base readiness processes on top of all the other documentation and systems that have been developed to evidence compliance against the standards and codes.

The Police FCI landscape has and will continue to change dramatically in England and Wales as we become an ISO accredited and regulated forensic discipline. The transition has not been easy, change is often unpopular, and it will continue to be challenging at times, however with it comes many benefits that have seen investments in technologies, vehicle fleet, estate, and training. It will provide consistency to the end user and the confidence that everything, from the science to the equipment, to the individuals ability and the outcomes of an investigation have been thoroughly tested, checked and quality assured. To quote William A. Foster Quality is never an accident; it is always the result of high intention, sincere effort, intelligent direction and skillful execution; it represents the wise choice of many alternatives."

Frances Senior

Head of the Forensic Collision Investigation Network,

National Police Chiefs' Council.

E-mail: -

frances.senior@westyorkshire.pnn.police.uk

FORENSIC COLLISION INVESTIGATION NETWORK

Rates for advertising in 'Impact'

'Impact' is published 3 times each year (April, September, December) and is circulated to all members of the Institute in the UK and overseas. In addition, there are many non-member subscribers (also in the UK and overseas), who receive the publication.

The journal reaches specialist police officers, researchers, private consultants, engineers and other professionals involved in collision investigation.

'Impact' is now in its 29th year ! Over that period, advertisements placed in the journal have proved highly effective in alerting its readers to -

- Specialist Courses
- Conferences
- Specialist equipment / software
- Career opportunities
- Professional services

Anyone considering advertising in **'Impact'** is invited to contact the Editor, who will be pleased to assist by providing further details and deal with any queries.

editor@itai.org

WREX 2023

April 17 – 21

Orlando, Florida

The next World Reconstruction Exposition, WREX 2023, will be held on April 17 – 21, 2023 at the Rosen Shingle Creek Hotel in Orlando, Florida. WREX 2016 was the largest crash conference ever hosted and many attendees said that it was the best they had ever attended. WREX 2023 is expected to be larger and even better than WREX 2016.

WREX 2023 will be hosted by a large group of international associations. Representatives from 24 groups are hard at work planning for, and refining, the next event. WREX 2023 will feature many of the top international speakers in the ever-expanding field of collision reconstruction. Crash Test Day at WREX 2023 will utilize multiple crash test teams to provide numerous high speed crash tests with minimal down time. The new off-site crash test location will facilitate easy access between staged collision events and provide for a better attendee experience. The Interactive Field-Testing Day (a.k.a. "Reconstruction Midway") at WREX 2023 will be held at a larger venue on site at the host hotel to accommodate even more exhibitors. High quality sit-down lunches will be served each day of the conference and are included as a part of your event registration fee. For those intent on getting the most bang for their training buck, evening presentations, including poster presentations of select collision reconstruction topics, will be available at WREX 2023.

The WREX 2023 planning staff can do a better job coordinating this event with your cooperation. The staff asks you to visit the conference website - www.wrex.org and add your name to the list of attendees ASAP. There is no cost to "pre-register" and no penalty for removing your name. An approxi-mate count of conference attendees will help the staff develop the best possible plan for the event. As a bonus for helping the staff by "pre-registering", two of the "pre-registered" attendees, whose names have been added to the list by September 30, 2021, will receive free admission to WREX 2023. Please help us to make this the best conference you have ever attended. Remember the attend-ee room block at the host hotel sold out in 2016. The WREX 2023 planning staff encourages you to reserve your hotel room ASAP to ensure your ability to stay on site while attending this sure-to-be spectacular event.

If you were unable attend WREX 2016, ask someone who did. We will see you at WREX 2023.

PRE-REGISTER NOW AT WWW.WREX.ORG

Video Analysis in Collision Reconstruction

The Institute of Traffic Accident Investigators announce the provision of a training course in the subject of Video Analysis in Collision Reconstruction, presented by FCIR. This course is aimed at Collision Investigators who routinely handle CCTV footage from numerous sources.

5 Day Training Course (Virtual Delivery)

Fully Booked

This course will discuss the fundamentals of image capture, image compression, image handling and artefacts relevant to the Collision Investigator. Techniques for establishing frame time intervals and subject positioning using photogrammetry are also covered within this training.

Image presentation is also discussed within this course, with example case studies. A competency examination will also feature at the end of the course with a certificate issued upon successful completion.

£550+VAT ITAI Members
£650+VAT Non-ITAI Members
CPD: 30 Hours

Please register expressions of interest for a second date in Spring 2022 at www.itai.org/events

FCIR
FORENSIC COLLISION INVESTIGATION & RECONSTRUCTION LTD