

Automotive Blind-Zones: A Review of Legislation and the Use of Close-Range Camera Systems

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ABSTRACT

The development of vehicular electronic vision systems for the automotive market is a growing field, driven in particular by customer demand to increase the safety of vehicles both for drivers, and for other road users, including Vulnerable Road Users (VRUs), such as pedestrians. Close-range automotive camera systems are designed to display the areas in the close vicinity of the vehicle to the driver, typically covering the blind-zones of the vehicle. Customer demand is matched by legislative developments in a number of key automotive markets; for example Europe, Japan and the United States are in the process of introducing legislation to aid in the prevention of fatalities to vulnerable road users, with emphasis on the use of vision systems. In this paper we discuss some of the factors that have promoted the introduction of this legislation. We show also that, by the use of wide-angle camera systems, these legislative requirements can be met.

Keywords

automotive camera, wide-angle camera, close-range camera, accident statistics, global legislation, blind-zone, blind-spot, vulnerable road user

1. INTRODUCTION

Safety in vehicles is an ever growing concern in most modernised countries. This has led to several initiatives being undertaken in both Europe and North America. For ex-

ample, the European New Car Assessment Program (Euro NCAP) [2], which was established in 1997, provides objective information on the safety of drivers and passengers in cars in crash situations. In a study commissioned by the Euro NCAP, 94% of respondents list safety in vehicles as a major concern [15]. There are similar organisations in both Japan [17] and the United States [4] (known as JNCAP and USNCAP, respectively).

However, more recently, the protection of VRUs, e.g. pedestrians and cyclists, has increased in importance. VRUs hidden in a vehicle's blind-zone¹ is a major cause of VRU injuries and fatalities globally, as we show later in section 2.1. It is somewhat ironic to note that, with vehicle manufacturers following customer demand by increasing the emphasis on improving the NCAP ratings of their vehicles by strengthening and increasing the size of the vehicles' A-pillars (the vertical or near vertical shaft of material that supports the vehicle roof on either side of the wind-screen), they can also considerably increase the size of the blind-zones caused by those A-pillars.

To match the consumer desire for increased safety in vehicles, the European Union have introduced legislation that requires Large Goods Vehicles (LGVs)² to have large portions of their blind-zones made visible to the driver. Japan is also in the process of introducing similar legislation. While European and Japanese legislation focuses primarily on LGV

¹The term "blind-zone" is used in preference over the other commonly used term "blind-spot", as this is the term used in some of the jurisdictions described in this paper, and more accurately describes the areas that cannot be seen by a driver of a vehicle.

²The term "large goods vehicle" is used in this paper, instead of the term "heavy goods vehicle", as this is the terminology used in most European Union documentation due to the fact that the word "heavy" does not have a direct translation in all European languages.

safety, in the United States legislation targeted at privately owned vehicles is proposed with the aim of preventing children being injured while within a moving vehicles blind-zone.

Wide-angle/fish-eye lenses can be used by automotive manufacturers to provide information about a vehicle's blind-zones to the driver. We will show that, considering the size of certain vehicles' blind-zones, in many cases a camera with a standard field-of-view will be unable to adequately display the blind-zone to the driver. In such cases, wide-angle cameras must be employed. While it is beyond the scope of this paper to investigate the side-effects of using wide-angle cameras, it should be noted that considerable distortion can be introduced when using such devices, although the distortion can be removed via appropriate calibration/correction.

In section 2, we identify the blind-zones that are present in all cars, Sports Utility Vehicles (SUVs) and LGVs. We also examine some statistics for fatalities and injuries on the roads that are linked to vehicle blind-zones in Europe and the United States. In section 3, we examine the legislation from three large automotive markets (Europe, the United States and Japan) that is designed to protect against VRU death and injury due to blind-zones. Finally, in section 4 we suggest how camera systems can be used to meet the requirements of the legislation and display the blind-zones to the driver, particularly by the use of wide-angle camera systems.

2. VEHICLE BLIND-ZONES

A vehicle's blind-zones are the areas around the vehicle that cannot be seen directly by the driver by looking forward or by using any of the vehicles' standard rear-view or wing mirrors. Figure 1 shows the areas around a vehicle that are not visible by the driver of a typical vehicle. The sizes of these areas are determined by the size and design of the vehicle and mirrors, and will vary according to car model and manufacturer.

Consumers Union [8] has examined the rearward blind-zone on many private (i.e. non-commercial) vehicles. The zone was measured by determining how far behind the vehicle a 28-inch (0.71 metre) traffic cone representing a young child needed to be before a person, seated in the driver's seat, could see its top while looking through the rear window. For a 5-foot 8-inch (1.73 metres) tall driver, the distance measured was up to 44 feet (13.41 metres) for a commercially available four-wheel drive Sports Utility Vehicle (SUV) registered in 2006. In the same vehicle, the blind-zone distance for a 5-foot 1-inch (1.55 metres) driver extends to 69-feet (21.03 metres).

The blind-zone for LGVs is naturally much larger than that of a private vehicle. Ehglen and Paidla [10] calculated the forward blind-zones of a given LGV as shown in figure 2. Furthermore, the rearward blind-zones of LGVs tend to be very large; we have measured that several LGVs have a rearward blind-zone that can extend up to 65 metres behind the vehicle on the ground plane.

In summary, the presence of vehicle blind-zones has been shown to be a significant factor in VRU injuries and fatali-

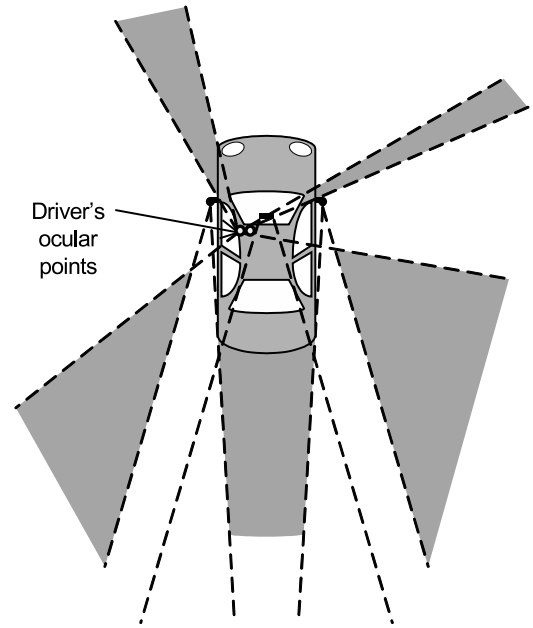


Figure 1: The five blind-zone areas (shown as the shaded area) in a standard left-hand drive car. The sizes of the blind-zones are dependent on the design of the car and the viewing angle of the mirrors.

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2.1 Blind-zone accident statistics

2.1.1 Europe

Official statistics for VRU deaths due to the victims not being visible to the driver of a vehicle in Europe are unavailable. However, the European Commission's CARE Road Accident Database [11] claims that there were 3,961 VRU pedestrian fatalities within urban areas in 2005. It is reasonable to assume that a significant portion of these deaths were caused by the VRU not being visible to the driver of the vehicle.

This assumption is supported by several statistics; the European Commission Directorate-General for Energy and Transport estimates that the lack of visibility in the blind-zone towards the rear of a vehicle directly causes 500 deaths a year in the EU [12]; The Commission of the European Communities estimates that every year, approximately 400 European road users lose their lives in accidents with LGVs, because the driver did not see them, when turning right [6]; the UK Health and Safety Executive reports that in 12 months between 2005 and 2006, 18 people were killed and 620 sustained major injuries due to the intentional motion of the vehicle (either forwards or backwards) in the workplace [22]; the Organisation for Economic Co-operation and Development (OECD) reports that 60% of child casualties occur within 500 metres of their home [20].

2.1.2 United States

Statistics for the United States are equally disjointed, with no official statistics directly available for VRU injuries due to vehicle blind-zones. However, the Kids and Cars Organi-

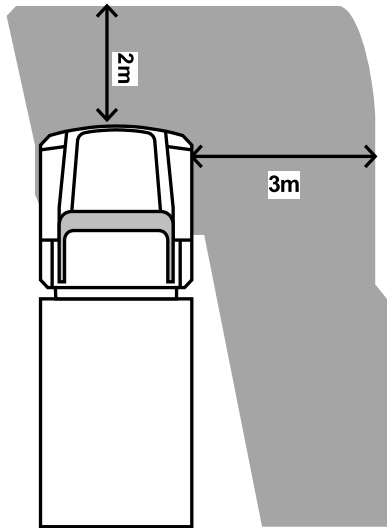


Figure 2: Blind-zones (shown as the shaded area) around the front of a given left-hand drive LGV.

sation in the United States [3] claims that between 2002 and 2006 there have been 941 children killed in non-traffic accidents in the United States. They further claim that 49.5% (or 466 children) of the fatalities were due to the vehicle reversing while children were present in a vehicle’s rearward blind-zone.

The Centers for Disease Control and Prevention (CDC) [18] in a study between July 2000 and June 2001, reported that there were an estimated 9,160 non-fatal injuries to children in non-traffic automotive accidents, with approximately 20% (or 1,832 children) of these injuries caused by the vehicle moving backwards. Between 2001 and 2003, the CDC reported that an estimated 7,475 children (2,492 per year) were treated for moving vehicle backover injuries [19]. Again, while the blind-zone is not directly implicated in these injuries, it is reasonable to assume that a significant proportion of these injuries were due to the children being present in the vehicle’s blind-zone.

Wang and Knipling [25] estimated that lane change/merge crashes in 1991 accounted for approximately 244,000 police-reported crashes with 224 associated fatalities. Furthermore, the authors reported that the principal causal factor in such crashes is that the driver “did not see other vehicle”.

3. LEGISLATION PROMOTING THE USE OF VEHICULAR CAMERA SYSTEMS

Due to the increasing awareness of the vulnerability of pedestrians, legislation has been introduced, or is in the process of being introduced, in several jurisdictions around the world. In this paper, we describe the legislative requirements or potential requirements for the EU, Japan and the United States.

3.1 Europe

In the EU, legislation in the form of Directive 2003/97/EC [13] has already been introduced. Although the initial re-

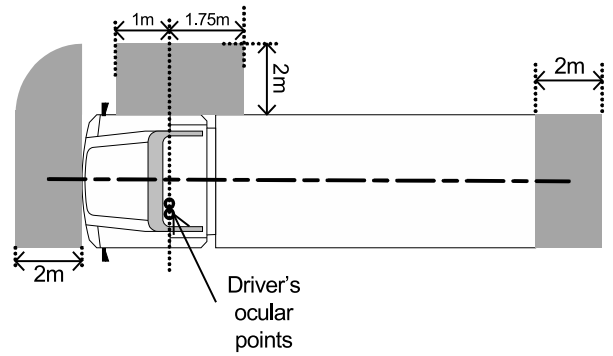


Figure 3: Area required by Directive 2003/97/EC to be visible to drivers of (left-hand drive) LGVs via the use of indirect vision systems (not including areas covered by the standard and wide-angle wing-mirrors).

quirements of this directive help reduce accidents caused by the blind-zones of LGVs and improve road safety for new vehicles circulating from 2006/2007 onwards, the legislation did not cover the existing fleet of lorries in EU. Partially due to the fact that it was estimated that existing fleets will not be fully replaced until 2023, Directive 2007/38/EC [14] was introduced requiring the retrofitting of the required indirect vision systems to all existing fleets. When these directives are fully applied to all LGVs, including new and existing fleets, the European Parliament estimates that approximately 1200 road fatalities could be prevented, which translates into around €2.4 billion to the EU member states, in terms of societal costs [7].

The shaded areas in figure 3 shows the areas of a left-hand drive LGV’s³ environment that must be visible to the driver via the use of “Indirect Vision Systems (IVS)”, as required by these directives. Examples of IVS’s include mirrors in addition to the standard rear-view and wing-mirrors, as well as camera-monitor devices. However, practical problems arise with the use of additional mirrors as the extra mirrors themselves can introduce additional blind-zones, as well having additional cost and styling implications.

There is a clear provision for the use of camera-monitor devices for the coverage of vehicle blind-zones in this directive. In fact, the use of camera-monitor devices over mirrors is often not only desirable, but necessary. For example, it is practically impossible to cover the area at the rear of an LGV with mirrors alone, so camera-monitor systems are the only practical solution.

3.2 Japan

In Japan, there is also proposed legislation to enable objects within a portion of a medium and large vehicles blind-zones to be detected by the driver, either directly, by mirror or by camera-monitor device (See figures 4 and 5) [24]. For the purpose of the proposed legislation, the driver of the LGV must be able to notice a cylinder 1 metre high with

³While the figure shows a left-hand drive vehicle, for right-hand drive vehicles within the jurisdiction of the legislation, the areas of required coverage are reversed

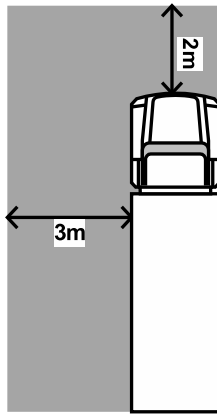


Figure 4: Proposed Japanese legislation: area in which a cylinder (1m high, 0.3m diameter) must be at least partially visible to the driver of a right-hand drive LGV (greater than 7.5 tonnes).

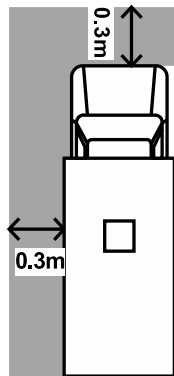


Figure 5: Proposed Japanese legislation: area in which a cylinder (1m high, 0.3m diameter) must be at least partially visible to the driver of a right-hand drive LGV (less than 7.5 tonnes).

a diameter of 0.3 metres placed anywhere within the coverage areas. However, in this legislation, it is proposed that objects within blind-zones caused by A-pillars and external mirrors need not be visible to the driver of the vehicle [23].

3.3 United States

In the United States, proposed legislation, in the form of S.694 (The Cameron Gulbransen Kids and Cars Safety Act of 2007) [1], is designed to protect against children being injured or killed in non-traffic incidents, such as when the vehicle is reversing. Specifically relating to the possible use of cameras, the S.694 bill requires a rearward visibility that enables the driver to detect the presence of a person in the rear blind-zone of a vehicle in order to prevent injury or death.

4. AUTOMOTIVE CAMERA SYSTEMS

As shown in figure 6, standard lens camera systems (e.g. 45° Field-Of-View (FOV) lenses) are unable to fully cover the blind-zone of some SUVs. Considering that camera-monitor systems generally display a “reference” point (i.e. part of

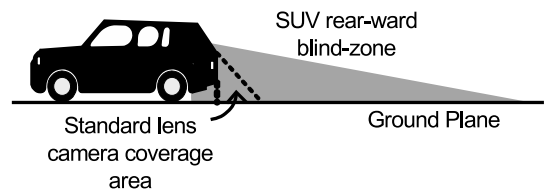


Figure 6: Example coverage area for standard lens camera (e.g. 45 degree field-of-view).

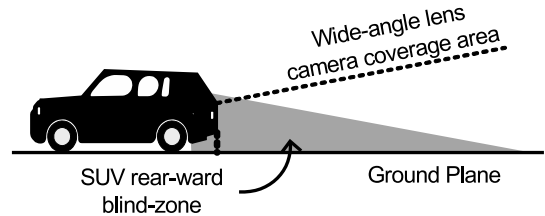


Figure 7: Example coverage area for wide-angle lens camera (e.g. 100 degree field-of-view).

the body of the vehicle) on screen, a standard lens camera with FOV of 45° can only cover perhaps 1m of the SUV blind-zone. Figure 7 shows how the use of a wide-angle lens camera system (e.g. > 100° Field-Of-View (FOV) lenses) enables the entire SUV rear-ward blind-zone to be covered.

Figure 8 shows sample areas that could potentially be displayed to a driver if a number standard VGA cameras with wide-angle lens systems were mounted on an LGV. Camera 1 is a 135° wide-angle camera, located approximately half-way down the length of the LGV and 3m off the ground plane. The optical axis of camera 1 is tilted at 15° from the side of the LGV trailer. Camera 2 is a 135° wide-angle camera, located in the middle of the front cabin and 2m off the ground plane. The optical axis of camera 2 is tilted at 20° from the front face of the cabin.

Figure 8 shows the areas in the vicinity of the vehicle that can be displayed to the driver (if video from both cameras were corrected for distortion that is evident in wide-angle cameras, using one of several calibration/correction techniques described in [21, 9, 5, 16], or other literature). From this figure, it can be seen that such a camera system would cover all the blind-zones of the LGV shown in figure 2, and would meet the requirements of both the EU Directive 2003/97/EC (figure 3) and the proposed Japanese legislation (figures 4 and 5).

The coverage of these distortion corrected wide-angle cameras extend far beyond that required by the legislations mentioned in the directions perpendicular to the vehicle side/front. However, these wide fields-of-view are necessary to obtain the coverage along the length and across the front of the vehicle.

The rearward coverage area required by the EU Directive (figure 3) could be covered by a standard lens camera. However, a potentially better product would be a wide-angle

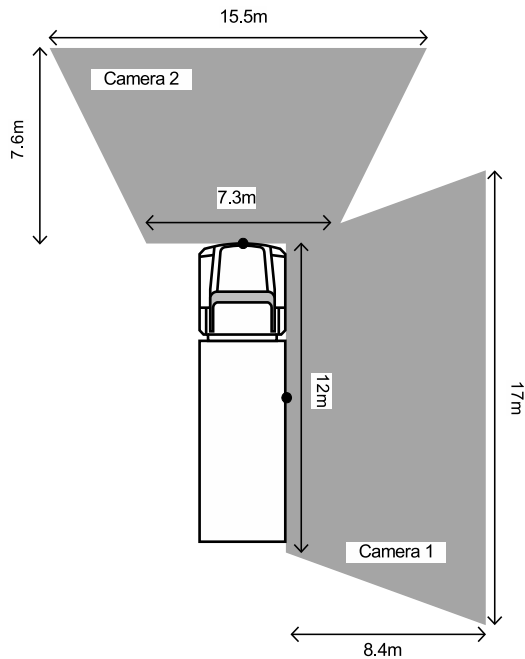


Figure 8: Example of a potential camera system for LGVs that would meet the requirements of the EU Directive 2003/97/EC and the proposed Japanese legislation.

camera mounted appropriately to display more of the rearward blind-zone to the driver. As we have already described in section 2, the rearward blind-zone of certain LGVs can be up to 65m, which is significantly larger than the area requiring coverage under the directive.

5. CONCLUSIONS

In this paper, we have discussed the rationale within the automotive industry for the on-vehicle use of camera systems. Specifically, with increasing numbers of vehicles on the world's roads, statistics show that a significant percentage of fatalities on the road are caused by VRUs being hidden in a vehicles blind-zones, and that increased visibility of these blind-zones will result in a reduced number of fatalities.

While customer demand for products that give information about a vehicles blind-zone to the driver is already high, pending and existing legislation is, de facto, making the placement of such cameras on vehicles a necessity, particularly for large SUVs and LGVs. However, while small vehicles are exempt from the European and Japanese legislation, in the United States legislation specifically targets the smaller private vehicles.

Ultimately, camera systems are becoming a necessity to increase vehicle safety, particularly in SUVs and LGVs. More specifically, we have shown that wide-angle camera systems would be required to display the potentially very large areas of coverage required by the legislation discussed. Indeed, we have shown in figure 8 that the use of a minimal number of

wide-angle camera systems can be used to display the blind-zones to the driver of the vehicle far beyond what is required by legislation.

6. ACKNOWLEDGEMENTS

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