Field of vision of modern cars – a study to improve the evaluation of car geometries based on real world accident scenarios documented in the ADAC Accident Research

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Abstract - Today's volumes of traffic require more and more responsibility from each individual road user in their interactions. Those who drive motor vehicles have the singular obligation to minimise the risk of accidents and hence the severity of injuries, particularly with a view to the most vulnerable road users such as motor bikes, bikes and pedestrians. Since responsible and pro-active driving depends first and foremost on the visual information relayed by our eyes and the visual channel this requires good command of the traffic and all-round visibility from our driver's seat. Granted that human error can never be fully excluded, improving visibility around the car is nevertheless an urgent priority. To do so, we need to rate visibility in the most realistic driving situations.

Since the existing visibility metrics and methodology are not applicable to real-life driving situations, this study aimed at developing a new visibility rating methodology based on real-life accident scenarios. On the basis of the cases documented by the accident research project, this study analysed criteria indicative of diminishing visibility on the one hand and revealing some peculiarities in connection with the visibility issue on the other.

Based on the above, the project set out to develop a rating methodology allowing to assess all-round visibility in various road situations taking into account both driver and road geometries. In this context, the assessment of visibility while turning a corner, crossing an intersection and joining traffic on a major road (priority through route) is of major importance.

The first tests have shown that critical situations can be avoided by adapting the relevant geometries and technical solutions and that significant improvements of road safety can be derived therefrom.

INTRODUCTION

Mobility is a basic requirement in today's world. It makes people more flexible and autonomous. In an increasingly complex traffic environment, road safety and driver comfort are two aspects of locomotion which must be safeguarded and maintained. Increasing fleets and mileages require the active road users to be more responsible in their use of motor vehicles on public roads. To ensure sufficient levels of safety and comfort, state-of-the-art vehicles must be equipped with advanced active and passive safety systems and they must provide good all-round visibility as a matter of greatest priority. While vehicle development has progressed in terms of new safety technologies over the last few decades, visibility has increasingly taken the back seat in favour of vehicle stability and occupant protection. This has significantly increased the risk of seeing other road users too late, if at all, due to body design, small side and rear windows etc. joining to encumber the motorists' field of view. As a countermeasure, the useful visual areas in vehicles need to increase again. This can be achieved by means of cabin design or visual aids such as rear-view mirrors, cameras or sensors. If cars come equipped ex works with systems such as the above, these visibility-enhancing measures must become part of the respective assessment methods. Therefore, adequate tests must be developed which allow the assessment of the actual visibility features on the basis of criteria derived from realistic driving situations. Such tests would allow general guidelines for vehicle design to be derived. Adequate vehicle design levels of quality necessarily require the continuous development of new or adapted assessment methods to reflect the evolution of the latest automotive concepts. The ultimate goal of car manufacturers should be to support motorists in their responsibilities in ever more complex traffic environments and so ensure higher levels of road safety.

HISTORY

Looking at the history of automotive development, we will find that the risk for humans and the environment is no longer caused by technical failure in the vehicles themselves. Automotive technical development has shifted the balance of risk clearly towards human error. This is due to the fact that individuals today seem unable to cope with the traffic situation around them and the control of their vehicles because they are simply overwhelmed by the volume of traffic and the complexity of state-of-the-art technology. Assuming that trends in road and traffic development will remain more or less the same, the further optimisation of traffic seems to be harder to achieve than vehicle-related solutions. The main reason for this state of affairs is the complex political environment created in the federal German system. Implementing adequate changes in road and traffic infrastructures, such as restructuring the road network, is much more problematic than promoting targeted measures in automotive design and engineering.

The benefit of passive safety features and legal requirements such as seatbelts and buckling up, mandatory side impact protection or the development of airbags is evident in the massive reduction of road fatalities. Nevertheless the most promising approach in achieving more road safety lies in active safety solutions. The accident risk diagram in Figure 1 serves as an illustration of the potential of active safety features in reducing the severity of injuries.

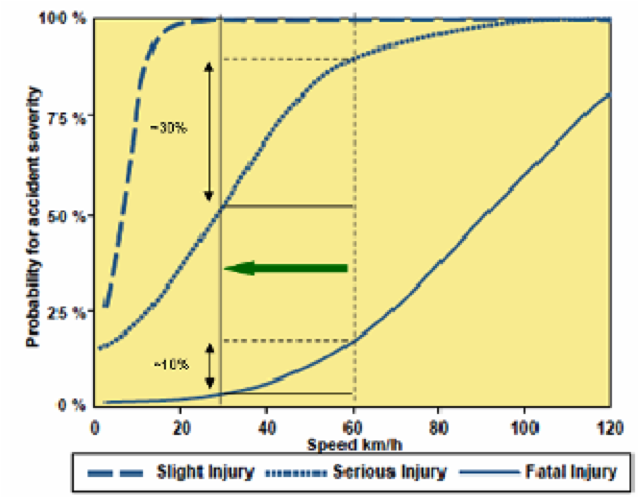

Figure 1: Impact of vehicle safety on accident severity [1]

Safety systems such as adaptive cruise control or brake assist reduce impact speed which is evident in the horizontal shift of the various curves in the diagram above. Where active systems reduce collision speed by 50%, e.g. from 60 to 30kph, this results in a much reduced injury risk (less severe injuries). The potential for reduction is around 30% for serious and severe injuries and approx. 10% for fatal injuries. Reductions in the severity of accidents of this order can no longer be achieved on the basis of passive safety measures since this technology has exhausted its potential and no major developments can be expected [1].

Active safety is not just a matter of improvements in the vehicles themselves, but also involves the driver and the man-machine interface. Interfacing here primarily means the flow of information the driver requires to control the vehicle. Responsible driving very much depends on the driver's fitness and information processing capabilities. Considering the factors above, incident-free driving at its best levels depends on the driver's experience, aversion or fondness of risk, motivation as well as the driver's physical and psychological fitness or condition [2-5]. Considering the fact that the driver acquires 90% of the relevant information through the eyes and related sensory system [6] it is quite clear how important the driver's visual perceptions are. However, in terms of safety, there is a deplorable trend in automotive design towards narrower fields of vision. For instance, some cabin pillars in state-of-the-art cars are likely to occlude other vehicles altogether so the driver perceives them too late, if at all (see Figure 2).

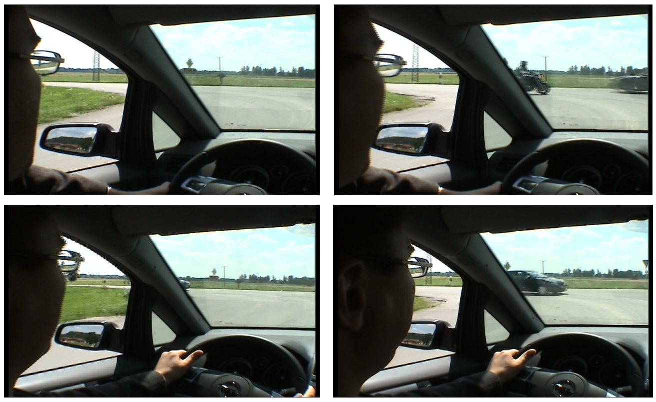

Figure 2: Other vehicles completely occluded by A pillar

The growing need for mobility in our society and the resulting higher traffic volumes require the driver to acquire and process more information quicker. This results in steadily higher requirements in terms of visibility from within contemporary cars and in visibility becoming a key element in active safety. From the driver's perspective, visibility is determined by a variety of factors which we may group in three categories [2]:

- ***External factors (environment)***
  The weather, position of the sun, surrounding geography
- ***Vehicle-related factors:***
  Vehicle geometry, interior layout, seat/mirror adjustment options
- ***Individual factors:***
  Height, physical proportions and posture of driver, seat position

In addition to the legal requirements for fields of vision, which are defined in purely geometrical terms, the automotive developer or designer needs to consider the driver's objective (angle values, occluded areas) and subjective perceptions and impressions (feeling cramped and unsafe) [3].
Since the requirements under which vehicles are developed and designed are so variegated, the developer/designer often faces conflicting goals with respect to the overall criteria. As far as all-round visibility is concerned, we have seen that this criterion is subject to some tensions between often contradictory aspects. Visibility from within a car is primarily influenced by body and interior cabin design, which is subject to certain contradictions. For instance, more massive or sweeping A, B or C pillars increase occupant safety in a crash. But on the other hand they reduce visibility to the outside. Some aesthetic aspects are dear both to the designers and the car buyer, for instance because they enhance elegance or sports car allure. At the same time, some design elements convey the feeling of more safety, e.g. high shoulder lines. But the narrower window surfaces become the more this affects visibility. In terms of aerodynamics, flatter windscreen angles and higher tail lines are usually inevitable but on the other hand they massively interfere with visibility. With a view to all-round visibility, there are tensions to reconcile also in terms of interior design. The position and layout of manual controls such as pedals, the steering wheel, the adjustment range of seats and other cabin elements have a direct impact on the driver's posture. In combination with individual driver anatomies, cabin layout and interior proportions are of primary importance for the driver's area of visual perception and perceptive capacity. It is evident that a constructive and design approach to all-round visibility is required since the direct fields of view cover only part of a vehicle's more or less immediate surroundings [2, 3].

STATUS

Legal aspects

The existing regulations with respect to visibility from within motor vehicles define the minimum requirements with respect to visibility. The requirements are attempting to take into account ergonomics as a primary factor to make the settings for driver/environment interaction as user-friendly as possible. This is the reason why the requirements are framed in very general terms, leaving much latitude in terms of personal responsibility and freedom of implementation to the car manufacturers. The problem here is that the variance in driver physical typologies is such that a one-for-all standard can hardly be defined on this basis. Obviously, the existing requirements are no more than a set of regulations intended to reflect certain ergonomic principles. As a result, they incorporate potentially contradictory requirements and moreover there is always the risk that the specific legislation may thwart the ergonomic intent altogether [2, 7].

Generally speaking, the legal requirements with regard to the design and layout of car windows and windscreens do not constitute minimum all-round visibility standards per se. The driver's forward (front, left and right) and rearward fields of vision (the latter defined only in terms of indirect visual aids such as rear-view mirrors or cameras) are defined separately. There is no unified definition for and treatment of all-round view. Moreover recent cabin body styles and designs are contributing towards a marked degradation of forward visibility. This is particularly obvious in the approaches to crossings and intersections where vehicles are occluded altogether by massive A pillars making them invisible to the driver (as shown in Figure 2). The case of rear view, for instance when joining a through route from a parallel slip road, is similar. In cases such as the merging slip road layout described above, the existing regulations and requirements are insufficient since they refer only to indirect visual aids. Here, driver assistance systems alleviate the situation somewhat but there is no legal framework for the use of such systems yet. The respective assistance systems are not mandatory, hence they do not need to be installed ex works. Another aspect with reference to the technical enhancement of visibility is that the relevant assistance systems are expensive and not readily affordable for all motorists. And finally, the increasing number of in-vehicle driver assistance systems may result in a sensory overload on the driver. This overload may be too much for some drivers and result in considerably slowing their responses. The drivers may not be able to control their vehicles optimally. With a view to car-to-car communication, the systems are not yet advanced enough to effectively compensate for the driver's difficulties in critical situations. We must ask ourselves how can it be possible that the car manufacturers have no problem complying with legal requirements whereas visibility from within cars constantly diminishes [2].

Physical and psychological limits

Processing visual information is one of the prerequisites for driving on public roads. Two factors are decisive for safe driving: one is sufficient visibility from within cars and the other is depth perception as a general ability. There are limitations which apply to both factors and can only partially be compensated. In terms of human anatomy, certain areas cannot be viewed directly or perceived only as a blur (monocular and binocular occluded areas). Such limitations can be overcome or compensated for by body movement and new angles of view. Visual aids such as mirrors and sensors have a positive effect on such limitations.

In terms of psychology, certain phenomena are not perceived correctly by the driver or perceived and evaluated correctly too late. Such errors are due to aspects of depth perception and absolute distance assessment, i.e. the realistic assessment of relative speed, acceleration and arrival time. The most common example here would be failure to recognise when an on-coming vehicle is on a collision course based on the minimal changes in constant bearing when vehicles approach an intersection at certain angles [8].

ANALYSIS

As a first step towards assessing vehicle geometries with a view to visibility problems we must refer to real-life accident statistics. In this case the relevant accident scenarios involve limited visibility accidents documented in the ADAC accident research database. For in-depth analysis, we looked only at collisions caused by passenger cars and where the cause of the accident was failing to see the other road user (see Figure 3).

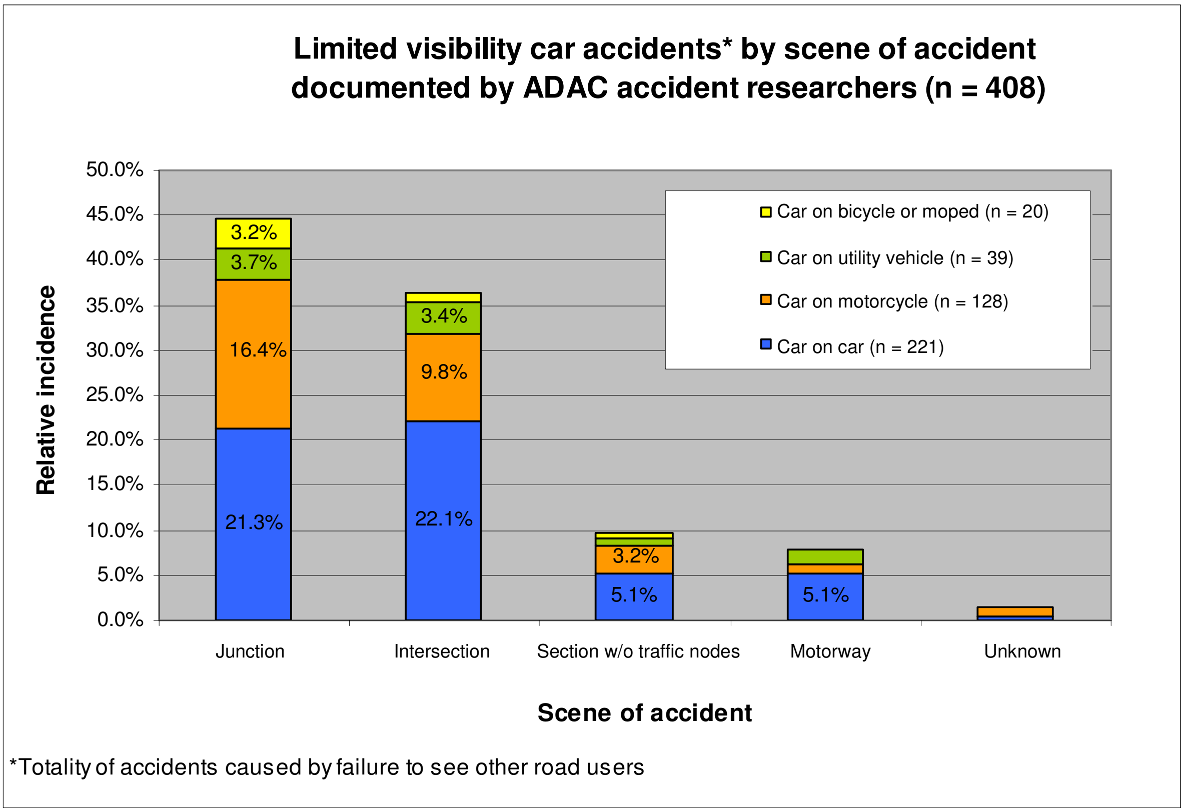

Figure 3: Limited visibility car accidents* by scene of accident

When it comes to limited visibility, crossings and junctions appear to be the most dangerous accident hotspots. The situation becomes critical because the vehicles approach from different points in a crossroads layout, further complicated by the disposition of the crossing or joining roadways and the relative angles at which they meet. This type of situation is more likely to give rise to the problem of limited visibility than for instance a same and/or opposite-direction traffic scenario. In order to make valid statements on the nature of the limited visibility (environmental, situational or vehicle-related), the actual crashes are analysed in more detail.
Assessing the relevance of window and windscreen layout in terms of safety requires a fundamental assessment of the traffic situation, accident constellation and last not least road geometry. The latter refers to the relative position of the colliding vehicles to one another. Road geometry is determined by the trajectory of the roadways (which may be straight, convex or concave) and the angle at which two roadways join. For the sake of clarity, the road geometries relevant for the types of accident under investigation were defined precisely (see Figure 4).

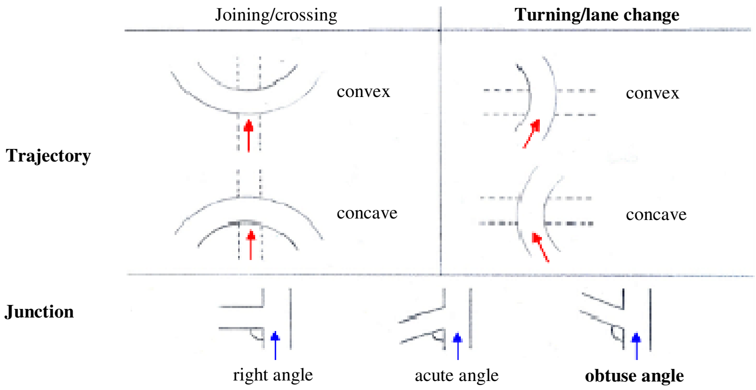

Figure 4: Definition of road geometries at the scene of the accident

Before drawing any conclusions on the impact of the individual windows/windscreen sections in terms of visibility, it appears necessary to discuss some conspicuous issues revealed by our analysis. We would like to point out that only limited visibility cases documented in the ADAC accident research database with a maximum of data such as operation logs, media coverage and last not least photographic documentation of the accident site were selected for a conclusive evaluation. Applying the above criteria, we obtained a total of 283 limited visibility accidents involving passenger cars which can fundamentally be classified into three types of accident. We investigated in detail two that are quite similar, i.e. joining/crossing and turning accidents, and in addition we also looked closely at accidents in same and opposite-direction traffic, i.e. lane-change accidents. Another important aspect in the accident profiles is the relative position to one another of the two parties in the collision. In accidents joining/crossing traffic there is a conflict between a joining/crossing vehicle obligated to give right of way and a vehicle having the right of way (at intersections, junctions, driveways or parking lot exits). In turning accidents, the conflict is between a vehicle attempting to turn off a road and road users approaching from the same or from the opposite direction. Table 1 shows the most frequent accident scenarios for the three types of accident investigated.

Joining/crossing accidents (n = 185)	
Turning left, opponent from left	44.3%
Crossing, opponent from right	25.4%
Crossing, opponent from left	17.3%
Turning left, opponent from right	10.3%
Turning accidents in cross-directional traffic (n = 72)	
Turn left, opposing traffic	87.5%
Turn left, same-direction traffic	9.7%
Lane-change accidents (n = 26)	
Veering left	80.8%
Veering right	19.2%

Table 1: Most frequent scenarios in the limited visibility accidents investigated

61% of the accidents joining/crossing traffic (of which approx. 44% left turns onto priority route accidents joining/crossing traffic and approx. 17% crossing) are collisions with road users approaching from the left. The reason for this causality is the relative closeness of the driver to the left-hand A and/or B pillar. When these objects are closer to eye level, they block out more of the visible area ahead than the more remote right-hand pillars. Nevertheless, in approx. 35% of all cases the right-hand (passenger) side of the car is in the focus in accidents joining/crossing traffic.

Both in turning/joining and in lane-change accidents, there is a clear prevalence in terms of the most frequent accident scenarios. In 87.5% of cases, the left-hand forward window/windscreen section is responsible for reducing the driver’s command of on-coming traffic in left turns. The situation is similar in lane changes, where veering to the left (approx. 81%) is considerably more frequent than veering to the right (approx. 19%), were the side and rear window sections are responsible for any reductions in visibility. Also, our investigation revealed some peculiarities relative to road trajectories. More than twice as many accidents joining/crossing traffic happen on straight and convex crossing layouts than on concave setups. Straight roads (times four) and concave curve layouts (times three) are also more prevalent in turning manoeuvres compared with convex curves. Very often accidents caused by errors in lane changing happen on straight road sections (approx. 38%). But in lane-change accidents, the prevalence of convex curve layouts is even clearer (approx. 50%). This is due to the fact that there is more than a good chance for vehicles approaching from the rear to be in the driver's blind spot and therefore for drivers not to see them. It is also quite evident that most of the intersections/junctions where limited visibility car accidents happened were in themselves clearly laid out and offered very good visibility. In over 90% of all joining/crossing and turning accidents the view was completely free or at least this was the case for the immediate junction point (visibility ahead at least three vehicle lengths). Poor visibility of the other road users was therefore not attributable to structures or vegetation at the junctions etc. obstructing the view. This is very strong indication that the limitations of visibility are a vehicle-related matter.

Other investigations into limited visibility car accidents focusing on vehicle superstructures, year of make, colour of the vehicle(s) involved, the age of the driver and severity of injuries also yielded substantive new insights into visibility problems in state-of-the-art cars.

In terms of cabin/superstructure design a similar prevalence of certain car types involved in limited visibility car accidents is documented by ADAC accident research. In the totality of cars involved in limited visibility accidents, the number of hatchbacks and saloons as well as MPVs and SUVs with roomier and more elevated cabins (and usually better command of the road) are much more prevalent than estate and sports cars. Better visibility does not necessarily have anything to do with more spacious cabins or a more elevated driver's sitting position.

In terms of the year of make of the vehicle causing the accident, the vehicle-specific analyses show a clear shift in accident constellations starting with YOM 2005. The cut-off year of make roughly represents the period when cars with sturdier cabins and more massive cabin pillars were launched with the aim of boosting crash safety. We observe a strong reduction in the numbers of car-on-car crashes (approx. 15%) and car-on-utility vehicle crashes (approx. 4%). On the other hand, we witness an almost equivalent rise in the number of limited visibility car-on-bike accidents. Whereas the number of crashes involving bicycle and moped rose from approx. 3% to 10%, the number of car-on-motorcycle accidents rose by approx. 12%. Over the course of the last decade we have also observed an all-over growth of the PTW fleet, with only marginal increases from year to year (source: Federal Motor Transport Authority – KBA). Since the PTW fleet had a growth rate comparable with that of other types of vehicles, this cannot explain the rise in the number of car-on-PTW accidents. However looking at the statistical development of the PTW fleet and the launch of safer car cabins seems to account very well for the trend. Since PTW riders produce slighter vehicle silhouettes, they are simply harder to see approaching due to the bulkier safety-enhancing cabin pillars than other types of vehicles. To allow putting the figures obtained in the proper relation, the various types of accidents were evaluated by YOM of the causing vehicle. We observed that cars of more recent make caused an increasing number of joining/crossing and turning accidents whereas at the same time the number of car-on-PTW accidents in same and opposite-direction traffic decreased over the same period. This downward trend is also supported by our earlier finding that the risk of not seeing another road user at an intersection or junction is considerably higher than on stretches without crossroads or junctions.

Inquiries into the colour of vehicles shows that the colour of the opposing vehicle at least tendentially has an impact on the motorist causing the accident. Generally, the data from ADAC accident research reveals a trend with respect to the colour that coincides with a ranking of the most popular colours for newly registered vehicles over the last decade. Our data shows that the majority of the road users drivers tend to overlook are dark (grey or black) in appearance. This is not incontrovertibly linked with the vehicle-related visibility problems we are concerned with but we may conclude that the combination of dark paint and reduced visibility from inside a car has statistical potential and therefore represents an increased risk. We have also observed that bright paint schemes designed for "signal" effect (red but also blue), especially, are represented very often in limited visibility accidents. This also indicates that the cars causing accidents have vehicle-related visibility issues.

Another contributing factor is the age of the driver. Whereas in terms of driver age the official accident statistics are in accordance with ADAC accident research data, the numbers from limited visibility accidents relating to the age bracket of drivers age 25+ are clearly divergent. Comparatively, ADAC accident research shows a significantly lower number for the age bracket of 25 to 65 years of age (approx. 47%) than the Federal Statistical Office (approx. 59%) or the ADAC accident database (approx. 58%) for the totality of accidents on record for the same period. Setting off limited visibility accidents against the totality of accidents, the opposite is the case for the age bracket of 65+ years of age older people are twice as likely to have some sort of sight impairment that could make them unable to see other road users and cause accidents. Of course the capacity for concentration and sight decreases with age. On the other hand the elderly are less flexible and at difficulty compensating for any occlusions due to vehicle geometry. Unlike the previous analyses revealed, this type of visibility problem cannot be reduced automatically to vehicle-related poor visibility. However, the combination of advanced driver age and poor visibility represents a considerable risk. Another argument supporting the increasing vehicle-related visibility problems comes from a look at the "young driver" age bracket. Once again, the official statistics and ADAC accident research data are reconciled and there is no indication that in limited visibility accidents there is an age-dependent accident propensity due to lacking experience or inattention when driving. Again, we may assume that this type of accident is owing to vehicle-related visibility issues.
The last criterion for analysing limited visibility car accidents is the specific severity of injuries. The injury pattern illustrated in Figure 5 represents the severity of the injuries (slight to fatal) suffered by all persons involved in relation to the direction of the impact. It should be noted that this analysis includes all injuries suffered both by car occupants and PTW riders.

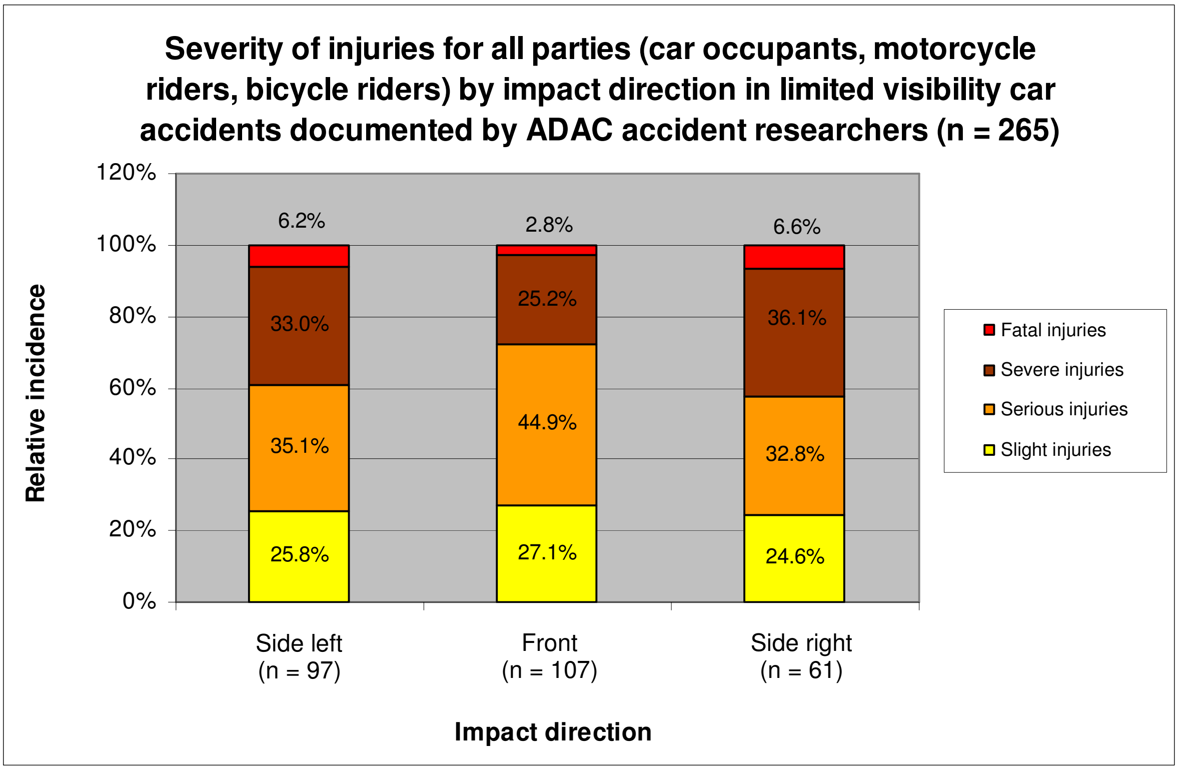

Figure 5: Severity of injuries in limited visibility car accidents by direction of impact

Slight injuries run to roughly the same percentage in all three scenarios. Since they range around a low 25% in all three cases, this emphasises the severity of injuries in limited visibility car accidents (in 75% of the cases injuries are serious, severe or fatal). However, the spread of injuries for side impact collisions relative to front impact collisions is noteworthy. Injury severity in side impact collisions is clearly greater: over 39% severe and fatal in left side collisions and almost 43% in right side collisions (brown and red). Severe and fatal injuries amounted to only 28% in frontal collisions. This disparity between the impact directions is the result of the vehicles' crush zone. In this respect, there is more potential in the front end structure of the vehicle than at the sides (doors and cabin frame). Deformations of the passenger cell happen earlier and are more pronounced, exposing the occupants to considerable injury risks.

We should also point out that, very often in the accident scenarios investigated (i.e. at crossings and junctions of all types), the road users involved were bicycle, moped and motorcycle riders or passengers. When collisions involve this type of road users the primary collision and subsequent fall result in severe to fatal injuries. This is also due to the fact that in this type of collision, the causing vehicles appear directly in front of the PTW riders and body contact between the riders and the vehicle body is immediate.

In analogy to the limited visibility car accidents we investigated other driving manoeuvres and situations for their potential for overlooking other road users. This includes cases in the ADAC database for which the cause of accident was defined as "errors in lane changing" or "ignoring up-coming traffic". However, based on the low amount of data available it was rather difficult to obtain clear results. The trends emerging from the analyses are similar to those in the limited visibility car accidents but they could not be used to draw representative conclusions. However, the lane-change accidents were used for in-depth evaluation of the accident situation (e.g. roadway trajectories, gradients and camber etc.) since they support important conclusions with reference to the assessment methodology we aim to develop.

METHODOLOGY AND TEST RESULTS

The results of the in-depth evaluation yielded the initial approach for the development of a methodology for the assessment of visibility from within cars. On this basis, with a view to devising a rating system for the scheduled tests, the windscreen/window sections in the test vehicles were included in weighting factors depending on their importance, that is to say depending on the degree to which the respective section of the bodywork contributed to a reduction in visibility in certain situations.

Furthermore an assessment of visibility from within a car requires a clearly defined test setup and procedure. An adequate test catalogue was developed to include certain traffic situations and all-round visibility tests. The selection of the specific manoeuvres was based on the preliminary analyses of accidents documented in the ADAC accident research database. The catalogue included 17 manoeuvres (joining/crossing, turning, merging into traffic and lane change) and 5 visibility assessments (manoeuvring into and out of parking bays and visibility of obstacles), which can be subdivided into three different categories. This includes an assessment of forward and rearward visibility (and the respective windscreen/window sections) and an assessment of general visibility. Depending on the situation, the side window sections may be crucial in terms of forward and rearward visibility when executing certain manoeuvres such as left turns or lane changes. It should be noted that the scenarios set up describe road sections, junctions and intersections with unobstructed visibility. The all-round visibility tests were also set up to reflect everyday practice and real-life road situations as closely as possible. To ensure that the test drivers executed the various scenarios precisely with a view to obtaining representative ratings, clearly worded test instructions needed to be compiled. The test instructions contain every procedural detail and specify the criteria to take into account in the various situations.

The test runs and the rating of the scenarios described in the test catalogue were executed by four test drivers. In their selection, we took care to make the test drivers representative in terms of height for the majority of real-life motorists. To obtain a well-weighted basis for assessing the impact of driver's height on the ratings we selected one test driver to be representative for the below-50th percentile (1.72m), two representative of the 50th to 95th percentile (1.82m and 1.85m) and one representative of the above-95th percentile (1.95m).

The scenarios in the test catalogue were run and rated independently by each driver in the respective test vehicle. The rating was based on the proven ADAC rating system. In this system 1 = very good and 5 = poor. The final overall rating also takes into account the aforementioned weighting factors and a number of additional upgrading or downgrading criteria. These factors and criteria aim to reflect the great variety of vehicle types and bodywork styles (coupes, convertibles etc.) as well as the manifold equipment options, e.g. driver assistance systems.

Results A pillar

The tests were conducted and validated with two test vehicles. The test results were compared with the results in the established ADAC all-round visibility test. The results for the smallest test driver correlate quite well with the metrics for the 50th percentile (1.75m tall) obtained in the ADAC test. The ratings for the taller percentiles are more divergent. This is obviously owed to the considerably higher seat posture of taller drivers. Figure 6 shows the comparative forward view on an unobstructed intersection with good visibility for the tallest and the smallest test drivers.

Test driver 1.72m

Test driver 1.95m

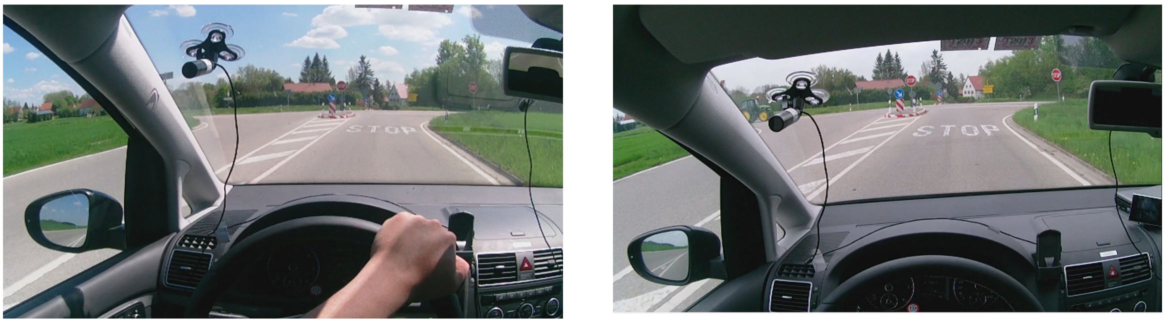

Figure 6: Impact of driver's height on forward visibility (compact MPV)

It is evident that view is more obstructed for the taller driver. Owing to the higher seat posture of the taller driver the angle of the driver's view changes to the extent that the A pillar occludes a wider portion of the driver's view than it does for a smaller person.

The run with the second test vehicle produces similarly divergent ratings. In both front end assessments, the worst ratings by far were applied in the ADAC all-round visibility test, whereas there is not much difference between the ratings of the individual test drivers. The extreme variation in ratings between the static ADAC all-round visibility test and the dynamic test run can be explained in terms of typical compensatory movements. Whereas the camera in the standard ADAC visibility test is fixed in one position, the real-life driver does not maintain a rigid posture, trying to compensate obstructions in visibility by adequate body movements. Slight movements of the head or torso are usually sufficient to compensate for the lack of visibility due to a higher seat posture. This can result in variations of up to 3 rating points. Figure 7 adequately illustrates this gain in visibility on the basis of the left A pillar assessment for the 1.72m test driver.

Figure 7: Impact of compensatory movements (supermini)

Results B pillar

As was the case with the assessment of forward visibility this test also shows a very good correlation of the ADAC all-round visibility test metrics with the results for the smallest test driver in the dynamic test. Overall, the worst ratings were also achieved in the standard ADAC test. Furthermore the ratings of the individual test drivers reveal a similar tendency for both sides. The most obvious observation is that the ratings of the taller test drivers are notably better than the 50th percentile rating. Here, the driver's seat posture is a decisive factor. Depending on the individual body metrics, each person has to adjust the driver's seat for comfortable posture. Smaller persons will slide the seat forward; taller persons will slide it back. The different seat positions result in different fields of view for the test drivers, e.g. when shoulder-checking. Figure 8 shows a shot taken at an acute angle junction.

Test driver 1.82m Test driver 1.95m

Figure 8: Impact of seat posture on visibility to the sides (compact MPV)

It is evident that for the smaller person, the B pillar is directly in the driver's field of view and blocks the view to traffic approaching from the left on the intersecting road. Taller persons sitting with the seat pushed back to the maximum have a different field of view. Sitting further back, the driver's field of view is actually wider to both sides of the B pillar and the driver's view of traffic approaching the junction is almost unobstructed.

Results C pillar and rear

The test runs did not reveal any problems observing traffic approaching from the rear. Road users approaching from the rear were always visible in the rear-view mirror and both test vehicles received very good ratings. However, the assessment of visibility to the rear depends on how much of the driver's view is obstructed by the C pillars. Strong variance was observed in the different test drivers' ratings. Again, the reason is grounded in the drivers' varying statures, the varying seat positions selected and the drivers' individual compensatory movements.

Test driver 1.72m Test driver 1.85m

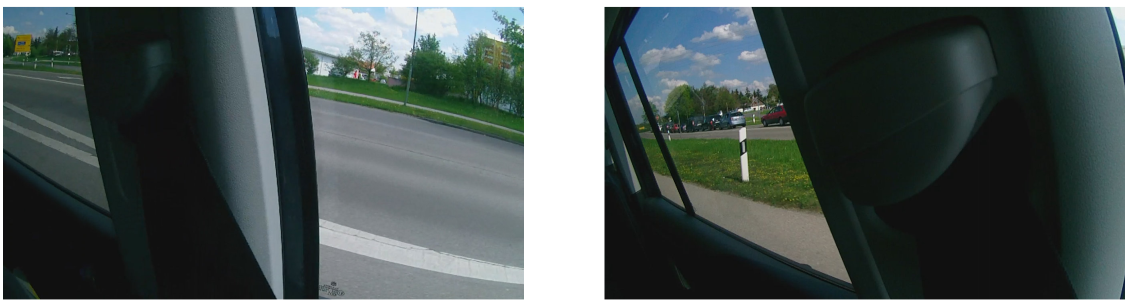

Figure 9: Impact of driver's height and seat posture on visibility to the rear (compact MPV)

Figure 9 is a graphic illustration of the above issues. Obstructions of view to the rear are particularly evident in merging manoeuvres. Effectively acquiring a view of any traffic approaching from the rear often requires extreme head and torso movements. Also, the position of the driver's seat and the driver's height have a fundamental impact on the ability to optimally observe traffic approaching from the rear or moving alongside the vehicle. For smaller persons sitting well forward, their rearward view is hardly obstructed by the C pillars. With hardly any interference from the C pillars, this window section received better rating from the smaller test drivers. Sitting further to the rear (rearmost seat position), taller persons are experiencing relevant obstruction from the C pillars. Since the rear section of most cabins comprises more bulky elements, notably the C pillars, the unobstructed field of view when drivers turn to check their rear is more reduced.

Overall results compared to ADAC all-round visibility test

For better comparability of the results, Figure 10 shows both the overall ratings given by the individual test drivers and the vehicle ratings from the ADAC all-round visibility tests (yellow mark). For easier orientation in terms of stature, the two relevant percentile points (50th and 95th) were marked with interrupted lines. It is evident from the diagram that despite the differences for certain statures discussed above, the overall results are similar.

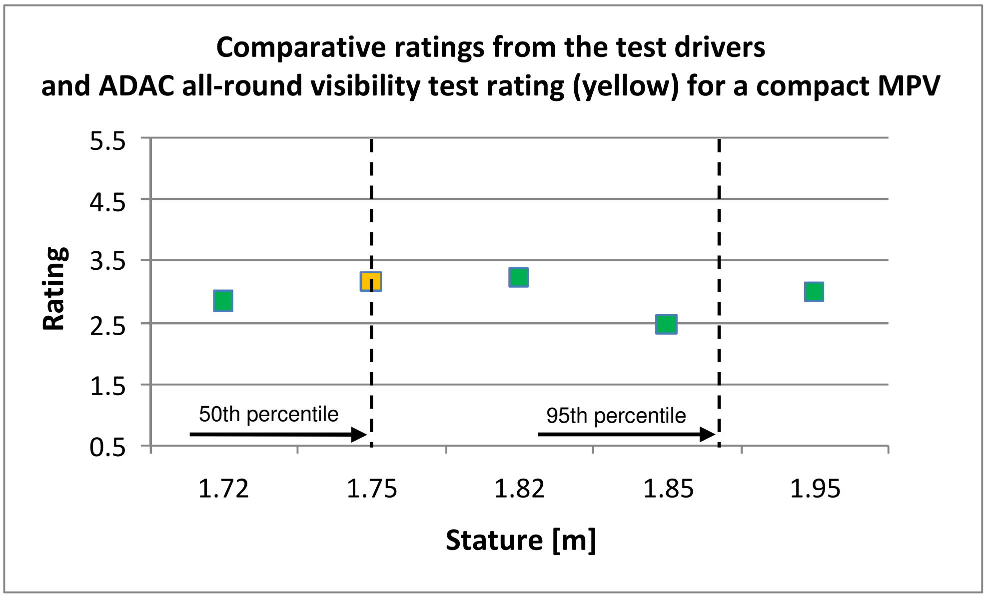

Figure 10: Comparative overall results (compact MPV)

This comparison shows more clearly that the static test setup in the ADAC all-round visibility test is compatible with the ratings in the newly developed test procedure. The variance in the ratings given by the test drivers on the basis of varying stature indicates that the static test setup and metrics ignore certain key factors of real-life human behaviour in road traffic. Since parameters such as stature, seat position and compensatory movements have decisive impact on visibility from within a car, such parameters must be included in the assessment of visibility.

Validation of methodology

Pertinent conclusions about the quality of the assessment methodology developed require a validation of the test procedure on the basis of the conspicuous issues noted during the test runs and in the analysis of the results. This investigation yielded a number of conditions that have to be met in putting this assessment methodology to work. One result of the validation is that certain K.O. criteria must be included in the assessment of visibility from within a car. It must be considered whether a vehicle being tested should be allowed to score a better overall rating if it scored a considerably lower rating in one of the test categories. Another decisive aspect is the robustness of the assessment/rating. The procedure allows only subjective assessments of visibility. The test does not ensure sufficiently high levels of reproducibility. The methodology is also heavily dependent on driver-related parameters such as stature and movement patterns while steering the car. Yet another factor is the overall traffic situation when running through the test catalogue. Since traffic at a given location and time may not always allow the inclusion of other road users in the visibility assessment, the ratings under different conditions may be subject to strong variance. Here, the selection of the test location is also decisive. Due to the high number and variance of test route trajectories and layouts, the test resists standardisation to a level that would allow precise and representative conclusions.

KEY FINDINGS

The analysis of the accident data from the ADAC accident research database and the consideration of the specifics of the particular area of operation of the ADAC HEMS crews clearly indicate that state-of-the-art cars have certain visibility issues in road traffic. Most of the relevant accidents occur at junctions and crossings presenting otherwise unencumbered visibility, i.e. there are no structures or vegetation obstructing the view. Limited visibility car accidents are caused mainly by motorists overlooking other road users approaching from the left while executing a merging/joining manoeuvre onto a through route, while crossing an intersection or ignoring opposite direction traffic while executing left turns. The overall percentage of 75% serious, severe and fatal injuries is indicative of particularly high injury risks in this type of accident. A group of road users particularly at risk are vulnerable road users, who are hard to see as well owing to their appearance or profile, such as motorcyclists and bicyclists. Car occupants are particularly at risk in side impact collisions as is the case in most limited visibility accidents.

PROSPECT AND LONG TERM GOALS

To allow effective measures for the improvement of car-related visibility, a dynamic visibility assessment methodology for cars was developed. Not only does it reveal the shortcomings of static assessment procedures, it also offers ways to compensate for such shortcomings by reflecting realistic traffic scenarios. It should be noted that the results obtained are based on some necessary assumptions and that the methodology needs to be verified with other test cars and adjusted where necessary. Furthermore, it must be ascertained how and to what extent the conclusions from this project can be incorporated in established and utilised test procedures. This requires adequate feasibility studies aimed at determining whether and how the new assessment methodology can be used to expand or to be combined with existing test procedures. Opportunities for development seem to exist with regard to extending the scope of percentile metrics to cover a greater variety of driver physiques and to improve correlation with test drivers of various statures. Furthermore, the inclusion of certain specific driving manoeuvres in static assessment methods seems promising with a view to optimising the assessment of visibility. This would entail chiefly the investigation of critical junctions, i.e. road layouts where roadway trajectories and the geometries of merging roads as well as the conditions of visibility are defined by certain characteristics. In addition to convex, concave trajectories, acute or obtuse merging angles, this would include gradients and the presence of structures and vegetation obstructing view. Effective solutions could also include reference to driver-related parameters such as stature and compensatory driver's movements.

It seems evident that there is considerable potential for improvement to achieve more road safety. This end requires both improvements in terms of infrastructure, legislative amendments and continuous progress in automotive engineering.

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