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Combating accidents on roads outside of built-up areas involving collisions with trees

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Preliminary remarks

931 people died on German roads in 2008 after a traffic accident involving a collision with a tree. That accounts for around 20% of all road fatalities. The chance of road users dying after a collision with a tree is around 2.3 times greater than the chance of dying in an average traffic accident on a road outside of a built-up area (excluding freeways).

The majority of collisions with trees happen at times when there is little traffic and at high speeds, and they have extremely serious consequences. Effective measures must therefore be taken to mitigate the consequences of these accidents (by ensuring roadside areas are „forgiving“ and by means of good vehicle design and safety features) and to enforce appropriate speed limits.

It appears there are physical limits to the extent to which passive vehicle safety can contribute to reducing the consequences of serious accidents like these.

Content

1 Introduction

The effects of accidents involving collisions with obstacles beside the road were unknown in Germany before 1995. On January 1, 1995, on the suggestion of the UDV (German Insurers Accident Research), which was at that time still the Insitut für Straßenverkehr Köln (ISK), the police began to record whether road accidents involved a collision with an obstacle at the side of the road and, if so, what the obstacle was. As a result, the serious consequences of accidents involving collisions with trees were revealed.

2 Trends in accidents involving collisions with trees

931 people were killed in accidents involving collisions with trees in 2008, and 6,350 were seriously injured. Of the 4,477 road fatalities that occurred in 2008, around one in five (931) were the result of a collision with a tree, 82% of them on roads (excluding freeways) outside of built-up areas [1]. About three out of every four accidents involving collisions with trees and resulting in personal injury took place on roads outside of built-up areas. Collisions with trees are the most common factor involved in fatal road accidents. Despite this, many road users underestimate how dangerous collisions with trees are. Eid et al. asked car drivers throughout Germany about what they considered to be the dangers of driving on roads outside of built-up areas [2].

Ran-king	Factors seen as dangerous	Frequency selected
1	Tight bends	51 %[1]
2	Narrow roads	42 %
3	Stretches of road with deer crossing	39 %
4	Winding roads	23 %
5	Roads without any markings	23 %
6	Level crossings	21 %
7	Downhill gradients	16 %
8	Junctions where forest or field tracks join roads	15 %
9	Stretches of road that pass through forest	14 %
10	**Trees very close to the side of the road**	**13 %**
11	Fast, wide bends	12 %
12	Intersections with give-way signs	11 %
13	Uphill gradients	7 %
14	Intersections with traffic signals	5 %
15	**Tree-lined roads**	**4 %**

1 The respondents could select up to three factors, which is why the percentages add up to over 100 %.

N = 1.650

Table 1:
Road users‘ assessments of dangerous factors when driving on roads outside of built-up areas [2]

Tight bends, narrow roads and stretches of road with deer crossing were seen as clearly the most dangerous factors (Table 1).

The numbers of fatalities and serious injuries on roads outside of built-up areas in Germany fell by over half between 1995 and 2008 (Figure 1) [1]. The fall was even more dramatic for accidents involving collisions with trees. Nevertheless, almost one in three people killed on roads outside of built-up areas died as a result of a collision with a tree. This proportion has hardly changed for this category of roads since 1995. For every 1,000 collisions with trees involving personal injury on roads outside of built-up areas in 2008, 76 road users died. That is 2.3 times the average rate for accidents on these roads.

Figure 2 shows the trend for road fatalities in Germany's 13 non-urban federal states (i. e. not counting Bremen, Hamburg and Berlin) between 1995 and 2008. Brandenburg (BB) had the most fatalities as a result of collisions with trees in 1995 (344). Targeted measures as part of road traffic safety programs reduced fatalities by 80%. 276 fewer people died as a result of a collision with a tree in 2008 than in 1995. In Lower Saxony (NI), on the other hand, fatalities fell by only 34% over the same period, although nationwide fatalities as a result of collisions with trees were reduced by around 60%.

Figure 3 shows the number of fatalities as a result of collisions with trees compared to other fatalities on roads outside of built-up areas in 2008. In Brandenburg there were 68 fatalities

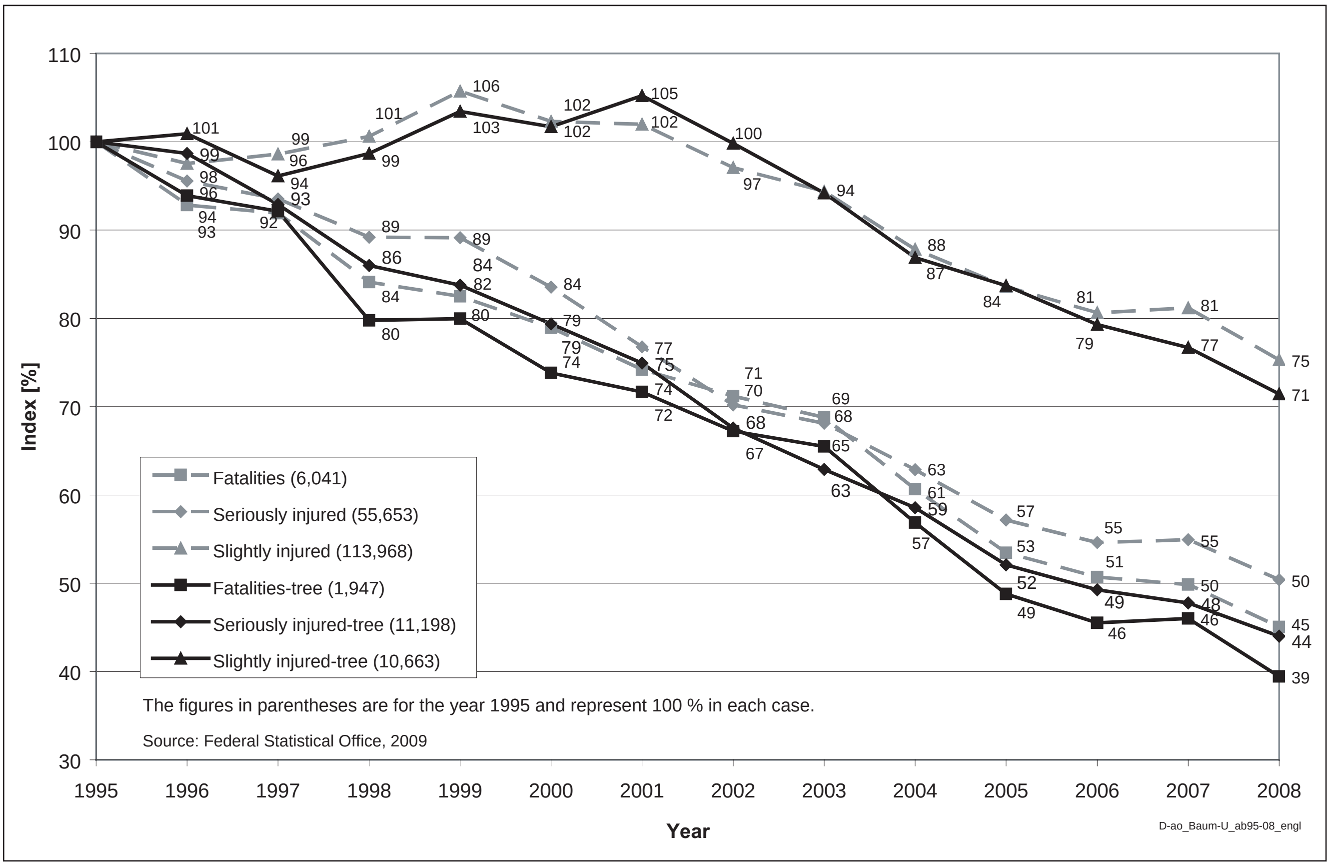


Figure 1:
Trends in fatalities on roads outside of built-up areas as a result of all accidents and of accidents involving collisions with trees [1]

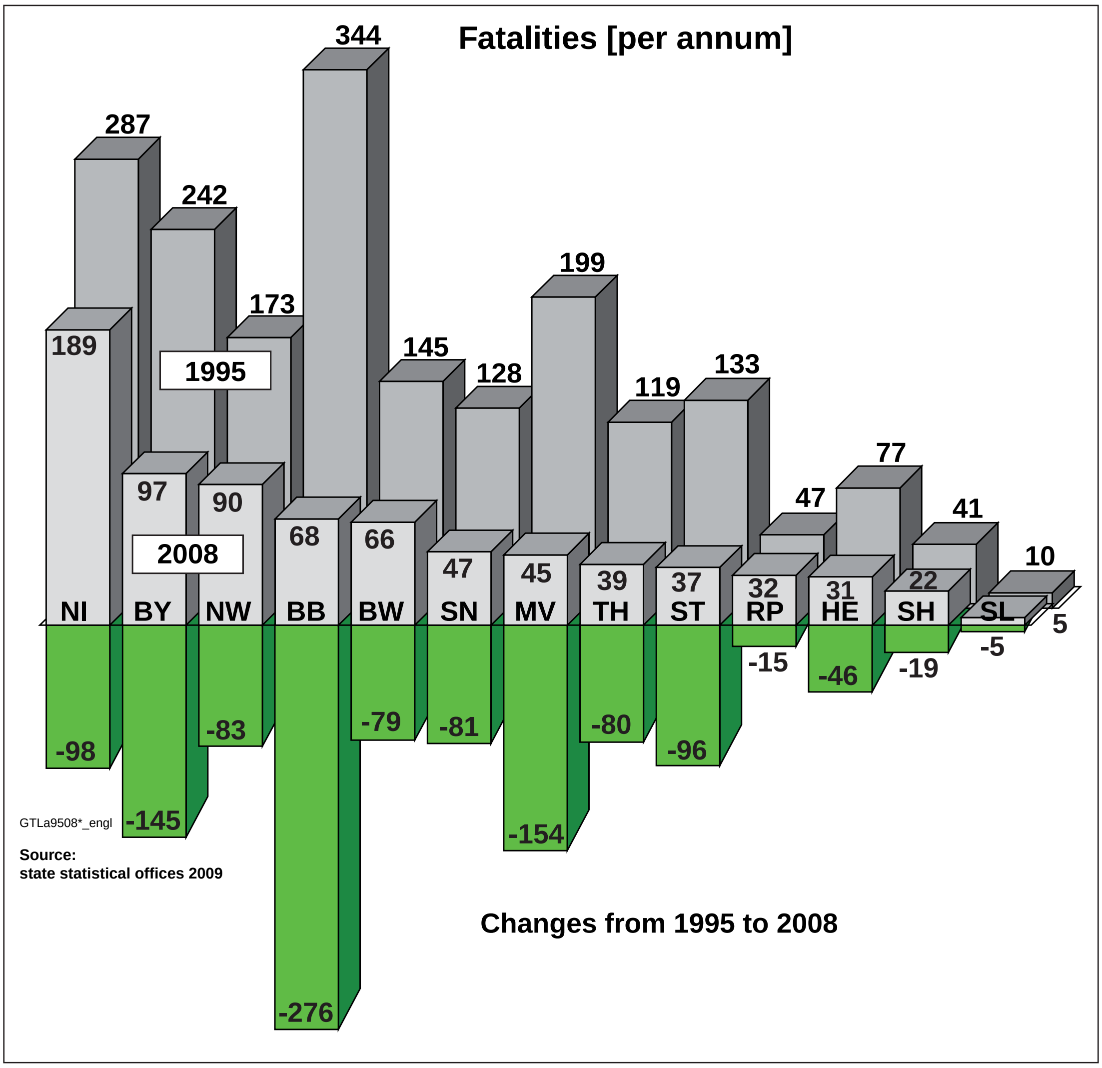


Figure 2:
Fatalities as a result of collisions with trees on roads outside of built-up areas by federal state [3]

as a result of collisions with trees and 65 as a result of other accidents on roads outside of built-up areas. The ratio in Lower Saxony of 189 fatalities as a result of collisions with trees to 240 other fatalities on roads outside of built-up areas also illustrates the problem represented by accidents involving collisions with trees.

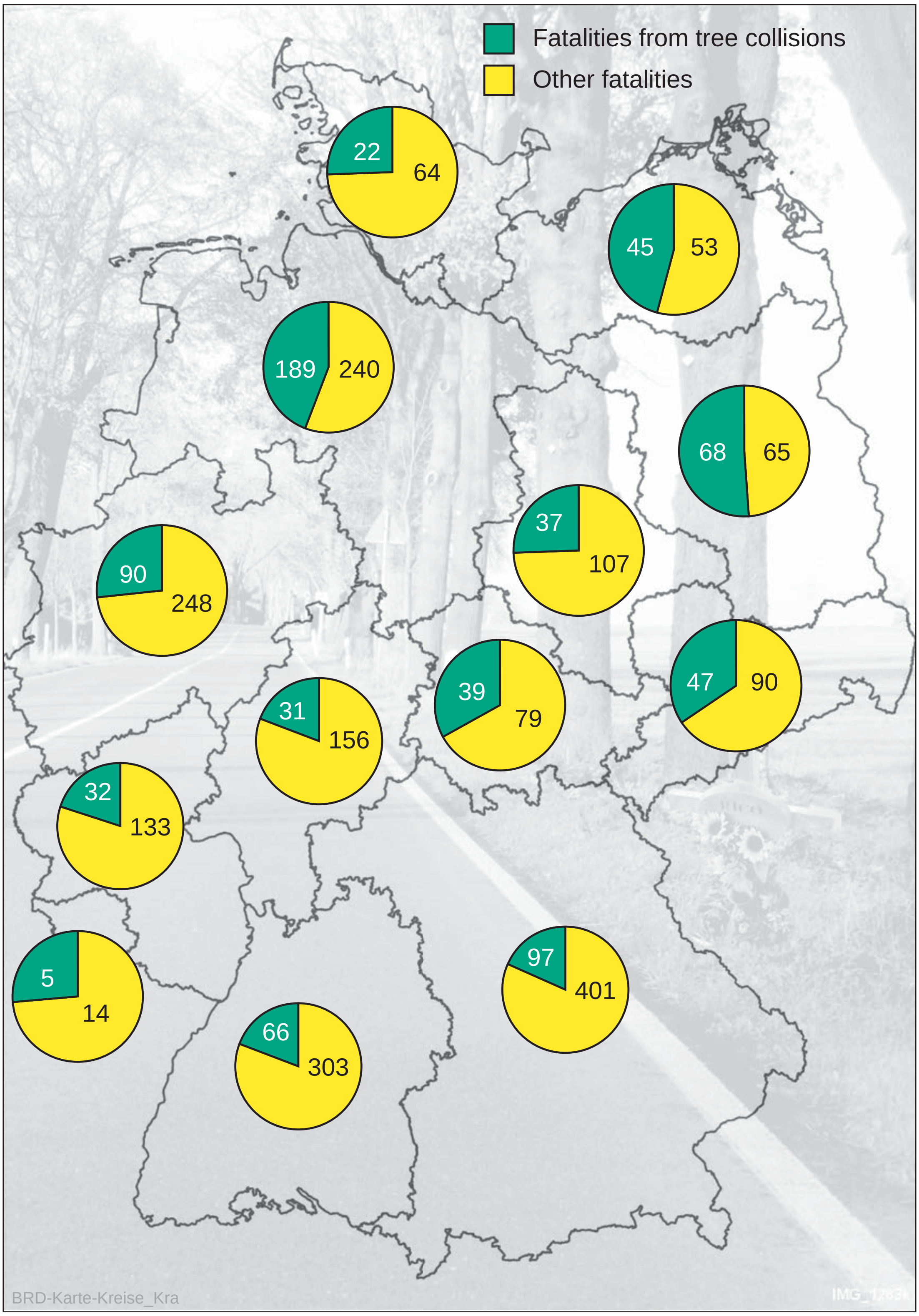


Figure 3:
Fatalities as a result of collisions with trees and fatalities caused by other accidents on roads outside of built-up areas in 2008 by federal state [3]

3 Consequences of collisions with trees

Meewes [4] found that around 85% of collisions with trees resulting in personal injury and serious damage to property are the result of a driver leaving the road unintentionally without a preceding collision. The consequences are worse than for collisions with a crash barrier or for accidents not involving collisions.

If a driver loses control of a vehicle at a speed of 100 kph and the vehicle leaves the road, its speed is still very high when it hits a tree at the side of the road (Figure 4).

Irrespective of whether there is a tree at the side of the road, such high speeds are not unusual, particularly at times when there is little traffic on the roads.

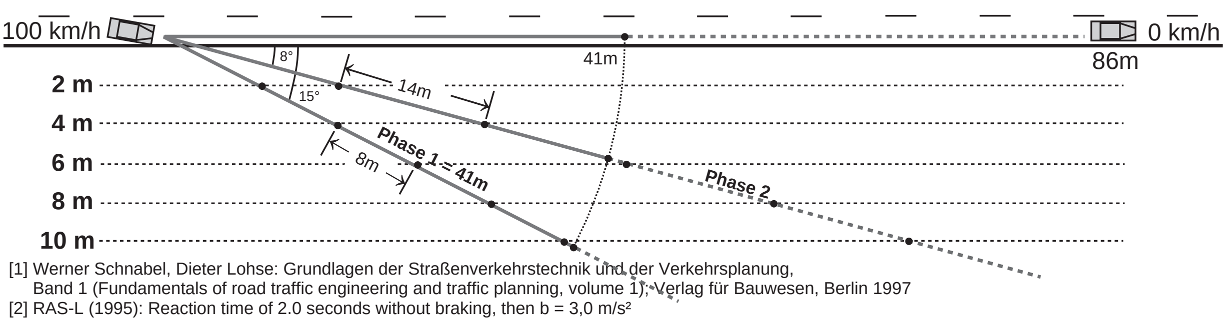
Crash tests carried out by the UDV in tandem with DEKRA at the Neumünster test site showed that even a side impact against a tree at 40 kph can result in extremely serious or even fatal injuries for the occupants of the vehicle (Figure 5). The pole used as a tree at the test site penetrated over 40 cm into the vehicle. The vehicle was subjected to a maximum g-force of 98g. The point of impact was in line with the B pillar. If the point of impact is in the door area, the consequences are much worse.

Angle at which vehicle leaves road	Speed on impact [kph] Distance of obstacle from edge of road				
	2 m	4 m	6 m	8 m	10 m
8°	99	98	96	85	74
15°	99	99	98	98	97

Conditions: Initial speed of 100 kph

1st phase: Reaction distance = 1.5 seconds [1], [2]
Deceleration b(s) = 0,6 m/s² (hard, level ground) [3]

2nd phase: Braking with b = 5 m/s² off road; 8,0 m/s² on road [2]



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[2] RAS-L (1995): Reaction time of 2.0 seconds without braking, then b = 3,0 m/s²
[3] Rein Schandersson: Trafiksäkerhet vid avkörning i vägens sidoutrymme, VTI Rapport Nr. 203, Linköping 1980

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Figure 4:
Speeds on impact depending on the angle at which the vehicle leaves the road and the distance of the obstacle from the edge of the road [4]

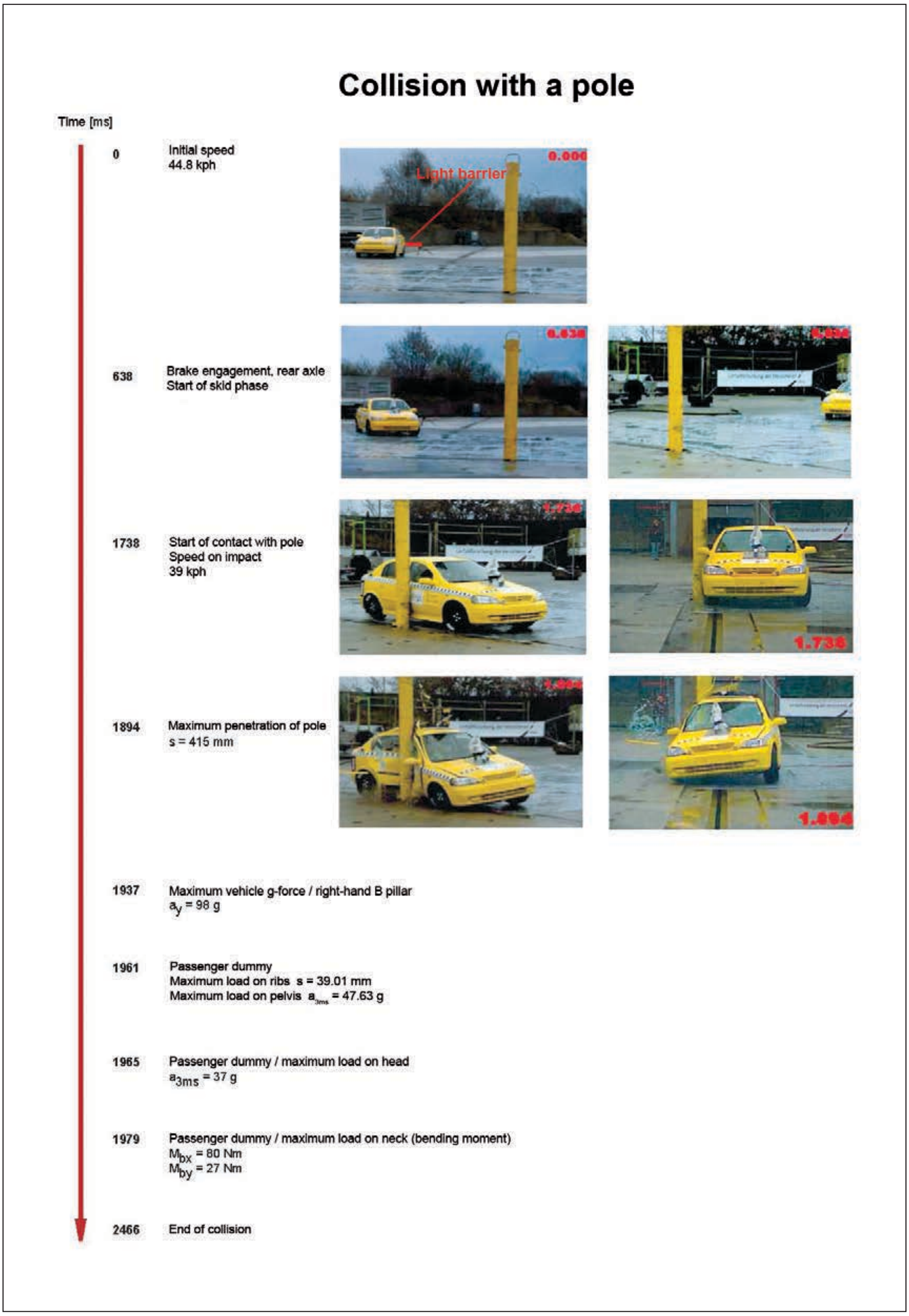

Figure 5:
Progress of the test involving a collision with a pole without a crash barrier

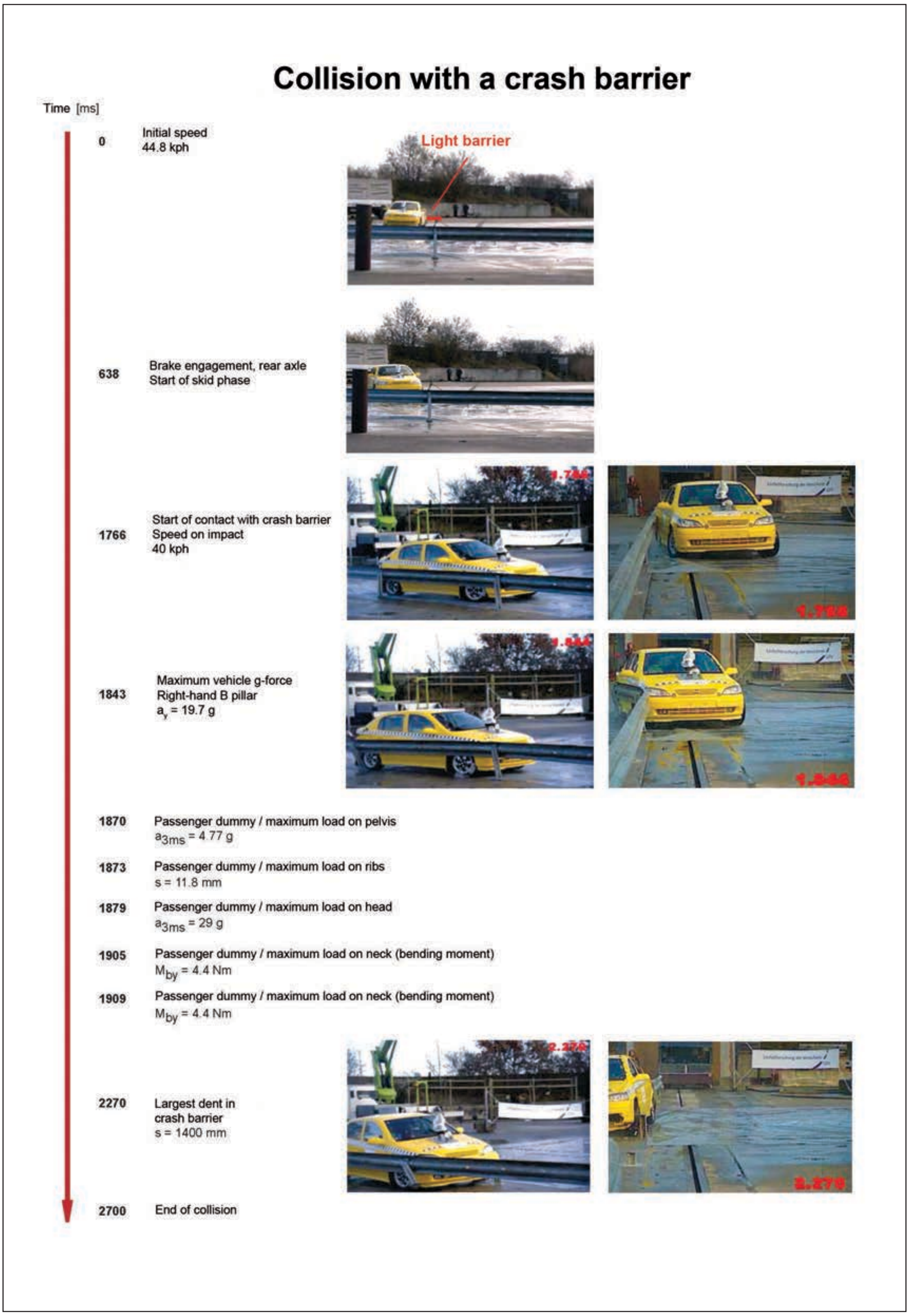

Figure 6:
Progress of the test with a crash barrier

Figure 7:
Collision of a 1994 Opel Omega B with a pole at 97 kph at an angle of 23° and with a test weight of 1,656 kg [5]

By contrast, a collision with a crash barrier can be survived by the vehicle occupants with less serious consequences than when there is no crash barrier at the roadside (Figure 6). The tests provided an impressive demonstration of the protection offered by a crash barrier.

When a vehicle hits a pole at 97 kph, it is completely torn apart (Figure 7). The vehicle's occupants have no chance of survival, as tests carried out by DEKRA demonstrated [5].

4 Measures for combating collisions with trees

Generally speaking, the measures taken to improve road safety fall into three categories: driver behavior, automotive engineering and infrastructure. In the case of collisions with trees, in particular, success can only be achieved if efforts are made in all of these areas. A long-term road safety strategy is the only way to combat accidents involving collisions with trees successfully. Brandenburg began its program against accidents involving collisions with trees in 1993 and 1994 by evaluating the state of tree-lined trunk roads and federal state roads. This was followed by measures such as the crash barrier program, the prohibition of overtaking on certain stretches of road, the reduction of the speed limit on tree-lined roads to 80 kph, enforced in some cases by means of mobile or fixed speed cameras, and the removal of isolated trees [6]. These measures resulted in a clear reduction in the number of fatalities and in the consequences of accidents overall.

As far as the vehicles themselves are concerned, modern vehicle structures can now cope better even with side collisions in which the vehicle is hit at its weakest point. This is due, among other things, to the contribution made by the Euro NCAP consumer protection tests since 1997 [7].

4.1 Infrastructure-related measures

The first step when targeting measures to combat accidents involving collisions with trees is to identify sites and stretches of road with significant numbers of accidents. To this end, electronic mapping showing accident types and incidences is evaluated. The recommendations for combating collisions with trees issued by the Forschungsgesellschaft für Straßen- und Verkehrswesen, a road and transportation research Association, include measures designed to reduce the number of accidents in which vehicles leave the road or to reduce the consequences of accidents involving collisions with trees [8].

The different measures vary in their safety potential (as measured by avoidable accident costs) [9]. To calculate the safety potential, it was assumed that, given the same number of accidents, their severity can be reduced by taking suitable measures (such as erecting crash barriers) in the areas where collisions with trees occur (Figure 8). The effects of obstacle-free roadside areas and of the enforcement of suitable speed limits were calculated in a similar way. Crash barriers significantly reduce the consequences of accidents. They cut accident costs resulting from collisions with trees by around half (Figure 8). These measures can generally be quickly and easily implemented at existing black spots, and in some situations it is acceptable to reduce the width of the carriageway in order to widen the road's shoulder. This can also be done on stretches of tree-lined roads with significant numbers of accidents when the full effect of crash barriers cannot be obtained due to the fact that there is not enough space between the crash barrier and the trees in most cases. The important thing here is to prevent direct collisions with trees.

Roadside areas should be kept free when work is done to improve or enlarge existing roads outside of built-up areas. In certain cases, it may

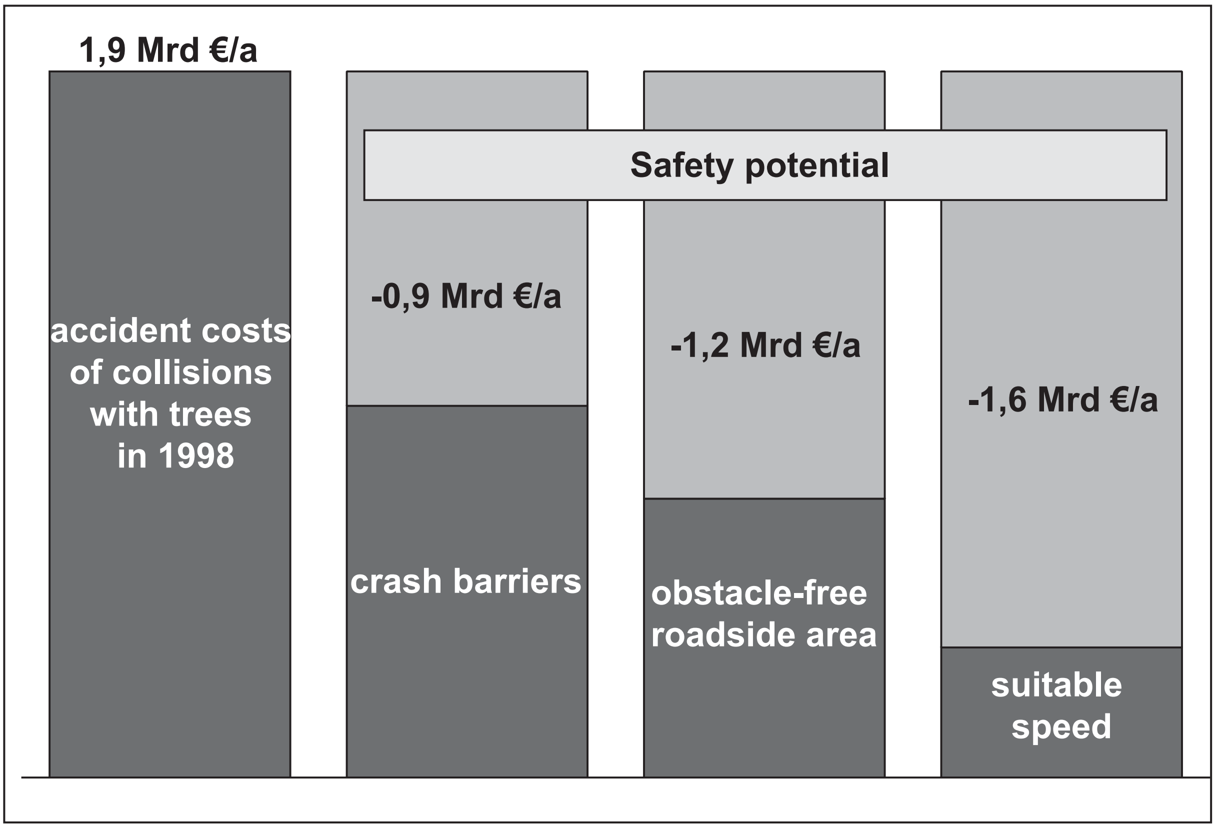

Figure 8:
Safety potential (as measured by avoidable accident costs) based on the accidents that occurred in 1998 [9]

be necessary to remove trees beside existing sections of roads with significant numbers of accidents. This can cut accident costs resulting from collisions with trees by around 60% (Figure 8). The same applies when new roads are built outside of built-up areas. New trees at the roadside become dangerous obstacles in a relatively short space of time (after five years at the latest) – before it becomes evident in the accident statistics.

Reducing the speed limit, adjusting it to suit the road as it stands and enforcing the limit in both directions by means of fixed speed cameras has proved to be one of the most effective measures that can be taken. This can cut accident costs resulting from collisions with trees by up to 80% (Figure 8). The latest results of the large-scale study of safety on roads outside of built-up areas carried out by the Federal Highway Research Institute (BASt) together with road construction authorities in selected federal states and the Technische Universität Dresden confirm that sequences of fixed speed cameras improve road safety overall over the longer term [10].

The above measures can also be combined. Further, additional traffic management measures, such as preventing overtaking by means of lines on the road that cannot be crossed (sign 295 or 296 in the German road traffic regulations) or warnings about dangerous bends by means of traffic signs, or operational measures, such as increased deployment of road crews to clear the roads in winter conditions, can also be effective.

Construction measures such as work to improve skid resistance and surface drainage are effective if the accidents generally happen in wet conditions. The state of the road surface, its transverse gradient and the functioning of the drainage facilities should be checked first. Variations in the radius of tight single bends that cause frequent accidents can be removed by increasing the radius of the bend.

White markings on trees and reducing the speed limit without regular speed checks have proved to be particularly ineffective measures. However, raised-profile road markings, planting lines of trees further from the edge of the road and putting up “educational” traffic signs designed to influence how drivers behave were also found in these studies to be ineffective in reducing the number and severity of accidents involving collisions with trees [9].

4.2 Vehicle-related measures

Measures to improve passive vehicle safety have a limited effect on accidents like these due to the extreme forces to which vehicles and their occupants are subjected. By contrast, driver assistance systems can help to prevent these accidents or reduce their consequences.

Electronic stability programs (ESP), which are among the most effective vehicle safety systems, can also have a positive effect on accidents involving collisions with trees and even prevent them. Studies by the UDV have shown that this effect applies to 25% of all car accidents involving personal injury and around 35% of all car accidents involving fatalities [11]. If you apply these findings to the accidents involving one or more cars in the official statistics for 2007, taking into account the fact that 36% of all cars were equipped with ESP, around 21,000 of these accidents involving injuries and around 400 accidents involving fatalities could have been avoided or their consequences could have been reduced. Unfortunately, the percentage of cars equipped with ESP in 2007 falls well short of the aim of achieving universal coverage. The statutory obligation to equip all new vehicle types with

ESP from 2011 and all newly registered vehicle models from 2014 will have a positive impact. However, there will still be a long way to go before 100% of cars have ESP. A combination of the federal government's scrappage scheme with a mandatory minimum level of safety equipment for new cars would have been a good way to speed up the process.

A more recent driver assistance system that can be helpful in preventing this kind of accident is the lane departure warning system. Current UDV accident analyses show that only limited theoretical safety potential of 4.4% can be realized for all accidents in the database. When it comes to accidents in which the driver leaves the road unintentionally, however, the safety potential rises to 33.6%. If the human factor is included in the calculation, the safety potential is 16% [12]. It should be noted, however, that these analyses of potential are not limited to roads outside of built-up areas. The figures apply to all accidents both inside and outside of built-up areas.

In the future, a further driver assistance system may be able to prevent collisions with trees or at least reduce their consequences. Analyses of the UDV have revealed, for instance, that an overtaking assistance system could prevent around 21% of all accidents in which drivers intentionally leave their own lane to overtake [12]. It is not unusual for accidents involving an overtaking maneuver to result in a collision with a tree.

The level of passive safety in modern cars is now very high. Although progress will continue to be made in this respect, we should be aiming in the future for integrated safety measures that help to prevent accidents or reduce their severity and then minimize their consequences. Ultimately, the vehicles of the future must meet demands for both active and passive safety.

5 Conclusions and recommendations

Collisions with trees are particularly serious accidents that happen when cars leave the road unintentionally, generally at high speeds. The UDV (German Insurers Accident Research) therefore makes the following recommendations:

- The speed limit should be reduced and surveillance introduced in black spots where there are significant numbers of collisions with trees. There should be a speed limit of 80 kph on tree-lined roads.
- Crash barriers should be erected at accident black spots.
- A judicious combination of known, effective measures should be implemented.
- No new trees should be planted without crash barriers.
- Vehicles should be equipped with effective driver assistance systems that improve safety.

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