



## Compact accident research

# Road safety around roadwork sites on motorways

## **Imprint**

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## Preliminary remarks

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Roadwork sites on motorways do more than just interrupt the flow of traffic. Although driving speeds at roadwork sites are lower than elsewhere on motorways due to the characteristics of the road layout at roadwork sites and the speed limits that are necessitated, they are often associated with more accidents - and in some cases with more serious accidents.

The UDV (German Insurers Accident Research) therefore commissioned Technische Universität Dresden to carry out a study to investigate where and why there are safety shortcomings in the vicinity of roadwork sites and how safety can be improved there.

The study consisted of an analysis of the statistics in the vicinity of all roadwork sites on German motorways (autobahns), an analysis of the accidents at 76 selected roadwork sites and a retrospective analysis of 12 completed motorway roadwork sites with a total length of 68 km that continued for a period of at least 12 months. In addition, a detailed analysis was carried out of eight existing roadwork sites with a total length of 57 km, involving the analysis of the driving behavior of car and truck drivers throughout the length of the roadwork sites and/or in characteristic areas in or near them.

This compact accident research report summarizes the findings of this study. You can obtain more detailed information from research report VI04, entitled "Untersuchung der Verkehrssicherheit im Bereich von Baustellen auf Bundesautobahnen" (Study of Road Safety Around Roadwork Sites on Motorways in Germany). You can download this report free of charge at [www.udv.de](http://www.udv.de).

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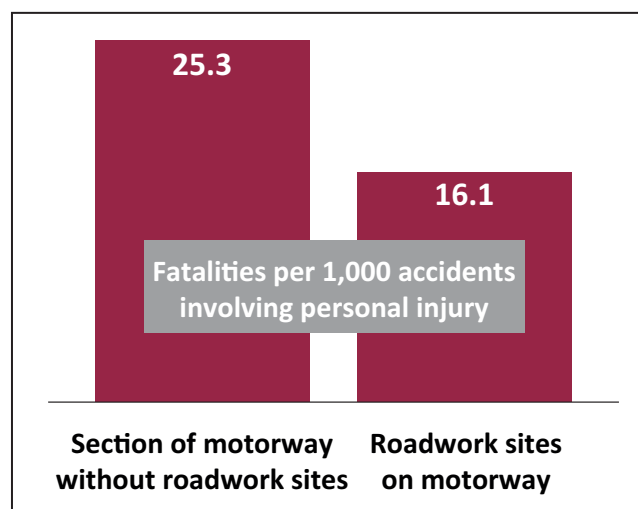
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## 1 General information about the accident occurrence on motorways

Motorways (autobahns) are the fastest roads in the German roadwork and have the highest level of safety - higher than either roads inside built-up areas or other roads outside built-up areas. Nevertheless, a total of 17,172 accidents involving personal injury occurred on motorways in the year 2011, 1,118 of them at roadwork sites. A total of 18 people were killed and 220 seriously injured (Table 1). The accident severity (fatalities per 1,000 accidents involving personal injury) of accidents that occur on sections of motorway without roadwork sites is up to 1.6 times higher than that of accidents that occur at roadwork sites. This is due, in particular, to the higher speeds of the vehicles (Figure 1).

In the year 2011, the social economic costs of accidents (accident costs in accordance with M Uko [1]) on sections of motorway without roadwork sites amounted to €2.2 billion, while those of accidents at motorway roadwork sites amounted to €121 million, which is about 5.4% of total motorway accident costs.

In the period from 2006 to 2008, the costs of accidents at motorway roadwork sites accoun-



**Figure 1:** Accident severity on motorways in 2011 (data source: Federal Statistical Office 2012; own calculation)

ted for around 5% of the total costs of accidents on motorways [2].

## 2 Initial situation

Roadwork sites interrupt the flow of traffic and reduce road safety, although these hazards are counteracted by means of special road equipment and speed restrictions. There are some discrepancies in the information provided in the literature about the factors that have an impact on the level of road safety at motorway

**Table 1:** Accidents and accident consequences on motorways in 2011 in accordance with "M Uko" [1]

Section of motorways	Accident in 2011 with					Casualties			Accident costs AC (I, SD) (€ 1,000/a)
	Personal injury	Serious damage to property	Fatalities	Seriously injured persons	Slightly injured persons	Fatalities	Seriously injured persons	Slightly injured persons	
Roadwork sites on motorways	1,118	678	16	172	930	18	220	1,574	120,767
Section without roadwork sites	17,172	10,898	384	3,737	13,051	435	5,003	21,884	2,233,442

Data source: Federal Statistical Office 2012; own calculation (at prices for the year 2009)

roadwork sites. While some studies attribute the reduced level of road safety to roadwork sites as a whole [3] and [4], others attribute it to specific sections in the vicinity of these roadwork sites, such as lane realignment points, or even to specific parameters such as the angle of realignment [5].

Accidents at motorway roadwork sites are generally accidents involving minor damage to property [6]. However, there is an absence of reliable findings on the impact of characteristic features of roadwork sites on the road safety of motorways (lane realignment points, carriageway changeover points and temporary slip roads). The same applies to the impact of how the traffic is routed, the length of the roadwork site or specific road equipment (e.g. road signs against a yellow background).

In a study of road safety and the flow of traffic, the accidents that occurred at different points at and in the vicinity of roadwork sites was analyzed in conjunction with their layout and drivers' driving behavior [6].

### 3 Methodology and sample

A three-step approach was chosen for the study. Figure 2 shows its main elements:

#### ▪ Macroscopic analysis of already completed roadwork sites

These served to determine the general impact of roadwork sites on the accidents that occurred on the relevant sections of motorways. The duration of the investigation, which needed to be as long as possible, was limited by changes in the layout and traffic

routing. Table 2 shows the essential features of the 12 roadwork sites in this step. These roadwork sites were already completed at the time of the analysis. For the great majority of the time, all traffic at the roadwork sites was routed along one of the motorway's two carriageways (4+0)<sup>1)</sup>. More unusually, the traffic was routed along both carriageways (2+2)<sup>2)</sup> or (3+1)<sup>3)</sup>. The specified lengths indicate the shortest length of the roadwork site during the period of its existence. In individual construction phases, some of the roadwork sites were really quite long, up to 12 km.

#### ▪ Microscopic analysis of the flow of the traffic and accidents at existing roadwork sites

In the microscopic analysis, the flow of traffic, drivers' driving behavior and the accidents that occurred were investigated. Seven roadwork sites (Table 3) were selected for this purpose that were in existence for a period of at least 12 months in 2008 and 2009, during which their form/layout and traffic routing remained largely unchanged. Roadwork sites D6 and D7 had the narrowest cross-sections with 5.50 m of available carriageway in each direction. A speed limit of 80 km/h was in operation.

Based on the results of both of these steps of the analysis, recommendations were made for improving road safety at motorway roadwork sites.

#### ▪ "Yellow roadwork sites" field test

Characteristic sections of roadwork sites where particularly significant numbers of accidents occurred were subjected to a more detailed investigation. The focus here was on an analysis of driving behavior when the

<sup>1)</sup> All four lanes within the roadwork site are routed along one of the motorway's two carriageways. On the other carriageway, there is no traffic.

<sup>2)</sup> On each of both carriageways are two lanes for traffic within the roadwork site in each direction.

<sup>3)</sup> The left lane in one traffic direction has been routed within the roadwork site along the carriageway of the opposite direction (3 lanes). The right lane remains on the appropriated carriageway.

road signs with the normal white background were replaced with the same road signs on a yellow backboard. The effect of this change on driving behavior was ascertained only at sections of the roadwork sites at which particularly high numbers of accidents occurred.

The effect of increasing the speed limit in stages after the roadwork site was also examined. It was not possible to analyze the accidents that occurred in these cases because the investigation period was too short.

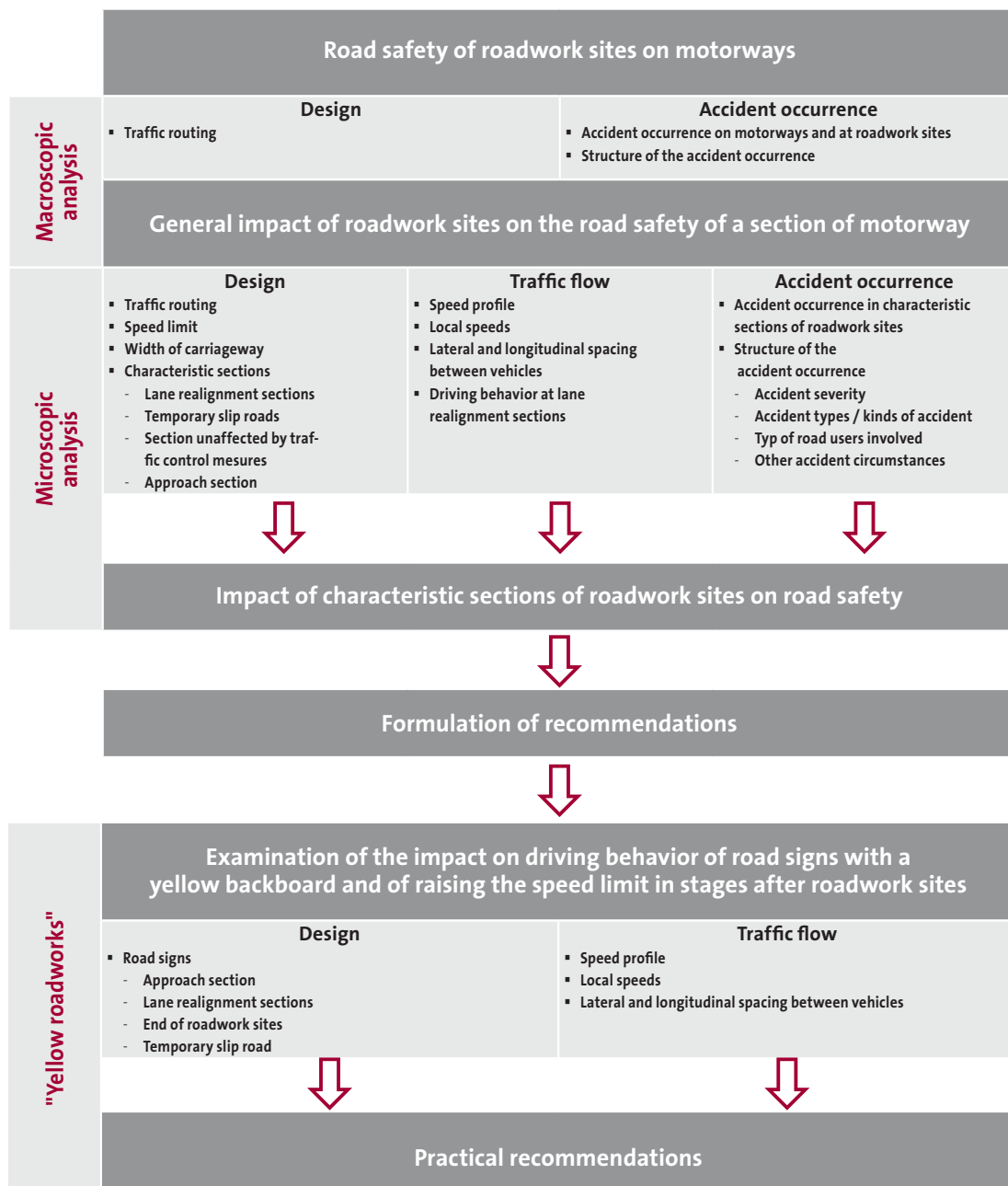


Figure 2:  
Methodology of the investigation

In order to obtain useful findings about the accidents that occurred, the analysis had to be carried out over as long a period as possible. The duration of the investigation was limited by changes in the layout and traffic routing. This resulted in some relatively short phases.

Sections of the investigation with a duration of under six months occurred frequently at the roadwork sites investigated, primarily due to the fact that the traffic routing was changed as the construction work progressed. In around 46 roadwork sites with a duration of

**Table 2:**  
**Roadwork sites in the macroscopic analysis**

No.	Length [km]	ADT** [Vehicles / 24 h]	Duration [a]	Traffic routing		Slip road [present]
				Constant	Changing	
1	6.3	64,660	2.6		3+1/4+0/3+2	no
2	8.4	92,619	2.6	4+0		no
3	9.1	58,623	3.3	4+0		no
4	5.5	61,999	3.8		4+0/2+2/3+1	yes
5	4.5	71,541	3.2		4+0/2+2	yes
6	4.1	58,465	3.3		4+0/2+2/3+1	yes
7	3.6	50,000	5.1		2+2/4+0	yes
8	6.0	60,000	3.8		2+2/4+0	yes
9	5.0	40,000	3.5		2+2/4+0	yes
10	5.0	35,863	2.5		4+0/2+2	no
11	5.9	53,455	3.4		4+0/3+1	no
12*	4.7	50,000	0.75		4+0/2+2	yes

\*) Accident data available for nine months only

\*\*) ADT: Average Daily Traffic

**Table 3:**  
**Roadwork sites in the microscopic analysis**

No.	Length [km]	ADT**** [Vehicles / 24 h]	Duration* [a]	Traffic routing		Slip road [present]
				Constant	Changing	
D1	6	58,456	1		3+1/4+0	yes
D2	10	45,000	1	4+0		yes
D3	6	53,455	1	4+0		yes
D4	14	45,000	1	4+0		yes
D5	3	55,000	1		4+0/2+2	yes
D6**	6	58,800	1	4+0		yes
D7**	6	58,800	1	4+0		no
D8***	6	37,663	0.3	4+0		yes

\*) Duration of examination (roadworks may have been in existence longer)

\*\*) Roadworks with narrow cross-sections (5.50 m)

\*\*\* Roadworks with modified road signs ("yellow roadworks")

\*\*\*\* ADT: Average Daily Traffic



under six months, a total of 24 accidents involving personal injury and 374 accidents involving damage to property were recorded, while in 30 roadwork sites with a duration of over six months, 106 accidents involving personal injury and 1,895 accidents involving damage to property were recorded (i.e. four or five times as many). An analysis of such short periods by standardizing them to a period of a year is associated with significant uncertainties.

Durations of less than six months were therefore not included in the accident analyses due to the low numbers of accidents involved and the associated distributions of the calculated parameters.

## 4 Macroscopic analysis

### 4.1 Principle

The roadwork sites shown in Table 2 served as the basis for the macroscopic analyses. The section of road investigated was subdivided before and after the roadwork site as shown in Figure 3, and the accidents were applied to these subsections accordingly.

The section of road between the first road sign announcing the roadwork sites (Z 123) until the first lane realignment point or carriageway changeover point was defined as the approach to the roadwork sites. The pre- and post-roadwork sites sections of road were defined as the 3 km sections of road both before and after each roadwork sites site. Since the flow of traffic, driving behavior and accidents in the pre- and post-roadworks sections of road were not yet or no longer influenced significantly by the existence of the roadworks, these sections of road served as a control group. The accidents on motorways with a two-lane carriageway in each direction (BAB/2+2 lanes) were used as an additional, supra-regional control group.

### 4.2 Structure of the accident occurrence

#### Vehicles involved in accidents

Significantly fewer single-vehicle accidents occur at roadwork sites (14 % of accidents there are single-vehicle accidents as opposed to 41 % of accidents on other sections of motorway), but trucks are involved in accidents at roadwork sites more often than elsewhere. Accidents caused by trucks account for 34 % of accidents at roadwork sites and 24 % of accidents on other sections of motorway. The percentage of large vehicles that are the second vehicle involved in an accident is even higher at roadwork sites. At lane realignment points and carriageway changeover points, trucks are involved in almost 70 % of all accidents involving more than one vehicle.

#### Accident types

Most accidents at roadwork sites are accidents in longitudinal traffic (68 % of all accidents) or driving accidents (13 % of all accidents). An accident in longitudinal traffic (accident type 6) is an accident caused by a conflict between road users driving in either the same direction or opposite directions. At roadwork sites, these occur in rear-end collisions or when drivers change lane. A driving accident (accident type 1) is an accident that occurs when a driver loses control of the vehicle as a result, for example, of not driving at an appropriate speed at the roadwork sites.

The percentage of accidents in longitudinal traffic that occur at roadwork sites is significantly higher than on the approach to the roadwork sites (49 %) or on the pre-roadworks section of road (53 %). However, it is not possible to say purely from the percentages of accident types whether this higher percentage is due to the fact that the lanes at roadwork sites are narrower.

### Kinds of accidents

The examination of the kinds of accidents showed that a large percentage of the accidents at roadwork sites involve vehicles traveling in the same direction. Accidents resulting from vehicles brushing against each other laterally (kind of accidents 3) occur particularly often. Accidents of this kind account for 50 % of accidents at roadwork sites, which is considerably higher than the 34 % of accidents they account for in the pre-roadworks section of motorway.

## 4.3 Accident consequences and safety levels

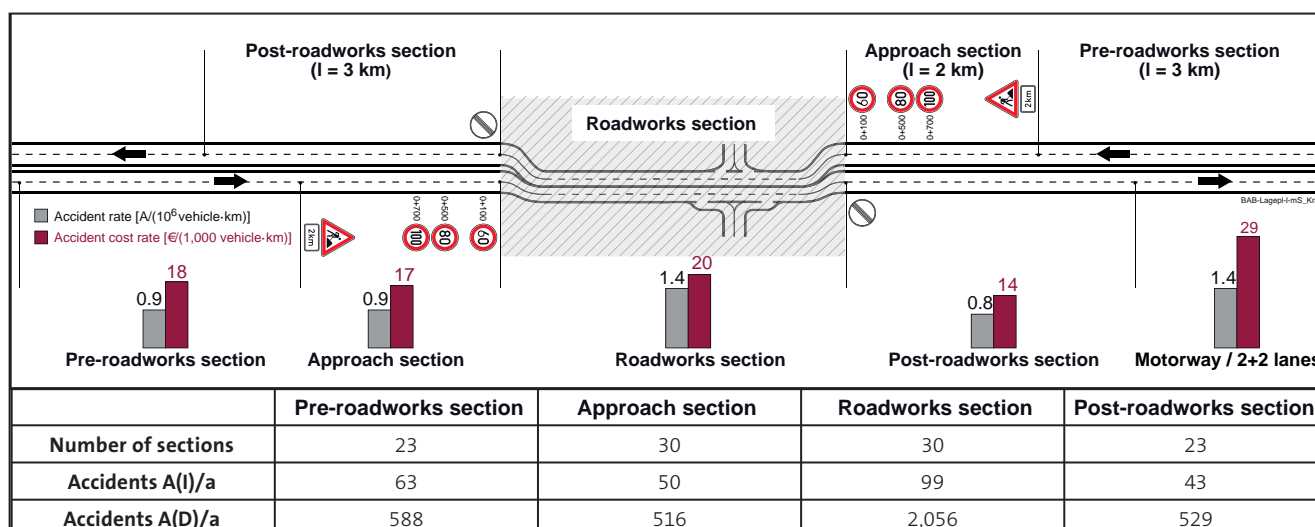
According to the Code of Practice for Evaluating Road Traffic Accidents - Part 1: Maintaining and Evaluating Accident Type Maps [7], it is possible

for a specific sample to adjust the accident cost rates on roads outside built-up areas based on the structure and severity of the accidents. A minimum of 100 accidents involving personal injury are required for this. Table 4 shows the number of accidents and the associated casualties at the roadwork sites investigated as well as the adjusted accident cost rates used to calculate the accident parameters.

Figure 3 shows the accident risk (accident rate) and safety level (accident cost rate) of different characteristic sections of motorway in relation to roadwork sites. Roadwork sites with a duration of at least six months served as the basis for assessing these risk parameters. Compared to the pre- and post-roadworks sections and the approach section, the roadworks section

**Table 4:**  
Accidents, casualties and adjusted accident cost rates (at prices for the year 2000) of the motorway roadwork sites investigated

Accidents with		Casualties			Adjusted accident cost rate for accident involving	
Personal injury A(I)	Damage to property A(D)	Fatalities	Seriously injured persons	Slightly injured persons	Personal injury	Damage to property
193	2,906	7	33	283	€ 95,000	€ 10,500



**Figure 3:**  
Safety levels of characteristic motorway sections along the 12 roadwork sites investigated

has the highest accident risk with 1.4 accidents/(106 x cars x km) and the highest accident severity with € 20/(1,000 x cars x km).

However, the accident severity at roadwork sites is significantly lower than that at sections of motorway without roadwork sites and with two lanes on each carriageway. This is attributable, in particular, to the lower speeds at which vehicles travel at roadwork sites compared to other sections of motorway. Measurements of speed (cross-sectional measurements and continuously tracked vehicles) indicated that the 85th percentile speeds generally exceeded the speed limit by "only" 5 km/h to 10 km/h.

#### 4.4 Length of roadwork sites and traffic routing

It was not possible to clearly ascertain in this study whether and to what extent the length

of a roadwork site has an impact on the accident occurrence. An examination of roadwork sites with lengths of over four kilometers indicated that the accident rate fell in the last third of the roadwork site. This was found for both long and short roadwork sites. However, this fall could not be explained on the basis of the speeds measured.

In 85 % of the roadwork sites investigated, all of the lanes in both directions were routed on a single carriageway (4+0). Forms of traffic routing in which the lanes were entirely split between the two carriageways (2+2) or partially split (3+1) tended to have an increased accident risk (Figure 4). However, the total number of kilometers involved in the roadwork sites with these forms of traffic routing was not high enough to make this finding statistically reliable.

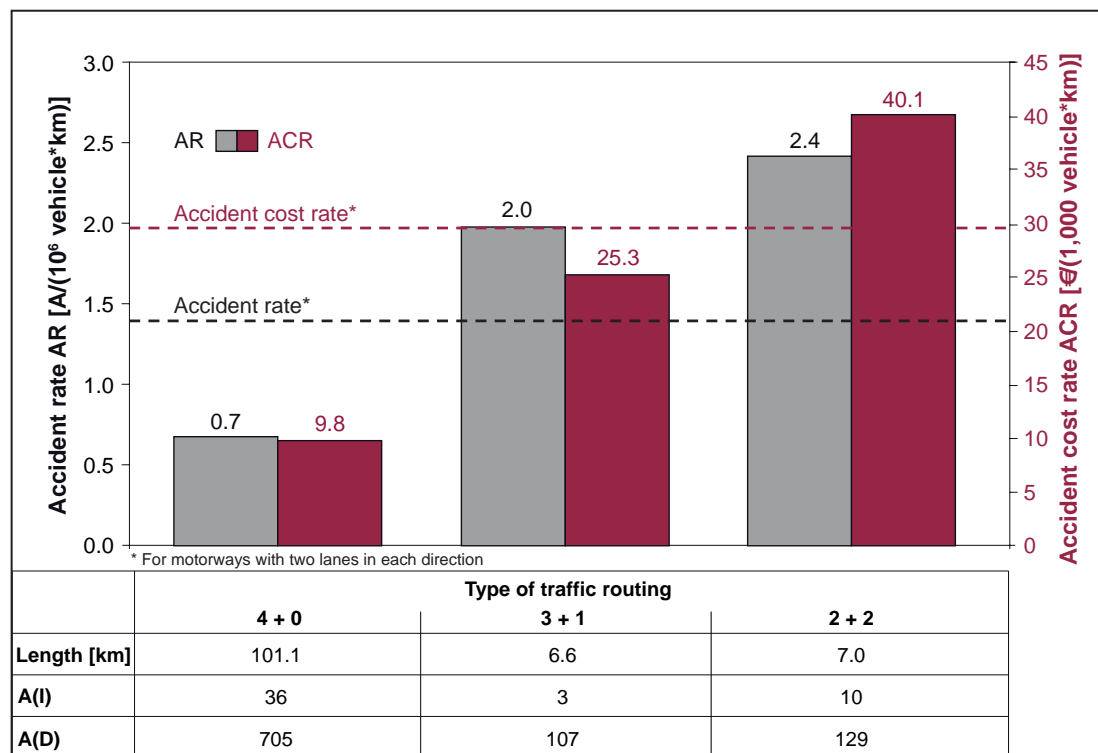


Figure 4:  
Accident rate (AR) and accident cost rate (ACR) for sections of road by type of traffic routing

## 4.5 Nature of other accident circumstances

The analysis of the accident circumstances in accordance with [7] and a comparison with the average numbers of accidents on German motorways show only a slightly increased percentage of accidents at night at roadwork sites (Table 5). On the approaches to roadwork sites, as defined by the road signs indicating there are roadwork site ahead, the reduction of the speed limit in stages and in some cases by a reduction in the number of driving lanes, an above-average number of accidents occurred in the dark.

In addition, the average values for motorways were also slightly exceeded at peak hours.

## 5 Results of the microscopic analysis

### 5.1 Comparison of characteristic subsections

The proximity of the vehicles to each other at roadwork sites, in conjunction with drivers failing to keep their distance from the vehicle

in front or straying slightly from their driving lines, results in an increased potential for conflict that can lead to accidents. In particular, changes to lanes (lane realignment points, carriageway changeover points) at the end of the roadwork site and temporary slip roads have a negative impact on the safety of roadwork sites. Compared to sections of road that are unaffected by traffic control measures, the accident risk is more than three times as high (Figure 5).

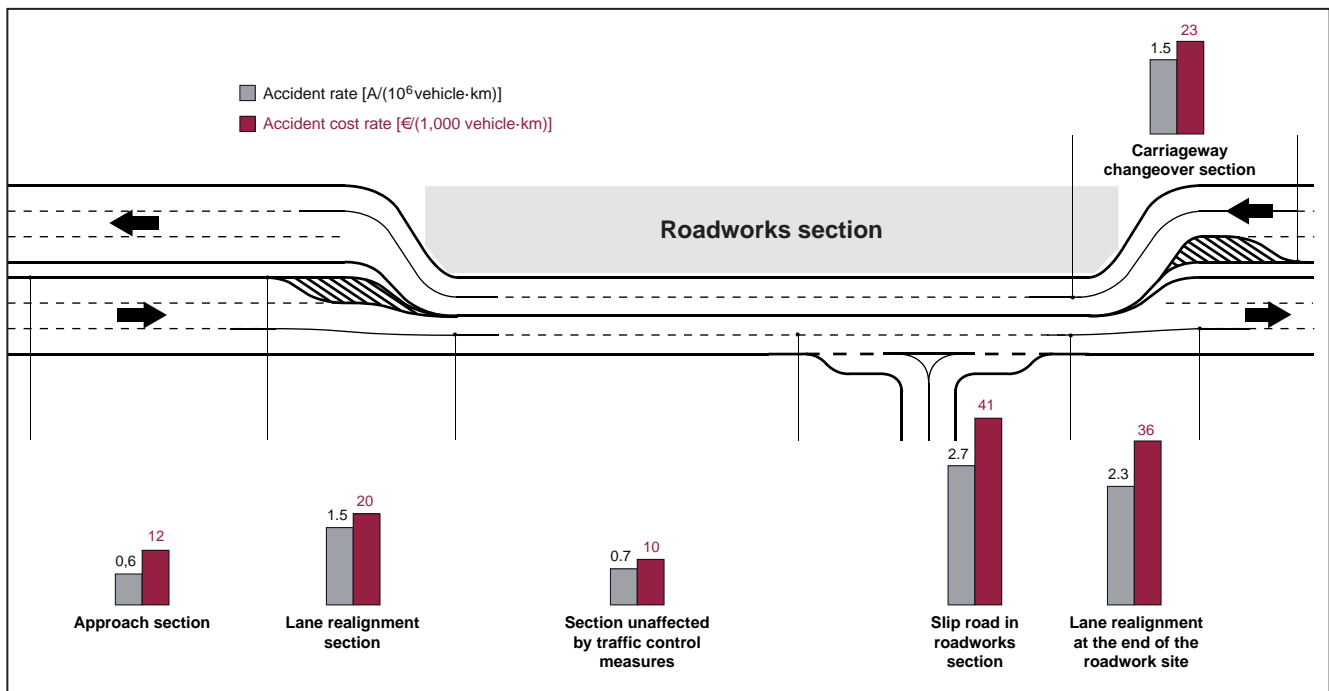
### 5.2 Approaches to roadwork sites

The accident risk on the approaches to roadwork sites is comparable to that at the roadworks section themselves. However, these accidents are more serious, particularly those that occur in the last 500 m of an approach section before the beginning of the roadworks section (Figure 6).

This is where both the greatest reductions in speed and the most accidents occur. The accidents are generally rear-end collisions or involve vehicles traveling in the same direction brushing against each other at the side. If the number of lanes is reduced, additional acci-

**Table 5:**  
Nature of the accident circumstances

Nature of the accident circumstances		Expected values for motorways	Values obtained at roadwork sites investigated	
			Approach section for 2 km before the first carriageway changeover section	Roadwork section
Winter	Dec - Mar	30 %	21 %	23 %
Weekend	Sat / Sun	30 %	19 %	17 %
Peak times	6 - 9 / 16 - 19	40 %	43 %	39 %
Night	poor light/dark	30 %	38 %	33 %
Wet/icy conditions	w / ic	40 %	24 %	19 %



**Figure 5:**  
Safety levels of characteristic subsections within a roadwork site

idents may occur, in particular as a result of vehicles leaving the road. Nevertheless, the accident rates for the approaches to roadwork sites are still lower than those for sections of motorway without roadwork sites.

Despite the reduction in the speeds of the vehicles, the 85th percentile speeds ( $V_{85}$ ) on the approaches to roadwork sites were up to 40 km/h higher than the speed limits. When entering the carriageway changeover point or lane realignment point at the beginning of the roadwork sites, most vehicles are still traveling at speeds above the speed limit.

### 5.3 Lane realignment points and carriageway changeover points

Accidents frequently occurred at lane realignment points (mostly to the right) as a result of vehicles leaving their lane to the left. There is a clear link here between high speeds (Figure 7)

and changes in driving direction. When all lane realignment points at motorway roadwork sites are examined, the kind of accidents 3 (side collision with a vehicle traveling in the same direction) is the dominant one. At carriageway changeover points, on the other hand, rear-end collisions (kind of accidents 2) and leaving the road (kinds of accidents 8 and 9) are more common.

The accident risk (accident rate) of lane realignment points with a speed limit of 80 km/h is three times that of lane realignment points with a speed limit of 60 km/h (Figure 8). The 85th percentile speed ( $V_{85}$ ) is almost the same at the first lane realignment point for both speed limits. Lane realignment points with a low realignment angle tend to have a higher accident risk.

Accidents at carriageway changeover points (to the left) at the beginning of a roadwork site were more serious and there was an in-

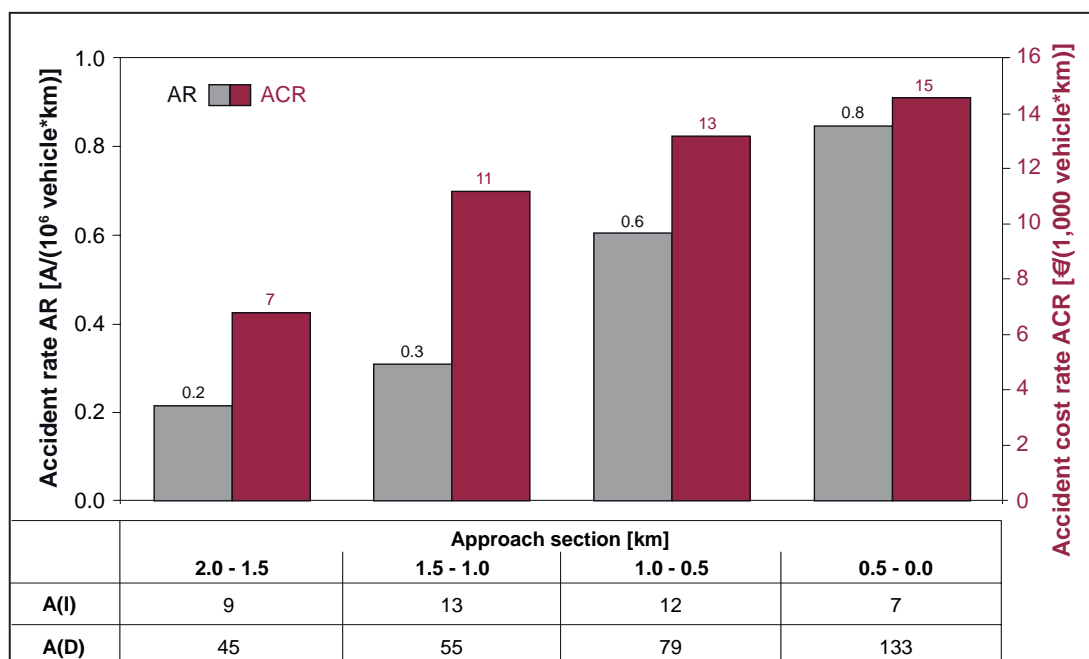


Figure 6:  
Accident rates (accident risk) on the approach section by distance from the beginning of the road-work site

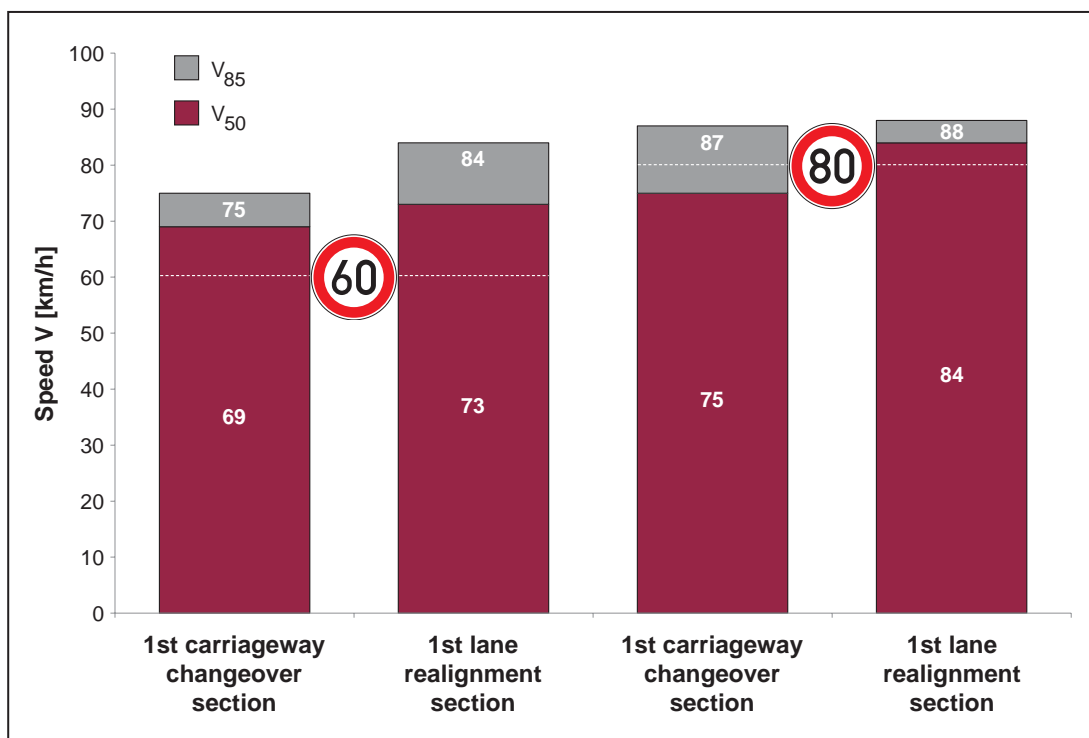
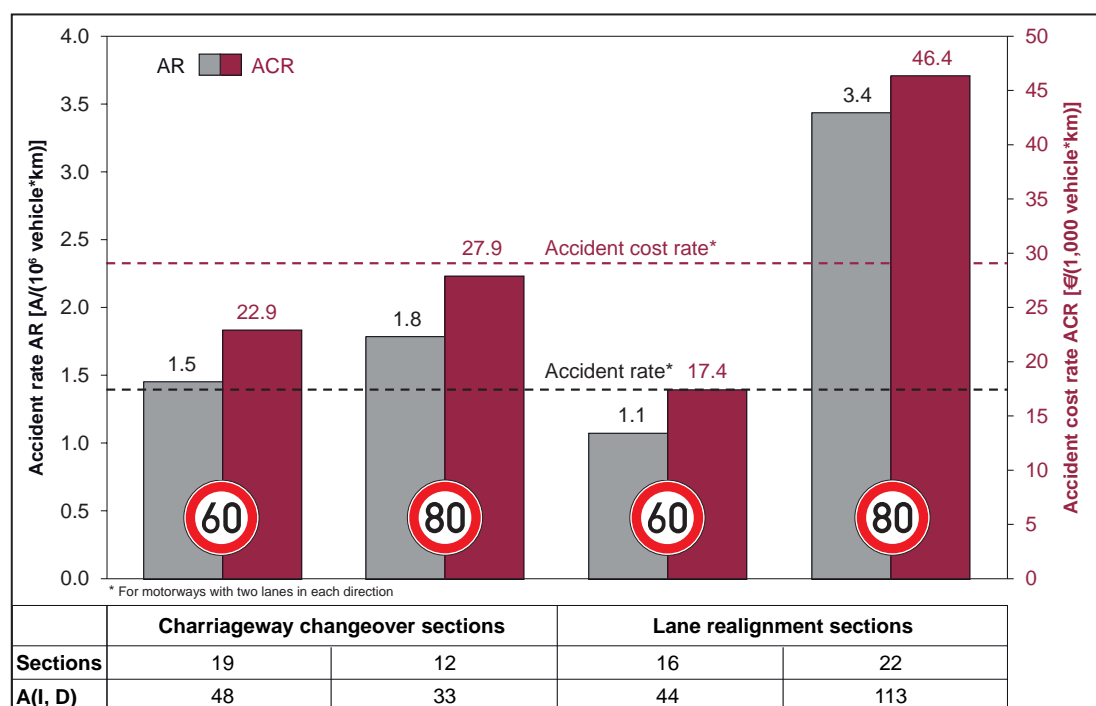


Figure 7:  
Speeds measured at carriageway changeover points and lane realignment points with different speed limits



**Figure 8:**  
Accident rates (AR) and accident cost rates (ACR) of carriageway changeover points and lane realignment points with different speed limits

creased percentage of accidents as a result of vehicles leaving the road to the right.

Carriageway changeover points generally have a higher realignment angle than lane realignment points, and drivers therefore negotiate them more carefully and more often avoid driving side by side. The accident risk at carriageway changeover points with a speed limit of 80 km/h is only slightly higher than at those with a speed limit of 60 km/h. The speeds measured at the first carriageway changeover point indicate that vehicles exceed the speed limit of 60 km/h by significantly less.

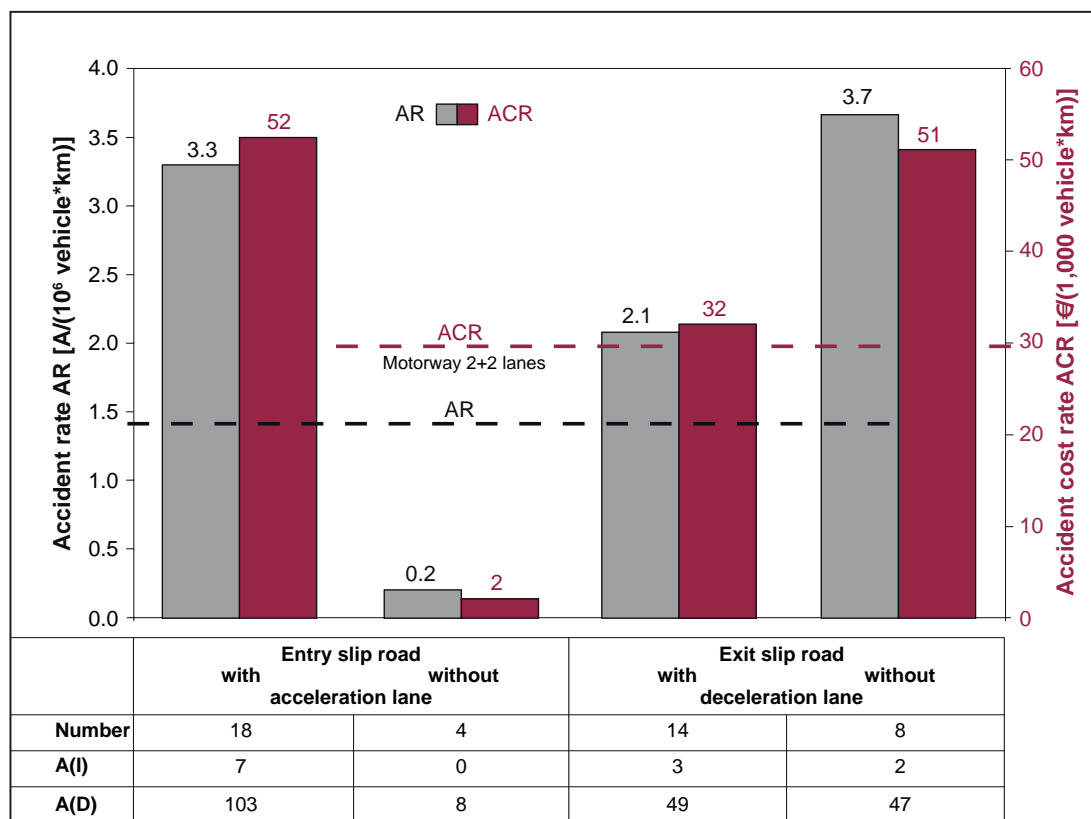
## 5.4 Temporary slip roads

Almost half of the accidents at temporary slip roads occur when traffic volumes are high with short time gaps of less than a second between the vehicles in the inside lane.

If there are no acceleration or deceleration lanes at entry or exit slip roads in roadworks sections, drivers have to decelerate or accelerate on the main carriageway. The absence of a deceleration lane has a particularly negative impact on safety. The absence of an acceleration lane does not appear to have this disadvantage, but the scope of the study is barely adequate for making a reliable statement (Figure 9).

## 5.5 Sections of road unaffected by traffic control measures

Accidents occur less often on sections of motorway where there are roadwork sites. The accident risk and severity of the accidents is below average compared to other sections of motorways (Figures 3 and 5). Accidents often occur when vehicles (a car and a truck) traveling in the same direction brush against each other (kind of accidents 3).



**Figure 9:**  
**Accident rates (AR) and accident cost rates (ACR) of temporary entry/exit slip roads**

The effect of the lane width alone on the accident occurrence has to be assessed carefully taking other factors into account. The analyses of roadworks sections with a speed limit of 80 km/h indicated a very high accident risk when the width of the available carriageway was 5.75 m (Figure 10). Sections with different widths (both wider and narrower carriageways) had higher safety levels.

Figure 11 shows the effect of speed restrictions on the safety of roadworks sections with a carriageway width of 5.75 m. At a speed limit of 80 km/h (and with an 85th percentile speed measured at around 90 km/h), both the accident rate and the accident cost rate were up to 60% higher than at a speed limit of 60 km/h with a measured 85th percentile speed of around 80 km/h. The analysis of parti-

cularly narrow cross-sections at roadwork sites showed that these cannot be generally said to be unsafe. Instead, the following factors were found to have a negative impact on road safety:

- the absence of hard shoulders
- the road appearing to become narrower as a result of the width of the hard shoulder being reduced as far as the right-hand lane markings
- damaged, dirty or non-existent yellow roadworks markings
- reduced lane widths (even small reductions)
- failure to remove white lane markings, which can put drivers off (Figure 12).

If these factors are taken into account, it is possible to reduce the level of risk at roadwork sites where the carriageway is narrow.



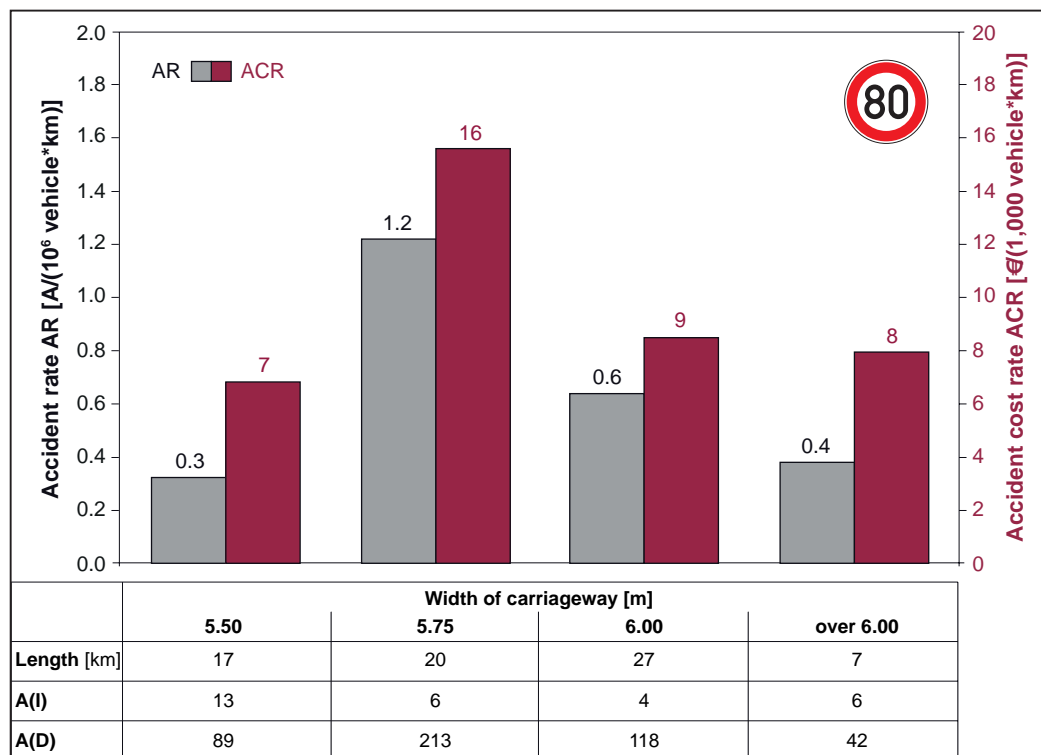


Figure 10:  
Accident rates (AR) and accident cost rates (ACR) for sections of road by carriageway width

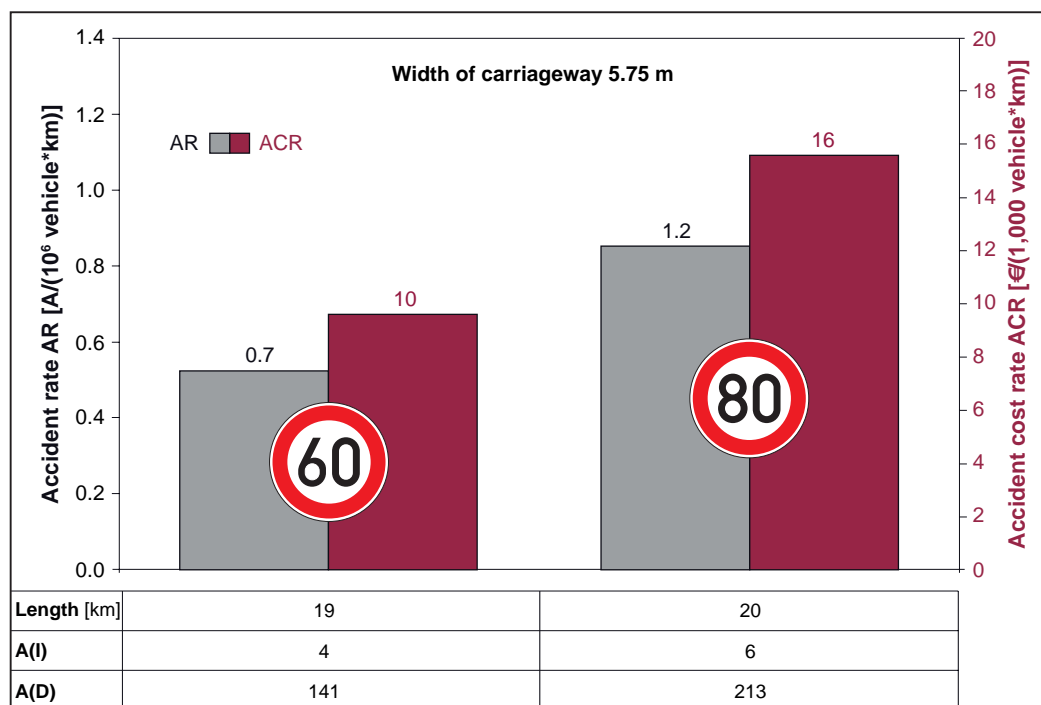


Figure 11:  
Accident rates (AR) and accident cost rates (ACR) for sections of road with a carriageway width of 5.75 m by speed limit (4+0 traffic routing)

## 6 Yellow roadwork sites

At one roadwork site studied, with the aim of reducing the speeds of vehicles entering the roadwork site, the normal road signs in connection with the carriageway changeover point or lane realignment point were used for a period (Figure 13) and then replaced with signs with a yellow backboard for a period (Figure 14). This measure was intended to make drivers pay

better attention in these areas and at the beginning of the roadwork sites.

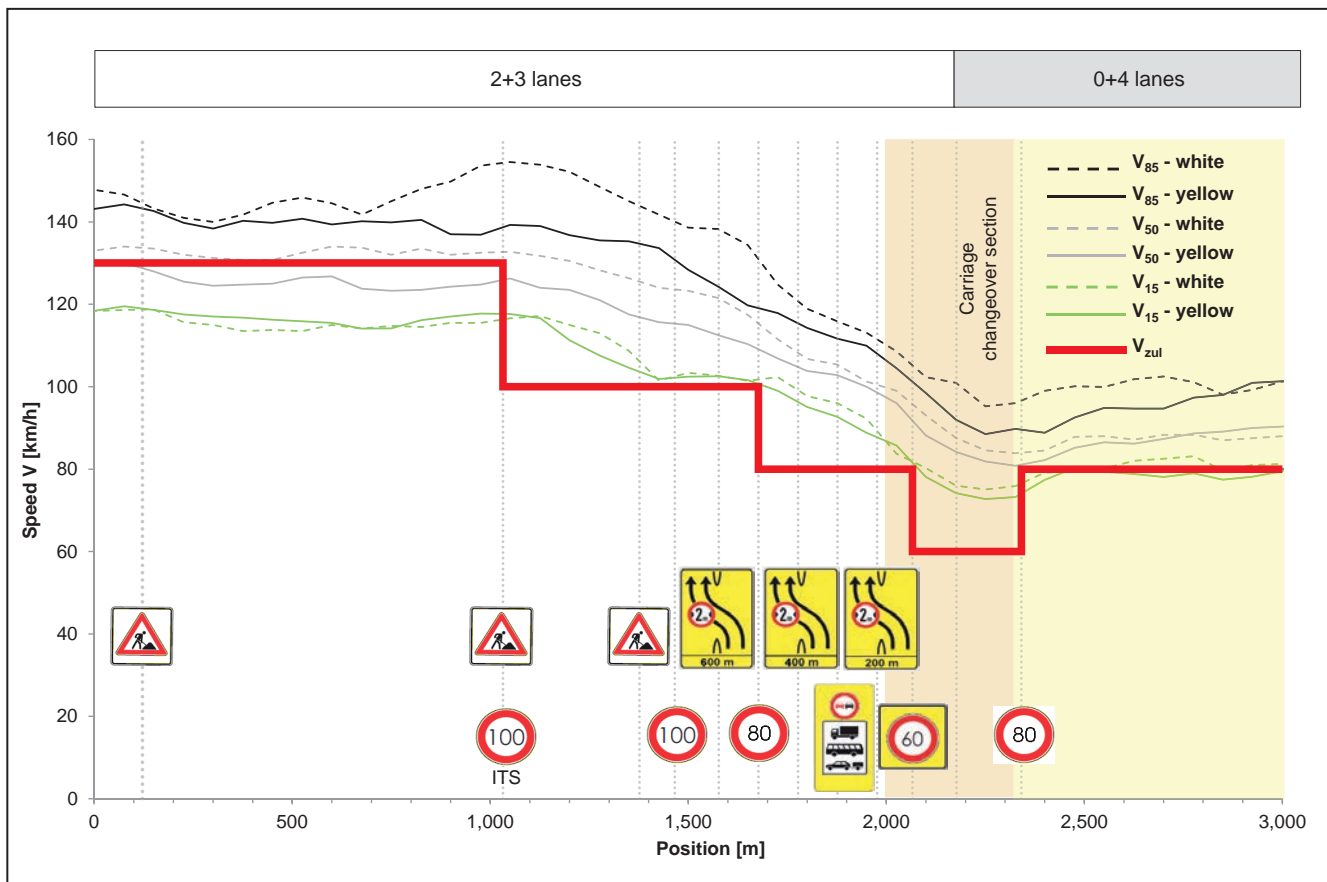
The use of the signs with yellow backboards as opposed to the normal signs in accordance with RSA 95 [8] at the beginning of the roadwork site caused speeds to be reduced earlier and resulted in lower speeds on entry into the lane realignment point or carriageway changeover point at the beginning of the roadwork



**Figure 12:**  
White signs in accordance with RSA 95 [8] indicating roadworks ahead (standard solution)



**Figure 13:**  
Modified "Yellow" signs indicating roadworks ahead



**Figure 14:**  
Profiles for the 15<sup>th</sup>, 50<sup>th</sup> and 85<sup>th</sup> percentile speeds on the approach section by sign type and with low traffic volumes

sites. This effect was seen for all three percentile speeds ( $V_{15}$ ,  $V_{50}$  and  $V_{85}$ ) shown for the direction of travel 1 in Figure 15. The biggest drop in speed was seen for the 85th percentile. The speed profiles show that the modified road signs also had a positive effect at the lane realignment sections. The speed limit was 60 km/h in these sections. While the 15th percentile and 50th percentile speeds were similar under both conditions, the 85th percentile speed was reduced by around 4 km/h in both directions.

Due to the limited period of investigation, it was not possible to study the long-term effect of signs with yellow backboards in roadwork sites with low levels of safety. In view of the fact that roadwork sites are generally only in

existence for a limited period, this would appear to be of secondary importance. It was also not possible to clarify whether the effects obtained could be maintained in standard use. However, it is suspected that the regular use of selective-yellow road signs reduces their impact [9]. Given the limited period of investigation and the limited period for which the road signs were in place, it was not possible to demonstrate that the yellow signs had an impact on the accident occurrence.

## 7 Summary and recommendations

The consequences of accidents at roadwork sites on motorways are generally less seri-

ous than for accidents at other sections of motorways. Nevertheless, there are problem areas in terms of road safety, particularly at the beginning and end of roadwork sites, lane realignment points, carriageway changeover points and temporary slip roads. Road users have to pay particular attention in these areas. Only when road users see in good time what is ahead of them and what traffic routing measures they have to negotiate can they adapt their speed and driving appropriately. The following factors are essential for road safety at roadwork sites:

- The beginning of the roadwork site must be easily recognizable, and the speed limit must be rigorously enforced.
- Changes to the routing of the traffic and particularly hazardous areas within the roadwork site must be easily recognizable.
- The road layout at roadwork sites, the road equipment used and the lane geometry must be consistent.
- The speed limits must always be appropriate for the lane widths and geometry.
- Unavoidable temporary slip roads must be carefully designed.

When designing the layout of roadwork sites on motorways, it is important to ensure that they are laid out and operate in a coherent way in order to improve public acceptance of the necessary speed restrictions. This applies, in particular, to the widespread use of suitable speed limits given the layout and traffic control measures used and factors such as the lane widths and the geometry of the lane realignment sections. The following measures are recommended to improve road safety at roadwork sites on motorways:

- The German guidelines for ensuring the safety in roadwork sites (RSA) require a speed limit of 80 km/h at roadwork sites.
- To ensure the safe operation of roadwork

sites at 80 km/h, the minimum width of the outside lane must therefore be 2.75 m and that of the inside lane 3.25 m.

- If these minimum widths cannot be adhered to, a lower speed limit of no more than 60 km/h must be in place. A recommendation that drivers do not drive side by side can also contribute to an improvement in road safety.
- Speed monitoring measures should be boosted at the beginning of roadwork sites in order to enforce the speed limit. The monitoring locations should be easily recognizable, and drivers should receive advance warning of them.
- In particularly hazardous sections, which impose greater demands on drivers, fluorescent yellow-green reflective tape of the retroreflection class RA 3 should be used as the basic tape. These hazardous sections include the following:
  - the beginning of roadwork sites if the lanes at a carriageway changeover point are at a realignment angle that deviates from that specified in RSA [8]
  - carriageway changeover points with a rapid change of transverse gradient
  - extreme lane realignments and narrow points at roadwork sites
- At carriageway changeover points and lane realignment points the central markings should be wider.
- White road markings should be removed when the roadwork site is set up and, in the case of new carriageways, not painted on until the completion of the roadwork sites.
- Acceleration and deceleration lanes in roadworks sections have always to be sufficiently long.
- At the end of a roadwork site the speed limit should be raised in stages and the overtaking ban for trucks should be extended.

The use of red and white arrow markers is also recommended throughout the roadwork site. Moreover, in individual cases it should be ex-

amined whether further road safety measures are required to make it easier for drivers to see and understand how the traffic is routed within the roadwork sites. For example, these include additional flashing warning lights, additional arrow markings on the road surface, the illumination of critical areas or profiled longitudinal markings.

It is also recommended that driver assistance systems and telematics applications, which also contribute to raising the level of road safety at roadwork sites on motorways, are further developed and that their effects on road safety are investigated. Subject to the clarification of the legal situation, speed monitoring by means of section control (average speed checking) in conjunction with clear communication of the appropriate speed to drive at could also contribute to an improvement in road safety at roadwork sites.

**More information is available at: [www.udv.de](http://www.udv.de).**

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