Compact accident research

Road safety in traffic-calming zones

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Preliminary remarks

Traffic-calming zones (sometimes referred to as "living streets"), identified by road sign number 325 in accordance with the German Road Traffic Regulations (StVO), were introduced in Germany in 1980. Municipalities have been using them ever since as a means of improving residential areas, quality of life and road safety. The background to their inclusion in the German Road Traffic Regulations was an extensive large-scale trial in North Rhine-Westphalia in the years from 1977 to 1979, which was overseen by a group of consultants. The UDV (German Insurers Accident Research) took the lead scientific role.

In recent years, traffic calming has again increasingly become a focus of public attention as a result of the discussion about strolling areas and shared space. Planners and local decision makers have also turned their attention to it.

Since there are no recent studies on the design and impact of traffic-calming zones in Germany, the UDV decided to bring the picture up to date.

Contents

Introduction

Traffic-calming zones were included in the German Road Traffic Regulations (StVO) for the first time in 1980. They are identified by road sign number 325 and are subject to Section 42, Paragraph 2 of the German Road Traffic Regulations. In the eyes of the public, these road signs are regarded as marking the beginning and end of "play streets".

In accordance with Section 42, Paragraph 2, Annex 3 of the German Road Traffic Regulations, the following rules apply in traffic-calming zones:

1) Drivers must drive at walking pace.
2) Drivers must not either endanger or hinder pedestrians. If necessary, they have to wait.
3) Pedestrians must not hinder traffic unnecessarily.
4) Drivers must not park outside the designated areas, except to allow people to get in or out or to load or unload.
5) Pedestrians can use the whole width of the street. Children can play anywhere.

These rules associated with road sign number 325 serve to ensure that traffic-calming zones work successfully: Low speeds make an essential contribution to road safety. The opportunities for adults and particularly children to use the road underscore the importance of improved residential areas and quality of life, which also depend on how attractive an experience it is to be in the road space.

The studies of the 1970s and 1980s were able to demonstrate the conditions that have to be met for the design of traffic-calming zones in order to achieve their objectives.

Measures mentioned in connection with the design of traffic-calming zones to reduce the volume of traffic include restructuring the road network with cul-de-sacs or diagonal diverters. Chicanes or speed bumps are examples of speed-reducing measures.

Initial experiences clearly showed that merely putting up road sign number 325 did not influence drivers' speeds. If the objectives of very low speeds and a road space that offers a highly attractive experience are to be achieved, traffic-calming zones must be recognizably different in design from roads on which it is possible to drive faster. The traffic-calming zones must require drivers to drive more slowly.

For this reason, the General Administrative Regulations of the Road Traffic Regulations (VwV-StVO) have this to say about road sign number 325: "Sections of road marked by

Figure 1:
Road signs 325.1 and 325.2 (StVO): beginning and end of traffic-calming areas

road sign number 325.1 must be designed in such a way as to give the impression that the most important function of the space is to allow people to spend time in it, and that its use for road traffic is of secondary importance. Generally speaking, this is achieved by means of a level surface across the whole width of the road space."

Although there are design examples available from the large-scale traffic-calming trial in North Rhine-Westphalia from 1977 to 1979, and the effectiveness of individual elements was examined, there are no strict guidelines for the design of traffic-calming zones in the way that they exist for roads outside built-up areas, for example.

A wide variety of designs for such areas or sections of road have thus developed in the intervening decades.

The current study examines the question of whether the previous findings on the design and road safety of traffic-calming zones can continue to be viewed as the state of the art. In addition, an attempt is made to take inventory of all the variants that have been implemented by different municipalities.

Methodology

The central focus of the study was a multi-level analysis of accidents in traffic-calming zones identified by the relevant road signs (numbers 325.1 and 325.2):

- The macroscopic analysis of accidents was carried out on the basis of statistical, anonymized data on accidents involving injury or serious property damage (Acc(I,SD)). The aggregated data from 1995 to 2012 was available for this in the official federal statistics. For each accident in these statistics, there is an indication of whether it occurred in a traffic-calming zone identified by road sign number 325. A total of 32,530 accidents involving injury or serious property damage (Acc(I,SD)) were recorded, of which 28,715 (88%) were accidents involving injury (A(I)). Furthermore, for four German federal states it was possible to analyze the accidents involving injury or serious property damage for the years 2007 to 2012, and for one federal state it was possible for the years 2007 to 2011 (a total of 4,332 accidents involving injury or serious property damage).
- The microscopic accident analysis was carried out for 278 traffic-calming zones throughout Germany. The anonymized accident data for six calendar years was analyzed (a total of 244 accidents involving injury or serious property damage).

Figure 2:
Examples of roads in a residential area (left) and a commercial area (right)

As far as the underlying data allowed it, the 278 zones included in the analysis of accidents were differentiated by type of road function:

- Residential street
- Local street in an urban district
- Collector road (connects local streets to arterial roads)
- Local access road
- Shopping street
- Other.

In addition, they were also differentiated by road design (type of traffic routing):

- **Mixed-traffic space:** no changes of level or demarcation elements. In other words, the entire width of the road space can be used by all.
- **Visual demarcation:** no changes of level or demarcation elements other than visual elements such as gutter channels or a change of road surface that suggest a separation of the roadway from the sidewalk. However, the entire width of the road space can still be used by all.
- **Structural demarcation:** changes of level that separate the roadway and sidewalk from each other.
- **Combinations of the above.**

In 50 of these 278 traffic-calming zones, video recordings were made to observe the traffic. The analysis of the traffic in these zones involved speed measurements and observations of behavior on working days from 2 p.m. to 6 p.m. (a total of 200 hours of observation).

To get an indication of what is actually happening in municipalities with regard to the planning, establishment and operation of traffic-calming zones identified by road sign number 325 (StVO), statements were obtained from 148 of the 500 or so most populous towns and cities in response to a survey.

Implementation practice in municipalities

There are no reliable sources available for analysis that provide an overview of the implementation practice of the municipalities with regard to traffic-calming zones identified by road sign number 325 (StVO). There are no strict guidelines for the design of these zones or their design elements, as there are in Germany for the cross-sections of roads outside built-up areas, for example. Until 2006, the design was based on the "Empfehlungen für die Gestaltung von Erschließungsstraßen (EAE)"

Figure 3:
Examples of mixed traffic and visual and structural demarcation (from left)

(recommendations for the design of local access roads) of the German Road and Transportation Research Association (FGSV). Since 2006, it has generally been based on the FGSV's guidelines for urban road design (RASt) or other information on road design in built-up areas such as the FGSV's "Hinweise zu Straßenräumen mit besonderem Überquerungsbedarf - Anwendungsmöglichkeiten des „Shared Space"-Gedankens" (notes on road spaces where there is a particular need to cross - applications of the "shared space" idea) or "Hinweise für barrierefreie Verkehrsanlagen (H BVA)" (notes on accessible road facilities), published by the FGSV in 2011.

In order to gain an impression of how municipalities are actually implementing these zones, an online survey was carried out in the 500 most populous municipalities in Germany. Responses were received and analyzed from a total of 148 municipalities (30%) (Figure 4).

Figure 4:
Overview of the 148 municipalities surveyed

- In 145 municipalities, traffic-calming zones are indicated on a point-by-point basis or for a stretch of road by means of road sign number 325 (StVO). 113 municipalities reported that they had extensive traffic-calming zones.
- In 76 municipalities there were traffic-calming zones in shopping areas, including around 30 identified by road sign number 325. In 18 municipalities there were zones where the roads took on the character of a shared space.
- 98% of traffic-calming zones with road sign number 325 are located in residential areas.

The most frequently mentioned aims for establishing traffic-calming zones are:

1) To improve the experience of spending time there or reduce the dominance of motor vehicle traffic in the road space (90%)
2) To improve road safety (80%)
3) To improve the design/layout of the road and urban environment (77%)
4) To reduce noise pollution (73%).

Improving the situation for pedestrians who cross the road is less important (56%).

Asked for their (subjective) experiences of how traffic-calming zones work, the municipalities gave the following assessments:

- There was a particularly positive impact on the experience of spending time in the space (mentioned by 82% of the respondents) and on speed (79%).
- Around 58% believed the situation had improved for pedestrians wanting to cross.
- 43% of the respondents believe the accident statistics will improve, while just over half (57%) expect no changes.

- 49% of the respondents stated that through traffic had been reduced.
- The municipalities gave a rather negative assessment of the impact in terms of the need for maintenance (20%).

Macroscopic accident analysis

The aim of the macroscopic accident analysis was to examine the accident statistics for traffic-calming zones on the basis of an extensive database. The basis used for this were the aggregated accident data for the accidents recorded in police reports for Germany as well as for the federal states of Baden-Württemberg, Hesse, North Rhine-Westphalia, Saxony-Anhalt and Thuringia.

An assessment of the trend in the numbers of accidents involving injury and serious property damage was made for the years 1995 to 2012. It was generally possible to analyze the accident structure in detail for the federal states from 2007 to 2011.

However, an initial analysis of the official accident statistics revealed a lack of precision in the data. The road accident statistics include a section in the accident report for recording particular features of the accident location. There are a total of six categories. The traffic-calming zone, which must be identified by road sign number 325, is one of them. However, the analysis of the accident data showed that this definition is often not adhered to. Accidents in 30 km/h zones, car parks, pedestrian zones, local access roads or roads with particularly low speed limits are sometimes incorrectly allocated to the "traffic-calming zone" category. It is not possible to accurately assess where this has been done because there is no reliable information on the number and location of traffic-calming zones indicated by road sign number 325. However, an attempt was made in this study to get a more accurate impression of the situation by searching through the documents of the municipalities and using the web-based data service OpenStreetMap. Random samples in the federal states of Baden-Württemberg, Hesse, Saxony-Anhalt and Thuringia show that between 40% and 70% of the accidents (an average of around 50% for the four federal states) allocated to the "traffic-calming zone" category actually occurred in other zones with reduced speed limits.

The results for the macroscopic accident analysis as a whole therefore apply to accidents not just in traffic-calming zones identified by road sign number 325 but also on stretches of road or in zones with a speed limit of 30 km/h or less. The generic term "zone with reduced speed limit" (ZRS) is used here to cover all these zones or areas, and the subset of traffic-calming zones identified by road sign number 325 is sometimes abbreviated below as TCZ.

Due to this blurring of the distinction between these zones, average or expected figures for Germany or individual federal states therefore cannot be obtained for the microscopic accident analysis. However, the statistics for both Germany as a whole and the individual federal stares do allow us to say that accidents involving injury or serious property damage (Acc(I,SD)) that take place in zones with reduced speed limits make up a very small percentage (0.7%) of all accidents that occur in built-up areas (BUAs). Accidents involving serious property damage that occur in zones with reduced speed limits (ZRS) account for only around 10% of all accidents involving injury or serious property damage (Acc(I,SD)).

An average of around 1,500 accidents a year involving injury (Acc(I)) occurred in zones with reduced speed limits in Germany in the last five

years, compared to a total of around 312,000 accidents a year involving injury in built-up areas. The accident risk per head of population (accident rate[1)]) remained roughly the same from 2007 to 2011 at around four accidents involving injury for every 1,000 people (P). Accidents in zones with reduced speed limits accounted for only 0.5% of the accident risk (AR) of all accidents in built-up areas and remained stable across the years studied at 0.019 accidents involving injury (Acc(I)) per 1,000 people (P) (Table 1).

The general trend for accidents in built-up areas in the various federal states is positive both overall and for zones with reduced speed limits. Baden-Württemberg was something of an exception: Although accidents in built-up areas fell by around 10%, accidents in zones with reduced speed limits doubled. The city

Table 1:
Comparison of the levels of accident risk for accidents involving injury (source: Destasis, own calculations)

Federal state	Accidents involving injury				Accident risk (AR) for Acc(I)					
FS	No. of A(I) (BUA)		No. of A(I) (ZRS)		AR [Acc(I)/1,000 P]				AR (ZRS) as % of AR (BUA)	
Name	2007	2011	2007	2011	2007 (BUA)	2011 (BUA)	2007 (ZRS)	2011 (ZRS)	2007	2011
BW	40,634	36,531	122	240	3.78	3.39	0.011	0.022	0.30%	0.66%
BY	56,162	53,119	146	162	4.49	4.23	0.012	0.013	0.26%	0.30%
BE	14,511	14,288	102	69	4.26	4.11	0.030	0.020	0.70%	0.48%
BB	9,581	8,395	41	34	3.77	3.36	0.016	0.014	0.43%	0.41%
HB	3,112	3,146	16	5	4.69	4.76	0.024	0.008	0.51%	0.16%
HH	8,426	7,704	11	9	4.78	4.30	0.006	0.005	0.13%	0.12%
HE	24,745	22,461	81	63	4.07	3.70	0.013	0.010	0.33%	0.28%
MV	6,781	5,469	42	41	4.02	3.34	0.025	0.025	0.62%	0.75%
NI	35,036	31,926	133	156	4.39	4.03	0.017	0.020	0.38%	0.49%
NW	68,190	62,055	411	409	3.79	3.48	0.023	0.023	0.60%	0.66%
RP	16,607	15,816	111	95	4.10	3.95	0.027	0.024	0.67%	0.60%
SL	4,878	4,201	26	20	4.69	4.14	0.025	0.020	0.53%	0.48%
SN	15,676	13,853	108	77	3.70	3.35	0.026	0.019	0.69%	0.56%
ST	10,178	8,395	44	39	4.19	2.03	0.018	0.017	0.43%	0.46%
SH	12,740	11,793	113	81	4.49	4.16	0.040	0.019	0.89%	0.69%
TH	8,588	7,114	22	26	3.73	3.19	0.010	0.012	0.26%	0.37%
All FSs	335,845	306,266	1,529	1,526	4.08	3.75	0.019	0.019	0.46%	0.50%
City fed. states	26,049	25,138	129	83	4.47	4.24	0.022	0.014	0.50%	0.33%
Wide-area fed. states	309,796	281,128	1,400	1,443	4.05	3.71	0.018	0.019	0.45%	0.51%

[1)] The accident risk relates the number of accidents to the size of the population and thus allows the federal states to be compared. Comparing absolute numbers of accidents would not be meaningful.

federal states significantly reduced their contributions to the accident risk for accidents involving injury (Acc(I)).

If you look at the accident structure of the accidents involving injury Acc(I) in zones with reduced speed limits (ZRS) for the five federal states of Baden-Württemberg (BW), Hesse (HE), North Rhine-Westphalia (NW), Saxony-Anhalt (ST) and Thuringia (TH), two accident types account for over half of the accidents (Figure 5):

- The accident type "accident caused by turning into a road or by crossing it": This is a conflict between a road user required to wait and another who has priority. These accidents typically occur at intersections and junctions but also at the entrances and exits of properties or parking lots.
- The accident type "other accident": Conflicts in connection with driving maneuvers such as entering and leaving a parking space, reversing or turning around are typical here.

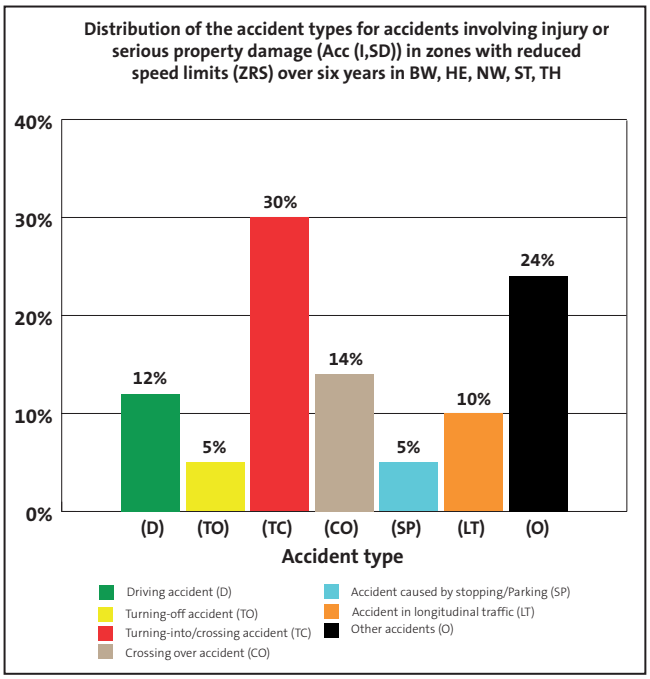


Figure 5:
Distribution of the seven accident types in zones with reduced speed limits (ZRS) for accidents involving injury (Acc(I)) in five federal states (n=4,162)

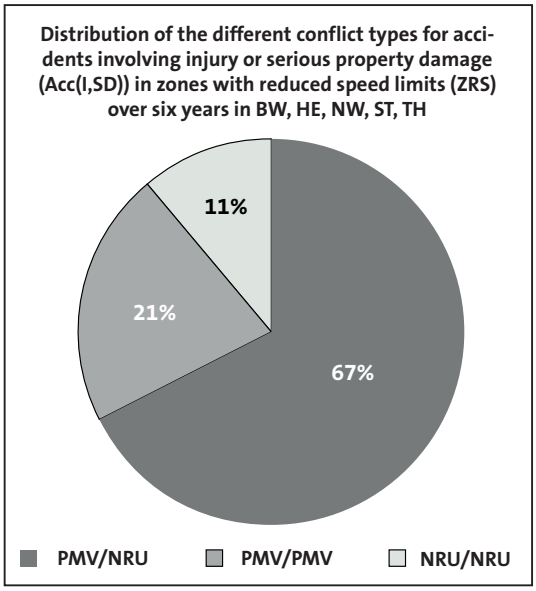


Figure 6:
Percentages of different conflict types for accidents involving injury or serious property damage (Acc(I,SD)) in zones with reduced speed limits (ZRS) from 2007 to 2012 in five federal states (n=4,332)

It is also worth noting that around two-thirds of accidents involving injury or serious property damage in zones with reduced speed limits occur when there are conflicts between private motor vehicles (PMV) and non-motorized road users (NRU), generally between a car and a pedestrian (Figure 6). About one in five accidents involving injury or serious property damage involve motorized vehicles exclusively. The rest of the accidents involve conflicts between pedestrians and cyclists or conflicts between cyclists (NRU).

Microscopic accident analysis

The underlying data

The microscopic analysis involved 244 accidents involving injury or serious property damage (Acc(I,SD)) in 278 examples of traffic-calming zones identified by road sign number 325 over six calendar years (Figure 7).

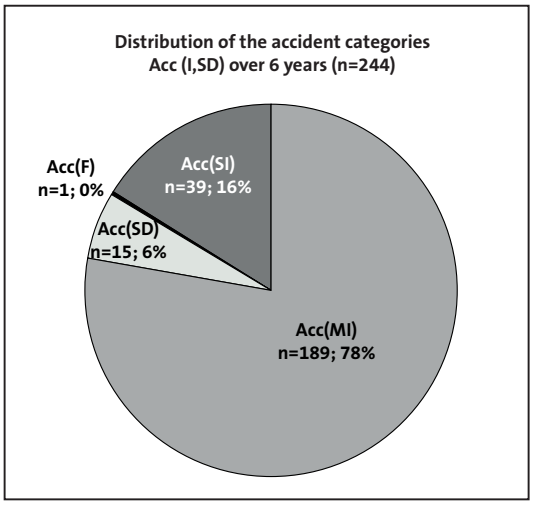


Figure 7:
Distribution of accidents involving fatalities (Acc(F)), serious injuries (SI), minor injuries (MI) or serious property damage (SD) over six calendar years

187 of the 278 traffic-calming zones (TCZ) were completely free of accidents for the whole six-year period (67%). Thus, the 244 accidents involving injury or serious property damage (Acc(I,SD) were distributed among 91 traffic-calming zones. Around a fifth of these had only one or two accidents. Around 11% of the traffic-calming zones had three or more accidents, with three being the most common number (6%). In other words, they had three Acc(I,SD) over six years.

The analysis was initially carried out for all of the accidents. They were then differentiated by road function or design (mixed traffic, visual demarcation or structural demarcation). Table 2 shows an overview.

The analysis revealed the following percentages for the 278 examples:

- 4% of the local access roads had 3% of the Acc(I,SD). These roads accounted for 6% of the entire road length in the study.
- 16% of the shopping streets had 54% of the Acc(I,SD). These streets accounted for 14% of the entire road length in the study.
- 20% of the local streets in urban districts had 21% of the Acc(I,SD). These streets accounted for 16% of the entire road length in the study.
- 44% of the residential streets had 9% of the Acc(I,SD). These streets accounted for 51% of the entire road length in the study.
- 16% of the category "other streets" had 13% of the Acc(I,SD). These streets accounted for 13% of the entire road length in the study.

The distribution of the types of road by function in the study as a whole corresponds to the statements made about the practice of implementation, with around a fifth being shopping streets and most being in residential areas (residential streets, local streets in urban districts, local access roads). Residential streets accounted for the highest percentage of the total road length but the lowest percentage of accidents. Shopping streets were at the opposite end of the scale: 54% of the accidents occurred on only 14% of the road length in the study. The distributions indicate that shopping streets with road sign number 325 are not as safe as roads in residential areas with road sign number 325. Purely residential streets appear to be the safest roads in residential areas. A precise analysis is provided by means

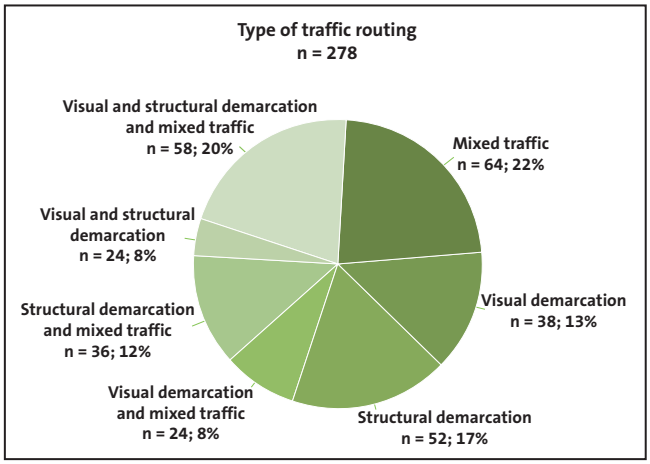


Figure 8:
Distribution and numbers of the 278 examples in the study, differentiated by type of traffic routin

Table 2:
Overview of the types of road by function and traffic routing in the microanalysis

Road function	Traffic routing	No. of acc. (cat. 1-4)	Length (m)	No. of TCZ
Local access road	Structural demarcation (StD)	0	1,060	3
	Structural demarcation and mixed traffic (StDMT)	0	301	1
	Mixed traffic (MT)	1	452	2
	Visual demarcation and MT (VDMT)	3	2,285	2
	Visual and structural demarcation (VStD)	3	885	3
	Total	**7**	**4,983**	**11**
Shopping street	Structural demarcation	81	3,715	17
	Structural demarcation and MT	6	377	2
	Mixed traffic	5	342	2
	Visual demarcation	12	1,862	7
	Visual and structural demarcation	27	4,349	16
	Visual and structural demarcation and MT (VStDMT)	0	563	1
	Total	**131**	**11,208**	**45**
Local street in an urban district	Structural demarcation	12	3,673	15
	Structural demarcation and mixed traffic	1	1,753	9
	Mixed traffic	7	819	3
	Visual demarcation	7	2,694	10
	Visual demarcation and MT	1	755	3
	Visual and structural demarcation	22	2,060	12
	Visual and structural demarcation and MT	1	547	2
	Total	**51**	**12,301**	**54**
Other	Structural demarcation	12	1,781	7
	Structural demarcation and MT	7	2,729	10
	Mixed traffic	1	1,266	10
	Visual demarcation	4	615	5
	Visual demarcation and MT	3	1,621	5
	Visual and structural demarcation	3	1,674	5
	Visual and structural demarcation and MT	2	511	3
	Total/average	**32**	**10,197**	**45**
Residential street	Structural demarcation	1	3,093	10
	Structural demarcation and MT	5	4,851	14
	Mixed traffic	6	15,558	47
	Visual demarcation	5	7,052	16
	Visual demarcation and MT	1	4,405	14
	Visual and structural demarcation	5	4,184	17
	Visual and structural demarcation and MT	0	1,438	5
	Total/average	**23**	**40,581**	**123**
	Total/average	**244**	**79,270 (Ø285)**	**278**

of length-normalized accident parameters (see the section headed "Accident cost densities").

Figure 8 shows the distribution of the types of traffic routing (road designs) for the study as a whole: Just over half of the 278 examples (56%) had uniform traffic routing throughout their length (mixed traffic, visual demarcation, structural demarcation), and 44% had a combination of these.

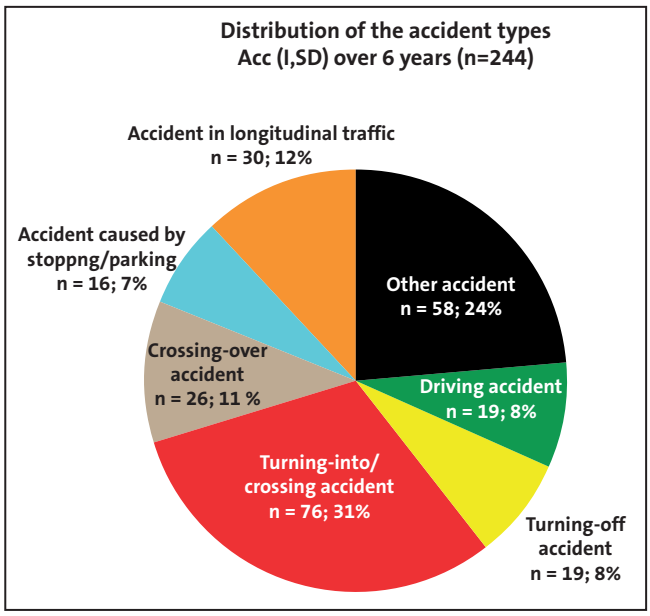


Figure 9:
Distribution of the seven accident types

Accident types

The distribution of the conflict situations, expressed by the accident type, is shown in Figure 9. The most frequent accident type, accounting for around a third of the cases (31%) is the turning-into/crossing accident (i.e. where there is a failure to observe priority). Any accident that cannot be allocated to one of the other six types is allocated to the "other accident" type. Typical conflicts or driving maneuvers in the case of the "other accident" type were primarily collisions between a vehicle and a pedestrian or collisions that occurred when turning around or reversing.

Road users involved in accidents

478 road users were involved in the 244 accidents involving injury or serious property damage in traffic-calming zones. 46% were in cars, 26% were cyclists, and 15% were pedestrians. This distribution differs from that for all accidents in built-up areas in 2011. Cars were involved in 62% of the 237,523 accidents involving injury or serious property damage in built-up areas, cyclists were involved in 16%, and pedestrians in 7%.

If we turn our focus to the road users primary responsible for these accidents, the following picture is revealed:

- Car drivers were most often primary responsible (PM) for accidents in both traffic-calming zones (59%) and in built-up areas as a whole (69%).
- Cyclists caused accidents in traffic-calming zones more than twice as often as in built-up

Table 3:
Percentage distribution of those involved in accidents involving injury or serious property damage in traffic-calming zones (TCZ) and built-up areas (BUA) as a whole in 2011

Type of road user	Percentage distribution (%)			
	PM (TCZ)	PM (BUA 2011)	RU02 (TCZ)	RU02 (BUA 2011)
Cars	59	69	34	46
Bicycles	29	13	24	18
Pedestrians	3.4	3.5	28	8.7

Table 4:
Combinations of types of road user involved in accidents involving injury or serious property damage in traffic-calming zones and built-up areas as a whole in 2011

Combinations of types of road user			
Type of road user		Percentage (%)	
PM	RU02	TCZ	BUA (2011)
Cars	Pedestrians	21	6.6
Cars	Bicycles	17	14
Bicycles	Cars	18	4.5
Cars	Cars	9.8	32

areas as a whole (in 29% of cases as opposed to 13%).

- The percentage of pedestrians causing accidents in traffic-calming zones (3.4%) was very low and scarcely differed from the percentage for built-up areas as a whole (3.5%). However, pedestrians were three times more likely to be the second party involved in an accident (RU02) in traffic-calming zones (28%) than in accidents in built-up areas as a whole (9%).

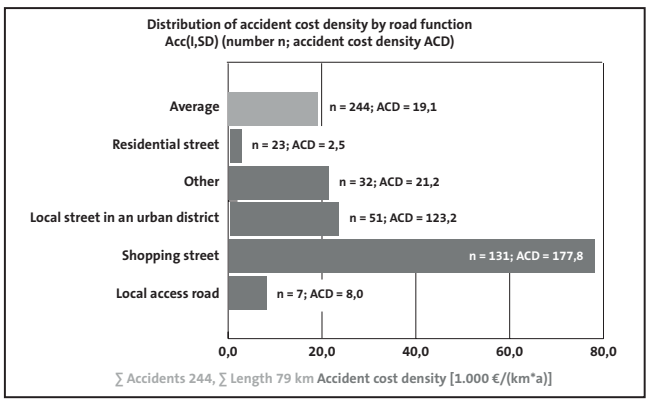
The most frequent combinations involved in road accidents in traffic-calming zones and in built-up areas were also different: Collisions between cars and bicycles were much more common in traffic-calming zones (around 35% of all accidents) than in all accidents in built-up areas (18%). The high percentage in traffic-calming zones was due to the high percentage of accidents caused by cyclists (18%).

Accident cost densities

Accident costs combine the number and severity of accidents in a single indicator. The density is a measure of the accident risk and expresses the accident statistics in relation to road length. The accident cost density (ACD) thus allows the combinations of road types by function and traffic routing (road designs) shown in Table 2 to be compared, despite the different lengths of road involved by expressing the accident statistics per kilometer within a specific observation period.

The average accident cost density for accidents involving injury or serious property damage ACD(I,SD) for all 278 traffic-calming zones was around 19,100 euros per kilometer and year (Figure 10). The accident cost density for residential streets was clearly under this at 2,500 euros per kilometer and year, and that for shopping streets clearly exceeded it (77,800 euros per kilometer and year).

The accident densities (the number of accidents per kilometer of road length) revealed an almost identical picture to the accident cost



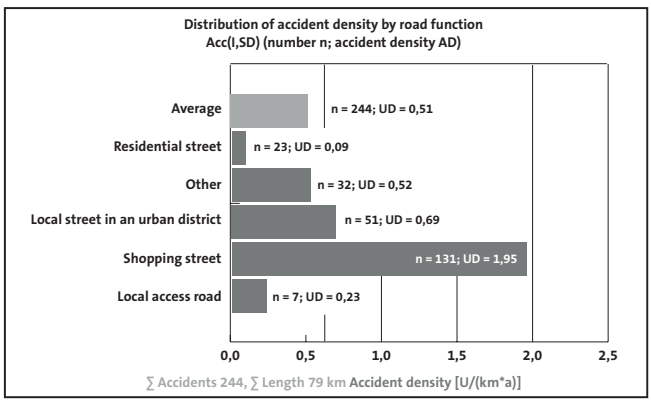


Figure 10:
Accident cost density and accident density differentiated by type of road function (at 2009 price levels)

densities. The severity of the accidents thus had a similar distribution across the different road types by function.

Analyses by type of traffic routing (road design) within the five groupings by road function revealed the following results:

- The risk of accidents was highest in shopping streets with mixed traffic routing (103,000 euros per kilometer and year) and/or structural demarcation (146,200 euros per kilometer and year) both within their group and overall.
- Mixed traffic routing was associated with a significantly greater accident risk in local streets in urban districts, although at a much lower level.
- The accident cost risks in residential streets by type of traffic routing were so low that they can be assessed as insignificant for all types of traffic routing.

Traffic observations

The purpose of the traffic observations was to shed light on three aspects:

- Speeds
- Use of the space
- Interactions between road users.

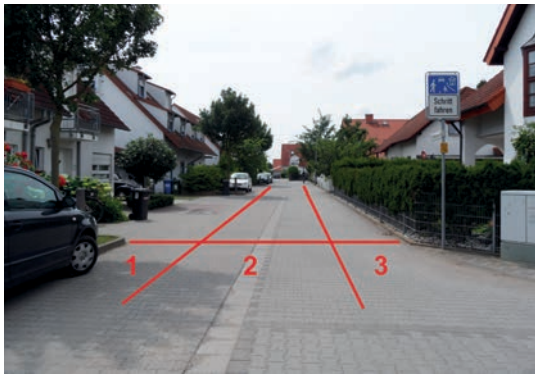


Figure 11:
How the space was subdivided, in this case in an example with mixed traffic routing

50 of the 278 traffic-calming zones involved in the microscopic accident analysis were included in the traffic observations. 22 zones with conspicuously high numbers of accidents (82 accidents involving injury or serious property damage) were selected and compared with 28 zones with low numbers of accidents. An effort was made to select zones with similar proportions of the different types of road by function in each of these two categories (Table 5). Based on the sample taken, it was not possible to differentiate these areas by type of traffic routing within the categories, except in a few individual cases.

In order to ascertain which road areas were used by the different road users, all 50 examples

Table 5:
Overview of all traffic observations

Type of traffic routing	Residential streets		Shopping streets		Local streets in urban district		Other streets	
	Number		Number		Number		Number	
	TCZ	Acc (I,SD)	TCZ	Acc (I,SD)	TCZ	Acc (I,SD)	TCZ	Acc (I,SD)
Mixed traffic (MT)	3	1	1	3	2	6		
Visual demarcation (VD)	1	2	1	3	2	1		
Structural demarcation (StD)	1		7	32	4	3		
Mixed traffic and visual demarcation (MTVD)					1			
Visual and structural demarcation (VStD)	4	3	10	12	9	14	1	2
Mixed traffic and structural demarcation (MTStD)			1		2			
Total	**9**	**6**	**20**	**50**	**20**	**24**	**1**	**2**

Figure 12:
An example of speed measurement as road users entered or left a traffic-calming zone

were subdivided into three sections: two edge sections and a central roadway section, regardless of the type of traffic routing involved. Figure 11 shows an example of how the mixed-traffic space was divided up.

Cross-sectional counts were taken at the beginning/end of each traffic-calming zone (Figure 12). All road users were recorded on video as they entered/left the zone, and the recordings were subsequently analyzed. In 11 of the 50 examples studied, it was possible to take cross-sectional measurements at multiple points on account of their length.

Speeds

The speeds measured for both motor vehicles and cyclists as they passed through were significantly above the required walking pace. There were no significant differences in average speed between the groupings by road function. The average 85% speed for motor vehicles in shopping streets was 25 km/h, whereas in local streets in urban districts and residential streets it was 22 km/h and 23 km/h, respectively. Speeds of above 35 km/h were rarely measured. The speeds of cyclists were found to be only slightly lower than those of cars at all measurement points. A comparison with speeds measured at points in traffic-calming zones in a further UDV study showed no significant differences from the drive-through speeds measured in this study. Table 6 provides an overview on the basis of the 4-hour measurements.

The analysis of the measurement results for each traffic-calming zone observed revealed

Table 6:
Average drive-through speeds by road function and vehicle type

Road function	Vehicle type	Drive-though speeds				No. of measurements
		V15	V50	V85	Vmax	
		(km/h)	(km/h)	(km/h)	(km/h)	Vehicles (4 hrs)
Local streets in urban districts	Cars	13	19	25	35	2,088
	Bicycles	11	14	18	26	269
Shopping streets	Cars	12	16	22	35	5,123
	Bicycles	9	13	18	34	2,219
Residential streets	Cars	13	18	23	32	339
	Bicycles	11	13	18	26	46

two things:

- Speeds were lower in traffic-calming zones with speed-reducing elements such as chicanes.
- Individual elements such as planters reduce speeds in the immediate vicinity.

Use of space

Pedestrians have priority over vehicles in traffic-calming zones. They must not hinder the traffic unnecessarily, but they can use the entire width of the road space, and children's games are allowed everywhere. The question thus arises as to whether and how they actually take advantage of this.

To assess the use of space by road users, distinctions were drawn between three ways of dividing up the road space:

- No changes of level or demarcation elements
- Visual demarcation
- Structural demarcation.

In summary, it can be said that there were few differences in usage between the three alternative types of design. Even in the case of traffic routing with no changes of level, road users generally continued to do what they had always done (learned behavior), depending on their means of transport:

- Car drivers used the central space (roadway) in 90% of cases and only occasionally departed from this (e.g. to avoid vehicles that were parking), when there were no changes of level. When curbs were used for demarcation, this percentage increased to 100%.
- When there were no changes of level, cyclists rode in the center of the space around 75% to 95% of the time. When there was structural demarcation, this percentage fell to around 62%.
- Pedestrians walked in the central part of the road space in around 38% to 46% of cases when there were no changes of level and otherwise used the edges of the space. When there was structural demarcation, in around 85% of cases they used the edges of the space, which were demarcated from the central part. They, too, were continuing with their learned behavior and only departed from it when "forced" to by obstacles or when doing otherwise was quicker.

Figure 13:
Example of the use of space by pedestrians in a residential street with mixed traffic routing

Interactions

As expected, traffic volumes for the three different types of road by function were very different. In the 200 hours of observation, around 55 road users (RU) an hour were counted in the nine residential streets, around 180 road users an hour were counted in the 20 local streets in urban districts, and around 800 an hour in the 20 shopping streets.

Virtually no interactions were observed in the residential streets. In the local streets in urban districts and shopping streets, which were busier than the residential streets, against expectations only a few interactions were observed, and all of these were free of conflict. The observations led to the conclusion that the use of space described above meant that only a few interactions occurred.

There was apparent uncertainty around the transitions at the end of the traffic-calming zones where they joined the rest of the road network. According to Paragraph 10 of the German Road Traffic Regulations (StVO), road users exiting a traffic-calming zone identified by road sign number 325.2 must exercise particular care and concede right of way. The usual rule of "right-before-left" priority, which normally applies in a traffic-calming zone, no longer applies here. The observations revealed that, when there was no change of level, the road users involved still tended to adhere to the "right-before-left" rule. However, the high percentage of accidents involving injury or serious property damage (40%) that occurred at these transitional points, particularly "turning-into/crossing" conflicts, indicated that this arrangement was not always successful (see the microscopic accident analysis).

Summary and recommendations

Traffic-calming zones identified by road sign number 325 of the German Road Traffic Regulations (StVO) have proved successful since first being introduced in the 1980s. They have no recognizable shortcomings in terms of road safety and are largely accepted by all road users. Municipalities use road sign number 325 extensively in residential areas but also increasingly for shopping districts, streets in (historic) urban districts and local access or collector roads.

However, it is clear that the objective of reducing the speed of traffic to walking pace in these zones is generally not achieved. In reality, average drive-through speeds are around 18 km/h, and speeds of over 35 km/h are rare.

If consistent design principles are applied, in particular in terms of the use of speed-reducing elements such as chicanes or speed humps, good road safety results can be achieved for streets with a traffic volume of up to 4,000 motor vehicles a day. Avoidance of any structural demarcation between the traffic and the edge of the road space (curbs, for example) can be viewed as a critical element that has a direct impact on speeds. In residential streets, on the other hand, the design of the road space is less important.

When accidents do occur in traffic-calming zones, non-motorized road users are particularly affected. Accidents involving pedestrians and cyclists are significantly more frequent in traffic-calming zones than those involving motor vehicles exclusively.

Road safety problems are easier to identify at the interfaces between traffic-calming zones and the rest of the road network. These transitional points account for between 30% and 55% of the accidents in traffic-calming zones, with "turning-into/crossing" accidents involving motor vehicles accounting for the majority. The findings obtained from the video observations indicate that road users at the exits to traffic-calming zones are often uncertain as to who has priority.

On the basis of this study, the UDV therefore has the following recommendations:

- Provided they are well designed, traffic-calming zones can be a suitable means of improving safety and the experience of spending time in the road space for roads with traffic volumes of up to around 4,000 cars a year. This also applies to shopping streets, for example, in which pedestrians dominate due to the extent to which the edges of the road space are used. This kind of volume of motor vehicle traffic is currently not covered by the provisions of the German Road Traffic Regulations (StVO) regarding

road sign number 325 (which assume very low levels of traffic). It should therefore be examined whether a suitable amendment to the regulations should be made. It should be examined whether this can be achieved with road sign number 325 or whether new signage is necessary.

- Efforts to improve the design of the road space should continue to be made in order to bring speeds down to a level that is more suitable for pedestrians and cyclists. These include, in particular, no changes of level and the installation of speed-reducing elements throughout the zone.
- The situation with regard to priority at the exits from traffic-calming zones must be clear to road users.
- The official statistics also include other zones with reduced speeds, such as 30 km/h zones, parking lots or roads with a particularly low speed limit, in the same category as traffic-calming zones identified by road sign number 325. It is thus not possible to make statements about the traffic-calming zones identified by road sign number 325 based on the official accident statistics. It is recommended that this lack of precision in the data should be rectified.

More information is available at: **www.udv.de.**

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