STRATEGIES FOR AREA-WIDE IMPROVEMENT OF URBAN ROAD SAFETY

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ABSTRACT

Standard procedures for safety improvement measures are widely focused on the treatment of frequent accident sites. This is not sufficient for various reasons: The regression to-the mean effect shows an only statistical caused accident reduction, thus the impact of the measures is described inaccurate. Furthermore only about 25% of all accidents happen at frequent accident sites. Furthermore this proportion is even less for the severe accidents with fatalities and serious injured persons. Analysis shows a high concentration thus up to 80 % of accidents concentrate at a limited number of sites. Therefore many significant safety deficits are not treated by the standard procedures.
Actually a sample of additional tools was developed to detect stretch-scaled safety lacks and to calculate the cost-benefit-ratio of appropriate measures. To define the potential of improvements it has to be defined the best safety standard for different parts of the urban road network. The challenge is to define a level of best practice in terms of accident rates so that it should be possible to calculate the difference between the existing accident rate and the best rate achievable. The amount of safety potential of each relevant section of the network concentrates in similar way like blackspots.

1. URBAN TRAFFIC SAFETY

Every measure to improve traffic safety focuses on decreasing the number of accidents. Often, we mainly concentrate on the number of people that died in traffic accidents because these numbers are easy to compare and the information is easily available. Goals to improve traffic safety often concern decreasing the number of fatal accidents. But only a very small percentage of all accidents are fatal: in Germany, only 1% of all urban traffic accidents are fatal. 85% of all persons involved in urban traffic accidents suffer minor injuries; 14% of all people involved suffer severe injuries. [10]

In general, the rather simplified indication of the number of accidents is problematic and hardly meaningful because the types of dangers on motor ways, rural roads and urban roads are completely different: most accidents that happen on motor ways are caused by motorized vehicles moving in the same direction: central barriers prevent the collision with oncoming traffic. Accidents with non-motorized vehicles do not occur here, because they are not used on motor ways. Accidents caused by disregarding the right of way or when turning lanes seldom occur because of the specific design of intersections.

On rural roads, three typical accident scenarios indicate a lack of safety and heavy accidents:
- Speeding: Vehicles come off the road and crash into obstacles sideways. The passengers can suffer severe injuries;
- overtaking: Drivers overtake regardless of oncoming traffic. Collisions with oncoming traffic often result in severe injuries because of the high speed;

- disregarding right of way: Intersections and t-junctions pose a serious safety threat, as do left turns.

Accidents involving non-motorized vehicles seldom occur: bicyclists usually use segregated cycle facilities and you will hardly find any pedestrians here.

The situation in urban traffic is totally different. Here, we find major overlap in traffic use because of the different types of urban and road situations. We find an overlap of motorized and non-motorized traffic, extraneous traffic and traffic in search of a parking space, individual and public transport of persons and goods and traffic flows along and across roads. Speed limits for motorized vehicles on urban roads are prescribed to create safe designs for all these complex traffic scenarios. In Germany, this speed limit lies at 50 km/hour. In the past, higher maximum speeds have lead to a deterioration of traffic safety. Suggestions to reduce the maximum speed to for example 30 km/hour have not been met with acceptance. We can make a clear distinction between primary distributors and residential streets. Primary distributors are mainly meant for through traffic, while residential streets are mainly meant as estate roads, allowing traffic access to properties or buildings. Prerequisite for effective safety planning and for the success of safety measures as well is a strict separation between the primary distributors network and residential areas and a clear structuring of road networks according to their function.

A relatively large percentage of victims in traffic accidents are non-motorized traffic participants: 38% in Germany in 2009. Amongst those who suffered severe injuries, the percentage increases. 57% Of all victims killed in traffic accidents were pedestrians or cyclists. With children (younger than 14 years of age), mainly non-motorized traffic, this percentage amounts to 61%. [10] We can conclude that urban traffic safety cannot be compared to traffic safety on rural and motor ways. We must develop and implement specific strategies to improve traffic safety in cities. Special focus should be on pedestrians and cyclists.

2. PRACTICES SO FAR

Methods to increase traffic safety on urban roads have so far been realized on two different levels:

2.1. A- Accident-oriented improvement measures

Traffic accidents are mostly registered by police – for legal reasons and to keep track of statistics. To do this, a standardized accident registration is designed. This standard registration is also used to evaluate the accidents. Because statistically accidents occur coincidentally, it is examined whether higher concentrations of accidents occur and whether these concentrations exceed empirical probability. These spots are defined as black spots. The definition is wide and considers whether each and every accident should be used for measuring black spots or just the ones with severe injuries on the one hand and on the other it also takes into consideration the similarities between comparable types of accidents or equal traffic participation of the victims. [3] Whether or not further criteria concerning danger exposure should be admitted into the calculation of black spots is subject to controversy. A disadvantage of taking into consideration such criteria is that specific dangers at road infrastructures with high traffic load would become less apparent.

Research in cities shows that less than 25% of all victims that die in traffic accidents are assigned to black spots. At the same time, 80% of all accidents happening at black spots take place at an isolated part of that sites. This means that a large part of the safety flaws are not processed using these standardized procedures. [1,7] Even so, detecting and improving these black spots is extremely important considering the fact that without these procedures, there would be 80 to 100 black spots per 100.000 inhabitants, while their number is now reduced to 20 to 50 per 100.000 inhabitants.[8]

2.2. B- Accident-unrelated procedures

Since it is a known fact that because of the work against black spots, only a small part of all accident occurrences can be processed, additional procedures, applied independently from any accident occurrence, are required. On the one hand, these are educational measures and measures to monitor the observance of traffic rules. The objective here is to inform people about traffic rules, create acceptance and make sure they follow the rules. Specific attention is given to traffic rules that concern safety, for example:

- which speed is appropriate for which situation
- keeping enough space ahead of and beside you
- do not use any types of alcohol or drugs while driving
- adapt your driving behavior in certain situations (at night, during rainy weather)

These rules do not merely apply to drivers of motorized vehicles but especially to pedestrians and cyclists. The possibilities to inform non-motorized traffic participants are limited and making sure that they understand and obey traffic rules is problematic because they do not need any kind of “driver’s license”.

Other accident-independent procedures concern the road infrastructure. Road safety inspections are carried out to check whether the equipment and arrangement of roads meet the standard. Site inspections are carried out systematically on the whole road network. Inspectors check whether all traffic signs are in the correct spot and placed visibly, whether the appropriate road markings and directional signs are in place and whether traffic is warned for obstacles on and next to the road ahead. This quality control must be carried out by law for safety reasons, but they do not really solve many serious safety problems since no actual changes are made to the roadside environment: these quality controls merely concern the inspection of the existing situation. [6]

One very important safety procedure is the road safety audit: standardized and formalized procedures check to what extent traffic designs are safety-oriented. These audits, however, are only carried out for the planning of new road constructions or road reconstructions. [7] This means that these audits are seldom carried out for existing road networks, although measurements have shown that they can contribute to the avoidance of severe traffic safety flaws. Audits identify approx. 10 safety-related flaws in each urban road planning, so that significant improvements can be described before their realization.

3. DEFICITS AND LIMITATIONS IN PRACTICE SO FAR

When the procedures prescribed are applied consequently and completely, an improvement in traffic safety should become visible. We should be able to see a difference between cities that go about these procedures thoroughly and those cities that do not. This is partly the case. Comparisons between cities do show clear differences in their level of traffic safety. [7] Although these differences cannot be completely ascribed to traffic safety work, the implementation of safety standards can be of great importance.

At the same time we can see that even measures prescribed by law are not implemented sufficiently. Main reasons for this are:

- Every German city and municipality has an “accident committee” concerned with the identification and improvement of black spots. These committees meet on a regular basis, analyzing accident occurrences. Unfortunately they do not have sufficient human and financial resources to work on every black spot in their city. A city like Dresden has more than 300 black spots. [1] During the committee’s monthly sessions, about five black spots can be discussed: about 60 every year.
- The committees do not have the financial resources to realize any significant measures to improve traffic safety. Because of the limited financial resources, only 20% of these 60 black spots (on a total of 300 black spots in the city) can be reconstructed every year.
- Thus, a significant part of all accidents occurring at black spots remain unprocessed, for only 25 to 30% of these accidents can be ascribed to the black spot. And of these, as mentioned, only 20% are discussed.
- If those sites on black spots with the highest statistical accident occurrence get top priority, it is possible to reduce the number of accidents without increasing the number of black spots discussed. Statistical analyses on the distribution of accidents and a thorough analysis of the accident circumstances can support the development of effective measures. A manual providing effective measures would be most helpful. [3]
- The Road Safety Inspection can provide an effective contribution to safety quality. In order to do this, the complete road network must be inspected in a limited period of time. This means that teams of inspectors must perform these inspections every two years on the complete priority road network, and every four years for every remaining street. If a road network covers a length of 500 kilometers (which means a typical midsize German citiy), an average of 20 kilometers per week must be visited and inspected and measures to improve traffic safety must be implemented. Actually inspections do not take place in this frequency. Instead, specific parts of the road network are visited on occasion. The effectiveness of such inspections is limited even more because non-safety-related considerations become the reason to make a specific inspection; the necessary inspection of the integral road network is seldom carried out.
- As far as accident-unrelated procedures are concerned, the effects of educational measures to inform and control are unknown. Here, effectiveness controls measure in which way traffic participants’ behavior changes at the observed sites. Accident analyses seldom take place, so that it becomes hard to evaluate the effectiveness of measures taken. The exception to this rule is speed limits: here substantial improvements of traffic safety have been measured.
- Safety audits can only be carried out by well-trained safety-auditors. Cities often do not have enough well-trained safety auditors at their disposal. Sometimes auditors from other cities or external auditors are assigned to carry out audits. Not in all planning processes, sufficient financial means are available so that in these cases, no audits are carried out when new constructions or reconstructions are realized. On top of that, due to the cities’ limited financial resources designated to road construction, a limited number of plans for new constructions are realized so that auditing procedures in general have limited effect on urban traffic safety as a whole.

It must be taken into consideration that, for all procedures to be put into practice correctly, traffic planners must be well-trained. A traffic engineers’ education is often not enough and at the same time traffic engineers are not always involved in traffic planning processes. Therefore, specific skills and knowledge must be learned in further training and seminars.

Unfortunately, only a small part of traffic engineers visit these seminars, and for all different kinds of reasons. Thus, if the previously described procedures are implemented in urban areas, this is not always done with the required competences and according to the latest knowledge.

4. ADDITIONAL PROCEDURES

Because the safety procedures so far have not been implemented sufficiently and not all safety flaws have been identified, further three standard procedures have been developed over the last years. These procedures can improve safety in black spots and outside of them as well. For example by network safety management the whole road network is cut up in parts (accident-related or according to the road structure) and evaluated according to their degree of safety [5]. If the actual risk of accident is significantly higher than it would be when effective safety measures were applied, a high safety potentiality can be identified. We can see that such safety potentialities are distributed unequally in road structures as shown later in detail. 80% of all safety potentialities are identified on about 20% of the road structures and more than 50% of the road structure shows no safety potentiality and therefore do not need improving. This analysis shows where high effects are obvious and which parts of the road structure do not need any further safety measures or which financial investments would not lead to any safety improvement.

The multimodal network analysis shows where motorized and non-motorized road structures cross, for example when bicycle routes are situated alongside busy traffic arteries without clear separation. For motorized traffic we can distinguish between individual motor vehicles and public transport. Research has shown that especially tracked public traffic (trams) has negative effects on traffic safety. Significantly more accidents occur on roads with trams. The multimodal network analysis shows those parts where these different kinds of traffic networks meet and it indicates the necessity to inspect traffic safety there [9] .

A third new procedure is an audit procedure for existing roads. Specific parts of the road network are inspected, accident-unrelated. This audit procedure complements the auditing of road planning, something which is carried out seldom. Inventory planning, however, can be carried out on a much larger scale, depending on the capacity available. A reason for an audit could be for example the taking into use of a by-pass road to relieve a cross-town link or a necessary road restructuring.

On the whole it can be seen that there are a number of traditional and new procedures which can be used to identify safety flaws in traffic. [2] For this safety work to be successful, it is not enough to simply carry out one procedure independent from the others: all procedures should be carried out parallel to and in combination with each other. This requires integrated concepts already put into practice in some German cities.

5. EXPERIENCE WITH SAFETY CONCEPTS

In Germany, reasons for developing safety concepts have traditionally been new insights on risk factors for inhabitants of single cities (see graph 1), or organizational changes in city government which give cause to change.

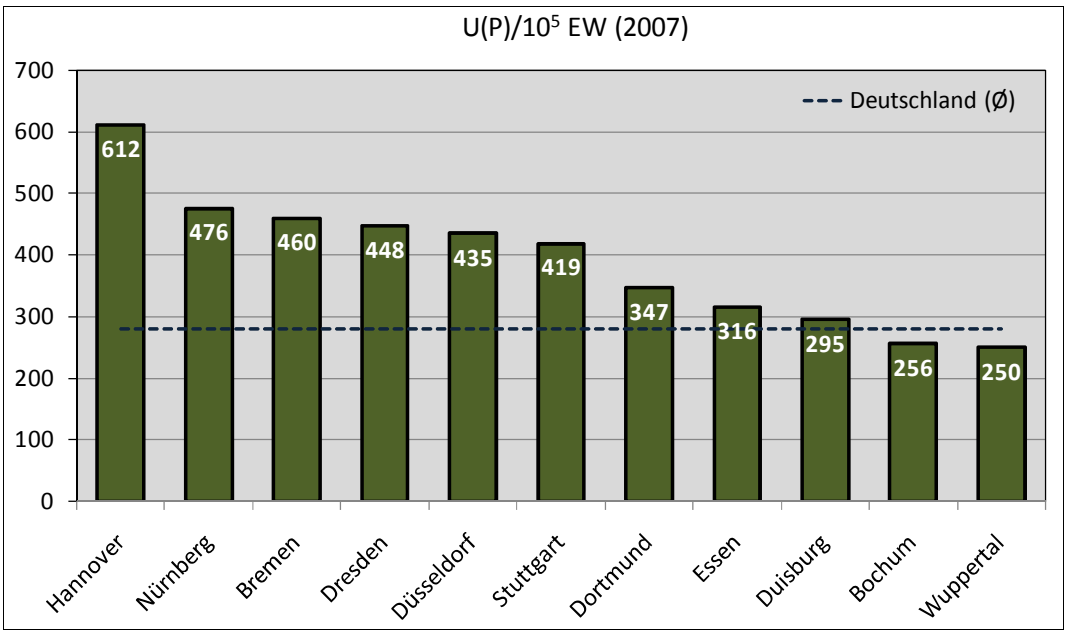

Figure 1 - traffic safety (personal injury and accident frequency) in various German cities per 100.000 inhabitants [1]

We will use three example cities to describe the results of such analyses. Experiences of the three cities are summarized in order to come to a set of general insights, avoiding isolated findings caused by local features.

5.1. Black spot management

In almost all German cities, for many years the investigation of black spots has been carried out regularly by accidents committees. This is the result of the right legal provisions and the availability of effective policies and experience reports. A closer look at these activities however showed the following deficits in practice:

- Not all black spots are dealt with, even though they are clearly identifiable on maps and are defined as black spots. Black spots are not treated completely and instead, single sites are selected for inspection. These, however, are seldom the really dangerous sites with a high number of heavy accidents.
- Accident committees often do not dispose of the right competences to conceive the required measures. They do not have sufficient financial and human resources for any necessary planning. Therefore, usually only simple changes to traffic signs and road markings are suggested, even though a road restructuring would be more appropriate.
- There is no visible combining of the various procedures to improve urban safety. Other activities in a city such as bicycle road planning or ongoing road construction plans are not checked for black spots. It may happen that a city plans the restructuring of a site without knowing any of the black spots close by because different officials are responsible.

In the scope of a systematic evaluation of black spots, many more sites are identified than could be treated in the short term. Therefore, we created an order of priority for the example cities. A double-stage procedure proved effective [1]:

First, we divide the black spots into categories, according to their accident severity. Doing that, we can exclude both spots that statistically show a high empirical probability of having coincidental accidents as well as non-systematic abnormalities. The pre-selection carried out in this first step makes the following step in the process easier.

In the next step, in order to complete the order of priority for those sites with a high accident rate, we include both the avoidability of dangers by taking technical measures as well as the financial resources necessary for making improvements.

In order to do this, we developed a procedure to complete the order of priority which includes

- the specific features of accidents (focus on accident similarities) that indicate the possibility of finding simple improvement measures;
- experience with the effectiveness of known measures for the assessment of the practical effects of these measures;
- estimates on the construction and operation costs of improvement measures to indicate the total effort.

It shows that with limited financial investments, substantial economic effects can be reached, as can be seen in graph 2:

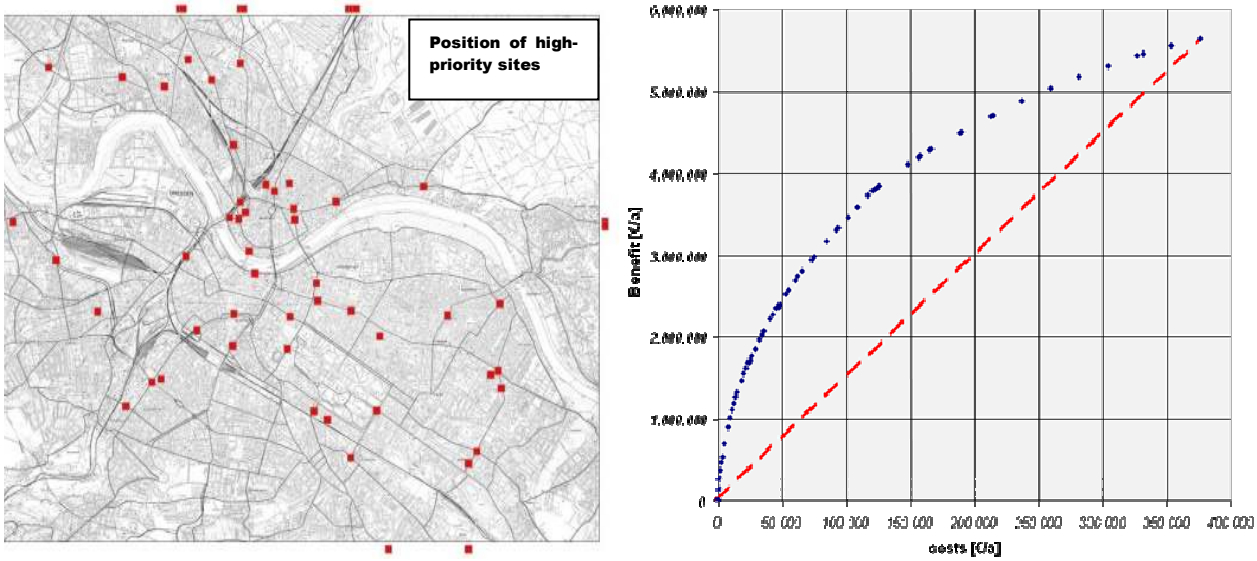

Figure 2 – position and priority ranking of black spots with regard to effectiveness analysis by estimating effort and effect

It can be seen that for a very limited part of all black spots, substantial effects can be expected. In one of our example cities € 2.8 million proved necessary on a total of 60 sites. The economic benefits amounted to € 5,6 million. It must be taken into consideration however that in this example city the black spots cover only about one third of all victims of traffic accidents.

5.2. Network analysis by investigating safety potentiality

In all example cities, the majority of all accidents (65%) do not take place in concentrated spots but along streets or they are distributed over an area. For an efficient improvement of traffic safety, accident analyses along streets need to be carried out. Three approaches are useful:

- In a standardized network analysis, safety potentialities are investigated in which observed accident densities are confronted with their expectancy value for safety which are considered unavoidable in case of optimal road design [2] . These safety potentialities are not distributed equally across the road network either and they show

street sections where effective improvements to traffic safety can be expected. Sometimes, also black spots can be found on these sites, so that combining these findings with local accident investigations (see 5.1) is required.

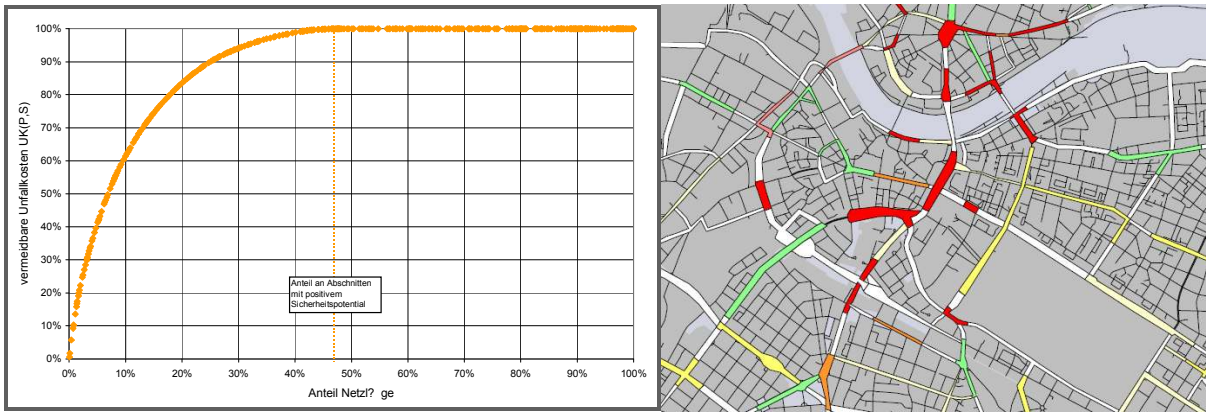

Figure 3 - distribution of safety potentialities in urban road structures [1]

- Within the scope of a multimodal network analysis, important interconnecting street sections such as the arterial highway network are overlaid with the network structures for non-motorized traffic (cyclists, pedestrians) and with the public transport network [9]. Using these overlaps, critical sites (concentrating on one specific spot or along a road) that might lead to safety hazards can be identified. The information obtained must be synchronized with results from previously carried out procedures in order to avoid a duplication of work.

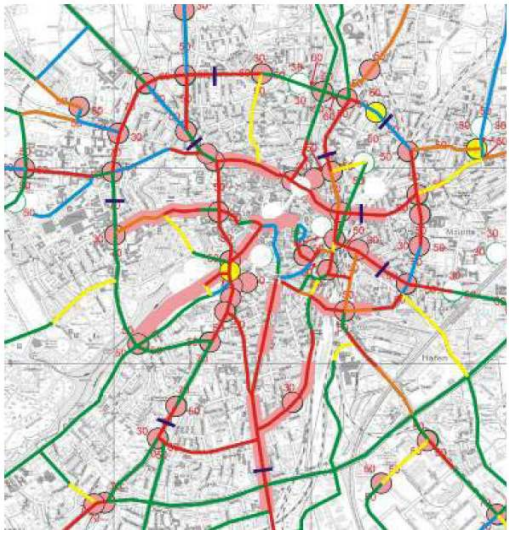

Figure 4 - critical sites after overlaying motorized road networks with non-motorized structures [9]

- Defining a safety potentiality will reveal only the rank of a site for the improvement but not the reasons for the safety deficit. For that, audits are required on the existing network. More thorough accident analyses, combined with the identification of safety-related deficits, lead to a result-oriented choice of measures. Currently these procedures are being developed and tested in Germany.

Especially dangers for cyclists and pedestrians are not recognized by isolated spot analyses. Updating the definitions for black spots therefore includes the suggestion of recording long stretches of dangerous zones, based on accidents with pedestrians [8] .

5.3. Findings on crucial traffic behaviour

For a comprehensive approach to improve urban safety, analyses should not merely include road infrastructure but also automotive engineering and the behaviour of all road users. To different degrees road users have a range of safety-related facilities at their disposal. What is important here is whether the use of a facility is prescribed by law, like for example the use of a safety belt in cars, or voluntarily, like for example wearing a helmet on a bicycle. Research shows a shocking difference in use of these technical facilities designed for a person's own protection: whereas even on the back seat of a car people wear safety belts (almost 90%), a mere 20% of all cyclists wear a helmet, even though their risk of injury is significantly higher (see graph 5).

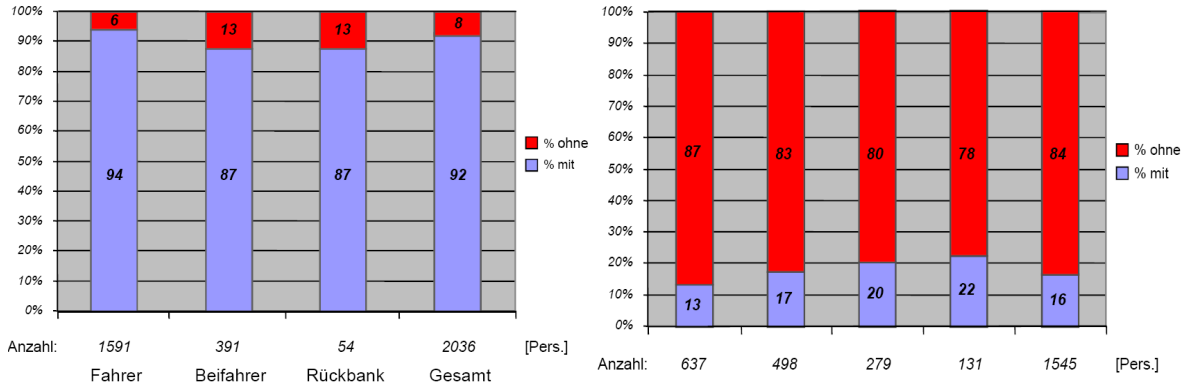

Figure 5 - varying uses of safety equipment: wearing a safety belt in cars (left graph) and wearing a helmet on bicycles (right graph) [1]

According to analyses in our example cities, other violation of important traffic rules systematically causes detectable dangers [9], especially:

- disregarding the right of way by cyclists, especially at traffic signals (7% ignores red lights);
- ignoring the right of way by motorists when turning off a road (approx. 30%);
- speeding at critical sites by motorists (one third);
- cycling in the wrong direction on cycle tracks (up to one fourth of all cyclists).

The possibilities of influencing this conduct with technical measures are limited and vary per type of violation. Ignoring the right of way can be dealt with by consequent and understandable rules, mistakes made by turning off a road are reduced by the eye-contact between road users. Monitoring devices can prevent speeding.

Thus these new procedures indicate similar measures already known to us from the traditional measures, confirming the necessity to combine the different procedures to come to an overall improvement of traffic safety.

5.4. Experience with other procedures

Audit procedures to examine the compliance of (re-)construction projects to safety standards are advisable [4]. In our example cities, however, according to our analysis this frequent auditing does not take place because cities are fully sovereign with regards to traffic planning and they do not need to follow any directives for the implementation of traffic plans. A voluntary agreement within the scope of a safety concept could contribute

to the realization of more audits. Certain general safety deficits which we found frequently in our example cities will be avoidable in future, such as the absence of separate phase for traffic turning left at traffic lights (see graph 6), unsafe bus and tram stops or incomprehensible rules concerning right of way.

Figure 6 - avoidable safety deficits caused by missing safety measures for participants turning left at traffic signals [7]

It should be kept in mind the importance of functional and accessible information continually guiding safety concepts. Because effective measures to improve safety have a deep impact on people's every-day lives (going to work, shopping, sight-seeing), they will be met with resistance. Publicity work and timely conveying the right information will increase the acceptance and is of great importance for the success of safety proceedings.

6. SUMMARY AND RECOMMENDATIONS

When developing safety concepts, usually a range of analyses focusing on identifying traffic and safety-related problems form the starting point. On top of that we produce findings on how well the traditional procedures have been carried out and which deficits can be identified when realizing certain safety measures. From that, short- and mid-term working steps are derived.

We have concluded however that the traditional procedures are carried out fragmentarily. Already in the safety analyses, deficits are reported only partly because the necessary means to implement any measures lack. The authorities do not feel any urge to act because the reports they see paint a more positive picture than the actual situation. We recommend that the necessary preliminary investigations be carried out by external, independent parties.

It is very important to combine the various procedures so that any findings from local and general analyses, as well as accident-related and accident-independent recommendations, are synchronized, before plans to improve urban safety are finalized. In addition, we should recognize the difference between short-term and mid-term strategies, so that any quick-wins are not ignored because of a long-term focus and vice-versa.

Within the scope of short-term strategies, a comprehensive deficit analysis should be followed by an optimization of traditional procedures, for example of the local accident investigation, as well as the non-accident-related procedures concerning traffic education and publicity work. As far as mid-term strategies are concerned, there is a focus on

network analysis and safety analysis of road networks. The result is a strategy for the city as a whole, with easily calculable costs and a high cost-effect ratio. The examples we used so far show a clear acceptance within the city administration and a significant increase in effects of existing procedures.

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