Scaling up of ADAS' Traffic Impacts to German Cities

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Abstract

The paper presents a methodology developed in the context of the German research project UR:BAN-VV in order to transfer and extrapolate the impacts of cooperative advanced driver assistance systems to German cities. To limit the simulation scenarios of the impact assessment and to focus on most relevant urban structures in Germany, real data of all 187 German cities larger than 50,000 inhabitants are considered for an analysis at two different levels of detail. Firstly, a questionnaire-based survey of all cities provides a solid overview of macroscopic structure of traffic management and control strategies in these cities. Secondly, a statistically supported approach that will help to identify most typical structures and attributes on a more detailed level (i.e. signalised intersections and road segments) is described. In this way, typical network elements and structures for German cities are identified. Microscopic traffic simulation will provide dedicated information on the effects of cooperative advanced driver assistance systems on traffic efficiency, sustainability and safety for these elements. The results are transferable to other cities. The paper presents the status of the first three steps of the methodology.

Keywords: Scaling up, Impact assessment, ADAS

Introduction

The German research project UR:BAN-VV (urban space: user oriented assistance systems and network management – networked traffic system) aims to develop cooperative advanced driver assistance and traffic management systems for the different areas of the urban road network (signalised intersection, road segment and network) to improve traffic safety, efficiency and in order to reduce harmful environmental effects. One of the major focus areas of the developed systems is the optimisation of the approaching and crossing of signalised intersections via an active signal time provision [1].

Besides the development of the systems, one of the main goals of UR:BAN-VV is to transfer and extrapolate the impacts of the systems which will be identified specifically in the projects' test sites in Düsseldorf, Brunswick and Kassel with a limited number of test vehicles to other German cities. As a basis for the extrapolation, microscopic traffic simulation is used in order to reproduce the situations and the observed impacts at the test sites and to modulate the performance of the systems in different surrounding conditions and with different equipment rates. Since in reality every city, network, road and intersection is unique regarding its static (e.g. number of lanes) and dynamic (e.g. signal control) attributes, it is obvious that a very high number of variations is available. It is impossible to investigate each single variation by its one.

Approach

To limit the scenarios for the impact assessment as well as to improve the transferability of the results, the most typical and common structures in German cities must be identified. This identification is based on an approach, which includes a survey on general structures of traffic management and control in German cities on the one hand and a more detailed statistical analysis of the road network of all 187 German cities larger than 50,000 inhabitants on the other hand.

For the survey, the representatives of the cities were asked to answer a questionnaire, which included questions like the general concepts of signal control and the prioritisation of public transport. With an overall return rate of 42%, this survey provides a solid overview on typical macroscopic structures that should be considered for the impact assessment, microscopic simulation environments and the development of systems like in UR:BAN-VV. Detailed information concerning the results of this survey can be found in "Structures of Traffic Management and Control in German Cities" [2].

To obtain a more detailed picture of the area where the systems should have an impact, the road network of the 187 cities on the level of the designated network elements signalised intersection and road segment is analysed. This analysis provides an overview of typical structures and traffic related network elements. To limit the high number of urban network elements to be analysed with according attributes and values, a statistically supported five steps approach has been introduced:

1. Identification of the basic population of the network elements
2. Definition of a limited number of attributes and according types to describe the network elements in traffic related detail
3. Determination and analysis of a significant random sample of elements
4. Microscopic simulation of most frequent elements based on real elements of the cities
5. Identification of the impacts of the driver assistance systems and extrapolation of results

1. Identification of the basic population of the network elements

The identification of the basic population, that means the total number of the network elements signalised intersection and road segment in 187 German cities, was collected manually by using areal pictures from Google Earth, Bing maps and the maps from the surveying offices of the different German states.

For the network element signalised intersection, only fully signalised intersections within the political city boundary were considered. Another limitation is given by using the main road network of the cities. This is justified by the fact that the highest traffic volume is expected on this type of network and it is the target area of the UR:BAN-VV systems. Figure 1 shows an example of the localisation of the 69 identified signalised intersections in Bayreuth, a German city with 71,500 inhabitants. The determination of the basic population for the network element signalised intersection is in the range of 21,600 fully signalised intersections.

Figure 1 – Signalised intersections in Bayreuth

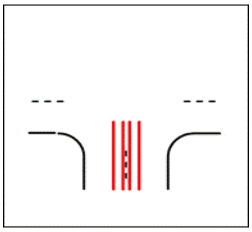
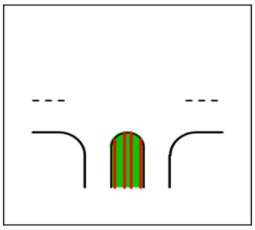
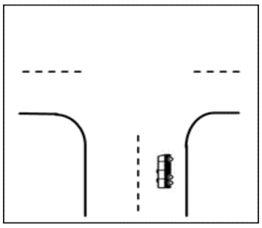
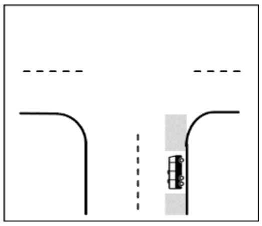
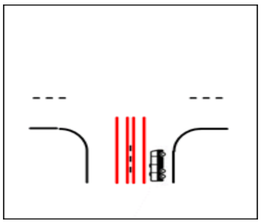
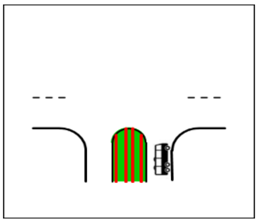
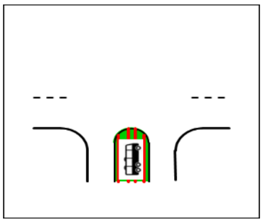
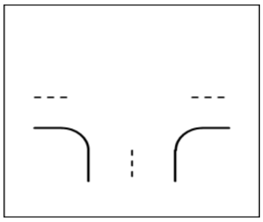
Although there is a definition of road segments in Germany, which splits up road segments regarding the functionality of the crossing streets [3], there is no appropriate definition that reflects the needs of the project, which are driven more from a technically traffic related point of view. Therefore, in this study, road segments will defined and analysed as a sequence of three to five signalised intersections with the following restrictions:

- Network element road segment includes a minimum of three and a maximum of five signalised intersections that are connected in a straight line and do not turn at intersections
- The distance between two signalised intersections is no longer than 750 metres [4]
- There is no roundabout between two light signalised intersections
- A road segment begins or ends at intersections with freeways or roads with a similar function like freeways or/and at the political city limits

2. Definition of a limited number of attributes and according types to describe the network elements in traffic related detail

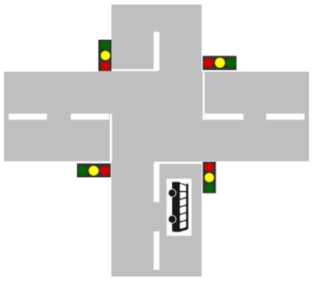
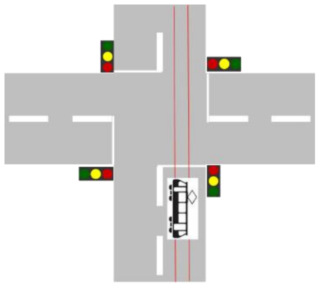
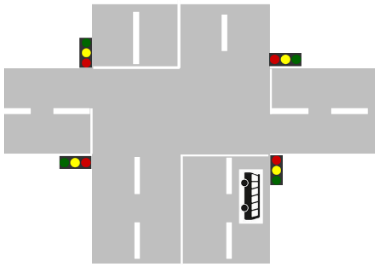
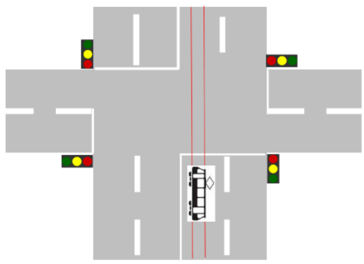
A network element is characterised by different attributes and these attributes take on different types. In the case of signalised intersections, attributes comprise the number of lanes, the availability and/or variation of turning lanes and the presence of public transport at the intersection. One attribute type describes the detailed situation the attributed can attain. For example, in the case of public transport the presence of a tram and/or a bus at the intersection would be the type of the attribute. For the definition of the attributes and their types, expert knowledge and the results of survey that was mentioned previously was considered. Table 1 shows the chosen attribute types of the attribute public transport, which applies for both network elements - signalised intersection and road segment.

Table 1 – Attribute types of public transport

			
tram track included in the individual transport	separate tram track	bus lane included in the individual transport	separate bus lane
			
tram track and bus lane included in the individual transport	separate tram track, bus lane included in the individual transport	separate tram track and bus lane	without public transport

The numerous combination of the different attribute types results in numerous possibilities to describe the network elements. Table 2 gives a simple example using two attributes, each with two types. The most relevant combinations of these attribute types are inputs for step 3 – the determination of a random sample size. The number of these combinations has a considerable influence on the sample size. Thus, it is important to minimise the number of attributes and attribute types.

Table 2 – Combination of attribute types of network elements

		Public Transport (attribute 1)	
		Bus (type 1)	Tram (type 2)
Number of lanes (attribute 2)	One lane per direction (type 1)	 combination 1	 combination 2
	Two lanes per direction (type 2)	 combination 3	 combination 4

3. Determination and analysis of a significant random sample of elements

The combinations of the attribute types of the network elements are categorical variables, so the population is multinomial. Therefore, the following multinomial model [5] is used to determine a representative sample size of the basic population of the network elements signalised intersection and road segment:

$$n = \frac{z_i^2\,(\pi_i\,(1-\pi_i))}{d_i^2} \qquad \text{[eq. 1]}$$

with

$$\alpha_i = 2(1-\phi(z_i)) \qquad \text{[eq. 2]}$$

and the restriction:

$$\sum \alpha_i \leq \alpha \qquad \text{[eq. 3]}$$

- n sample size
- z_i percentile of the standard normal distribution of category *i*
- π_i proportion of the population of category *i*
- d_i half- interval widths of category *i*
- α significance level
- α_{i} significance level for category i
- $\phi()$ cumulative standard normal distribution

The pre-defined significance level α and the pre-defined half-interval width d_i influence the sample size. Furthermore, as described previously, the sample size depends on the number of combinations of the attribute types. Restriction [eq. 3] considers this influence. The following calculation explains this influence in more detail:
The number of the combinations of attribute types defined in step 2 is 50, $\alpha = 0{,}5$ and $d_i = 0{,}025$. According to restriction [eq. 3] the maximum $\alpha_i = 0{,}001$ and so, using formula [eq. 2], $z_i = 3{,}09$. Because of the fact that the proportions π_i of the population are unknown, the "worst case scenario" is used in which all proportions are distributed equally. In this "worst case scenario" each $\pi_i = 0{,}5$. By using the formula [eq. 1] with all these inputs the minimum sample size to be analysed is $n = 3820$.
After the calculation of this sample size, a random generator is used to determine the sample to be analysed in detail from the basic population. The sample will be analysed by the combinations of attribute types, which were defined in step 2. For this task, maps from Google Earth, Bing and maps of the surveying offices of the different German states are used again. The result of step 3 is the distribution of the combinations of attribute types for the network elements signalised intersection and road segment in Germany.
The analysis of the first 1000 signalised intersections shows a clear tendency towards the frequency of occurrence of the T-intersections and intersections with four arms having one and two lanes on each approach. Figure 2 and Figure 3 depict the type of the intersection and shows their frequency of occurrence.

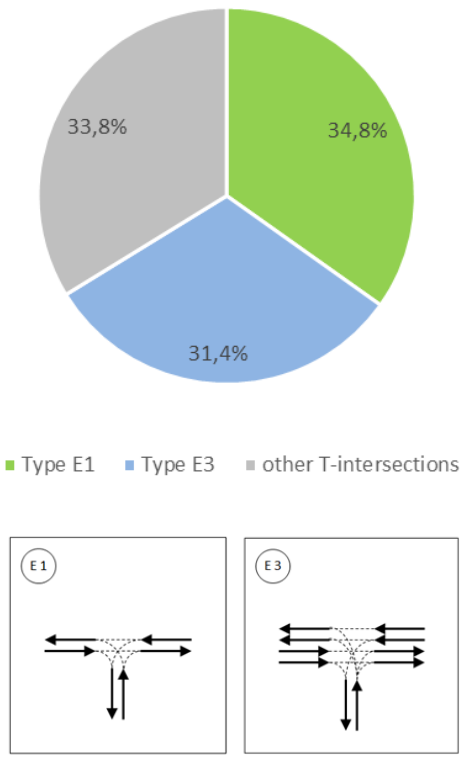


Figure 2 – Types of signalised T-intersections

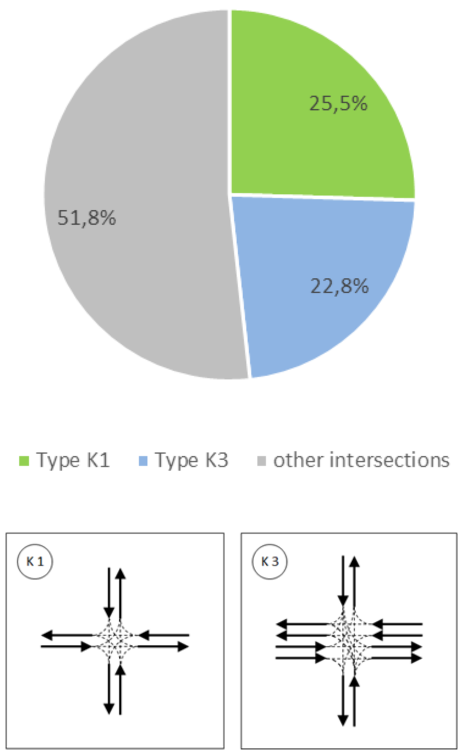


Figure 3 – Types of signalised intersections

4. Microscopic simulation of most frequent elements based on real elements of German cities

With the results of step 3, the most common combinations of characteristics of attributes of network elements in Germany will be reproduced in microscopic traffic simulations. To generate results based on real data for the identified network elements for a transfer to other German cities input data is needed. Being project partners, the cities of Brunswick, Kassel and Düsseldorf will provide real data for the signalised intersections and road segments, such as traffic volumes and signal programs. On this basis, the UR:BAN-VV systems, for example the "traffic light phase assistant" will be implemented in the microscopic traffic simulation using Python scripts, a congenial procedure already applied in the German Field Operational Test (FOT) sim^{TD} [6].

5. Identification of the impacts of the driver assistance systems and extrapolation of results

The last step includes the impact assessment and the extrapolation of the results of the impact assessment to a bigger context, for example one or more German cities. The impact assessment focuses on traffic efficiency and environmental impacts. Parameters to determine the impact on traffic efficiency are for example the change in the travel time, the number of stops and the average speed. Figure 4 graphically summarises the five steps and presents the connections between the steps in more detail.

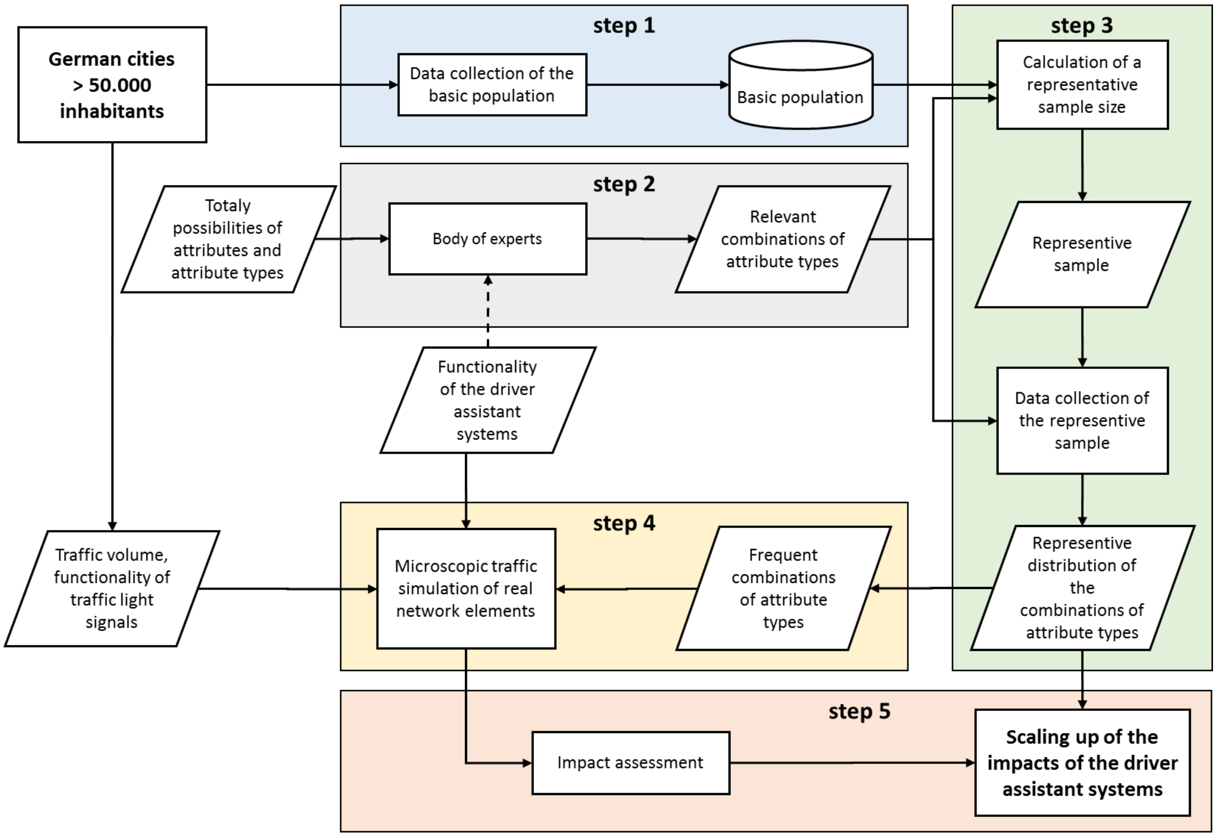


Figure 4 – Approach of scaling up impacts of ADAS

Conclusion

The described methodology shows an approach to extrapolate impacts of infrastructure based cooperative driver assistant systems to the network elements signalised intersection and road segment to German cities. The statistically supported approach combines two inputs, a survey on general structures of traffic management and control in German cities and a more detailed analysis of the road network of the cities. The latter is described in more detail with its five steps and first results.

Currently, a main part of step 1, the identification of the total number of the element signalised intersection on the major network of all 187 cities, is completed and provides with this basic population one of the main elements needed for the statistical approach. Step 2, the definition of a limited number of attribute types to describe the network elements more detailed, is also completed for the network element signalised intersection. In Addition step 3, the determination of a significant random sample of signalised intersections, has already started. So first results of the analysis were presented. In the further course of the impact assessment, the information gained on the typical structures of the network elements will be used to generate an input to define the scenarios to be considered in the microscopic traffic simulation.

The final results will represent the impacts and potentials of UR:BAN-VV systems for different typical network situations in Germany. These results will help decision makers to develop suitable implementation strategies for the deployment of cooperative driver assistant systems in the daily life.

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[1] Not yet published

[2] Published only project internally