Abstract

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Topic: Effects of pedestrians at exits on the capacity of roundabouts

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Roundabouts are one of the standard forms of intersection design and over the last years they gained increasing importance. Traffic is permanently changing, traffic demand, as well as traffic behavior changes over time. For traffic planners, it is therefore important to be able to assess the capacity of the transportation system. The capacity of a roundabout must be proved according to the guidelines for dimensioning road traffic facilities (HBS 2001) before it can be built. Based on the HBS (2001) this is currently only possible for roundabout access roads. In there the pedestrian influence is covered through a reduction factor. In practice, however, the question is always raising, whether pedestrians at roundabout exits also have an impact on the capacity of intersections. This thesis investigates the effects of pedestrians at exits on the capacity of roundabouts. An international literature research was used as a basis for a roundabout field study.

There are different forms of roundabouts. The mini-roundabout is applied where small intersections should be arranged safer and more efficient and offers a good alternative to traffic signals. The big roundabout is usually equipped with traffic signals in Germany, which regulate the traffic. The small roundabout is the most commonly used form. Efficiencies between 15,000 pce/24h to 24,000 pce/24h can be achieved. In comparison to a priority regulated intersection this one has only 8 instead of 32 conflict points. The access roads as well as the circular lanes may be operated with two lanes in Germany, exits, however, only with one lane. The international literature research and the field study are applying to small roundabouts.

According to the German road traffic regulations (StVO) pedestrians always have the priority to the outgoing vehicles at roundabout exits. At the roundabout access pedestrians only have the priority if there is a crosswalk (Z 293 StVO). Often these are planned at all intersections with pedestrian crossings, to create consistent and clear priority rules. A separating island between the entry and exit serves the crossing pedestrians as a refuge and separates the different conflict areas, where no crosswalks are present (Z 293 StVO). Between the circular lane and the crosswalk, a space for at least one vehicle should be provided.

The determination of the capacity can be performed by three possible approaches. There is the possibility to use the time gap theory, the empirical regression method as well as the simulation, or a combination of these methods. The time gap theory is based on the assumption that all road users behave the same way and the traffic rules are always followed. The complex behavior of drivers is idealized through follow-up time gaps and critical time gaps. The critical time gap is a time interval within the minor traffic stream which can be used by one vehicle of the subordinate stream to enter. The follow-up time gap, however, is a time interval within the main stream which can be used by two or more vehicles to enter.

The empirical regression method is based on a mathematical model considering geometry, driver behavior and other different traffic parameters. Field study measurement results are investigated regarding their relationship and described by functions which are derived from measurement series. The measurements are taken at fixed intervals

for example 30 seconds or 1 minute, and when a saturated traffic is available. All factors can be taken into account as long as they have been observed in field studies.

Determination of roundabout capacity can also occur through traffic simulations. This can be done at various levels, for example at the macro level, to present large-scale contexts, or at the micro level that allows examining individual drivers' behavior. This can be also done in more detail at the nano level to understand different behaviors of individual road users. The development of simulations is very complex and mostly the models cannot be directly applied to other roundabouts.

The influence of pedestrians on the capacity of access roads can be determined by means of Marlows and Maycocks queuing theory or by Brilons, Stuwes and Drews' empirically determined reduction factor. Marlows and Maycocks approach divides the access into two areas. First, the performance of the crosswalk is examined and second, the entrance to the circular lane. Subsequently, the overall capacity is determined. Thereby the grouping of pedestrians is not taken into account. In the HBS (2001) it is recommended to determine the capacity by Brilon et. al. . Here, the capacity of the access is determined and then by a reduction factor depending on the number of crossing pedestrians and the traffic volume of the circular lane, the capacity reduction is established. For exits there is currently no generally accepted method of calculation available. The HBS (2001) only notes that the maximum capacity of exits lies between 1200 pce/h and 1400 pce/h and that the influence of pedestrians should be taken into account.

The international literature research has shown that Switzerland, as the only country so far, has adopted the exit capacity into a standard, considering the influence of pedestrians. The number of pedestrians per hour as well as the width of the exit lane served in this case to determine the maximum possible capacity. Other countries such as Germany, the UK, France, USA and Australia so far do not consider this factor. With the Capcal software, Sweden is currently trying to investigate exit capacity by determining the number of hourly pedestrians exit blockings. In Japan, the influence of pedestrians to roundabouts is currently evaluated with the help of simulations.

Target to the field study of this thesis was to demonstrate the influence of pedestrians on exits on the capacity of roundabouts. Two models were developed using the measured data. The volume of the traffic exit, and the follow-up time gap and the critical time gap were determined as influencing parameters for the time gap model. For the second model, the empirical regression, the traffic composition and the traffic volume of the exit, as well as the number of pedestrians, the number of crossings and the number of blockings were examined in more detail.

The field study was conducted at a roundabout in Aschaffenburg. Data from two exits were collected and analyzed using a video survey. The positioning of the two cameras was chosen, so that the entire intersection was detected. One of the cameras was located close to a pedestrian crossing, so that the evaluation of the time gaps could be performed. The second camera recorded the other pedestrian crosswalk and served the evaluation of the empirical regression model. The visual evaluation was carried out in full seconds and only intervals with saturated exit traffic were considered. As a boundary condition 4 seconds were estimated for the gross time gap. For the time gap model, the time interval between two crossing pedestrians interrupted by at least one exiting vehicle was collected. 133 time gaps of 1 to 5 vehicles with a linear relationship were collected and evaluated. According to the approach of Siegloch, a critical time gap of $t_g = 7.6$ s and a follow-up time gap of $t_f = 2.6$ s were determined. These time gaps were evaluated to determine the capacity by the approach of Griffith and Siegloch.

The model of the empirical regression was evaluated in 30 second intervals for the two exits, while the number of all pedestrian crossings, the number of overall crossings and the number of blockings were collected separately. The number of crossings is considering the collective crossing of pedestrians as one influence. The number of blockings results from the number of vehicle stops within an interval. There were 297 saturated intervals recorded. The data analysis has revealed that the number of crossings shows the highest significance. The number of all pedestrian crossings, as well as the number of blockings point to a lower significance and a greater scattering. The scattering is increased for all parameters. On one hand this indicates measurement inaccuracies; on the other hand it shows the possible inhomogeneous behavior of road users. A linear and an exponential function were determined for each influencing parameter. Following-up, a cross-validation was carried out for the number of crossings, to verify which of the approaches is more suitable. There was no significant difference observed.

An influence of pedestrians on exits to the entry and the circular lane could also be observed in the field study. To what extent this should impact the capacity will be analyzed in further studies.

The transferability of the developed models to other roundabouts was examined for the first model based on results of different studies. The field study results show lower capacities than those of Hubberten (2008). In comparison, the results of Schmotz (2014) are comparable. For the second model, there were no further measurement data available. Therefore, the two examined exits were compared; it was found out that capacities vary slightly. At higher pedestrian loads the results are comparable.

The field study has shown the influence of pedestrians on exits on the capacity of roundabouts. It could be derived from the models that allow assessing the exit capacities. The inhomogeneous behavior of pedestrians with and without crosswalks should be addressed in further studies. In further studies, these results should be supplemented by measurements of other roundabouts. More influential parameters such as the geometry could then be incorporated and it would be possible to integrate more variables into the functions. Simulations could generate more information. The effects of pedestrians at roundabout exits should be included in the capacity analysis of the entire intersection in the future. The pedestrian can have a significant impact on exit capacity.

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