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# Editorial: Calculation of Passenger Car Equivalents at Roundabouts

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## Editorial on the Research Topic

## Calculation of Passenger Car Equivalents at Roundabouts

The effect of heavy vehicles on traffic operations has historically been accounted for through the use of Passenger Car Equivalents (PCEs), by which a mixed fleet of vehicles can be transformed into a fleet of equivalent passenger cars and therefore employed to perform the analysis of capacity and the determination of the level-of-service of roads and intersections. Although the calculation of passenger car equivalents for heavy vehicles represents a starting point for the operational analysis of road entities and other traffic management applications, very few studies have looked at the effect of heavy vehicles on traffic operations at roundabouts. The highly curvilinear nature of the roundabout design in both the urban and rural environment has significant effects on the paths that heavy vehicles need to travel; as a consequence, the interaction between the dimensions and performance characteristics of the heavy vehicles and the geometric features of roundabouts can produce higher impacts on traffic operations than other at-grade intersections. The PCEs at roundabouts can be affected by numerous and specific factors such as geometric and traffic properties, driver behavior, and environment, the effect of which can be significant under conditions of unlimited traffic with high saturation degrees of the traffic streams.

Most of the methodologies of traffic analysis use PCEs to account for the impact of heavy vehicles on traffic stream behavior due to their dimensions and performances. The analytic method for the operational analysis of the modern roundabouts that the subsequent editions of the US HCM propose also involves adjusting the flow rate for each traffic movement to account for the characteristics of traffic streams by using PCEs. However, PCE for roundabouts is indifferent to the performance of heavy vehicles or traffic level, since it is independent of the vehicle type and the percentage of heavy vehicles.

Since scientific literature refers that only a few studies have been based on field data or have calibrated PCEs for roundabouts, academics and practitioners during the last decade have been using microscopic traffic simulation to calculate the PCEs also on roundabouts. Thus, many challenges and research themes are still open both for modern and alternative roundabouts.

Therefore, the Research Topic presents original research and review articles both aiming to verify the effect of geometric and traffic-related determinants on the calculation of PCEs for heavy vehicles at modern roundabouts and alternative types of roundabouts, and opened to studies related to the assessment of the operational performances of roads and intersections for the role played in the road design process. The Research Topic includes a body of work representing the efforts of five papers, which are referred to below.



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Giuffrè O. et al. present a synthesis review on Passenger Car Equivalents (PCEs) for heavy vehicles at roundabouts which allowed the authors to make an overview of the Research Topic and to draw some conclusions for roundabouts.

The first level of literature analysis allowed them to point out that heavy vehicles contribute to reducing the entry capacity at roundabouts, and this reduction is even more marked as the percentage of heavy vehicles entering the roundabout increases and the type of vehicle changes. However, the physical and behavioral processes at roundabouts operating under mixed traffic are not yet fully known. The authors also examined more recent studies where PCEs at roundabouts have been calculated by statistical methods and microscopic traffic simulation models. Since many differences were detected among the values of PCEs calculated by different methods, the authors concluded that each different methodological approach may have affected each PCE determination and, in the current state of knowledge on the topic, they cannot express themselves on which method is preferable. However, microscopic traffic simulation models can represent an appropriate tool to assess changes in traffic quality since they allow for conceptualizing traffic scenarios not observable in the field and to produce their replication to provide a large amount of data to analyze. In the studies examined, there was evidence that PCEs mainly change with the percentage of heavy vehicles in traffic, the geometric characteristics, and type of roundabout (single-lane or multi-lane roundabout where PCEs can vary for each entry lane), and traffic conditions. However, the authors concluded that many research themes are still open for application to roundabouts and future studies should focus both on the calculation of PCEs for different types of heavy vehicles, (keeping in view of the introduction of new vehicle technologies), and on the optimization of calibration parameters of microscopic traffic simulation models. On the whole, the results obtained in this study can represent a guideline for transportation engineers in planning, design, and capacity analysis of roundabouts that operate under conditions of mixed traffic.

Pajecki R. et al. presented a study on estimating the PCE of various sized heavy vehicles in roundabouts with respect to different entry flow rates. The Authors focused on a single-lane roundabout under predefined mixed traffic and demand scenarios in VISSIM micro-simulation environments and tested the individual and group behavior of four separate heavy-vehicle types (single-unit trucks, buses, small semitrailers, and large semitrailers). The average estimated PCE values for the different heavy vehicles in mixed traffic were 1.30 for single-unit trucks, 1.40 for small semitrailers, 1.60 for buses, and 1.70 for large semitrailers. In order to further test the different impacts of each truck-type on the roundabout, the authors also grouped the four vehicles above and recommended more dynamic values in relation to traffic demand scenarios. The authors found lower PCE values than those suggested in the United States road design guidelines. They argued that the PCE values for roundabouts presented in the design guides were often overestimated, and the impact of multiple vehicle types should be better considered. However, they highlighted the need for further research to confirm the PCE values of individual vehicle types using real-world data and to study in more depth other factors that affect roundabout performances for specific heavy-vehicle types. It has been found to be valuable the general equation developed to relate vehicle proportions and heavy-vehicle reduction factors that would be useful for professionals to analyze the operational performance of roundabouts with better accuracy.

Macioszek calculated the Passenger Car Equivalent Factors for heavy vehicles on turbo roundabouts located in Poland and presented the results in terms of numerical values of PCEs for trucks, buses, trucks with trailers, and articulated buses. Having in mind the goal to determine PCEs, the author examined the effect of heavy vehicles on critical gaps, follow-up time, and time gaps between the vehicles moving on turbo roundabout roadways, and recognized longer headway parameters with the increasing of the percentage of heavy vehicles in traffic than those under conditions of passenger cars only. The analysis allowed the author to conclude that the passenger car equivalent factor on Polish turbo roundabouts for trucks and buses is 1.74 at entries, with the value of 1.71 for the left entry lane and 1.77 for the right entry lane, while the passenger car equivalent factor for trucks with trailers and articulated buses is 1.86 at entries, having a value of 1.82 for the left entry lane and 1.90 for the right entry lane.

The analysis gave an insight from a methodological point of view, but the results should be treated as preliminary and pilot results. To obtain generalizable results, the author proposed an extension of the number of turbo roundabouts to be examined in future research and to explore the effect of the variation in the percentage of heavy vehicles in traffic on the values of PCEs. Further analyses should also account for the varied geometry of turbo roundabouts and various cases of road traffic control both in the turbo roundabout circular roadway and at entries.

Ahmed and Easa presented two alternative direct models for estimating percent time-spent following (PTSF) that provide interesting ideas to study the waiting phenomena for road entities. Based on data generated from the corridor micro-simulation (CORSIM) software, the authors developed a general linear regression model by using typically-used input variables and a non-linear form by using only the follower density. In the first case, all significant input variables that affect the examined key parameter were used in a single relationship that can be convenient to employ. This form eliminates the additional computational efforts for adjusting the base PTSF proposed by the Highway Capacity Manual (HCM 2010). In the second case, in turn, a function of only the follower density was developed, however easily measured from the field. Both PTSF models showed better performance in estimating the simulated PTSF compared with the HCM methods. Although the models proposed by the authors were based on micro-simulation, they can be calibrated and validated with local conditions. Based on this research, the authors argued that factors such as free-flow speed and drivers' sensitivity indicators can also affect PTSF in addition to the typical input variables of hourly flow, directional split, percent of heavy vehicles, and percent passing zones. However, both proposed models could be more promising generally after calibration of the coefficients using real site-specific data rather than using the default internal values of CORSIM. The study allowed the authors

to highlight the overestimation and underestimation of PTSF by HCM (2010), but with a lower margin of mean errors than those reported in the literature. Although the results of this research can be useful for a direct estimation of directional PTSF of two-lane highways, in the near future the authors propose to carry out further research to test the proposed formulas by incorporating the variations in horizontal and vertical alignments of the simulated highway segment and passing opportunities to assess whether it is can be expected or not a significant impact on PTSF.

Granà A. et al. presented a methodological approach based on traffic microsimulation for estimating Passenger Car Equivalents (PCEs) for heavy vehicles at two-lane and turbo roundabouts. The authors introduced a criterion of equivalence to find the PCEs that reflect traffic conditions at multi-lane roundabouts, where the capacity is estimated for each entry lane. Based on the equivalence defined by the proportion of capacity used by vehicles of different classes, the criterion implied comparison between the capacity that would occur with a traffic demand of passenger cars only and the capacity reached starting from demand with a certain percentage of heavy vehicles. Considering the conversion of an existing two-lane roundabout into a basic turbo roundabout with comparable size, empirical capacity functions by lane were derived as target values to which compare the capacities simulated in AIMSUN as the traffic composition varied.

A comparison was made between PCEs estimated for each entry lane characterized by a similar mechanism of entry at both roundabouts. The results showed the feasibility and soundness of the methodological approach which used traffic microsimulation to estimate PCEs for heavy vehicles at roundabouts. The results also highlighted that the use of appropriate PCEs should be considered in view of the conversion of the existing layout of two-lane roundabouts into the configuration of basic turbo roundabouts, and factored into the estimation of the life-cycle costs of roundabout design alternatives before the implementation and installation in the real world. The authors wish that the methodological approach presented in this study can be applied to a more complex scheme of intersections and roundabouts to contribute to addressing design problems that transportation engineers have to solve in their professional context when applying traffic microsimulation for real-world case studies.

In conclusion, we believe that findings from the papers included in this Research Topic can contribute to providing an overview of the current knowledge concerning the estimation of PCEs and especially for the study of roundabouts can represent a guideline in the capacity analysis under conditions of mixed traffic as we observe in the real world.

## AUTHOR CONTRIBUTIONS

AG, EM, and TG wrote the editorial.

**Conflict of Interest:** The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.