International Co-operation on Theories and
Concepts in Traffic Safety

Long-Term Analysis of Driver Behaviour in the Dilemma Zone at a Signalized Intersection

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Introduction

Intersections are widely recognized as some of the most hazardous locations within road networks due to the diverse behaviors and interactions of road users (Shirazi und Morris 2017). At intersections, injuries occur during rear-end or side-impact conflicts, particularly when vehicles engage in abrupt deceleration within the dilemma zone (Najmi et al. 2019; Papaioannou 2007). The dilemma zone was first studied in the 1960s and was defined as the area where vehicles approaching a signalized intersection, upon the onset of a yellow signal, are unable to either safely stop before the stop line or clear the intersection before the signal turns red (Gazis et al. 1960).

Our study concentrates on acceleration and deceleration patterns in the dilemma zone. This approach aligns with Papaioannou et al. (2021), allowing for a direct comparison of our findings. The contribution of our research is the usage of a large-scale trajectory dataset and inclusion of nighttime driving behavior, which has been largely overlooked in previous studies except in the study from Gates und Noyce (2010). The nighttime data, in particular, allow us to test the hypothesis that road users in the dilemma zone are more likely to proceed through the intersection rather than brake during nighttime conditions. Furthermore, the extended data collection period increases the likelihood of identifying rare or extreme cases, contributing to a more nuanced understanding of driver behavior in the dilemma zone.

Methodology

Data for this study were recorded over multiple months at the Application Platform for Intelligent Mobility (AIM) Research Intersection (Knake-Langhorst und Gimm 2016). The dataset includes 20 Hz vehicle trajectory data, traffic light data, and weather data. A sample dataset from one day in 2023 is publicly available (Schicktanz et al. 2025).

Our study focuses on the Type II dilemma zone and follows the assumption by Hurwitz et al. (2012) that it can be characterized by the time to intersection (TTI). Therefore, we will extract the vehicles in the dilemma zone from the trajectory data and categorize these vehicles into four groups: stop, go, passed with red, and stop after the stop line. Using these classifications, we generate descriptive statistics in line with the methodology of Papaioannou et al. (2021). His results are depicted in Figure 1. We then compare and interpret our findings against their results, placing particular emphasis on extreme values. The objective is to evaluate whether utilizing a larger dataset facilitates the identification of additional extreme cases and to conduct a more in-depth analysis of the behavioral patterns within them.

Variable	Description	Behavior	Mean	Std. Deviation	Minimum	Maximum
Distance (m)	Distance from stop line at the onset of the yellow signal	Stop	97.14	21.78	39.06	128.90
		Go	48.39	23.89	6.55	104.10
		Passed with red	95.80	16.81	61.15	127.90
		Stop after stop line	86.54	18.69	61.32	125.70
Speed (m/s)	Approaching speed at the onset of the yellow signal	Stop	17.66	3.59	3.92	27.37
		Go	22.65	3.40	11.81	32.95
		Passed with red	20.59	3.07	12.81	26.34
		Stop after stop line	18.91	3.26	13.35	25.10
Acceleration/Deceleration (m/s^2)	Acceleration/Deceleration at the onset of the yellow signal	Stop	0.27	0.87	−2.52	2.72
		Go	1.13	1.13	−2.00	10.06
		Passed with red	0.94	0.70	−0.18	2.92
		Stop after stop line	0.14	1.24	−2.79	1.34

Figure 1: "Descriptive statistics of main variables based on drivers' behavior" from Papaioannou et al. (2021) Table 3.

Results

Since up to 40,000 road users are detected daily at the AIM Research Intersection, this long-term study is based on a large dataset collected over several months, comprising several million trajectories. Accordingly, tens of thousands of road users are expected to have been recorded within the dilemma zone. Given that the speed limits in the study by Papaioannou et al. (2021) were higher than those at the AIM Research Intersection, the recorded distances, speeds, and braking maneuvers in our dataset are expected to be lower. This study will also provide a descriptive analysis of how these lower speeds influence the following traffic when vehicles engage in braking maneuvers.

Furthermore, due to the larger volume of analyzed data, we anticipate more pronounced extreme values, leading to greater standard deviations. The recorded extreme situations will be examined in detail, also in scene videos, to provide deeper insights into safety critical driving behaviors.

Discussion and Conclusions

Unlike previous studies (Liu et al. 2007; Gates et al. 2007; Chauhan et al. 2022), which analyzed multiple locations, our study focuses on data from a single intersection. This enables a detailed examination of behavior under consistent traffic signal conditions while allowing for a more comprehensive dataset over an extended period. By utilizing long-term recording, we aim to capture behavioral patterns that may have been previously unobserved. The extended data collection period increases the likelihood of identifying rare or extreme cases, contributing to a more nuanced understanding of driver behavior in the dilemma zone.

Additionally, our implementation of real-time processing algorithms demonstrates the feasibility of analyzing ongoing traffic conditions. This capability opens possibilities for real-time monitoring and adaptive traffic signal control, potentially improving intersection safety and efficiency.

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