Exploring the Impact of Deceleration Rates on Traffic Incident Probability: A Case Study of Motorways in the Netherlands

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Short summary

This study investigates the impact of traffic deceleration on incident occurrence on Dutch motorways, using a dataset enriched with incident locations and traffic data, including congestion patterns. Currently, a wide array of indicators is employed to gauge road traffic safety, yet the connection between these indices and actual road incidents remains ambiguous. Therefore, this research explores whether average (maximum) deceleration distributions can act as surrogate safety measures, to potentially enhance traffic safety and management. It also examines the correlation between deceleration and incidents, aiming to fill the research gap on this relationship. The methodology involves a comprehensive data analysis of incident frequency and traffic deceleration over a five-month period. Findings from this study could aid traffic management centers in prioritizing road safety interventions and inform the development of in-vehicle warning systems, contributing to safer road environments in the Netherlands.
Keywords: Deceleration Rate; Road Incidents; Traffic Speed; Safety Evaluation.

1 Introduction

Road safety is of high importance due to its economic and societal impacts. A comprehensive understanding of traffic incidents, the factors influencing them, and strategies for improvement are crucial for reducing their adverse effects. Numerous factors can be identified to affect accidents' occurrence, and these can be categorized into human behaviours, traffic conditions, network geometry, and characteristics, and environmental factors (Roshandel et al., 2015). Above all, traffic speed is often regarded not only by road users but also by traffic management systems as a crucial factor in determining a route's convenience and efficiency (Dutta & Fontaine, 2019; Choudhary et al., 2018). Additionally, it is a key element in both geometric design and safety assessments, often linked to the occurrence and evaluation of accidents (Apostoleris et al., 2023).
Typically, the safety of motorways is assessed using incident data (Yao et al., 2023). To deepen our understanding of this dynamic, it is crucial to analyze time-series traffic data across a range of time intervals. This method will more accurately capture the evolving patterns of traffic flow that precede the occurrence of a crash (Sun & Sun, 2015). However, despite extensive research into the causes of traffic incidents, due to the low probability of such events only a limited number of studies have examined the relationship between deceleration patterns and incident rates using real-world data (Du et al., 2023). Moreover, the effectiveness of current road traffic safety indicators is unclear, as their connection to actual road accidents is not well-defined. Therefore, understanding the relationship between road risk assessment indicators and traffic accidents is essential for choosing appropriate evaluation metrics and thresholds (Du et al., 2023).
To underscore the significance of the relationship between real traffic data and safety equipment, van Lint et al. (2020) suggest that the distribution of average (maximum) deceleration could act as an indirect measure of road safety. This method discerns clear differences between road segments with Congestion Warning Systems (CWS) and those without. Their research underscores the potential of using aggregate data as an alternative metric for assessing the impact of CWS on traffic safety, emphasizing the need to consider various influencing factors for a thorough analysis (van Lint et al., 2020). However, their study does not address the gap between incident occurrences and maximum deceleration rates. Therefore, the current research is intended to fill this critical gap by asking: *"Can a surrogate safety measure (safety index), based on deceleration variations, effectively indicate the occurrence of incidents?"*

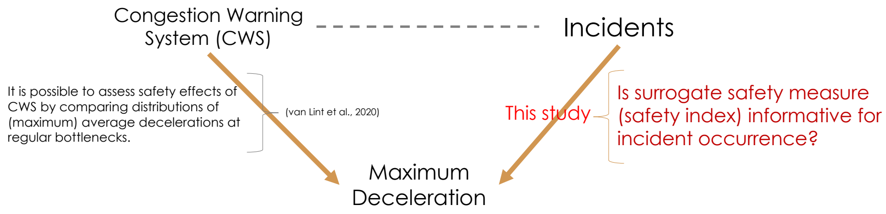
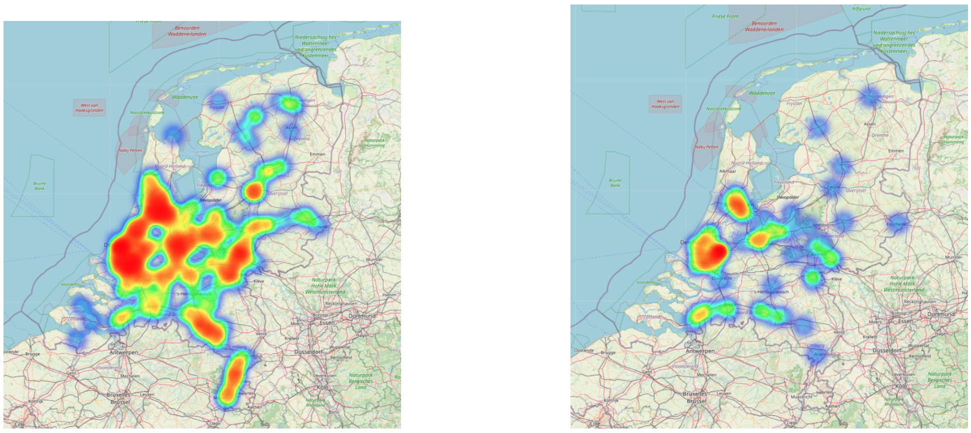


Figure 1: Scope of the current study.



(a) (b)

Figure 2: Density visualization of all incidents (a) and accidents (b) in the Netherlands (August-December 2019). Warmer hues represent a higher concentration of incidents.

To address this question, this paper investigates the relationship between traffic deceleration and the occurrence of incidents. The scope of this paper with respect to the most closely-related studies is depicted in Figure 1.

2 Methodology

Comprehensive data analysis serves as the methodological approach to uncover insights from the acceleration measurements validated by incidents' frequency. In this study, a dataset encompassing the entire network in the Netherlands will be explored and analyzed. The data covers a time range of five months, starting from August and concluding in December 2019. In the study period, the location of incidents in the Netherlands is depicted in Figure 2.

The NDW (Nationaal Dataportaal Wegverkeer) in the Netherlands serves as the principal entity for the aggregation of road traffic data, including speed, flow, and travel time (Ministerie van Infrastructuur en Waterstaat, 2023). This data has been systematically archived for over a decade and is proactively disseminated in an open-source format, accessible both in a real-time context and from a historical perspective. The latter form of the data is extensively employed in the domains of traffic analytics and academic research.

In parallel, NDW maintains a comprehensive compilation of road incidents, spanning nearly a decade, available in the public domain. This repository predominantly consists of manually collected data by road authorities, supplemented with insights from police records, phone calls, and emergency service narratives. It meticulously documents occurrences on national highways across the Netherlands and is organized into three primary classifications: (1) Accidents: encompassing collisions, vehicular fires, etc., (2) Vehicle obstructions: detailing instances of vehicles becoming stationary on the road or in emergency lanes, and (3) General obstructions: addressing unforeseen impediments not assignable to the previous categories.

The incident dataset includes all the unplanned, unexpected, and sudden happenings on the network. Thus, other road disruptions, such as roadwork and bridge openings, are not included in this dataset. For each incident following features have been recorded in the raw dataset: ID, Type, Start time, End time, Longitude and Latitude.

In this study, two distinct datasets, namely the incident point dataset and the traffic spatiotem-

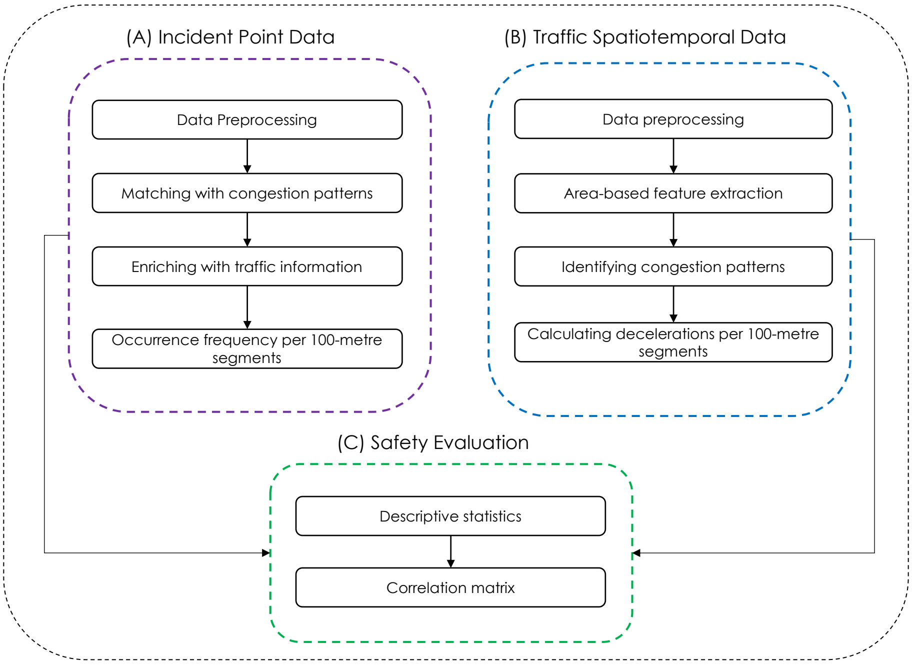


Figure 3: Developed framework to investigate the relationship between incident occurrence and traffic deceleration.

poral dataset, are merged to gain more detailed insights. The study begins with the construction of an incident dataset and preprocessing, which was subsequently enriched with detailed traffic information. The incident preprocessing includes filtering data, finding the direction of incidents on the motorway linestring, and projecting the location onto the assigned linestring. It is important to note that not all incidents result in congestion. To discern incidents that alter traffic patterns and cause congestion, map-matching techniques are employed with existing congestion patterns. All notable congestion patterns were identified using the methods established in Krishnakumari et al. (2017); Nguyen et al. (2019). Following this, the incident dataset is enriched with the spatiotemporal attributes of the matched congestions. The frequency of incidents per 100-metre segment was calculated to quantify incident occurrences. Subsequently, deceleration data was measured based on the traffic data, with a complete methodology for this calculation detailed in van Lint et al. (2020). To explore the impact of deceleration on incident frequency, deceleration rates for 100-metre segments were also determined. Later, the relationship between these deceleration values and the incidents matched with identified congestion patterns will be further analyzed using descriptive and quantitative statistics. The findings from this study will be instrumental in conducting safety evaluations and establishing priorities for the enhancement of the road network infrastructure. Figure 3 provides a visual summary of the framework employed in this study.

3 Results and Discussion

The preliminary incident dataset has been enriched to include the projected latitude and longitude coordinates of the incidents' locations, which have been mapped onto the corresponding linestrings of the motorway. Additionally, the direction of each incident and relevant traffic data have been integrated for those incidents that correlate with identified congestion patterns. Figure 4 presents a space-time diagram that features a highlighted example of this integration: an accident on the A4 motorway on August 27, 2019, that has been matched with congestion.
The dataset was subsequently employed to create maps depicting the frequency of incidents per 100-metre segments of road throughout the duration of the study. Figure 5 displays the distribution of incidents along 100-metre intervals of the road A13 (an important motorway) over the study period, which is also located in red zones as it is depicted in density maps (Figure 2). In Figure 5, the vertical axis denotes the number of incidents recorded, while the horizontal axis represents the sequential count of 100-metre segments extending from the beginning of the linestring. This figure highlights the two segments that experienced the highest number of incidents, marking them

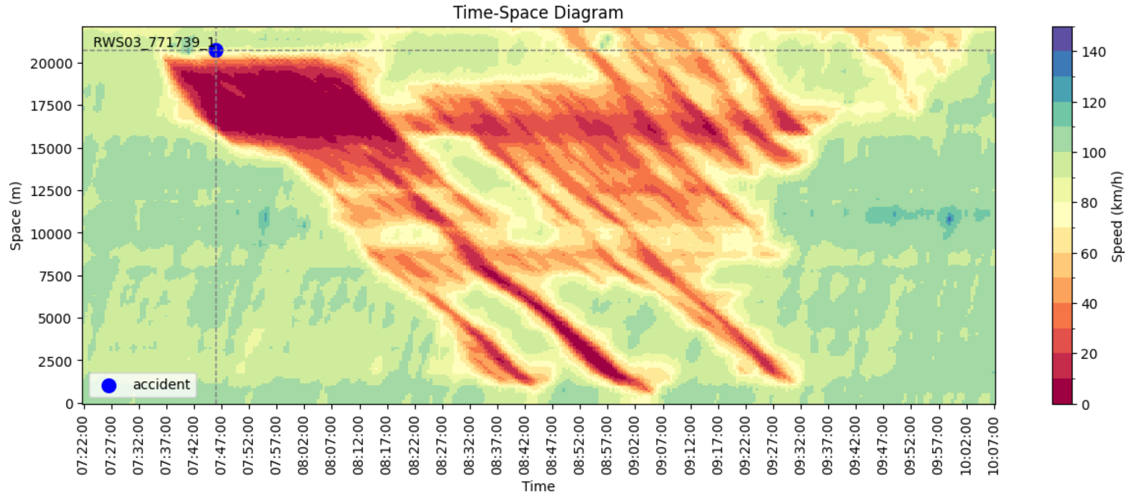


Figure 4: Example of an accident matched with an identified significant traffic congestion on road number A13 (August 27, 2019).

as key areas of interest for subsequent in-depth analysis involving deceleration values. Figure 6 depicts the critical areas of the A13, which have a high incidence of accidents.

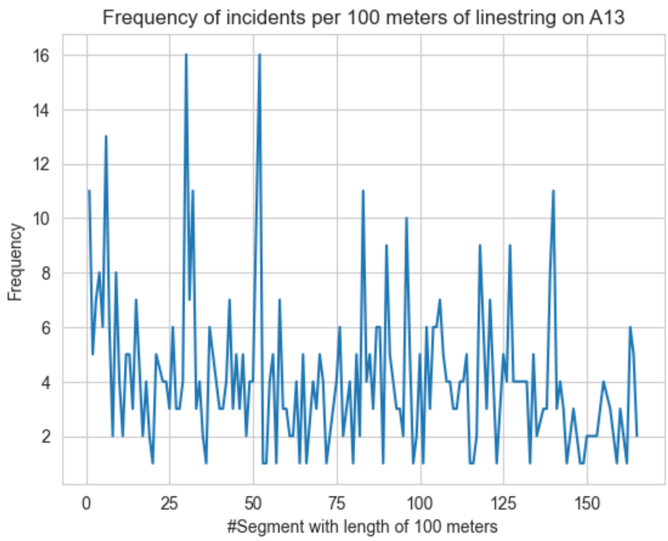


Figure 5: Frequency plot of incidents per 100-metre segments during the study period for the A13.

The segments identified in these figures will undergo further analysis by correlating them with traffic deceleration data. This analysis aims to map the frequency and intensity of deceleration patterns within these specific areas. Additionally, incorporating infrastructure information for these regions, such as the number of lanes and proximity to interchanges and ramps, will provide deeper insights into how various factors influence incident occurrence. Finding correlations between these parameters and incident occurrence will be advantageous in enhancing incident management strategies.

4 Conclusions

Comprehending incidents, particularly accidents, is crucial for efficient incident management. Insight into the specifics of accidents enables incident management teams to react swiftly and offer essential aid, thereby enhancing public safety. Furthermore, a thorough understanding of incidents is key to developing effective traffic control strategies. Among different factors affecting incident occurrence, in this research relationship between speed inherent uncertainties and incidents will be

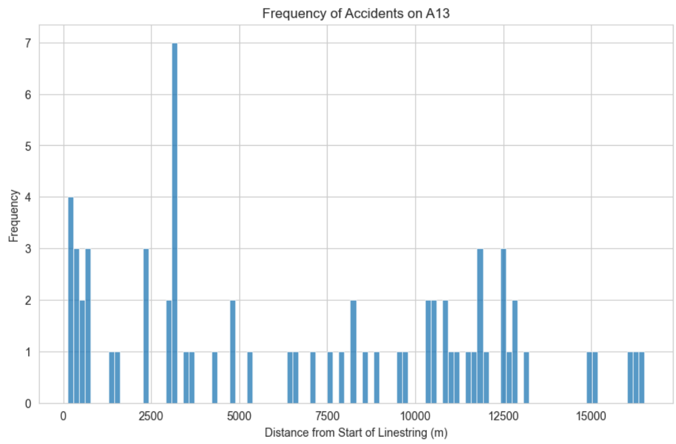


Figure 6: Frequency plot of accidents throughout during the study period for the A13.

discovered and quantified.
To do this, initially, an extensive incident dataset has been enriched with traffic information. Measuring the deceleration rates from traffic data, the correlation between incident occurrence and deceleration rates will be investigated.
This approach will primarily assist traffic management centers in assessing and prioritizing road segments according to safety metrics, subsequently facilitating the formulation of efficient traffic strategies. Additionally, the results are beneficial for in-vehicle warning systems, laying a valuable foundation for future studies and extensive investigations in this field.

Acknowledgements

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