# EFFECTS OF WET WEATHER ON DRIVERS' RISK ACCIDENT PERCEPTION DURING MOTORIST-FOLLOWING BEHAVIOUR ON TWO-WAY TWO-LANE HIGHWAY

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**DEDICATION**

*I hereby dedicate my thesis to my beloved father soul, dearest husband, lovely children and beloved mum, whom without their enthusiasm and encouragement; I would never have been able to complete this journey to fruition.*

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## ABSTRACT

Motorist-following behaviour is expected to be influenced by driving environment such as weather conditions. In road accident studies, close or unsafe motorist-following behaviour is considered as one of the main factors of rear-end collisions. Therefore, it is imperative that such a fundamental aspect of motorists' behaviour is clearly understood so that effective accident mitigation strategies can be formulated. Driven by this requirement, this study examines the effect of wet weather conditions on drivers' perception of safe following distance and to predict dynamically its effect on potential accident risk. Motorist-following behaviour was analysed based on different types of vehicles driven, i.e. car following car, car following heavy good vehicle (HGV), HGV following car, and HGV following HGV at two types of highway geometry i.e. passing and no-passing zones. Traffic data for more than 200,000 vehicles were collected using automatic traffic counter at 12 selected sites in Johor and Pahang States, Malaysia, during dry and wet weather conditions. Five-minute interval rainfall data were obtained during the study period, from the rain gauge stations located within 2 km of the study sites. Regression techniques were then used to develop empirical models of motorist-following behaviour. The developed models on time to collision (TTC), accident probability index (API) and chosen risk index (CRI) were used to predict and evaluate the effect of wet weather on traffic conflict, accident probability and severity during motorist-following behaviour. The analysis revealed that the shift from dry to wet weather showed an increase in time gap and a reduction in mean speed irrespective of highway geometry and vehicles following category. This is supported by the observed increase of time gap in the range of 12.15% to 17.88% and 7.33% to 17.61%; and the decrease of mean speed in range of 9.23% to 10.74% and 11.44% to 12.14% at passing and no-passing zones, respectively. The results revealed that traffic conflict occurred at lower speeds during wet weather compared to dry weather irrespective of highway geometry and vehicles following category. The analysis showed that the API values for wet weather conditions are lower than the API values for dry weather conditions. Such a result suggests that the wet weather condition increases the accident probability when compared with the dry weather conditions. Based on API, the percentage of vehicles travelling at relatively safe speed during dry weather was found to be 51% and 53 % compared to 25% and 22% during wet weather at passing and no-passing zones, respectively. The results of the analysis also showed that the potential accident severity under wet weather conditions is lower than that under dry weather conditions. This is indicated by lower CRI values during wet weather compared to dry weather. Based on CRI, the percentage of vehicles travelling at relatively safe speeds during wet weather was found to be 29.5% and 27% at passing and no-passing zone, respectively. In summary, all objectives of the study were achieved. The study provides new information that is essential in traffic safety management which includes the effects of wet weather conditions on potential accident risk for motorist-following situation.

# ABSTRAK

Kelakuan pengekoran pemandu dijangka dipengaruhi oleh persekitaran pemanduan seperti keadaan cuaca. Dalam kajian kemalangan jalanraya, memandu pada jarak yang rapat atau tidak selamat dianggap sebagai salah satu faktor utama kepada kemalangan jalan raya jenis langgar belakang. Oleh itu, adalah penting untuk memahami dengan jelas aspek asas kelakuan pemandu supaya strategi mencegah kemalangan yang efektif dapat dirangka. Susulan daripada keperluan ini, kajian ini menilai kesan keadaan cuaca lembap terhadap persepsi pemandu bagi jarak pengekoran selamat dan meramal secara dinamik kesannya terhadap potensi risiko kemalangan. Kelakuan mengekor pemandu dianalisa berdasarkan perbezaan jenis kenderaan yang dipandu, seperti kereta mengekori kereta, kereta mengekori kenderaan berat (HGV), HGV mengekori kereta, dan HGV mengekori HGV bagi dua jenis geometri jalan iaitu zon memotong dan tidak boleh memotong. Data lalu lintas yang lebih daripada 200,000 kenderaan dicerap menggunakan pencerap data lalu lintas automatik di 12 lokasi terpilih sekitar Negeri Johor dan Pahang, Malaysia, semasa keadaan cuaca kering dan lembap. Data hujan dengan sela lima minit diperoleh semasa tempoh kajian daripada stesen-stesen sukat hujan yang terletak sekitar 2 km dari lokasi kajian. Teknik regresi digunakan untuk membangunkan model-model empirikal bagi kelakuan mengekor pemandu. Model-model masa pelanggaran (TTC), indeks kebarangkalian kemalangan (API) dan indeks risiko terpilih (CRI) yang dibangunkan digunakan untuk meramal dan menilai kesan keadaan cuaca lembap bagi konflik lalu lintas, kebarangkalian kemalangan dan tahap keterukan kemalangan semasa kelakuan mengekor pemandu. Analisa mendapati perubahan daripada cuaca kering kepada lembap menunjukkan peningkatan dalam sela masa dan penurunan laju purata tanpa mengira geometri jalan dan kategori kenderaan yang mengekor. Penyataan ini disokong dengan hasil pemerhatian yang menunjukkan peningkatan sela masa antara 12.15% hingga 17.88% dan 7.33% hingga 17.61%; dan penurunan laju purata antara 9.23% hingga 10.74% dan 11.44% hingga 12.14% masing-masing di zon memotong dan tidak boleh memotong. Keputusan ini menjelaskan bahawa konflik lalu lintas berlaku pada kelajuan yang rendah semasa cuaca lembap berbanding cuaca kering tanpa mengira geometri jalan dan kategori kenderaan yang mengekor. Analisa menunjukkan bahawa nilai API bagi keadaan cuaca lembap adalah rendah berbanding nilai API bagi keadaan cuaca kering. Keputusan ini menggambarkan keadaan cuaca lembap meningkatkan kebarangkalian kemalangan berbanding keadaan cuaca kering. Berdasarkan API, peratus kenderaan yang dipandu secara relatif pada kelajuan selamat semasa cuaca kering didapati sebanyak 51% dan 53% berbanding 25% dan 22% semasa cuaca lembap, masing-masing di zon memotong dan tidak boleh memotong. Hasil analisa juga menunjukkan bahawa tahap keterukan potensi kemalangan dalam keadaan cuaca lembap lebih rendah berbanding dalam keadaan cuaca kering. Penyataan ini ditunjukkan oleh nilai CRI yang rendah semasa cuaca lembap berbanding cuaca kering. Berdasarkan CRI, peratus kenderaan yang dipandu secara relatif pada kelajuan selamat semasa cuaca lembap didapati sebanyak 29.5% dan 27%, masing-masing di zon memotong dan tidak boleh memotong. Secara ringkasnya, semua objektif kajian tercapai. Kajian ini menghasilkan informasi baru yang diperlukan dalam pengurusan keselamatan lalu lintas yang merangkumi kesan keadaan cuaca lembap terhadap risiko potensi kemalangan bagi situasi mengekor pemandu.

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| | | |
|---|---|---|
| AADT | - | Average Annual Daily Traffic |
| API | - | Accident Probability Index |
| ATC | - | Automatic Traffic Counter |
| CRI | - | Chosen Risk Index |
| DID | - | Department of Irrigation and Drainage |
| DS | - | Driving Simulation |
| FT | - | Full-scale Test |
| GPS | - | Global Positioning System |
| HCM | - | Highway Capacity Manual |
| HSM | - | Highway Safety manual |
| HGV | - | Heavy Goods Vehicles |
| ILD | - | Inductive Loop Detectors |
| ITS | - | Intelligent Traffic System |
| JKR | - | Jabatan Kerja Raya (Public Work Department) |
| LED | - | Light Emitting Diode |
| MMD | - | Malaysian Meteorological Department |
| MHA | - | Malaysian Highway Authority |
| MTE | - | Metro-count Traffic Executive |
| NE | - | Northeast |
| SE | - | Southwest |
| TC | - | Traffic Counter/Classifier |
| TG | - | Time Gap |
| TMS | - | Time Mean Speed |
| TTC | - | Time to Collision |
| VANET | - | Vehicular Ad-Hoc Networking |
| VC | - | Video Cameras |
| DGPS | - | Differential Global Positioning System |

## LIST OF SYMBOLS

| | | |
|---|---|---|
| Ao | - | Vehicle length |
| $A_1$ | - | Driver reaction time |
| $C$ | - | Constant corresponding to the desired confidence level |
| $E$ | - | Permitted error or tolerance in the average speed estimate |
| $H$ | - | Headway |
| $L$ | - | Vehicle length (predicted) |
| $V$ | - | Vehicle Speed |
| $W$ | - | Vehicle Weight |
| N | - | Minimum number of measured speeds |
| S | - | Estimated sample standard deviation |
| $x_i$ | - | Speed of the following vehicle |
| $x_{i-1}$ | - | Speed of the leading vehicle |
| $D_{x_i}$ | - | Distance headway at $x_i$ |
| $g_j$ | - | Number of observations in group j |
| $p_j$ | - | Middle value of variable in group j, |
| n | - | Total sample size or number of observations |
| s | - | Standard Deviations |
| t | - | Driver reaction time (predicted) |
| Y | - | The target or dependent variable |
| X | - | Explanatory or independent variable (of the linear regression equation), |
| $\alpha_1$ | - | Slope of the linear regression equation |
| $\alpha_2$ | - | Intercept of the linear regression equation |

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# CHAPTER 1

# INTRODUCTION

## 1.1 Background of the Study

Traffic safety is an ever-increasing concern because of random occurrences of accidents and their severe consequences. The rising numbers of road traffic accident alongside its consequences is one of the most discussed health and social policy concern worldwide, accounting for the third most causes of injuries and deaths (Goniewicz *et al.*, 2016; Goniewicz *et al*., 2017). In fact, vehicles' crashes are perceived as complex events which are often influenced by traffic demands, roads' geometry, drivers' behaviours and driving environments (Andrey, 2010; Lee *et al.*, 2018; Theofilatos and Yannis, 2014).

Among the diverse contributing factors of vehicle collisions, weather conditions play a predominant role. Specifically, precipitation and wet weather occurrences deteriorates drivers' visual equity as well as pavement skid resistance, leading to negative impact on the driving performance and traffic safety (Cai *et al.*, 2013; Liu *et al.*, 2017; Saha *et al.*, 2016; Theofilatos, 2017). Moreover, at a particular speed, the driver's ability to maintain safe following distance is more accurate during dry weather compared to wet weather with short sight distance and long stopping distance (Black *et al.*, 2017; Kassu and Anderson, 2018; Rahman and Lownes, 2012).

In a traffic stream, unsafe car-following distance among drivers not only increases the risk of rear-end collision but also raises the possibility of several other types of accidents (Li *et al.*, 2016; Wang *et al.*, 2012). Especially, if the close-following are coupled with accelerated passing manoeuvres, the risk factors for accidents increase (Yu *et al*., 2017). This basic aspect of driving performance is called drivers' car-following behaviour. On the same lane of traffic stream, the theory of car-following behaviour usually describes driver's response in relation to the leading vehicle's speed. The theory was introduced since 1950s and continues to be examined until today, and perhaps over a long time to come. Generally, the driving task during car-following behaviour is categorised to three related subtasks i.e. perception, decision-making and, control. These subtasks are highly dependent on the driving environment.

On two-way two-lane highways, a high traffic volume on a wet day with poor visibility and little pavement friction often limits the chances for overtaking manoeuvres. This in turn builds up rapid platoon wherein an adjacent group of vehicles travel in same speeds (Puan, 2004). In those situations, the drivers' decision to initiate, continue, or complete a passing manoeuvre is even more complex than the decisions involved in car-following. During passing process, the drivers may reduce the headway to a point where they cannot maintain a safe distance with the car ahead, leading to an increase in the rear-end crash probability. To control the errors, the drivers need to know how to judge the speed of overtaken vehicle and the oncoming vehicle. Thus, drivers must be able to predict accurately, the gap and time to overtake a vehicle. Certainly, a small error while overtaking could end up with serious consequences which could lead to fatal accident. Besides, for safe passing manoeuvre, drivers need to judge the speed and acceleration potential of their vehicle, the speed of the leading vehicle, the speed rate of the closure of the approached vehicle, and the presence of an acceptable gap in the traffic stream (AASHTO, 2010, 2011).

Although, careful drivers depend on the risk perception to maintain a safe speed and following headway (the average time interval between successive vehicles), precipitation while driving can considerably increase the chance of road accidents occurrence, mostly, the rear-end collisions (El Faouzi *et al.*, 2010; Hamdar *et al.*, 2016; Jaroszweski and McNamara, 2014; Kopelias *et al.*, 2007).

The evaluation of the effect of weather condition on potential accident risk in the form of rear-end collision during car-following behaviour is essential for designing safe roads, effective traffic safety interventions, and evaluation of highway safety levels. For instance, many studies have established a statistical correlation among traffic-weather characteristics, and accidents probability and/or severity (Abdel-Aty *et* *al.*, 2012; Ivan *et al.*, 2010; Liu *et al.*, 2017; Saha *et al.*, 2016; Theofilatos, 2017; Xu *et al.*, 2013a). However, empirical research on evaluating pre-accident drivers' responses during car-following behaviour is limited. In fact, most empirical research on driver's car-following behaviour concerns  identification of the significant factors affecting headways choices and safety margins of rear–end collision (Yeung and Wong, 2014), characterization of driver response to different roadway geometries and weather conditions by analysing the differences in time gaps and speeds between normal and adverse weather condition (Hamdar *et al.*, 2016; Rahman and Lownes, 2012). Lastly, Hjelkrem and Ryeng (2016) have defined indices to describe weather effect on the perception of accident probability and severity during car-following state. These indices are; Accident Probability Index (API) and Chosen Risk Index (CRI). However, empirical research on such important indices via the surveillance of weather and highway traffic data has not been adequately explored.

Lately, research on mitigation approach of accidents caused by adverse weather became a central focus worldwide (Ahmed *et al*., 2018). Such knowledge would help highway traffic agencies to enhance highway design and build up robust traffic safety management strategies. In this regard, safety intervention and orientation of drivers during adverse weather condition play critical role in alleviating accident risks (Alfelor *et al.*, 2013; Murphy *et al.*, 2012; Nellore and Hancke, 2016). Traffic-weather management schemes are categorized into three stages such as advisory, control and treatment strategies (Kim *et al*., 2013; Theofilatos and Yannis, 2014). To achieve its goal in the advisory and control stages, traffic safety management must not only be reactive but also need to be proactive. That means to include weather warning systems, speed limits and vehicles' spacing administration, and improvement of highway design. Indeed, such strategies must be dynamically adjusted following the already observed traffic-weather condition to ensure speed adjustment for matching and modifying the level of the potential accident risks (Hollnagel, 2018; Li *et al.*, 2014).

In Malaysia, wet pavement and reduced visibility caused by rainfall is very common (Ben-Edigbe *et al.*, 2013; Mashros *et al.*, 2014; Mukhlas *et al.*, 2016). Such environment reduces drivers' ability to adjust to a safe following distance, which in turn poses the risk of rear-end collision and possibility of multiple accidents resulting from tailgating as well as unsafe overtaking. According to Malaysian Institute of Road Safety Research (MIROS), this country has the highest rate of road traffic fatalities per 100,000 population among all ASEAN countries and more than 50% of the road accident fatalities involve motorcyclists (Eusofe and Evdorides, 2017; Sultan *et al.*, 2016). The number of road traffic deaths in rural area (66%) is significantly higher compared with that in urban areas (34%). While the statistics based on road category revealed that the number of road traffic deaths is the highest for federal two-way two-lane roads (Darma *et al.*, 2017; Mohamad *et al.,* 2019). The percentage of fatality cases involving motorcyclist from 2008 until September 2017 is the highest (61.2 %) compared to other category followed by car (20.3 %) and the lowest is fatality cases involving bus (Idris *et al.*, 2019). To resolve such issues related to traffic accident fatalities, various initiatives, strategies and programmes have been undertaken by the Malaysian Government (Darma *et al.*, 2017). The implementation of such programmes have been outlined in Malaysian Road Safety Plan 2016, which cited more enhancement through better understanding of the factors that considerably contribute to accidents occurrence and fatality (JKJR, 2014).

As mentioned earlier, Hjelkrem and Ryeng (2016) identified the indices (API and CRI) which describe the influence of weather on the perceived accident probability and its severity during motorist-following state. However, empirical study on such important indices via the surveillance of weather under varying roadway geometric conditions has not received the desired attention from experts in the field of traffic engineering. Hence, this called for an utmost need to explore on these indices via an empirical approach.

Therefore, this study examines the effects of wet weather on drivers' risk accident perception during motorist-following behaviour on two-way two-lane highway at passing and no-passing zones, respectively. For the purpose of clarity, the term motorist-following is synonymous with car-following as the latter is the mostly used nomenclature in describing driver-following behaviour. On the basis of this clarification, the duo terms; motorist-following and car-following would henceforth be used interchangeably throughout the thesis depending on the appropriateness of either at a particular instant.

## 1.2 Problem Statement

Despite the substantial advances in drivers' car-following behaviour research, the characterisation of safe following distance under adverse weather condition is controversial. For instance, traffic safety regulations for safe following headway was initially based on the minimum break reaction time and/or minimum stopping distance required for collision avoidance. Licensing manuals and California Driving Manual recommend headways greater than 2 s to follow a vehicle safely (Ayres *et al*., 2001; Risto and Martens, 2014b). However, following headway is subject to many factors beside the human aspects, such as vehicles dynamic state, visibility conditions and/or traffic environment factors. Therefore, most of the drivers travel at average headway less than the recommended value by break reaction time studies due to perceptual bias and individual differences.

On the other hand, the British Highway Code Macpherson (1993) recommends safe following distance based on theoretical safe braking distance computed under good driving condition. Thus, it is not consistent with the assessment and/or the comparisons of safe following distance between normal and adverse weather condition. Moreover, safe braking distance approach is expected to recommend for greater vehicles spacing than that is observed on nowadays traffics. It is thus worthy to appreciate the headway control technologies concerning the distance range between the equipped and leading vehicles. Although these applications have limited influence on the drivers' human aspects related to perception reaction time, it has greater effect on the vehicles dynamic state i.e. the break beadles and the accelerator control. Therefore, driving environment and highway traffics which include high portion of automated vehicles pose safety assessment challenges.

Most of the aforementioned researches aimed to evaluate the effects of weather condition on traffic safety during car-following behaviour (Hjelkrem and Ryeng, 2016;

Liu *et al.*, 2017; Saha *et al.*, 2016) were conducted in various countries where the traffic characteristics, road geometry, traffic regulations, drivers' behaviour and driving environment are different from those obtainable in Malaysia. In addition, in most cases the highway safety analysis during car-following behaviour is based on non-dynamic concept. For instance, no study so far has applied dynamically pre-accident indices on motorist-following behaviour using highway traffic and rain gauge station data. Such approach would help on the conceptualisation of the potential accident risk, prediction and evaluation of the highway traffic safety level, thereby gaining deep insight regarding better roadway design and implementation of effective traffic safety management strategies. Hence, this study examines the effects of wet weather condition on drivers' accident perception during motorist-following behaviour (as against the conventional practice of non-dynamic approach) under varying road's geometrics on two-way two-lane highways.

## 1.3 Aim and Objectives

It can be hypothesized that weather condition, highway geometry involving the passing zone provision and vehicles types have significant influences on drivers' car-following behaviour and the potential accident risk as well. In this viewpoint, the present study is aimed to examine the effects of wet weather condition on driver' risk accident perception during motorist-following behaviour on two-way two-lane highways. To achieve the stated aim, the study was conducted based on the following objectives:

(a) To develop empirical models of drivers' car-following behaviour for examining the effect of wet weather on drivers' perception of safe following distance.

(b) To determine the effect of wet weather incidence on traffic conflict and safety-critical traffic situation during car-following behaviour.

(c) To evaluate the effect of wet weather incidence on the drivers' perception of accident probability during car-following behaviour.

(d) To determine the effect of wet weather incidence on the perceived accident severity during car-following behaviour.

## 1.4 Research Scopes and Limitations

Mainly, the scope of this study includes two aspects: data collection and the analysis of the collected data. Regarding the data collection, traffic data were gathered from selected sites at point level on various two-way two-lane highway segments based on individual vehicles' observation. These chosen sites were the best representative of two-way two-lane rural highways on free flow for both passing and no-passing zones, where high proportion of impeded vehicles are most likely expected. However, in terms of the analysis, the developed empirical models address only drivers' car-following behaviour. Specifically, the effect of wet weather on the drivers' perception of safe following distance compared to dry weather at both situations of close and normal following behaviour i.e. at passing and no-passing zones. The limitations of the research scope include the following:

(a) Selection of site for the collection of individual traffic data was not a random based. The basis for the choice of Johor and Pahang States as study area is because these states receive much rainfall during monsoon season. In addition, selection of 12 study sites on two-way two-lane federal highways satisfied the most needed criteria for the work. Furthermore, since Peninsular Malaysia's temporal storm profiles is described in terms of East and West Coast Regions (Kok *et al.*, 2017), Johor State (southern Malaysia) is characterized by both South-East and South-West coast monsoons while Pahang State (middle of Malaysia) is characterized by the North-East coast monsoon. Hence, the two states serve as representatives of the two coastal regions describing the Peninsular Malaysia's temporal storm profiles.

(b) The selection of specific traffic sites was made based on the availability of rain gauge station in its proximity.

(c) Consideration of only rainfall incidence regardless of its intensity to define the wet weather condition.

(d) Inclusion of all types of motor vehicles for evaluating the potential accident-risk except motorcycles because this type of vehicle often displays non-lane-based movements.

(e) Application of the models only for the speeds greater than 25 km/h depending on the wide range of collected traffic data from typical free flow two-way two-lane highways.

(f) Analysis of drivers' car-following behaviour during daytime only for better visibility.

(g) The perceived accident risk indices for traffic conflict, accident probability, and severity have considered only the indirect safety measures related to the enforcement of car-following behaviour.

## 1.5 Research Significance

The current research would be gaining high significance since highway safety issues is not only relevant to the implementation of transportation strategies, but also to solve major public health problems and to the achievement of worldwide development goals. The main contribution of this research is the introduction of empirical approach to predict, conceptualise and evaluate the potential traffic accident risk caused by adverse weather condition during motorist-following behaviour. Unlike the time headway regulations and stopping distance models, the proposed approach adopts the dynamic interaction between the vehicles. The proposed approach involved the application of TTC in the ranges of the speed during car-following behaviour as adopted traffic conflict indicator in the field of traffic safety surrogate measure. Moreover, the application of API and CRI which incorporate drivers' behaviour and vehicle dynamics factors that include the vehicles speeds and time components.

The analysis and the results of this study are essential for the improvement of highway design and the application of pro-active traffic safety management strategies. Empirically, the adopted approach and the results of this study are important to design variable speed limits as traffic management tool to regulate vehicles speeds and reduce the accident risk. Moreover, to achieve highway traffic safety and efficiency, the applicability of TTC, API and CRI in the ranges of the speed allows for investigating the influence of such strategies on drivers' behaviour i.e. speed and headway behaviour. It is important theoretically because most of the existing microsimulation tools on the market model driver behaviour as a function of following distance and speed, improvements in understanding should lead to improved performance of these tools in modelling transportation systems in adverse weather conditions.

The application of TTC, API and CRI provide fundamental information for Vehicular Ad-Hoc Networking (VANET), an important component of Intelligent Transportation System (ITS). VANET is a wireless system that supports traffic safety via vehicle-to-vehicle communication without fixed infrastructure. In this system, vehicles act in dynamic vehicular networking together with the adjacent vehicles on the highway. The main aim of implementing VANET technologies in the ITS arena is to enhance roadway safety by reducing accident risk. However, its direct objective is to detect risky driving situations and alert the drivers. This implies that the driver is not the primary party that perceives the risky situation and respond appropriately.

## 1.6 Thesis Outline

The present Chapter provides a brief background of the study, the existing research gaps, objectives, research hypothesis, scopes, limitations, and research significance.

Chapter 2 presents a comprehensive and critical literature review of the theoretical background of drivers' car-following behaviour and empirical car-following models. Traffic safety issues are reviewed in detail including the traffic conflict indicators, the concept of potential risk of accident probability and severity, chosen risk indices, and the effects of wet weather on traffic safety. Finally, an overview on the Malaysian highway and the weather is discussed.

Chapter 3 explains the overall process employed for the generation relevant data needed for the study from various sites. The description encloses the data requirement, and site selection criteria, usage of equipment and devices for data acquisition, the site set-up, employment of survey method, data reduction and processing, analytical tests and techniques of the empirical model development and implication.

Chapter 4 outlines and discusses the baseline statistics and data overview. It emphasises the descriptive statistics of the speed, headway as well as development and comparison of drivers' car-following models.

Chapter 5 presents and discusses the traffic safety indicators and indices concepts including time-to-collision (TTC), accident probability index (API) and chosen risk index (CRI). It presents the application of the developed models on Speed-TTC, Speed-API, and Speed-CRI relationships to predict and identify the effect of wet weather on traffic conflict, accident probability and severity, respectively.

Chapter 6 concludes the thesis with results, novelty, contributions and future outlook.

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