マレーシア地方道路の無信号T交差点での重傷事故と車両危険挙動の解析

Analysis of Fatal-Serious Accidents and Dangerous Vehicle Movements at Access Points on Malaysian Rural Roads

2014

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ANALYSIS OF FATAL-SERIOUS ACCIDENTS AND DANGEROUS VEHICLE MOVEMENTS AT ACCESS POINTS ON MALAYSIAN RURAL ROADS

DISSERTATION

Submitted in partial satisfaction of the requirement for the degree of

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By

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To my parents
Mustakim Bin Mohsin
and
Moltfiah Binti Masood
For the support, motivate, encourage and trust

To my beloved wife
Rosmah Binti Sarmin
For her patient and love
To my sons
Muhammad Fateh
Muhammad Abbas
Muhammad Muaz
For the cheerful and peaceful
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ABSTRACT

Traffic accidents have been recognized as one of the major causes of human and economic losses in both developed and developing countries. In 2010, Malaysia recorded a total of 414,421 accidents, resulting in an average of 19 deaths from road accidents every single day. This research analyzed the factors relevant to fatal and serious accidents on rural federal roads in Malaysia. The objective was to identify the dangerous vehicle movements and factors posing significant risks for fatal-serious accidents at access points (non-signalized minor junctions) and to suggest countermeasures.

This research consists of seven Chapters. Firstly, Chapter 1 provides a discussion of accident trends and traffic studies in general. In Chapter 2, the scope was then narrowed down to focus on the accident black spot in order to identify the hazardous or black spot sections. Chapter 3 further examines the quantitative accident records and traffic characteristics for each of the selected sections. Next, Chapter 4 focuses on vehicle movements at non-signalized intersections. Chapter 5 provides the methodology and procedures adopted in the development of accident prediction models. Chapter 6 focuses on the development of gap acceptance model. Finally, Chapter 7 provides the development of serious conflict model.

This research carries out numerous surveys to observe various traffic movements, including right and left turns, from minor and major roads, in addition to many other characteristics, in order to construct accident analysis models. One of the findings is that right-turn motorcycles caused serious conflicts and right turn movement was considered
to be the most dangerous movement. Based on this finding, this research further examines the driver behavior of gap acceptance and serious conflicts using the proposed four gap patterns for a right-turn vehicle from minor to major roads at access points in Road Section 10 of the Federal Road 50 (Unchannelized intersection connected 2-lane minor and 4-lane major roads). In addition, further analysis is performed to identify the gap pattern and the factors relevant to serious conflicts. The results demonstrated that right-turning vehicles, especially motorcycles, apparently intended to start turning right in a very short gap and the approaching speed and the gap between a pair of vehicles from opposite directions in the mainstream were the critical factors causing serious conflicts to the right-turn vehicles. In addition, this research studies more on the other two non-signalized intersections located in Road Sections 2 (Channelized intersection connected 2-lane minor and 6-lane major roads) and 9 (Unchannelized intersection connected 2-lane minor and 4-lane major roads with a traffic signal in close proximity) of the Federal Road 50. The results found that the existence of channelization on the intersection encouraged the right-turn vehicle to accept a longer gap. Furthermore, the combined analysis of all the three un-signalized intersections (Road Sections 2, 9 and 10), reveals that angular serious conflict, nose-tail conflict, and if the second vehicle in the pair in the mainstream is a motorcycle or a passenger car, can significantly influence the right-turn vehicles to accept a short gap. On the other hand, a traffic light located in a relatively close distance to the access point, as well as channelization on the intersection can cause the right-turn vehicles to accept longer gaps.
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The number and year of publication of the reference and equation are given in common parenthesis ( ).
CHAPTER 1

INTRODUCTION

1.1 Introduction

Approximately 1.3 million people die each year on the world’s roads and between 20 and 50 million people sustain non-fatal injuries. According to the World Health Organization (2009) in 2004, deaths due to road accidents was the ninth cause of deaths worldwide and in the year 2030 it is predicted to be the fifth leading cause of deaths worldwide. The Global Status Report (WHO 2009) on road safety carried out a broad survey road in 178 countries which revealed that road traffic injuries are on the most significant public health problems, especially for developing and undeveloped countries. Motorcyclists, pedestrians and cyclists appear to be most likely killed on the roads. More attention needs to be given to these road users in road safety program (WHO 2009).

Growth in urbanization and in the number of vehicles in many developing countries has led to the increase in traffic accidents on road networks which were never designed for the volumes and types of traffic which they are now required to carry. In addition, unplanned urban growth has led to incompatible land uses, which has resulted in high levels of pedestrian/vehicle conflict. The drift from rural areas to urban centre often results in large numbers of new urban residents who are unused to such high traffic levels.

As a result, there has often been a severe deterioration in driving conditions and a significant increase in hazards and competition between different classes of road users of the road system. In addition, the inherent dangers have often become worse by poor road maintenance, badly designed intersections and inadequate provision for pedestrians. All of these have contributed to serious road safety problems now commonly found in developing countries.
To many road projects could be the reason why road agencies responsible for the maintenance of the road network cannot keep pace with road construction. The result is that roads are often badly in need of maintenance, traffic signage is often inadequate, facilities for pedestrians are poor and guidance to drivers via channelization or other control measures is rarely available. These general deficiencies in the operational and control aspects of the road systems are worsened by the fact that drivers are rarely adequately trained and tested, traffic law enforcement is ineffective and driver behavior in respect of compliance with the road rules is frequently very poor. The net result of these inadequacies is the very high incidence of road accidents involving casualties and fatalities.

Gradual elimination of the most hazardous locations on the road networks and the adoption of safety conscious approaches to the design and planning of new road networks have contributed greatly towards improving traffic safety. Even though the eventual solutions may differ, the approaches and systematic methods used in industrialized countries to improve road safety are readily applicable to the developing world.

1.2 Objective of the Study

In light of the above, the main aim of this study is to identify the dangerous vehicle movements and factors which significantly contribute to road accidents causing serious injuries and fatalities at access points (non-signalized minor junctions) and to suggest countermeasures. To accomplish this, the following objectives were set:

1. To identify accident trends and severe accident spots (black spots) on the Malaysia rural Federal Road 50.
2. To collect data for all traffic volumes, movements (including right and left turnings, from minor and major roads, and by type of vehicles), approaching speeds, gaps (headway) and road geometry.
3. To identify the dangerous vehicle movements and factors posing significant risks for fatal-serious accidents at access points (non-signalized minor junctions) and to suggest countermeasures.

4. To carrying out an in-depth analysis of the behaviors on gap acceptance and serious conflict as the dangerous movements at access points (non-signalized T-junction) in order to clarify the factors causing fatal and serious accidents.

5. To identify gap pattern for right turning vehicles from minor road to major road at non-signalized junctions on Malaysia rural Federal Road 50.

6. To develop serious conflict models by using logistic regression in order to identify the critical gap patterns and factors relating to serious conflict at the non-signalized intersection.

1.3 Scope of Study

The scope of the project cover stretches from KM1- KM38 Batu Pahat –Ayer Hitam and investigates accident trends and identifies black spots. The accident record data used in the study was collected over a 10 years period from 2000 to 2010 from the District Police Traffic. The study also used an accident database on selected road sections from 2006 to 2010 for accident analysis. An appropriate statistical analytical tool was required to identify the hazardous location that caused the accidents, thus enabling the recommendation of improvements at selected sites to reduce the accident rate. The study developed an accident prediction model that included eleven sections of road: Section 2, 5, 8, 9, and 10 of the Batu Pahat area and Road Section 19, 20, 21, 22, 23 and 24 of the Parit Raja area. The study concentrated on Road Section 10, 9 and 2 of Batu Pahat area for the purpose of carrying out an in-depth analysis of the behaviors on gap acceptance and serious conflicts, as the dangerous vehicle movements at access points in order to clarify factors causing fatal and serious injury accidents. Furthermore, this study purposed four gap patterns for right turning vehicles from minor road to major road and established the fatal and serious conflict model by using the technique of logistic regression.
1.4 Structure of the Thesis

The rest of the thesis is organized, as follows;

This research is presented in seven major chapters. The first chapter, we discuss the objective and scope of the study.

The second chapter presents a review of the literature on accidents on rural roads and problems causing accidents in undeveloped and developing countries. The chapter also includes a compilation of accident data in Malaysia and highlights the significance of the study.

In Chapter three, the main characteristics of accident and traffic studies at non-signalized intersections on Malaysian rural Federal roads are identified. This is done in five steps. First, the subject is put into perspective through a discussion of accident trends and traffic studies in general. The scope is then narrowed down to focus on accident black spot studies to identify the hazardous or black spot sections. The third step focus on quantitative accident records and the traffic characteristics of each selected section. The next step focuses on vehicle movements at non-signalized intersections. Finally the methodology and procedures adopted for the development of accident prediction models are presented and the different developed models are discussed. In this chapter, we analyze the accident factors relevant to fatal and serious accidents and investigate the accident point weighting using a correlation coefficient and regression technique.

Chapter four, analyzes the factors affecting to fatal and serious traffic accidents on the Malaysia rural Federal Road 50, with respect to access points and various vehicle movements. Base on the result of the previous chapter, we carried out an in-depth analysis of dangerous vehicle movements, gap acceptances and serious conflicts with of right-turning vehicles (including motorcycles and passenger cars) from minor roads, to ascertain their importance contributing to fatal and serious accidents. This chapter also presents the methodology and procedures adopted for developing a of
gap acceptance movement model and established the serious conflict models for section 10 intersection.

**Chapter five** concentrates on the two non-signalized access points located in sections 2 and 9 of the Batu Pahat area. The development of gap acceptance models and the analysis of right-turning vehicles for these sections were similar to that for section 10—in chapter four except the fatal and serious conflict model. Four gap patterns were proposed at access point (non-signalized minor junctions) in Road Section 9. Meanwhile five gap pattern were introduced at access point in Road Section 2.

**Chapter six**, deal with three access point in Road Sections, namely (2, 9 and 10). Several gap acceptance models have been developed involving two types of combined Section – the first combination is Road Section 10 and 9; and, the second combination is Road Section 2, 9 and 10. The gap pattern analysis has been carried out for each Road Section.

Finally, **chapter seven** presents the main findings of this study and the recommendations for further research. The methodology applied to achieve the objectives of this study is shown in the flow chart in Figure 1.
Figure 1: Research methodology flow
CHAPTER 2

REVIEW OF PREVIOUS STUDIES

2.1 Introduction

As the road networks in developing countries are at an early stage of development, engineers in those settings have the opportunity to draw upon the experience of developed countries where road networks have already passed through similar stages (although less rapidly than is being currently experienced in developing countries). The adoption of proven strategies from industrialized countries (such as accident black spot elimination and safety conscious design and planning of road networks) offers unparalleled opportunities to make significant and lasting improvements to road safety. Many developing countries continue to repeat mistakes made by numerous industrialized countries, such as still permitting linear development with direct access from frontage properties along major roads, even though this is known to lead to road safety problems.

One factor that all industrialized countries have found to be of crucial importance in their effort to improve road safety is the availability of accurate and comprehensive accident data, so that the problems can be properly defined and suitable remedial measures can be devised. Consequently, before developing countries can emulate industrialized countries, it is essential that comprehensive accident data systems be established.

In order to maximize the impact of engineering on safety problems, it is necessary to apply measures at various stages throughout the development of road networks. By incorporating good design principles from the start, it is possible to avoid many problems simply by planning and designing new roads in a safety conscious manner. Even where this has not been done, it may still be possible (although more expensive) to improve existing roads by the subsequent introduction of safety or
environmental-related measures such as selective road closures, road humps to reduce speeds and the prohibition of heavy goods vehicles in residential areas.

It is also possible to identify hazardous sections of the road network so that appropriate remedial measures can be undertaken to reduce the likelihood and severity of accidents at those locations. This has proven to be one of the most cost-effective ways of improving road safety in industrialized countries (Silcock et al. 1991).

Although human error, in one form or another, has been identified as the main contributory factor to most accidents, road-related factors are no less important. There is rarely one isolated cause of an accident, and human error will usually always occur alongside engineering-related deficiencies in the road infrastructure. For example, accidents resulting from vehicles crossing onto major roads from minor roads at non-signalized intersections are usually associated with unsafe infrastructure, such as the absence of channelization or road dividers. Engineering measures therefore play a vital role in accident reduction.

2.2 Traffic Accidents in Malaysia

Figure 2.0 illustrates the total number of motor vehicles by types. In year 2010, motorcycle had highest number of vehicle (9,441,907) followed by motorcar (9,114,920).

![Figure 2.0: Total Motor Vehicles by Types (Ministry of Transport Malaysia 2010)]
Traffic accidents have been recognized as one of the major causes of human and economic loss in both developed and developing countries. In 2010, Malaysia recorded 414,421 accidents (Figure 2.1), resulting in an average of 19 deaths from road accidents every single day. In 2006, there were 23.6 deaths in Malaysia, for every 100,000 inhabitants recorded (Royal Malaysian Police). This figure is extremely high, especially compared to countries such as the Netherlands and Japan, which had 4.5 and 5.7 deaths per 100,000 people respectively in the same year. In Malaysia, motorcycles constitute nearly half of the total registered vehicles in the country (49%), with passenger cars making up 45%. Figure 2.2 shows that among the total fatalities resulting from traffic accidents, motorcycle fatalities accounted for 60% of fatalities, while car facilities accounted for only 22% (Royal Malaysian Police, 2009), thus illustrating that motorcycle fatalities were three times higher than car fatalities.

**Figure 2.1:** Number of vehicle accidents in Malaysia (2000-2010)

**Figure 2.2:** Fatality distribution by mode of transport (Royal Malaysian Police 2009)
2.3 Problems Associated with Motorcycles

Land use in Malaysia can be categorized into the form of activities undertaken, such as industrial, residential, commercial, educational and other uses. In Malaysia, the Town and Country Planning Department or local authority in each district are responsible for the land use activity. The classifications of land use applied by the Town and Country Planning Department are residential, industry, business and service, institutions and public amenities, open space and recreation, vacant land, transportation, infrastructure and utilities, agriculture, livestock and aquaculture, forest, and water body. Transportation and land use are two sides of the same coin. Development in land use will affect transportation and vice versa. Different types of land use may attract different levels of traffic, which in turn, may cause road accidents.

Figure 2.3 presents data on accidents involving motorcycles by land use type. The data show that there were uniform trends in the number of motorcycle accidents in the six year period between 2005 and 2010. Rural areas recorded the highest number of fatalities (66.62%), compared to city (4.6%), urban (11.49%) and built-up areas (17.29%). Rural areas are defined as mainly agricultural, while suburban areas are defined as areas with populations exceeding 50,000. Urban areas are defined as areas within the territory of a city council.

![Figure 2.3: Motorcycle accidents by land use type (2005-2010) (Malaysia Institute of Road Safety Research 2011)]
Accident prediction models have been developed through statistical analyses with the goal to reduce the number of accidents. Accident models are typically in Poisson and generalized linear forms, but more recently, negative binomial models which are a variant of the Poisson model have been used in accident modeling. An accident model is generally an algorithm pitting a dependent variable against several independent variables, each of which is assigned a constant. The dependent variable in an accident prediction model is the number of accidents, while the independent variables may be quantitative variables, such as road cross-section dimensions, horizontal curvature and traffic volume, or qualitative variables such as the type of terrain, road shoulder and median.

The estimation of accident numbers is not only performed to determine the effect of design elements, but may also be used to estimate the reduction in accidents attributed to changes in the cross-section of roads, assessing the potential safety impact of alternative cross-sections when upgrading roads, predicting the costs associated with accidents and as a measure of safety. Statistical models enable highway agencies to select design standards that are essential to highway safety and to allow comparisons among alternative designs that will optimize the overall safety of the road system. These models can also be used to test the sensitivity of accident rates to changes in a specific geometric variable.

2.3.1 Motorcycle Fatalities by Collision with Vehicle Type

The data presented in Figure 2.4 shows that the most frequent fatal traffic collision in Malaysia was between a motorcycle and a passenger car. Collisions between two motorcycles and single motorcycle accidents (that is, not involving any other type of vehicle) were the second most common type of road accident resulting in fatalities, both accounting for 25% of fatalities. Accordingly, motorcyclists were involved in 50% of fatal collisions, either in single vehicle accidents or in accidents with other motorcycles.
**Figure 2.4:** Motorcycle fatalities by collision with vehicle type (Royal Malaysian Police 2009)

### 2.3.2 Motorcycle Fatalities by Occupancy

The data presented in Table 2.1 shows that on average over five years, 89% of the total motorcycle fatalities are riders. The data also illustrate that a motorcycle rider is eight times more likely to be involved in a fatal accident than a car passenger.

<table>
<thead>
<tr>
<th>Year</th>
<th>Rider (Total %)</th>
<th>Passenger (Total %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005</td>
<td>3181 (88.6)</td>
<td>410 (11.4)</td>
</tr>
<tr>
<td>2006</td>
<td>3243 (87.8)</td>
<td>450 (12.3)</td>
</tr>
<tr>
<td>2007</td>
<td>3197 (87.7)</td>
<td>449 (12.3)</td>
</tr>
<tr>
<td>2008</td>
<td>3459 (88.7)</td>
<td>439 (11.3)</td>
</tr>
<tr>
<td>2009</td>
<td>3640 (89.4)</td>
<td>430 (10.6)</td>
</tr>
<tr>
<td>Average</td>
<td>3344 (88.5)</td>
<td>436 (11.5)</td>
</tr>
</tbody>
</table>

### 2.4 Review of Previous Theoretical Studies

The review of previous studies included a review of accident prediction models, gap acceptance movement models and traffic conflict studies.
2.4.1 Accident Prediction Models

Considerable research has been carried out regarding road safety analysis, especially on accident rates (or the number of accidents). The Safety Research Center at University Putra, Malaysia, analyzed accident factors using the generalized linear models developed by Radin et al. (2001). The analysis found that traffic volume on the major road, lane width and access points were relevant to the rate of accidents.

Harned et al. (2003) developed a prediction model for motorcycle crashes at non-signalized intersections on urban roads in Malaysia and found that traffic flows (straight directions), speed, lane width and land use were significant factors in motorcycle crashes. However, this study was carried out in urban areas which have a different road situation to rural areas and did not consider fatal-serious accidents, dangerous vehicle movements and traffic volumes in and out from minor and major roads.

Donaldson et al. (2006) analyzed the fatality risks from the crash records of motor vehicles in Utah in the United States. They found that the risk was higher on rural roads than on urban roads.

Wedagama and Dissanayake (2010) investigated fatal accidents in Bali. Their study indicated that the probability of fatal accidents was higher for female drivers than for male drivers; their study only concentrated on accident factors related to the gender and age of the driver. On the other hand, Hagiwara et al. (2010) studied various factors in relation to the number of accidents resulting in fatalities and injuries using long-term accident data from Japan. They indicated that driving mileage per age was more desirable as an exposure value. Patwary et al. (2010) analyzed many influential factors that affected injury severity and collision type for traffic accidents using a Japanese accident database, which was composed of signalized and four-leg intersections.

Hadi et al. (1993) used negative binomial regression analysis to estimate the effect of cross-section design elements on total fatality and injury crash rates for various types of rural and urban highways at different traffic levels. The studies were carried out
on a Florida roadway. The results showed that increased lane width, median width, inside shoulder width and outside shoulder width were effective measures in reducing crashes. The results also indicated that the high number of access points was associated with higher crash frequency.

Karlaftis et al. (2002) investigated the relationship between rural road geometric characteristics, accident rates and their prediction, using hierarchical tree-based regression. The study, conducted in Indiana, found that median width and access control were the most important factors, followed by pavement condition factors.

Xin Ye et al. (2009) developed collision type frequencies to account for the possibility of common factors affecting crash frequencies. The dataset used rural two-lane intersection crash records for 38 counties in the state of Georgia. The model estimation results showed that a host of roadway geometry, intersection control and traffic volume characteristics significantly impacted on crash frequencies.

Haleem et al. (2010) analyzed crash injury severity at three and four-leg non-signalized intersections in the state of Florida. A binary probit model was used in that study. The study reported several important factors affecting crash severity. These included traffic volume on the major approach, the number of through lanes on the minor approach, left and right shoulder width, number of left turns on the minor approach and number of right and left turn lanes on the major approach. These analyses identified the 90-degree intersection design as the most appropriate safety design for reducing accident severity.

Kim et al. (2006) investigated endogeneity between the left-turn lane presence and angle crashes in intersections in Georgia. Limited information-maximum likelihood estimation approaches were used in the analysis. The research showed that without accounting for endogeneity, left-turn lanes appeared to contribute to crashes. However when endogeneity was accounted for in the model, left-turn lanes reduced angle crash frequencies as expected by engineering judgment.
Motorcyclists are neglected in right-of-way violation crashes in which a vehicle from the conflicting stream encroaches into the path of an approaching motorcycle. Furthermore, drivers tend to over-estimate the motorcycle arrival time approaching the intersection, hence increasing the possibility of a collision (Caird et al. 1994). Motorcycle fatalities are more frequent in rural areas due to greater speed and less traffic control (Silva 1978).

The above studies have clarified several factors significant to traffic accidents. However, most of them have been developed in countries and settings where accident collections, human behavior, infrastructure and traffic characteristic are very different from those in rural Malaysia. Several unclear situations related to fatal and serious accidents on rural roads in Malaysia are still poorly explained. Since numerous serious conflicts occur on rural roads in Malaysia, the analysis of dangerous vehicle movements and their relationship to fatal and serious accidents in that setting is important in order to reduce accident rates and social damage. In addition, previous research has paid little attention to the consideration of all traffic movements, traffic volume from all directions, and right and left turnings from minor and major roads by type of vehicle.

2.4.2 Traffic Conflict Studies

Traffic conflict studies, based on the Traffic Conflict Technique, were originally proposed by Perkins and Harris (1968) and have been used as an alternative approach to evaluating the accident potential of intersections. In this approach, the traffic conflict is perceived as a proxy, or surrogate measure, for accidents and the extent of conflicts observed is said to reflect the level of accidents that “might have been”. Thus, some patterns emerge from the analysis of observed conflicts on the basis of which deficiencies at the given intersection can be identified and promptly remedied. A key advantage of this approach is that the potential accident problem is identified and solved in a more proactive manner, instead of waiting for several years to accumulate enough accident data which can then be analyzed. Hence, if applied in a systematic manner, conflict studies could enable traffic engineers to keep pace with (or even ahead of) the development of accident problems within their jurisdiction. In
addition, because conflicts are much greater in number than actual collisions, it means that the database for traffic conflict analyses would normally constitute better statistical samples than the corresponding actual accident data.

Nonetheless, an important question which has not been sufficiently addressed is whether the safety diagnosis for a given location, reached on the basis of traffic conflict analysis, is as accurate and informative as the one that would have been drawn from the relevant accident data. In response to this question, a number of researchers have investigated the relationship between traffic conflicts and accidents; however, the findings and conclusions from these studies have not been consistent. Glauz et al. (1985), for example, analyzed conflict and historical accident data at 46 signalized and non-signalized intersections in the greater Kansas City area. A methodology was also developed to identify “expected” and “abnormal” conflict levels for these intersections. The study concluded that, overall, certain types of traffic conflicts could produce estimates of average accident rates nearly as good as those produced from historical accident data.

To improve confidence and consistency in the use of traffic conflict analysis for safety purposes, particularly in establishing direct relationships between conflicts and actual accidents, Malaterre and Murad (1980) advocated the need for further improvement in the technique of conflict data collection. In their opinion, sufficient reliability can only be reached through a more refined definition of criteria to detect and grade conflicts and more thorough training of observers, neither of which is “ever simple”. It is also noted that more recent developments show that the use of audio-visual equipment could greatly enhance the task of conflict data collection. All things considered, however, it is acknowledged that conflict studies remain “very helpful, only if there is insufficient accident data to produce an estimate” Glauz et al., 1985.

The existence of a “safety continuum” is regarded as a prerequisite for most safety indicators suggesting the existence of “safe interactions” at one end and “accidents” with outcomes of varying severity at the other. This conceptualization is useful for traffic safety research, providing connectivity between the bottom-up approaches to traffic safety found in behavioral sciences and the macroscopic (top-down)
approaches of traffic safety represented by accident frequency and outcome severity. This relationship has been described in many different models over the years, such as of the model developed by Von Klebelsburg (1982) (Figure 2.5).

![Figure 2.5: Traffic safety and the relationship between errors, standard behavior, traffic conflicts and accidents (Von Klebelsburg 1982)](image)

### 2.4.3 Gap Acceptance Movement Model

In the analysis of accident rates conducted in the present study, the gap acceptance behavior of right-turning vehicles is found to be an important factor causing fatal-serious conflicts in Malaysia. There are some studies on gaps for left-turning vehicles (in right-hand traffic). One of the earliest works is from Mahmassani and Sheffi (1981) who developed a probit model to analyze the gap behavior of left-turning passenger cars at a non-signalized intersection.

Other works such as Devarasetty et al. (2012) and Harwood et al. (1999) used logistic regression to model the gap acceptance for left-turning passenger cars from major roads at non-signalized intersections. There were also attempts to include the characteristics of drivers (such as socio-economic characteristics and risk loving or cautious attitudes) into the model such as the studies by Hamed et al. (1997) and Pollatschek et al. (2002). On the other hand, Gattis and Low (1999) developed a logit gap model and found that drivers who were involved in conflicts were too comfortable with short gaps. However, these studies focused only on the movements of passenger cars and did not analyze the relationship between gap acceptance and serious conflicts. These studies were also carried out in the US where drivers drive on the right side and have different characteristics to Malaysian drivers.
Several researches including Tuan et al. (2009) and Jenjiwattanakul et al. (2011) have analyzed the gap acceptance movements in Asia. They analyzed the gap acceptance for U-turning and left-turning vehicles. However, these gap movements are very different from that of right-turning vehicles because U-turning and left-turning vehicles do not cross the opposite directional lanes.

Madanat et al. (1994) used logit modeling to predict the probability that randomly chosen motorists will accept a given gap in a conflicting traffic stream based upon the characteristics of the gap. The gap-acceptance function was then used in a stochastic queuing model to predict vehicle delay. Their study is applicable to right-turning traffic at stop controlled approaches to highway intersections. It was carried out at a T-intersection in Zionsville in the United States.

A clear definition of gap patterns has not yet been provided in the literature. Ragland et al. (2006) defined the gap for left-turning vehicles (in right-hand traffic) as the time that passes between the departure of the rear bumper of the first vehicle and the arrival of the front bumper of the second vehicle of the vehicle pair to the left-turning path. Ghani et al. (2010) also defined some gap patterns of right-turning and left-turning vehicles at a T-junction. However, there are many situations that occur as the opportunities for turning vehicles, and the gap definitions provided by these studies may not be sufficient to explain all the possible gap patterns.

2.5 Collection and Compilation of Accident Data in Malaysia

The framework for the collection of Malaysian accident data is summarized in Figure 2.6. The first step in the production of the national database is the compilation of all traffic accident report forms POL27 (Pin.1/91) in the respective police districts.

The details of each accident are provided by the police, with the original copy of the form (printed on white paper) sent to the State Police Contingent and then subsequently dispatched monthly to the Traffic Branch Police Headquarters, Bukit Aman. At this branch, all forms are checked and delivered, batch by batch, to the Computer Branch, Bukit Aman. The data are then keyed in at the data entry
terminals and doubled-checked by police personnel. Any miscoded accident data are returned to the Traffic Branch for further investigation. The forms are stocked temporarily in a special store room at Bukit Aman before being dispatched to the Road Safety Research Center at Universiti Putra. At this center, the forms are classified, catalogued and bound for easy access for safety research.

The first version of the forms (printed on green paper) may also be obtained from the respective police districts. They are stored at the Traffic Section of each district. Each district has access to the forms if the need arises, although they are not catalogued or compiled as at the Road Safety Research Center. The police district can key in the accident data, based on the POL27 form, and information about the accident data can be accessed.

The second copy of the form, which contains only the first and last pages of the POL27 form (Amendment 1/91) is taken to the office of the Public Works Department in the respective district. The district engineers or their assistants are required to check the location data and forward the forms to the Highway Planning Unit, Ministry of Works Malaysia. This is followed by further checking, coding and keying-in of the location codes by the Highway Planning Unit. Copies of the forms may also be obtained from the Highway Planning Unit.
Figure 2.6: Malaysia accident data collection

2.6 Accident Computer Program System

Advances in computer technology have enabled the efficient interpretation and analysis of large quantities of accident data. The data input, processing and analysis framework adopted is summarized schematically in Figure 2.7. Specification files, text files and pointers in MAAP (Microcomputer Accident Analysis Package) are modified and customized in order to exactly match the accident information contained in the POL27 form. This data are entered directly into the microcomputer using the first MAAP program option, NEWACCS. Geographical maps have been spatially digitized using Autocad Release 11 software and an A1 size digitizer. The digitized data are later used for the graphical display of the accident information using either the MAPINFO Geographical Information System (GIS) or the new
version of MAAP (version 5 Prototype). In the latter case, the digitized data are converted from .DWG format to a simplified .DCM format.

Figure 2.7: Data input and processing framework

Additional data are extracted from the Computerized Accident Recording System (CARS) database for fatalities, serious injuries, minor injuries, damage only and other incidents. The CARS database is located at the Royal Malaysian Police Headquarters.
2.7 Significance of Study

In the present research, we analyzed the factors affecting fatal and serious accidents on Malaysian Federal Road 50, taking into consideration access points and various vehicle movements on this rural road by using regression techniques. We adopted two types of dependent variables, namely, the number of fatal and serious accidents and the accident point weighting (APW) which is commonly used for accident evaluations in this section of road. Numerous surveys were conducted to observe traffic volumes and movements, including right and left-turnings, from minor and major roads and by vehicle type, in order to capture the very dangerous movements and other factors causing fatal and serious accidents. Based on the findings, we carried out a further in-depth analysis of the behaviors related to gap acceptance and serious conflicts in the dangerous movements at access points (non-signalized T-junctions), in order to clarify the factors causing fatal and serious accidents.

The significance of the study is summarized as follows:

1. Previous studies have clarified that traffic volume and access points were significant factors contributing to traffic accidents. However, past studies have not examined all traffic movements and their volumes, such as right and left-turnings from minor and major roads by type of vehicle. As such, several fatal and serious accidents on rural roads in Malaysia have not been adequately explained.

2. Previous research has not examined all the vehicle movements and serious conflicts and did not focus on the dangers associated with right-turning vehicles, especially motorcycles and passenger cars on rural roads in Malaysia.

3. Although several risk factors affecting motorcycle accidents have been documented in Malaysia, problems specific to the fatalities and serious injuries involving motorcyclists on rural roads have not yet been studied.

4. Previous research has not specified in detail the gap patterns in the acceptance model. We propose four gap patterns to take into consideration
all the possible gap patterns for right-turning vehicles from minor roads at non-signalized T-junctions. For the purpose of this study, we refer to vehicles that waited or started to turn right from a minor road to a major road as right-turning vehicles (RTVs). The RTVs include all type of vehicles.

5. This study develops serious conflict models by using logistic regression analysis. Serious conflict models are developed to identify the significant factors causing fatal and serious accidents at access points (non-signalized T-junction) in the study area. This type of model has not been discussed in previous studies.

2.8 Summary

This chapter has addressed issues regarding the phenomenon of the road accidents in Malaysia. Motorcycle fatalities represented the highest proportion of fatalities in traffic crashes (60%), while passenger cars accounted for more than 22% of all fatalities (Royal Malaysian Police 2009). Rural areas recorded the largest number of fatalities (66.62%) compared to city (4.6%), urban (11.49%) and built-up areas (17.29%). In a 5 year period (2005 to 2009), 89% of motorcycle fatalities were riders.

The present research was the first to analyze the factors affecting fatal and serious accidents on Malaysian Federal Road 50 considering access points and various vehicle movements. This study included an in-depth analysis of dangerous movements, gap acceptance and serious conflicts of right-turning vehicles (including motorcycles and passenger cars) from a minor road as important factors in fatal and serious accidents. Moreover, this research proposes a new approach to gap acceptance using four gap patterns to consider all the possible gap patterns for right-turning vehicles from a minor road at an non-signalized T-junction.
CHAPTER 3

ANALYSIS OF ACCIDENT CHARACTERISTICS

3.1 Introduction
Traffic accidents have been recognized as one of the major causes to human and economic losses. In Malaysia, traffic accident has been increasing in numbers, especially on rural federal roadways; for example, on Federal Route 50 (Fr50) traffic accidents have rapidly increased 10 times in the last 10 years (Figure 3.1). In the rural federal roads, population along the roads and traffic volume are increasing rapidly. At the same time, there are many non-signalized T-junctions (hereafter called access points) and high speed vehicles. An access point is a non-signalized 3-leg intersection connecting minor to major roads. Several researches in Malaysia indicated that access point is an important factor causing numerous fatal-serious accidents. During an hour of observation, several severe conflicts and dangerous vehicle movements, like almost traffic accidents, occurred. It is important to analyze the relationship between such dangerous vehicle movements at access points and the fatal-serious accidents in order to consider the proper countermeasures to control the accidents from now on.

Figure 3.1: Federal Route 50
References


35) The Bureau of transport and Regional Economic of Australia BTRE (2001)