Risk Analysis, Driver Behaviour and Traffic Safety at Intersections in Motorcycle-Dominated Traffic Flow

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Abstract

Firstly applied by the U.S. Nuclear Regulatory Commission, risk analysis has quickly become an efficient methodology to apply in many industries, which have to deal with uncertainty. The nuclear industry, and more recently transportation (land and air), space, and food safety industries promote a greater use of risk analysis in their operations, and policy decision making.

Aiming at modelling the cause-and-effect chain of driver behaviour, a new methodology of risk analysis, Darmstadt Risk Analysis Methodology (so-called DRAM), has been developed 15 years ago. This present study explains the application of DRAM in the situation of motorcycle-dominated traffic flow.

In recent years, along with an amazing economical development, mobility demand in Vietnam has increased quickly, which can be clearly seen with the increased number of registered mobile vehicles. Due to its characteristics of movement and economics, motorcycles (two-wheeled vehicles) are still the most common transportation mode in the whole traffic system in Vietnam. They are also main causes to the unordered and unsafe situation of traffic system at present. The author presents findings from analysing the current situation of traffic safety. From statistical data, human behaviour is at the highest rank in the list of causes leading to traffic accidents.

The study describes different approaches to conduct risk analysis in motorcycle-dominated flow based on analysing the accident progress (dealing with the gap between normal situations and critical situations). From the physoslophy of Conflict Technique in car traffic flow, it is provided with two concepts of “conflict zones” and “conflict time segments” which can be further developed to determine the hazard that drivers have to face with in their left-turning movement at intersections in motorcycle-dominated traffic flow. Both concepts are relevant in case of the distinguishing characteristics of non-lane based movement of motorcycles.

After general analysis the situation, the study focuses on the main cause of the traffic unsafety in Vietnam nowadays: driver behaviours of violating road traffic regulations. Applying risk analysis methodology of DRAM, the study aims at answering three questions: (i) why do drivers violate the traffic regulations? (ii) how often do they violate the traffic regulations; and (iii) what are the consequences of such kind of behaviours. The chain of “Driver behaviours of violating traffic regulations” based on “General attitudes towards road traffic regulations” and “Specific-scenario acceptance of rules” is constructed. A case study of two policies in Vietnam is analysed as the illustration. The results are recommended to apply to evaluate and verify traffic safety measurements in the future.

Abstrakt

Die Risikoanalyse wurde im größen Umfang zum ersten Mal von der U.S. Nuclear Regulatory Commission angewandt. Heute findet diese Methodik Anwendung in vielen Industriebranchen, die sich mit Unsicherheit beschäftigen. In der Kernkraft-, Raumfahrt- und Lebensmittelsicherheitsindustrie und in der letzten Zeit im Verkehrswesen wird die Risikoanalyse mehr und mehr für den Betrieb und für strategische Entscheidungsprozesse eingesetzt.

Zur Modellierung von Ursachen-und-Wirkung-Folgen von Fahrerverhalten wurde vor 15 Jahren eine neue Methodik zur Risikoanalyse namens Darmstadt Risk Analysis Methodology (DRAM) entwickelt. Die vorliegende Arbeit beschreibt die Anwendung von DRAM für kraftrad - dominierten Verkehr.

In den letzten Jahren ist in Vietnam der Mobilitätsbedarf mit der Wirtschaftsentwicklung enorm angestiegen. Dies kann durch die Anzahl der amtlich registrierten Krafträder bestätigt werden. Aufgrund der Bewegungseigenschaften und der Wirtschaftlichkeit bleiben Krafträder (Zweiräder) weiterhin das dominierende Verkehrsmittel in dem gesamten Verkehrssystem in Vietnam. Diese Dominanz ist Grund für das „sehr lebendige“ und aber auch unsicher Verkehrsystem. Analysen zeigen dass die meisten Verkehrsunfälle mit fehlerhalben menschlichen Verhalten zusammen hängen.

Die Arbeit beschreibt verschiedene Ansätze zur Risikoanalyse der mit kraftrad-dominierten Verkehr, die auf der Analyse von Unfallabläufen und dem Unterschied zwischen normallen und kritischen Situationen basieren. Ausgehend von dem Gedanken der Konflikttechnik für automobile Verkehrsflüsse werden die Konzepte “Konfliktzonen” und “Konflikt-Zeitabschnitte” weiter entwickelt, um die Gefahren für den Fahrer bei Linksabbiegungs-Bewegungen an Kreuzungen zu ermitteln. Beide Konzepte sind geeignet zur Charakterisierung der Eigenschaften von nicht-spurgebundenen Bewegung von Krafträdern.

Nach der allgemeinen Situationsbeschreibung konzentriert sich die Arbeit auf die Hauptursache der Verkehrunsicherheit in Vietnam: nicht den Verkehrsregeln entsprechendes Fahrerverhalten. Mit Hilfe von DRAM sollen drei Fragen untersucht werden: (i) Warum verletzen Fahrer Verkehrsregeln? (ii) Wie oft tun sie das? und (iii) Welche Konsequenzen folgen aus solchen Verhalten? Die Kette von Verkehrsregeln entsprechendes Fahrerverhalten wird aus der “Grundhaltung zur Verkehrsregeln” und der “fallbezogenen Akzeptanz der Verkehrsregeln“ aufgebaut. Eine Fallstudie von zwei Richtlinien in Vietnam wurde zur Veranschaulichung der Methodik diskutiert. Die Ergebnisse werden zur Bewertung und Verifikation von Verkehrssicherheitsmaßnahmen empfohlen.

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List of Abbreviations

DRAM	Darmstadt Risk Analysis Methodology
DRAT	Darmstadt Risk Analysis Tool
FMEA	Failure Mode Effect Analysis
ISD	Intersection Sight Distances
JBIC	Japan Bank for International Cooperation
JICA	Japan International Cooperation Agency
MD traffic flow	Motorcycle-dominated traffic flow
MOPS	Ministry of Public Security, Vietnam
MoT	Ministry of Transport, Vietnam
NTSC	National Traffic Safety Commitee
ODV	Opposite direction vehicle
PCU	Passenger Car Unit
PRT	Perception – Reaction Time
TPB	Theory of Planned Behaviour
TRA	Theory of Reasoned Action
TTC	Time to collision
TTI	Time to Intersection

1. Introduction

1.1.Background

It is well known that traffic accidents are of high importance to the public health spectrum in the world. Moreover, in developing countries such as Vietnam, the mortality rate from road traffic accidents is rather high in comparison with other countries in the whole area of South East Asia. Not only the majority of the people killed and seriously injured significantly affect the quality of life of the citizens, but it has also bad influence on the economic and social development in the country.

From 1990s, thanks to its “Doi Moi” (renovation) policies, Vietnamese government gained significant achievements in economy: GDP doubled for past 10 years. In the economic structure, contribution portion of industry and services are increasing. In strategy on the national economic development for the period from 2001 to 2010, the estimated growth rate will be able to remain continuously at a rate of 7.5% per year. Furthermore, social and economical living standards have very high progress. Demand for people and goods transport has the significant increase in both quantity and quality.

At the same time, Vietnam has experienced a disturbingly high increase in traffic accidents, both in number and damage rate. Statistics data reveals that number of people died and injured by traffic accident is much larger than any of the most serious diseases.

The very high occurrence of traffic accidents in Vietnam has become one of the country’s major social issues. The past has seen many researches and applications in the field of traffic safety. This results in the application of traffic safety measures that alleviated problems in such areas of traffic infrastructure, (in-)vehicle, traffic environment, traffic management and operation, and their impacts to "traffic safety problems".

However, the importance of human factors in transport policy discussion is growing. There is a realisation that policy options that appear beneficial in principle have to be checked for the feasibility of implementation. Understanding and describing driver behaviour becomes a challenge when one tries to identify driver errors in determining accident/conflict causal factors and countermeasures.

Since 1980s, risk analysis and driver behaviour becomes the modern and advanced trend in road traffic safety research. Risk analysis in general is a systematic, model orientated and modular approach to analyse safety issues and impacts on roads. It is well known from safety analysis of nuclear and chemistry plants. Developing on the background of conflict technique, it is possible for risk-based methodologies to overcome the lack of data when accidents are such rare events. Briefly speaking, risk analysis aims at comprehensively analysing the chain of causes and effects, in order to answer three questions: (i) how (how often) do people behave in specific situations? (ii) Why do they behave that way? (iii) What are the results (how dangerous are) of such different behaviours?

In recent years, having understood the serious effects of traffic accidents to the whole society, scientific researchers, traffic engineers and policy makers in Vietnam developed many projects and researches in the field of traffic safety. Human factor is also considered as the central element in the whole system. The final target is to organize a traffic environment, which is convenient and safe for road users.

1.2. Problem Statements

There is a distinguishing characteristic between traffic flow in Vietnam (and in many other Asian countries) and those in developed countries: two-wheeled vehicles (so-called motorcycles) consist a high percentage in the road traffic system.

Motorcycle dominated (MD) traffic flow is very much different from car traffic flow due to motorcycles´ distinguishing characteristics (which can be summarized as flexibility and manoeuvrability). Therefore, there appears the need to evaluate and verify such findings and measurements concluded from car traffic flow before applying in the MD traffic flow.

Statistical data prove that in those countries with MD traffic flow, most of road traffic accidents are caused by motorcycles. Motorcycles are also classified as vulnerable users (along with pedestrian and bicycles) because there are not adequate safety facilities for motorcyclists in comparison with car drivers.

The situation of road traffic accidents in Vietnam is nowadays in an emergency situation. Since 1992, road traffic accidents have rapidly increased until 2002, the peak year of traffic accidents. The number of accidents, fatalities and injuries has reached 27,134, 12,800 and 30,999, respectively. During this ten-year period, the number of fatalities in particular has increased by 2.1 times. From 2003, the number of accidents and injuries has been dramatically decreased, but the number of fatalities is still in critical level with more than 11,000 persons per year. In comparison with those countries in the area, Vietnam has almost the worst position in traffic accidents (JBIC, Project SAPFOR for Traffic Safety Improvement in Vietnam, 2008). It is particularly needed to pay attention that the number of fatalities may be not completely reported. There is also no regulation in Vietnam in the case that there are some days from the accidents to the patient death to be calculated as death by traffic accidents.

There are several reasons leading to traffic accidents. Inadequate infrastructure network is now considered as one of the biggest reason for traffic accidents. However, the problem is to find out whether it is worth investing in constructing and/or upgrading roads network. Sometimes, in newly-built roads, as drivers can reach the very high speed, traffic accidents may have much more serious results. Almost other related elements in the whole road traffic system (such as public transport, vehicle quality, traffic management and operation, etc.) are facing with such inappropriate problems with highly increasing mobility demand. Current unbalancing situation of traffic system is displayed by that status of traffic congestion and serious accidents. At the moment, road users in Vietnam are also not qualified enough to adapt with the current situation of modern and advanced developments in the road traffic system.

Traditional methodologies mostly focus on single effects of causing parameters to traffic unsafe situations. For example, in most of the statistical reports on traffic safety in Vietnam, it is written “Speeding behaviour has the highest percentage in all causes of traffic conflicts and/or accidents”. However, there is the fact that traffic accidents in most cases are not the result of just a single reason. If a driver rides at a very high speed, but he concentrates very much in his task of driving, and if there is no unexpected obstacle (a crossing vehicle, road sliding surface, etc.) then the probability of a traffic conflict or accident is rather low (may equal to zero). Analysing impacts of different parameters to traffic safety as well as their interacting effects can be clarified just by the modular structural approach of risk-based methodologies.

In order to be able to control traffic accidents, it is required to understand driver behaviours, their causes and consequences (effects) to road traffic safety. Many measurements can be applied to fulfil the objectives. In Vietnam, up to now, there is an urgent need of building consensus on priorities for regulation and standardisation process.

The cost of safety measures is also the very important thing to take into consideration. Many traffic safety measurements, regulations and policies have been developed and implemented in Vietnam in recent years, but the efficiency is not appropriate (high expenditures but the unsafe situation has not been much improved). The general situation in Vietnam traffic flow (especially in urban areas with condensed population) is unordered traffic, with the high percentage of traffic regulation violators. Awareness and attitudes towards legislation of road users are at a poor level. Many campaigns of legislation enforcement and educations have been released, however, such kind of campaigns are costly (in all aspects of man powers, time and expenditure). Analysing the main reasons for such kind of violating behaviours, their likelihood and their dangerous levels are responsibility of risk analysis.

In conclusion, current problems need to be solved are the fact that (i) motorcycle dominated traffic flow has many distinguishing characteristics from car traffic flow; (ii) the current situation of road traffic unsafety in developing countries with MD traffic flow, in particular in Vietnam, is the emergency problem of the whole society; (iii) simultaneous effects of different elements in traffic system need to be analysed by a modular structure of risk-based methodologies; and (iv) driver behaviours of violating traffic regulations (their causes and effects to traffic safety) has the first priority to conduct research as they lead to inefficiency of traffic operation and management.

1.3. Goals and Objectives

The research aims at establishing a modular structure to conduct risk analysis of driver behaviours relating to violating traffic regulations at intersections in motorcycle dominated traffic flow.

The final goal will be finding out answers to the question why and how often drivers (in mixed traffic flow) violate traffic regulations at intersections. These questions are organized systematically into discrete steps that involve identifying different behaviours of violating traffic regulations, determining the likelihood of their occurrence, and identifying their consequences.

In order to reach such goals, the following objectives should be fulfilled:

- Doing research on models of risk analysis and road traffic safety.
- Doing research on the current situation of traffic safety and accidents with emphasis in Vietnam motorcycle dominated traffic flow.
- Analysing to understand driver behaviours of violating traffic regulations at intersections in urban areas.
- Constructing concepts and methodology of risk analysis and driver behaviours in motorcycele-dominated traffic flow.
- Establishing a modular structure of cause-and-effect chain to conduct risk analysis of driver behaviours in a specific scenario.

1.4. Organization of the Study

The study is structured into seven Chapters:

After the first chapter of Introduction, chapter 2 provides general overview on the literature review, dealing with human behaviour and risk analysis (focusing on introducing both qualifying and quantifying models). Some researches on motorcycle traffic flow and driver behaviour at intersections are also mentioned in order to provide guidelines for the whole research.

Chapter 3 describes methodologies using in the research. After providing concepts and terminology using in the whole study, there is a brief comparison between risk analysis methodologies and traditional diagnosis methodologies. From that point, a methodology of risk analysis, named as DRAM, is discussed briefly. The progress of constructing cause-and-effect chain of driver behaviour as well as working with probability distribution variables/data (so-called risk values) is consequent topics in this chapter.

Chapter 4 aims at understanding left-turning movements at intersection in the motorcycle traffic flow. The chapter focuses firstly on the accident progress, which deals with the gap between normal driving and reaction to critical situations. Description on the scenario of left-turning movement as well as different approaches to conduct risk analysis at intersections in motorcycle dominated traffic flow in big cities in Vietnam is provided. There are arguments on two concepts of “conflict zones” and “conflict time segments” which can be further developed to determine the hazard that drivers have to face with in their left-turning movement at intersections in motorcycle-dominated traffic flow. Both concepts are developed from the physolophy of Conflict Technique in car traffic flow, with the modification in order to be relevant in case of the distinguishing characteristics of non-lane based movement of motorcycles.

Chapter 5 deals the driver behaviour of violating road traffic regulations. The chain of “Driver behaviours of violating traffic regulations” based on “General attitudes towards road traffic regulations” and “Specific-scenario acceptance of rules” is then constructed. This chapter would like to analyse the influence of external parameters on the behaviour of violating traffic regulations. Enforcement and its effects on driver attitudes towards driver behaviour is the very first topic. Congestion and “fear of getting stuck” are mentioned the next. The other interested parameters are those of traffic signals, infrastructure and rules of priority at intersections.

Briefly speaking, in order to construct the cause-and-effect chain, the research focuses on the central idea that driver behaviour of violating traffic regulations are results from “general attitude towards legislation” (long-term) and “specific-scenario acceptance of rules” (short-term). The final target of chapter 5 is explaining all (external) influencing parameters as well as (internal) driver cognition-motivation-action (behaviour) chain.

In chapter 6, the constructed cause-and-effect chain of violating traffic regulations will be described with all parameters and their developments. Discussion on parameter classifications/values and their probability distribution will be provided. Data requirements and data availability as well as suggested methodology of collecting and processing data will be the next theme. Final topic will be case study from field surveys in Vietnam.

Conclusions and some recommendations for the future work can be seen in the last chapter.

2. State of the Art

2.0. Introduction

This chapter provides general overview on the literature review, dealing with human behaviour and risk analysis (focusing on introducing both qualifying and quantifying approaches). Some researches on motorcycle traffic flow and driver behaviour at intersections are also mentioned in order to provide guidelines for the whole research.

2.1. Human Behaviour and Risk Analysis

2.1.1. General Overview on Methods to Analyse the Past Events

Most of the recent investigations were based on statistical analysis of accidents. They focus on subject-specific parts of the complex system road traffic. Knoflacher et. al. [1983], Baumann [1984] and Durth, Bald [1988] already mentioned that the complexity often leads to practical and methodical problems.

On the one hand, practical problems raise due to lack of data because accidents are very rare events. On the other hand, accident data is often of poor quality as the police officers have to produce them in addition to other tasks. The poor quality of data may be solved by special training programs but in reality there is still no practicable solution.

The main methodical problem is the difficulty to make safe statements because of the complex system road traffic with many degrees of freedom of many non-linear correlations and lack of knowledge on variable correlations.

Statistical Regression and Correlation

Regression analysis tries to find the correlations among variables ("input", "output") by analysing the dispersion (correlation) and approximately by finding formulas (regression) [e.g. Durth, Bald 1988].

Many research groups worked on the task of regression and correlation analysis on road traffic systems during the 1980s. They used this methodology to work on traffic safety and find the correlations between the road environment (road design and infrastructure) and accident causes (e.g., Neuman, Glennon and others [1983], Palavisini [1983]).

In general, correlation analysis is a statistical technique that evaluates the relationship between/among two or more variables; i.e., how closely they match each other in terms of their individual mathematical change. The question is whether the second variable (Y) also moves or changes in such a similar or complementary direction if one variable (X) moves or changes in a certain direction,.

The partial correlation considers not only of the connections between one input variable and the output variable but between different input variables [Durth, Bald 1988].

The goal of regression analysis in the stricter sense is to determine the best coefficients for a function to fit the real/practical correlations. In linear regression, the function is a linear (straight-line) equation. If there is more than one response variable, it is called multivariate regression.

A special case of this analysing method is the analysis of variance (ANNOVA). It is used if the correlations can not be described by a formula. The influences of the system are grouped in several independent nominal variables with assumed different effects to the system. The analysis of variance investigates whether the differences between the influence of the different variables is bigger than the variance of the influence of each variable itself. The analysis can confirm the purpose of the subdivision of the variables.

The research does not lead to well founded results because of the non-linearity of the whole system. There is a need for another methodology which considers the real cause-and-effect-chain between the variables and the accident. The driver behaviour, the design of the vehicles, infrastructure, etc. should be included in analysing the chain of causes and effects.

Conflict Analysing Techniques

A big problem of statistical analysis of accidents is the lack of data. Accident events is very rare. To enlarge the amount of data the analysis of conflict situations started in the 1960s. In Germany, Erke et. al. [1978] and Zimolong [1982] gave a first overview. Perkins and Harris [1968] started using conflict analysing techniques consequently [PIARC, 2003]. In 1985, Erke et. al. formulated a handbook for such topic.

The assumption for using that method is that situations with many conflicts have a higher probability than accidents. Trained observers regard traffic situations, classify with specific (target) criteria and count “conflicts”. Conflicts are actions of road users, which may lead to problems (late braking, cutting of bends, …). Several measurements have been proposed to characterize traffic conflicts in detail. For example time to collision (TTC), deceleration rate (DR), encroachment time (ET), post encroachment time (PET), etc. are used to determine the severity of a traffic conflict objectively [PIARC, 2003].

This technique enlarges the amount of data but the used parameters resulting from the manoeuvres are not necessarily direct indicators for risk of accident and reduction of severity.

Those methodologies are constructed at the aim at well understanding events which already happened. Risk analysis methodologies have the central idea of conducting diagnosis and forecasting for the future events.

Risk-based methodologies

In the 1980s Mahalel [1983] proposed the methodology of analysing the whole system “road traffic” to describe the correlation between reference values and accidents. Most of these correlations are non-linear. Therefore Mahalel demands on considering complex correlations: “The task of the researcher involved in risk analysis may be seen as the search for a black box in which input is exposure and in which output is accidents and their probabilities”.

Risk analysis in general is a systematic, model orientated and modular approach to analyse safety issues and impacts on road traffic system. Different methods are available in the domain of (traffic) safety to model a system and to obtain risk values. Among them are such techniques as hazard and operability analysis (HaZOP) (CCPS 2008), event and fault trees, elicitation of expert judgement, human reliability analysis (e.g., Bieder et al. 1998, Macwan and Mosleh 1994, Swain and Guttman 1983), simulation, FMEA (Failure Mode Effect Analysis). In order to estimate risk values, there may be such techniques as quantitative, semi-quantitative, qualitative techniques, or a combination.

Based on FMEA methodology, Darmstadt Risk Analysis Methodology (DRAM) with its tool Darmstadt Risk Analysis Tool (DRAT) have been constructed 15 years ago. Details on the methodology will be explained in the next chapter. The methodology is also further developed in order to apply into solving traffic safety problems in motorcycle-dominated traffic flow.

Durth et al. (1994) distinguishes qualitative and quantitative models based on criteria of diagnosis correctness and application easiness.

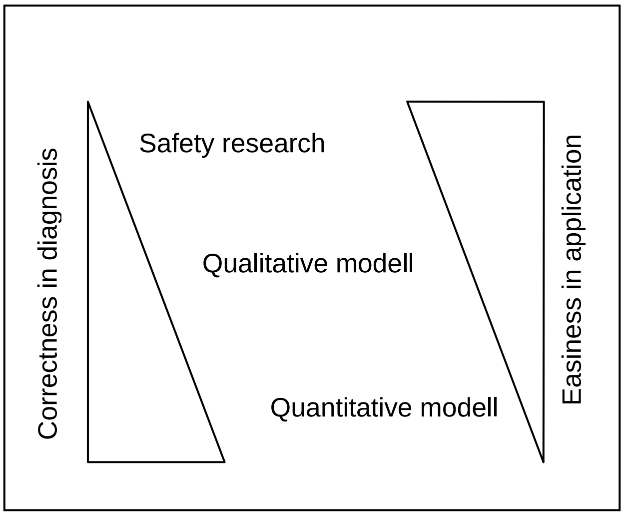


Figure 1. Qualitative and quantitative models

The following parts discuss on the state of art related to different approaches of risk analysis.

2.1.2. Qualitative Models

The importance of human factors in transport policy discussion is growing. There is a realisation that policy options that appear beneficial in principle have to be checked for implementation feasibility.

O. Carsten (2001) argues that the problem is not unsafe drivers or unsafe road users, but the unsafe complex system. If we identify human error as the major component in traffic accidents and then implicitly blame the driver, we are in danger of blaming the victim of a poor traffic system. We know that the individual accident is an unpredictable event, but we also know that accidents as an aggregate are systematically over-represented at certain locations and in certain circumstances (at junctions, urban junctions, at night, ...).

Understanding and describing driver behaviour become a challenge when one tries to identify driver errors in determining crash causal factors and countermeasures. Access to data related to crashes is usually based on crash statistics and restricted to general characteristics of the involved drivers, such as gender, age, type of vehicle driven (Kim et al. 1999). Very rarely are the actions and manoeuvres that led to a crash addressed. The investigation of pre-crash actions and manoeuvres usually relies on either focus groups involving officers who respond to crashes or drivers involved in crashes (Wierville et al. 2002, Larsen and Kines 2002). They therefore rely on subjective sources. Another approach adopted for understanding why crashes occur consists of linking general characteristics with known issues of specific group, such as age linked with perceptive and cognitive deficits (Hakamies-Blomqvist 1996).

Wierville et al. (2002) proposes the following definition of driver error based on Reason's seminal work: "… the failure to achieve a sequence of mental or physical activities through a thought-out plan-of-action. For example, within the driving environment, an error is committed when a driver does not successfully stop for a red traffic light because he or she depresses the accelerator instead of the brake pedal".

Wierville et al. 2002 classified driver errors into groups of inadequate knowledge, training, skill (lack of understanding or misunderstanding of traffic laws, vehicle kinematics, physics, driving techniques, driver capabilities, limitations), impairment (fatigue and drowsiness, Use of illegal drugs, alcohol , health related to illness , lack of use of, incorrect use of medication, disability, uncorrected disability), wilful inappropriate behaviour (purposeful violation of traffic laws, regulation, aggressive driving, use of vehicle for improper purposes), infrastructures/environment problems (traffic control device related; roadway related: alignment, sight distance, delineation; weather, visibility related). The driving performance problem can be raised up as: failure to perceive or perceive correctly; incorrect assumption; incorrect cognitive processing; failure to act and incorrect action.

TRB 2002, [118] also mentioned the definition of human risk factors as those factors attributing to the people in the system and "include both factors that cannot be directly changed (e.g., age, gender, personality, information processing, cognitive ability) and those that can be changed (e.g., experience levels; training, education, and qualifications; substance use; compliance; peer pressure)". Relating to this approach, there are many states of art conducting in-depth analysis of a limited amounts of real accidents in order to have good understanding on accidents and their causes. Then give out qualitative assessments of driver behaviour. Many researches classify drivers based on their age, genders, etc. and evaluate risk levels of each group of road users. The following part tries to summarize some common models of risk analysis in this approach.

One technical discipline that provides methods and tools for modelling and analysing human contribution to risk is known as human reliability analysis (HRA) (TRB 2008, Special report 293). Objectives of HRA are (i) to identify human failure events in the context of risk scenarios; (ii) estimate human error probabilities; and (iii) provide a causal explanation for the errors to support the development of preventive or mitigating measures.

The application of decision-making models to driving behaviour has recently included the application of naturalistic models to drunk driving and speeding behaviour (Harrison, 1998, 1999b). Naturalistic models of decision-making describe the processes underlying decision-making by experienced people in dynamic, complex environments such as those experienced when driving. They are well suited to application in the more-general area of hazard perception and are discussed here as a framework for better understanding hazard perception as a cognitive process with behavioural outcomes.

The recognition-primed decision making model (RPD) of Klein (1989, 1993) was used by Harrison (1998, 1999b) in relation to speeding and drink-driving behaviours. It seeks to provide an underlying cognitive structure for decision-making in contexts such as driving, where behaviours must be generated in response to complex, dynamic sensory inputs when the decision-maker is time-pressured and operating under competing motivations. The model is summarised as follows.

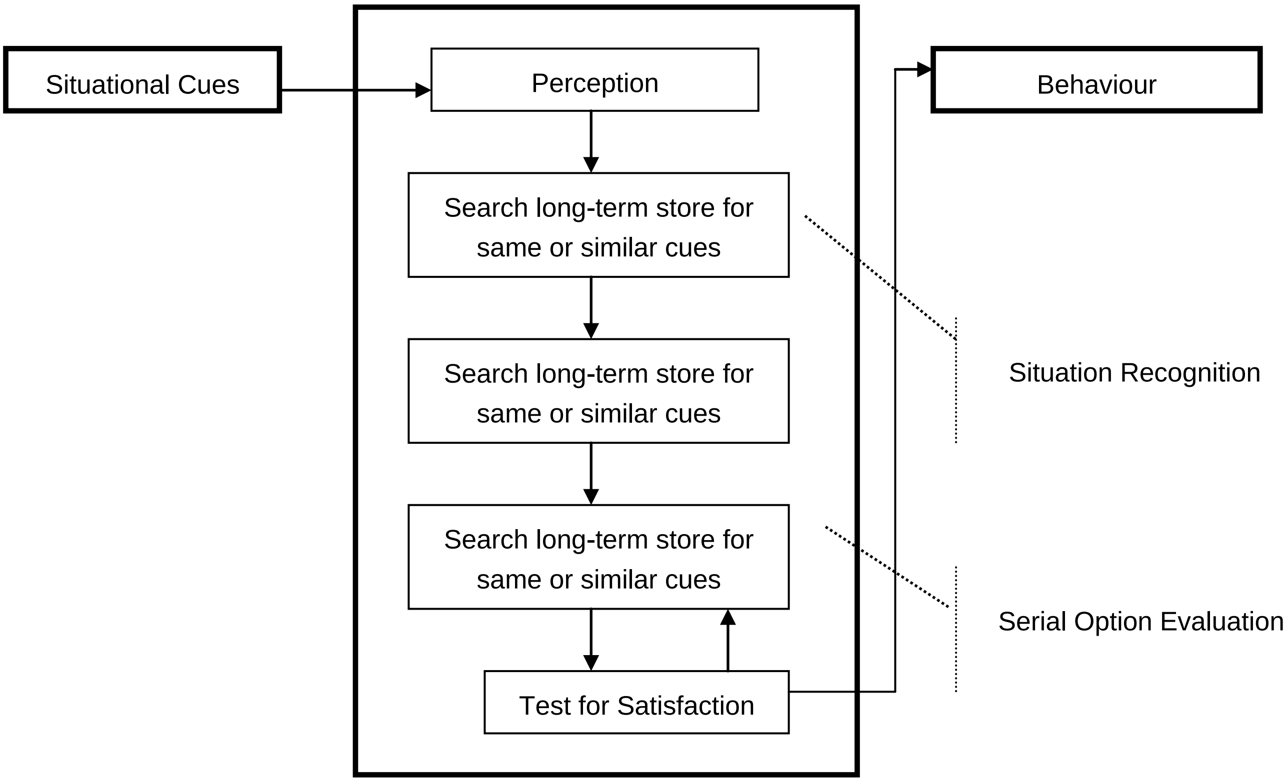


Figure 2. Recognition-primed decision making model

The RPD model emphasise the role of experience in decision-making, recognising that experience in a particular behavioural context provides the basis for the cognition of common situations and the generation of behaviours or choices based on previous experience. The RPD model therefore provides a mechanism that allows faster, more efficient (and potentially more reliable) decision-making in complex situations such as those faced by drivers. Where situations and cues in the driving environment can be matched to commonly-experienced situations, behaviours associated with them in the past can be used in the present to reduce the need for a conscious decision-making process. The potential value of this mechanism for hazard-related behaviours is clear.

Klein suggests that there are a number of stages in the behavioural decision making process. The first stage (Situation Recognition) involves the classification of the context or situation as either novel or familiar. This most likely involves the mapping of current perceptions onto internal representations of previously experienced situations until a match is found. Where a match is found, potential behavioural responses depend on what behaviours were successfully used in that situation before.

Thus the send stage (Serial Option Evaluation) of the RPD model involves the generation of an “action queue” of potential behaviours ordered in terms of their “typicality” as responses to similar situations in the past, and then the evaluation of them one at a time until one is judged to be a satisfactory behaviour in the current context or situation. Evaluation of the potential behaviours is based on a mental simulation of the likely consequences of the behaviour based on prior experience and other expectations, and under the RPD model the cognitive computations required to evaluate these consequences are only required for as long as it takes to find a satisfactory (not necessarily optimal) behavioural response.

Thus the driver might be viewed as responding to the changing situation in the driving environment by a constant mapping of current perceptual cues onto stored information about prior driving experience, and favouring behavioural responses that match behaviours commonly associated with those cues in the past.

Qualitative parameters are normally stated in the verbal ways at which point, DRAM methodology shows one of its advantages which allows to describe and coordinate parameters and their relationship in verbal variables

There are some qualitative models to describe driver behaviour including (applying in order to proceed predicting and ultimately changing the behaviour that leads to crashes): HBM (the health belief model), TRA (Theory of reasoned action), TPB (Theory of planned behaviour). These theories draw mainly on the disciplines of sociology and psychology; in particular, social psychology.

The HBM was developed in the 1950s, with the central idea of concerning over people's unwillingness to take up disease prevention initiatives. Essentially it consists of four aspects such as:

- Perceived susceptibility: the extent to which someone feels that they are likely to contract the condition;
- Perceived severity: how severe the consequences would be if they did contract the condition;
- Perceived benefits: whether the individual feels that taking preventative action would indeed reduce the risk of contracting the condition; and
- Perceived barriers: the estimated negative effects of taking the health action (costs, discomfort, time, pain, difficulty, etc.)

(Janz & Becker, 1984)

HBM theory was applied in some works, for instance, Rutter et al., 1995 with 2051 postal questionnaires to assess beliefs relating to behaviour and crashes. Then a second questionnaire was posted 12 months later to examine the self reported behaviours, crashes, and other measures such as exposure that had occurred during that 12 month period. They found that the best predictor of crashes was the self-reported behaviour of breaking laws and rules (i.e., speeding, breaking traffic law, breaking the highway code, riding too close). Once demographic factors such as age, sex, education, experience and training were accounted for, four significant predictive factors of law breaking behaviours are such as feeling safe, having fun, good bike performance and safety, and risk of crash (Rutter et al., 1995).

TRA (Theory of reasoned action) (Ajzen & Fishbein, 1980; Fishbein, 1980; Fishbein & Ajzen, 1975) postulates that intentions are the best predictor of behaviour. Intentions are formulated via a reasoned process whereby the individual considers the consequences of their actions, either implicitly or explicitly. The behaviour reasoned to be the most likely to achieve the most positive outcome for the individual is then enacted.

The TRA Hypothesises two determinants of intentions: attitudes and subjective norms (see Figure 4) which are underpinned by attitudinal and normative beliefs about the consequences of the behaviour. The strength of a person's attitude (i.e., their positive or negative evaluation of performing the behaviour) combined with the weight of social pressure they perceive they are under to perform the behaviour (subjective norm) will influence the strength of their intention to perform the behaviour and the sub-sequent action.

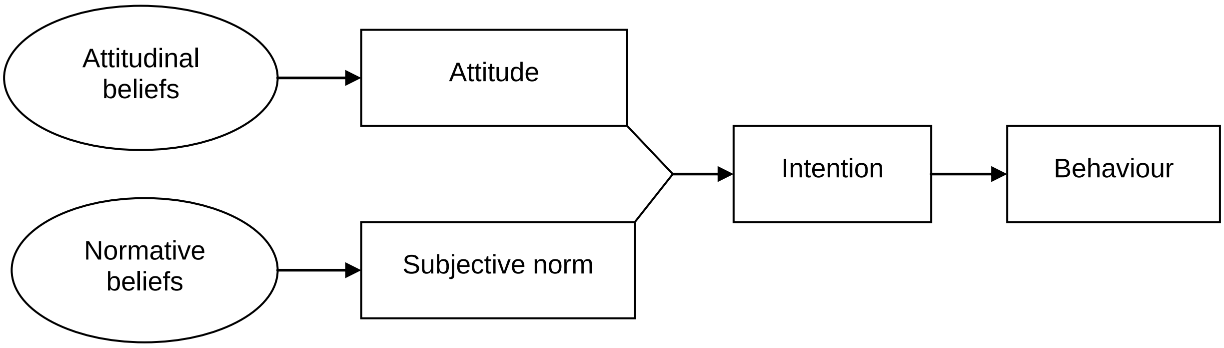


Figure 3. The theory of reasoned action

(Source: Figure adapted from Fishbein and Ajzen (1975))

Some other researchers also study driver behaviours using TRA models such as Budd, North and Spencer (1984), Stasson and Fishbein (1990), Rutter et al. (1992), Trafimow and Fishbein (1994), Beck (1981) and Carbonell Vaya et al.

The theory of planned behaviour (TPB) has been used as the basis of a number of road safety studies in an attempt to understand issues such as speeding and other traffic violations (Newnam, Watson & Murrary, 2004; Parker, Manstead & Stradling, 1995; Parker, Manstead, Stradling, Reason & Baxter, 1992; Parker, Stradling & Manstead, 1996), bicycle helmet use (Lajunen & Räsänen, 2004; Quine et al., 1998; Quine, Rutter & Arnold, 2001), pedestrian behaviour (Evans & Norman, 1998), transport modal choice (Bamberg, Ajzen & Schmidt, 2003; Forward, 2004), drink driving (Gordon & Hunt, 1998; Sheehan et al., 1996) and seatbelt use (Gordon & Hunt, 1998).

Aen (1985; 1988; 1991) formulate the TPB to take account of behaviours which are subject to factors over and above an individual´s motivation to perform the behaviour; that is, factors which may be outside the volitional control of the individual (see Fig. Duoi). Essentially, like the TRA, the TPB assumes that a person´s salient beliefs underpin behaviour. With the TRA, beliefs influence the attitudes and subjective norms, which in turn are determinants of intention, which then leads to the resuliting behaviour. The TPB introduces a third determinant, perceived behavioural control (PBC). PBC is also underpinned by beliefs and is included to take account of factors which are perceived to be not completely under an individual´s control.

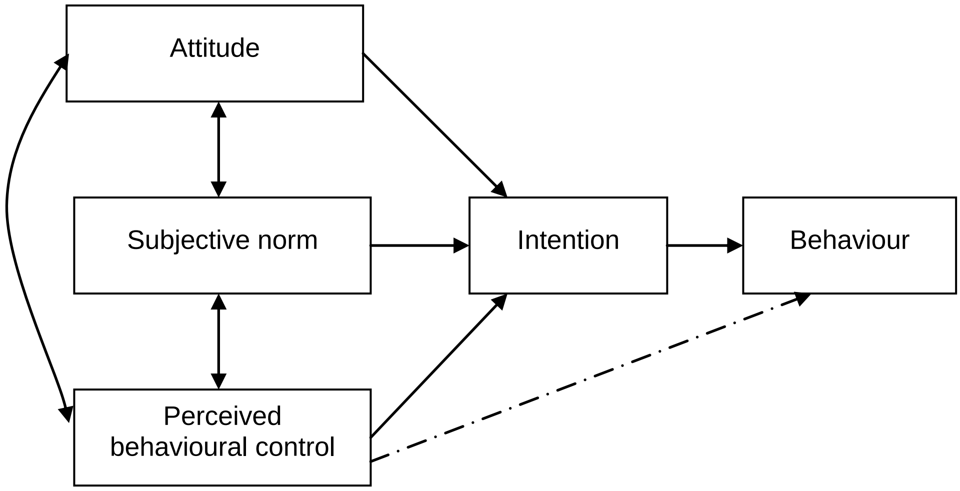


Figure 4. The theory of planned behaviour

Ajzen (1991) argues that the predictive value of the determinants of intention and behaviour will vary across situations and individuals. For example, for some situations, attitudes may be a more important predictor than normative influences. In others, or for other individuals in the same situation, perceived behavioural control may be the best predictor. In short, the theory Hypothesises that these three factors (attitude, subjective norm, perceived behavioural control) influenced the behaviour of most people, although the exact amount of influence exerted by any one of these factors varies according to the particular person and the particular situation. In most people, however, the strength of intention in conjunction with estimates of perceived behavioural control (PBC) will determine the behavioural outcome. Where a person has sufficient actual control over the behaviour in question, intentions alone will predict this behaviour.

Applying Theory of planned behaviour (TPB), Bary Watson et al. reveal six types of behaviours which were commonly believed to influence the safety (or risk levels) of motorcycle riding.

Extending the TPB. The TPB model allows for additional predictive constructs to be included in the model provided they can be argued as causal to intention or behaviour and independent of the theory's existing constructs (attitude, subjective norm, and PBC) (Ajzen, 1991). In an attempt to develop a better predictive model for a given behaviour, many recent studies have extended the TPB to incorporate other independent variables. This is at least in part, due to the relative weakness of the subjective norm to predict intentions or behaviour found in many studies Ajzen, 1991; Armitage & Conner, 2001a; Farley, Lehmann & Ryan, 1981; Johnston, White & Norman, 2004; Terry & Hogg, 1996; Terry, Hogg & White, 1999). The poor performance of subjective norm, according to Ajzen, shows the importance of "personal considerations" over "perceived social pressure" (Ajzen, 1991). However, Terry and Hogg (1996) argue that social influences are important and have not been adequately captured by the traditional TPB realisation of this construction.

The weakness of the subjective norm may also be partially explained by findings which show that, for the majority of people, their attitudes are most likely to predict their intentions. Some people's intentions are influenced primarily by the social component of the model which is represented by the subjective norm (Trafimow & Finlay, 1996). Whilst this finding suggests that people are predisposed to being more attitudinally or normatively controlled, further studies have found that specific behaviours may also be more usually attitudinally or normatively controlled, regardless of the individual's disposition, and that attitudinally controlled intentions are more likely to be carried out than normatively controlled intentions (Sheeran, Norman & Orbell, 1999; Trafimow & Finlay, 2001). These findings were supported by Johnston, White, and Norman (2004) who further speculated that strengthening the subjective norm with a social identity construct may improve the norms-intention relationship for all people, regardless of their attitudinal or normative disposition.

In summary, Barry Watson et al. conclude that there are empirical evidence of main factors relating to motorcycle crashes, providing clear evidence that the vast majority of motorcycle crashes are the result of human error.

Whilst external factors, such as other vehicles and poor road surfaces, are acknowledged as serious problems that require separate attention and intervention, the fact remains that a more defensive and attentive riding style could reduce the frequency and seriousness of these types of crashes.

The authors also raised up three research questions.

- What behaviours do riders identify as being directly related to safe and risky riding?
- What are the psychological factors that influence rider intentions and behaviour?
- What is the impact of other riders on intentions and behaviour in a group riding situation?

Such questions reflects exactly three main research question in the approach of risk analysis. Theory of Planned Behaviour will be applied to give the first clue in the research when taking into consideration driver behaviours of violating road traffic regulations.

2.1.3. Quantifying Models

There are also many researches aiming at quantified elements related to driver behaviours in order to conduct modelling and simulation with computer supports. This approach focuses on distinguishing driver behaviours between different groups of drivers. The common criteria to separate driver groups are age, experience and gender.

Factors related to driver behaviours which are taken into consideration are those of hazard perception skill, sensation seeking and risk behaviour (Jonah, 1997), personality and social factors (Jung & Huguenin, 1992), drink driving (Deery & Love, 1996), automation, and workload management.

Quantified elements applied in the fields are such as perception – reaction (decision) time, acceleration/deceleration, headway, gap acceptance,… Then some models calculating risk levels in traffic flow have been developed such as: models of lane-keeping, car-following, gap acceptance…

Karin F. M. Aronsson (2006) reviewed researches on speed and factors influencing drivers´ speed choice. Karin F.M.Aronson summaried models (mathematical) of operating speed for urban conditions.

Numerous studies measured speed on rural roads and in free flow traffic conditions. The free vehicles are in many studies defined as having a minimum headway of 5s to the vehicle ahead.

A number of methods for speed modelling were developed and used. The collected empirical data built a foundation for analysis of speed and flow relationships and the estimation of passenger car equivalences (PCU/PCE) for all vehicle types.

There are some speed models on urban roadway in the U.S which is summarised by Wang, Dixon, Li and Hunter (2006) and are listed in the following table (see review of Karin F.M.Aronsson (2006)). The models are based on operating speed, which is defined as the speed at which drivers are observed operating their vehicles under free-flow conditions as defined in the AASTO Green Book 2001 (Fitzpatrick, Carlson, Brewer et al. 2003). The 85th percentile of the distribution of observed speeds is frequently used as a measure of the operating speed in the U.S. for design purposes. The majority of the speed models are empirical and based on spot speed measured at horizontal curves. Local roadway characteristics serve as the independent variables.

Wang et al. (2006) developed operating speed models for low speed urban street segments based on roadway alignment, cross-section characteristics, roadside features, and adjacent land uses. The model was computed from second-by-second in-vehicle GPS data from two hundred randomly selected vehicles in Atlanta, Georgia. Regression analysis was used to select the model variables. Conclusions of the study were firstly that the number of lanes per direction of travel has the most significant influence on drivers' speed on urban streets. Variables such as kerbside parking, pavement presence, roadside object density and offset, T-intersection and driveway density, raised kerb, and adjacent land use were also significant.

Karlgren (2005) developed a speed model for nine streets in Gothenburg, Sweden, by use of multiple regression analysis. Observed mean speed for street segments was formulated as a function of the parameters average carriageway width, number of passing vehicles per hour in the current direction, number of parked vehicles per 100 metres, number of pedestrians and cyclists crossing the street per hour and 100 metres, and average width from pavement to nearest building or tree. A simplified model was developed and presented in an equation of segment speed (as the output) and vehicle flow per hour, average carriageway width and number of crossing pedestrians and cyclists per hour (as input values).

Godthelp, Milgram and Blaauw (1984) proposed that drivers control their lane keeping task using time-to-line-crossing (TTL) as a control variable. This means that, for every moment on the road, a driver knows (or he/she has an impression of) how much time it takes before the vehicle crosses the edge or center line and drives off the road.

Another continuous control task in driving is car following, for which a time-base control variable can be defined as well. It was first proposed by Lee (1976) who described a model in which drivers, when following the car ahead, control braking by means of a time-related measure, or time-to-contact. In this, driver adjust speed by accelerator and brake application to control the time available to the moment of collision with the rear-end of the vehicle ahead.

Besides, there are also other researches conducting on other quantified values such as PRT (perception and reaction time), acceleration rate, gap acceptance, etc.

In conclusion, there are three big groups of quantified values which are often deal with time, distance and vehicle dynamics (speeds, acceleration rates, etc.). However, this study would like to work with driver behaviour as the central point of the whole traffic system. The major target will be constructing fundamental concepts and framework to deal with the new methodology of risk analysis. Therefore, the study just applies the physolophy of TPB as the fundamental for analysing driver behaviours of violating traffic regulations in MD traffic flow. Other quantified values can be applied in the next step of working with the modelling and simulating driver behaviours.

2.2. Motorcycle-dominated Traffic Flow

2.2.1. Movement Characteristics of Motorcycles

So far, researches in the field of transportation and traffic engineering in general and road traffic safety in particular are normally proceeded in the knowledge basement of car flow traffic. However, in Vietnam and most of developing countries in the area of South East Asia, motorcycles are the dominating transportation mode, causing Asian cities significantly different from other regions. In Hanoi and Hochiminh city, Vietnam, for example, two-wheelers accounted for more than 80% of the total transportation means. Motorcycle ownership and usage in Asia are influenced by several agents different from those of western countries. These include the weather, climate, the economic and infrastructure development, population density and social/cultural environment. While providing affordable mobility to millions of people, these vehicles significantly contribute to transportation and traffic system.

In Asian countries, the term “motorcycle dependent city” has been used to indicate a city with low income, high density land use and motorcycles’ domination in traffic flow. Chu (2001) gived out a list of distinctively advantageous characteristics that validate the popular usage of motorcycles in this region/Asia. Among them, he focuses on the size, flexibility and manoeuvrability of the motorcycle, economy in fuel consumption and price. Besides, there are such disadvantages in comparison with cars as being easily effected by bad weather, requiring balancing during the travel, inability to carry cumbersome or heavy goods or high number of passengers. The motorcycle is a rather suitable with developing countries because of their distinguished climate, national economics status, crowded traffic, etc. The author emphasized that “motorcycles have agility and capability to weave through queues in congested area. Motorcycles are capable of zigzag manoeuvres and creep up slowly to the front of the queue while four-wheelers need to stop during red light at a signalised intersection”. This movement characteristics of motorcycles may be used to explain the motorcyclist behaviours during the “waiting phase” in the signalised intersections. The research also argued that the safety concern is one of the main reasons against the development of motorcycles. It does not provide sufficient protection like a four-wheeled vehicle. It has a high degree of exposure which makes the motorcyclist and passengers more vulnerable if a collision occurs. Motorcycles seem to be the most hazardous traffic mode. This characteristics is also mentioned in many other studies, when motorcyclists, bicyclists and pedestrians are considered as vulnerable road users.

So far, there have been very few researches conducted on traffic operation of motorcycles. In literature review, there are several researches on bicycle traffic which may be useful and applicable to motorcycles since they are all two-wheeled vehicles, especially in the aspect of driver behaviour.

Dealing with driver behaviour at intersections, there are several researchers paying attention to bicycles´ speed distribution. Opiela et al (1980) determined intersection approach speeds for bicycle traffic, then found the normal distribution of speed is closed to the field collected data. Forester (1994), Navin (1994), Botma et al (2000) also computed speeds of bicycles on links. Ling et al (2004) identified the signalised intersection crossing speeds for bicycle traffic. The speed values were classified into through and left-turning manoeuvres, both of which are proved to have the normal distribution. However, the results must be reconsidered and recalculated before applying in motorcycle traffic flow as bicycles are not motorized.

Bary Watson et al. proves that riding a motorcycle is associated with a higher risk of injury or death than driving a car. The design of a motorcycle provides the rider with little protection in the event of a crash compared to that provided by a car, and undoubtedly, this fact contributes to this higher risk of injury.

Paolo Perco (2008) says that motorcyclists are a particularly vulnerable group of road users because they run a higher risk of being injured or killed in an accident compared with passenger car drivers. In fact, accidents involving motorcycles and mopeds can easily result in severe injuries or fatalities. In the research, the author conclude that PTW (Powered two wheelers) speeds are always considerably higher than passenger car speeds. Moreover, the corresponding operating speeds are correlated. Therefore a prediction equation to estimate the PTW operating speed in urban areas starting from passenger car operating speeds was developed:

$$V_{85PTW} = 1{,}162 \times V_{85PC}$$

with $R^2 = 0{,}94$

Whereas: V_{85PTW} = 85th percentile speed on tangent of PTW (km/h)

V_{85PC} = 85th percentile speed on tangent of passenger cars (km/h)

R^2 = coefficient of determination

The author discussed that this equation can help highway designers to estimate expected PTW speed that can be effectively used in safety evaluations when the significant percentage of PTWs in the traffic flow suggests that this vehicle type should also be considered.

Narelle Haworth and Christine Milvihill (2006) argued that motorcyclists are subject to the hazards faced by car drivers but, because motorcycles have only two wheels, they are more susceptible to difficulties and hazards created by the design, construction, maintenance and surface condition of roads (ROSPA, 2001). For example, motorcyclists are at risk from situations such as gaps in bridge decking wide enough to catch a motorcycle wheel but too narrow to affect a car tyre. The reactions required from riders also need to be different, as motorcycles handle differently to cars. The extent of potential harm associated with any given hazard is commonly greater for motorcyclists, given their comparative lack of protection.

In this research, the authors point out that there are two major groups of hazards to motorcyclists which are road-based hazards and hazards associated with the behaviour of the other road users. In their opinions, while road based hazards can, in some cases, cause loss of control over the motorcycle, their roles are more often contributory when the motorcycle is performing a complex manoeuvre such as turning or braking. The hazards associated with the behaviour of other road users can be thought of as arising from failures of hazard perception by other road users. Thus, many factors that interfere with hazard perception by car drivers (e.g. distraction associated with mobile phone use) contribute to those car drivers being hazardous to motorcyclists.

Many researches in Australia also focus on motorcycle safety since in this country, percentage motorcycles participating in traffic flow and involving in accident is rather considerable (Bary Watson et al. (1997)).

However, in fact, it is rather inappropriate to apply such researches in motorcycle safety in developed countries in Vietnam situation. The reason is that in such countries automobile vehicles (four-wheeled) consist a large percentage in the transportation whereas in Vietnam two-wheeled vehicles (motorcycles) contributes mostly in traffic flow. The characteristics of motorcycle traffic flow, motorcycle driver behaviours in two different contexts are therefore very much different. In the first group of countries, motorcyclists are not a homogenous group, whereas in the second group of countries, motorcyclists are rather a homogenous group as most of road users ride motorcycle in order to fulfil mobility demand. This comment has been proved with Krige´s research (1995 a; 1995b). She studies provide some of the most in-depth descriptive information on the social nature of motorcycling in Australia. Motorcyclists in her sample were fairly evenly distributed between white (37%) and blue (44%) collar workers. Only 12% belonged to any form of motorcycling club, however, over half the sample (54%) stated that they sometimes rode in a group. According to Krige (1995a), a kind of “mateship” exists between motorcyclists, largely because of the negative attitudes the rest of the community hold towards motorcyclists.

2.2.2. Motorcycle-dominated Traffic Flow

In recent years, due to the increase in importance level of conducting research on motorcycle traffic flow, as their distinguishing movement characteristics in comparison with car traffic flow, there have been many researches on the traffic flow in which motorcycles contribute the highest proportion.

For motorcycle speed analysis, Hsu et al (2003) stated that in the local alleys, motorcycles can ride faster than cars. The authors showed the speed distribution across time series with the mean of 20 (km/h). The motorcycle data were collected in the local alley in Taipei, Taiwan. However, this survey may be helpful just in the case of heterogeneous traffic flow rather than in the case of homogeneous flow. Normally, the car homogeneous flow has higher average speed than the motorcycle homogeneous one, especially in highways or expressways as motorcycles are not adaptable with long distance trips.

Hussain et al (2005) analysed motorcycle speed at 9 sites which have different lane widths in Malaysia. The study was also conducted at low and high volume conditions. The authors indicated that in the low volume condition, flow is less than 1900 (MC/h/lane), the motorcycles´mean speeds vary from 45 to 61 km/h. In the high volume condition, in which flow is higher than 2500 MC/h/lane, depending on different sites, the motorcycles´mean speeds range from 11 to 34km/h.

Hsu et al (2003) review motorcycle traffic flow characteristics as follows, according to the field observation results in Taiwan, Malaysia and Vietnam.

The motorcycle traffic flow on the road section:

- Motorcycle will drive normally on the side-lane of a street; the car will try to drive on the middle lane of a street (Hsu etc., 1995).
- The speed of motorcycle in mid stream is usually less than the car (Hsu etc., 1995).
- The acceleration noise of motorcycle traffic is more than the car traffic (You, 1993).
- The mixture of motorcycle traffic will enhance the capacity of a street probably.
- The motorcycle drives not only with the concept of car-following and lane-changing, but also with a side-by-side following and overtaking behaviour (Hsu, 1994).
- In Vietnam, due to the high motorcycle volume, on the street without physical median traffic island, the motorcycle will drive onto the opposite direction.

- In the local small alley, normally with one-way regulation, the motorcycle will violate the rule to drive on the wrong direction, e.g., the existing situation in Taiwan.
- On the rural highway, there is normally a shoulder-lane for the motorcycle. The safety of motorcycle can be enhanced. In Malaysia and Vietnam, the rural highway has normally no additional space for motorcycle; the overtaking of motorcycle by the car will cause more hazardous situation.
- In Taiwan, it is not allowed of motorcycle onto freeway and expressway. In Malaysia and Vietnam it is allowed. The conflict between the motorcycle and car will cause hazardous situation.
- By providing the motorcycle exclusive lane, the capacity and travel speed and safety performance of the whole street can be enhanced, according to the experience in Taiwan and Malaysia.

The motorcycle traffic flow at the intersection:

- Motorcycle will swarm the stream at the intersection, i.e., many motorcycles depart together within very short time. It will generate a motorcycle wave after the signalised intersection.
- Motorcycle will have negative starting delay (Hsu, 1982). Many motorcycles stop over the stop line and waiting for the green time on the pedestrian crosswalk. This situation occurs in these three countries prevailing.
- The acceleration rate of motorcycle is higher than car at the starting, but less than the car while driving with a speed higher than 40 kph (Wu, 1983).
- The saturation flow of motorcycle will depend on the layout for queuing motorcycle near the stop line (Hsu, 1996). Because of the swarming departure phenomenon of motorcycle at intersection, the capacity at signalised intersection will be enhanced by providing the reserved head-start area for motorcycle. The PCE of motorcycle will become less due to the motorcycle flocking phenomena.
- In Vietnam, due to the high density of motorcycle, the non-signalised intersection is often jammed by the conflicted motorcycle and full with the stop-and-go motorcycle.
- In Taiwan, the left-turn motorcycle should follow two-stage rule to make the left-turn with two times straight-out. The conflict situation by turning motorcycle is not so seriously like the situation in Malaysia and in Vietnam; they have not the two-stage left-turn rule. This rule will reduce the performance of motorcycle traffic and consume the capacity of whole intersection.
- In Taiwan, the cycle length is normally longer than prevailing situation in views to enhance the intersection capacity for automobile traffic. Therefore, the cycle length and green time is normally too long for motorcycle. In conversely, the cycle length of signal in Vietnam is normally shorter than the automobile traffic need. The cycle length in Vietnam is made shorter with the aspect of that the motorcycle needs not so long green time.

The above-mentioned characteristics made it essential to do some adjustments to European technology (which is specialised with car traffic flow) in order to fit well with motorcycle traffic flow.

2.2.3. Legislation Obey in Motorcycle-dominated Traffic Flow

In his research on driver interaction, Gunilla Björklund (2005) discussed the fact that for various reasons, road users do not always act according to road traffic regulations. Now and then, some persons do deliberately violate the formal rules to get personal favours. Some persons also use other ways to communicate and interact, that is, by means of informal rules and signals, to improve road user interactions. The informal rules supplement or contradict the formal rules. Some of them may facilitate interaction between road users, but some may lead to conflicts or accidents, such as when different drivers comply with different rules. In most cases, disobey to traffic regulation lead to larger range of expectations to road users in a specific case, which may lead to conflicts (a larger possibility of driver errors).

Many empirical research conducted in Vietnam showed that traffic rule obey (disobey) is now a serious problem to traffic safety in this country. Traffic rule offence is the biggest reason for traffic accidents.

In a report of National committee of Traffic safety on reasons for 7683 road traffic accident in 2004, the main reasons are:

- Driver behaviour: 5588 accidents (72%)
- Unsafe facility: 115 (1,5%)
- Infrastructures: 23 (0,3%)
- Other reasons: 1498 (19,5%)
- Unknown reasons: 459 (5,9%)

Report of JBIC study (2005) on current situation on road traffic safety in Vietnam gives out the model 3E of traffic enginering, traffic enforcement and road users´ education. The study discuss that human behaviour is the result of relationship between human himself and his environment. In the field of road traffic safety, establishment of both fields such as road safety environment and road safety education are required.

Traffic enforcement issues are such as: unclear jurisdiction on traffic enforcement and monitoring, limited manpower and budgetary allocation for future enforcement operation patrol, limited training opportunities and quality for coercive approach to enforce traffic law, unsystematic coercive enforcement, limited effects of punishment against traffic law violation.

In the aspect of traffic safety education, there are some emerging issues such as lack of the local environmental situation with safety education, lack of road user education (insufficient pupils´ and students' education, lack of safety education within the community, insufficient driver education).

Such distinguishing characteristics of motorcycle movements from state of the arts lead us to the idea of studying motorcyclists with the main focus on their flexibility and maneuvrability. Motorcyclists can move rather independently from other road users than car drivers due to their non-lane based movement. At the same time, their vehicle-follow-vehicle moving characteristics is even higher than cars´ ones as they can keep up with their heading vehicles more easily by adjusting their speeds. They do not need so much space (both in horizontal and vertical directions). Then it is very common to observe the condensed group of motorcyclists in the similar moving manner. Here is the point of combining macro and micro points of view in studying motorcycle traffic flow.

2.3. Intersection Problem: Understanding Driver Behaviours

In order to provide insight for the modeling task, two aspects are investigated, the identification of existing drivers' models at intersections and driver behaviour description.

The support to the data collection is realized through the identification of parameters to measure as well as a method to obtain necessary data.

2.3.1. Human Factors at Intersection Issues

Intersection issues analysed in the approach of analysing driver behaviour are nearly the same as general issues of human behaviour in common traffic flow (as mentioned above). This part just aims at making clear researches conducted specifically in turning movement at intersections, especially left-turning.

An intersection can be regarded as a zone of transition along the road where the driver may have to adjust his speed and/or trajectory so as to comply with the regulatory and/or functional requirements resulting in a change from the previous driving situation. In the viewpoint of risk analysis, an intersection can be defined as a zone of potential interaction with one or several other road users. A number of researches have shown that when crossing intersections, driver display a certain inertia in the regulating actions they take or take time to become aware of conflicts with other drivers, and these are factors that can lead to accidents.

Farida Saad (2001) has conducted an experimental observations from within an instrumented vehicle (equipped for measuring several indicators, such as drivers´ speed or braking actions, and for making a video recording of the journey) during an actual drive on the public of the highway. In addition, in-depth interviews were conducted with each driver after the journey using two types of aid (presentation of the video recording of their journey and slides of different scenarios of interacrion with other drivers at the junctions studied).

When crossing the intersections located on the main road, drivers´ speed adjustment appeared to be a function of the characteristics of the intersection and of traffic conditions. No significant difference in behaviour was found between experienced drivers and novices. The speed reduction was linked to infrastructure characteristics that represented a discontinuity in relation to the previous driving situaion (e.g. extent of the road installations and visibility over the whole intersection, or a change in the conditions of progress, such as a reduction in the number of lanes approaching the intersection).

When there was a vehicle visible on another approach to the intersection, there was a significant reduction in speed at all four intersections. The presence of another user at the cross-roads thus contributed to the representation of a change in the driving situation calling for some regulating action. This indicates, moreover, that although they had priority, drivers took account of the interaction situation created by the approach of another road user. Drivers´ speed adjustment may be seen as a means of giving themselves more time to assess the risk of interference and to be prepared for dealing with it.

The effect of driving experience is also revealed in the survey. The experienced drivers modified their speed significantly at the intersection, while the novices did not. These differences seem to be linked to the difficulties of detecting the intersection in the approach to it (an effect of perceptual continuity) and to the representation of the relative status of the two roads (associated with the level of traffic flow).

In interviews, the research highlighted the diversity of cues they use to gauge the likelihood of interference with others (such as their position at the intersection, their relative proximity and their approaching speed), as well as the “interactive” dimension of the regulating action they took (in the sense that it depends on the behaviour of the other and is aimed at influencing that behaviour of need be). Depending on the outcome of their assessment and on how the interaction situation evolves, driver resort to different types of regulating action (to keep an eye on the other driver´s behaviour, giving him a signal if there remains any doubt about his intentions, or making a significant adjustment in speed). It has to be pointed out, however, that drivers control the interaction in a way that is essentially aimed at ensuring that the other user will stop when they approach. This strong sense og priority and the difficulties sometimes encountered by driver in processing the variables characterising the interaction situation and in interpreting other road users´ behaviour and intentions are at the origin of some accidents at intersections (Malaterre; Van Elslande et al.).

The author concluded in some major points:

- The characteristics of the intersection itself, as well as the characteristics of its approach, play a significant role in drivers´ speed adjustment
- The onset of an interaction situation, when another road user is seen to approach the intersection, also induces a change in behaviour

Helmers and Äberg (1978) have identified three variables in the traffic environment that are important to drivers when they enter an intersection: the design of the intersection, other road users´ expected and actual behaviour, and the rule of priority in the intersection. Previous results indicate that all three variables appear to have an influence on the behaviour of drivers (e.g., Helmers & Äberg, 1978; Janssen, van der Horst, Bakker, & ten Broeke, 1988; Johannessen, 1984; Kulmala, 1991) (see review of Gunilla Björklund (2005)).

Some researches are conducted at interupted traffic (intersections with traffic signals) and uninterupted traffic (without traffic signals).

An intersection requires several actions from the driver:

(i) detect the presence of the intersection;

(ii) detect and interprete traffic control (interpret timing in case of traffic light);

(iii) anticipate other vehicle acceleration/deceleration;

(iv) detect and anticipate oncoming, cross traffic;

(v) overcome obstruction; and

(vi) negotiate the turn.

Applying the physolophy of accident progress in analysing driver behaviour, this study continue to develop this approach of human factors at intersection issues. Variables in traffic environment which have influences on drivers (i.e., the design of the intersection, other road users´ expected and actual behaviour, and the rule of priority in the intersection) will be further analysed.

2.3.2. Quantified Parameters

Understanding and describing driver behaviour becomes a challenge when one tries to identify driver errors in determining crash causal factors and countermeasures. Access to data related to crashes is usually based on crash statistics and restricted to general characteristics of the involved drivers, such as gender, age, type of vehicle driven (Kim et al. 1999). Very rarely are the actions and maneuvers that led to a crash addressed. The investigation of pre-crash actions and maneuvers usually relies on either focus groups involving officers who respond to crashes or drivers involved in crashes (Wierville et al. 2002, Larsen and Kines21 2002). They therefore rely on subjective sources. Another approach adopted for understanding why crashes occur consists of linking general characteristics with known issues of specific group, such as age linked with perceptive and cognitive deficits (Hakamies-Blomqvist 1996).

There are two different measurements to collect data on driver behaviours: direct measurement of behaviour when it actually happens, in a real vehicle or simulator, and indirect measurement via self-reports.

The driver behaviours which have been used as accident predictors and are of interest here are “driver control actions and vehicle motions” (Greenshield & Platt, 1967; Wilson & Greensmith, 1983), “speed control and direction control” (Gully, Whitney&Vanosdall, 1995), speed (Kloeden, McLean, Moore & Ponte, 1997; West, French, Kemp & Elander, 1993) and headways (Evans & Wasielewski, 1982; 1983; Rajalin, Hassel & Summala, 1997).

The common property of these behaviours is that they all lead to changes in the speed of the vehicle, something that will be called driver celeration behaviour. How are these accident predictors to be interpreted as celeration behaviour? For acceleration and deceleration in the “normal” sense, i.e. changes in longitudinal speed, it is probably easy to see how they add to such a measure.

Peter T. Martin et al. (2003) figures out the approach speed and location of the driver from the intersection generally influence his decision of whether to stop or proceed. Some factors influencing the driver´s decision of whether to stop or clear the intersection are:

- vehicle approach speed,
- color of the traffic signal when noticed by the driver,
- vehicle location form the stop line,
- length of phase change interval or yellow time,
- driver´s perception-reaction time,
- sight distance,
- rate of deceleration,
- intersection clearing time,
- road surface conditions,
- adverse weather conditions such as snow, fog, rain, etc.

There are some formula to quantified values related to driver behaviours in left-turning movement at intersections.

Stopping distance (d_0): A driver can stop at the intersection if he has enough stopping distance (d_0) in front of him at the onset of the yellow signal. The driver should decide to come to a stop when he is at a critical distance from the stop line.

The critical distance is computed using the following equation:

$$d_0 = v\delta + \frac{v^2}{2a}$$

whereas: v = speed of approaching vehicle

δ = perception-reaction time of the driver

a = maximum comfortable deceleration rate of the driver

Clearing distance (d_C): A driver can clear the intersection if he has enough clearing distance in front of him when he perceives the change in signal. If d_0 is the distance from the stop line where a driver travelling with the speed limit will not be able to clear the intersection safely or legally on yellow, then

$$d_c = v\tau - (w + L)$$

A successful clearing manoeuvre can be represented as:

$$d + w + L - v_0\delta \leq v_0(\tau - \delta) + \frac{1}{2}a_1(\tau - \delta_1)^2$$

where:

L = length of the vehicle

d = vehicle position from the intersection stop line

w = width of the intersection

a_1 = rate of the deceleration of the car

The right hand side of the equation represents the distance traveled from an initial speed (v_0) at a constant acceleration (a_1) during the time interval (τ - δ_1) subsequent to perception – reaction time and before the onset of the red signal.

Elements taken into consideration in literature review (relating to left-turn movement at intersections) consist of:

- Time to collison (TTC). Due to Richard van der Horst, in research on Traffic Conflicts Techniques, Hayward (1972) initiated a search for objective measures to describe the danger of a conflict sitaution and concluded that the Time-To-Collision (TTC) measure is a dominant one. He defined TTC as "The time required for two vehicles to collide if they continue at their present speed and on the same path". TTC at the onset of braking, TTC_{br}, represents the available manoeuvring space at the moment the avasive action starts. The minimum TTC (TTC_{min}) as reached during the approach of two vehicles on a collision course is taken as an indicator for the severity of an encounter. In principle, the lower the TTC_{min} is, the higher the risk of a collision will be.

From the concept of TTC, there are definition of Time-to-intersection: Whereas the TTC measure deals with interactions between two road users, the Time-to-intersection (TTI) is a time-based measure to describe road user behaviour relatively to the road environment itself. For example, when approaching an intersection, TTI is a defined as the time that is left till the intersection area will be entered, given by the distance to that area divided by the instantaneous speed. For each approach, the moment of entering the intersection area is taken as t = 0s. TTI decreases linearly with time. By decelerating differentially it is possible to reduce the decrease of TTI, to keep TTI constant for a while, or even to increase TTI. Similar to TTC, TTI at the onset of braking (TTI_{br}) and the minimum TTI (TTI_{min}) as reached during the approach, if any, can be distinguished.

The article do research on different behaviours of road users in the progress of approaching and negotiating intersections with the aim to develop sound criteria for the distinction between normal and critical behaviour. The conclusion provided here is the fact that in negotiating an intersection, road users have to consider potential interactions with other road users. How they deal with them, depends highly on the type of priority regulation that applies at a specific intersection (in distinguishing between minor and major roads). The TTI measure is related to the road itself and enables a direct comparison of approaching behaviour with and without other traffic involved. Whereas, TTC directly relates to another road user and descrives interacting behaviour during the approach process.

The article also summarized some quantified results of previous researches on PRT, braking time, etc… The author discussed that, the analysis of drivers´behaviour in terms of TTI gives rather consistent results. At a yield intersection, for example, minor road car drivers start braking (defined as the moment the deceleration level exceeds a value of $-1 m/s^2$) at a rather constant TTI of about 3s away from the intersection, independently of the type of manoeuvre, type of party on the main road, the direction the party is coming from, or approach speed.

- Perception – Reaction time (PRT) (decision time): In emperical researches on PRT, there are common conclusions of the value of 2s (especially in designing traffic signals, as well as standards on transportation and traffic management). Some scientific researches also tried to devide PRT into small segments (perception time, decision time,…) and supposed that driver characteristics and driver behaviour have influence on those segments.
- Lag and gap acceptance and rejects

AASHTO introduced the definition of intersection sight distances (ISD), which are the minimum sight distances required for drivers to safely negotiate intersections, including those with no control, stop control and signals, and including those for drivers turning left, right and going straight through.

Until the 2001 version of AASHTO policy, ISD values have been calculated using models that assume a serial process whereby PRT is completed while the driver is stopped at the stop bar, followed by an acceleration time. Based on PRT, there is an equation for ISD as follows:

$$ISD = 0,278\ V_{major} (J + t_a)$$

Where ISD = intersection sight distance (length of the leg of sight triangle along the major road (m)

V_{major} = design speed of major road

J = PRT required to determine if an available gap or lag is acceptable (s)

T_a = maneuvre time (MT) to accelerate and traverse the major highway pavement (for a crossing manoeuvre) or to accelerate and reach 85% of the major highway design speed (for a turning maneuvre (s))

Since the version of 2001 AASHTO policy, ISD is no longer based on the serial model assuming that PRT starts when the driver is stopped at the stop bar, is completed before leaving the stop bar, followed by an acceleration time. Instead ISD is based on a gap acceptance model, in which the time gaps accepted by drivers for the various maneuvers made at intersections are the basis. PRT is completed once drivers have decided to accept the gap, bit before they move forward. The time gap accepted must be of sufficient length to accommodate their estimated MT, without requiring substantial braking from the oncoming driver. The formula for ISD is as follows:

$$ISD = 0,278\ V_{major}\ t_g$$

Where ISD = intersection sight distance (length of the leg of sight triangle along the major road (m)

Vmajor = design speed of major road

t_g = time gap for minor road vehicle to enter the major road

In these equation, t_g is the gap in seconds accepted by drivers 50% of the time it is presented for crossing or turning maneuvres. The object height is considered to be equipvalent to the driver´s eye of 1,08m above the surface of the intersecting road.

From the behaviour perspective, it should be noted that both the PRT-based ISD equation and the gap acceptance ISD equations contain an assumption of some cooperative behaviour from the conflicting (major road) traffic. If approaching traffic does not slow to some degree, the equations may not work. AASHTP (2001) notes that the values given for sight distance "provie sufficient time fot the minor road vehicle to accelerate from a stop and complete a left turn without unduly interfering with major road traffic operations". Further considering the values for the gap acceptance model, AASHTO states "Observations have also shown that major road drivers will reduce their speeds to some extent when minor road vehicles turn onto the major road. Where the time gap acceptance values are used to determine the length of the leg of the departure sight triangle, most major road drivers should not need to reduce speed to less than 70% of their initial speed"

- Braking and sight stopping distance: the concept of sight stopping distance obviously involves the feature of availability: drivers should always have sufficient time to detect an obstacle in their path, and sufficient time to brake and stop their vehicle safely in front of it. Speed and road environment together determine the time available for drivers at any moment. The corollary is that available time can be thought of as determining speed as well as steering control to guarantee adequate management of the vehicle.
- Driver states in terms of attention or awareness: a driver can be surprised or non-alerted (Olson 2002)

There are some literature reviews on motorcyle at intersections (reviewed by Chu, 2007). Powell (1997 and 2000) stated that motorcycle crossing the stopline in the first 6s of effective green time have a PCU value of 0 and those crossing later had a PCU value that varies from 0,53 to 0,65, depending on the lateral position of the motorcycle and its turning movements. The author also developed the model to describe motorcyclist behaviour at signalized intersections. An amended first order macroscopic model was used to represent motorcyclist behaviour and multiple regression analysis explained inaccuracies resulting from this technique. The model predicted the number of motorbikes, which set off from the front of the queue before the end of the first 6s of effective green time.

Holroyd (1963) estimated the effect of motorcycles on saturation flow at traffic signals and expressed the results in terms of PCU. The author analyzed separately the first one-tenth minute of the green period and the remains of the saturated period was calculated to be 0,33. Other studies of motorcycle capacity, such as the research has done by Wigan (2000), have been conducted in developed countries. However, for the most parts, the results of these studies have not been appropriated to apply in developing countries since the role of motorcycles, as a means of urban transportation characteristics is not similar.

Similarly in the case of quantified parameters in studying driver behaviours in general, quantified parameters in motorcycle-dominated traffic flows provide with hints to further develop the modelling and simulation in the future.

3. Risk-based analysis

3.0. Introduction

The chapter aims at describing methodology applying in risk analysis modells based on chain of driver behaviour. Central ideas will be DRAM methodology which is described in details after clarifying concepts and terminology using in the research. The modelling process is explained afterwards, with the final objective of building a cause-and-effect chain of driver behaviour. The way to apply the methodology in motorcycle traffic flow is also provided. The last but not least part is methods of collecting and processing data to support the whole process.

3.1. Concepts and Terminology

The basic principle of the research will be applying modern and advanced technology in enhancing road traffic safety in Motorcycle (two-wheeled vehicles) traffic flow, particularly in Vietnam. In order to reach the target, there are several concepts and terminology needed to be firstly clarified.

In discussing ***traffic safety***, the focus is actually very much on the opposite concept, traffic unsafety. It is difficult to give a precise definition for both concepts, and to find adequate parameters for their measurement and assessment, as they have a highly subjective and qualitative character. Generally, traffic accident statistics are taken as assessment indicators, in particular parameters like accident frequency, accident severity, number of fatalities, number of injuries and amount of material damage.

An ***accident*** is defined as an unstabilized situation with at least one harmful event. An accident is that occurrence in a sequence of events that produces unintended injury, death or property damage. Accident refers to the event, not the result of the event.

Conflicts are undesired phenomena. Serious conflicts are shown in the same way as traffic accidents, the result of a breakdown in the interaction between the road user, environment and vehicle. A serious conflict is characterised by the fact that no one voluntarily gets involved in such a situation. The necessary evasive action is usually braking, but may also be swerving or acceleration, or a combination of these. Since the similarity between accidents and serious conflict is striking, accidents can be avoided by circumventing conflicts.

The concept of traffic conflicts was first introduced in 1968 (reference) and continues to be developed nowadays. A ***traffic conflict*** is an observable situation in which two or more road users approach each other in space and time to such an extent that there is risk of collision if their movements remain unchanged.

Based on this theoretical definition, operational explanations of conflicts to recognize both the occurrence at a given time of a collision course between two road users, and the performance of a critical evasive action by at least one of the road-users involved were developed by different research teams in order to detect, count and describe conflicts in real traffic situations.

Historical crash data have been used widely as a direct measure of safety at intersections and other locations. However, attempts to estimate the relative safety of a highway facility are usually hindered by the unreliability of crash records and the long period to achieve adequate sample sizes. To overcome these problems, Perkins and Harris (*29*) first introduced the concept of ***traffic conflicts*** as a surrogate measure for predicting crash rates in 1967. A traffic conflict is defined as “an event involving two or more road users, in which the action of one user causes the other user to make an evasive manoeuvre to avoid a collision" (*30)*.

With such definition, it is possible to distinguish with the terminology of "hazard".Obviously, the terminology of harzard cover cases of not only vehicle-vehicle but vehicle-obstacles also.

In this research, ***conflicts*** are defined as those situations where the vehicle (the group of vehicles) are forced to change its speed (accelerate/decelerate) and/or its trajectory (swere).

Many researches (e.g. Bald 1991, Bald et al. 2008) define ***safety*** as the absence of possible damage, or implies freedom from danger. The ultimate level of safety desired by human beings is to be in a situation without any risk of personal accident, injury or material damage. In reality, this is impossible because a widespread set of dangers cannot be avoided completely. So safety generally refers to the level of danger that is socially acceptable in a real-life situation. The safety performance of a technical system (transportation system) is the measurable consequence of the extent to which it behaves as expected, with and without the interaction of human beings. The objective is to come as close as possible and reasonable to the ideal safety performance.

Traffic safety can be described best by risk value. In Bald |1991|, ***risk*** is explained as the product of the probability and the extend of a possible damage.

Risk can be described as the combination of this product for all possible extend values of damage. The important characteristics of the risk term are:

- It is a probability statement about the future.
- The risk is higher, the more often the damage occurs.
- The risk is higher, the bigger the damage will be.

Bilal M. Ayyub (2003) and Mohammad Modarres (2006) also stated that risk is ameasure of the potential loss occuring due to natural or human activities. Risk assocuated with an event or a scenario of events, therefore, has two primary attributes of interset: risks are the occurrence likelihood and occurence consequence of an event. Such definitions are also relevant with the above definition of risk.

External risks and internal risks. The research aims at breaking new ground in road traffic micro-simulation for safety assessment, particularly applying in MD traffic flow. The new method is supposed to be constructed with the co-operation of micro and macro simulation methods. That means, in a MD traffic flow, each group of motorcycles (classifying into groups based on specific driver behaviours) will be treated as an independent object.

External risks are defined as risk level of a motorcycle group in the context of potential conflicts/damages with other vehicle groups. Internal risks, in turn, are determined as levels (and its probability) of potential conflicts/damages among vehicles in the same group.

In the 1980s Mahalel [1983] proposed to analyse the whole system "road traffic" to describe the correlation between reference values and accidents. Bald et al. (2008) defined: ***Risk analysis*** in general is a systematic, model orientated and modular approach to analyse safety issues and impacts on roads**.**

Risk analysis methods define safety as a state of very low probability to suffer damage (mathematically risk is a number considering the probability and the extent of (negative) consequences). Historical data which describe the past may give hints to find values for these probabilities. The distribution probabilities are assumed to describe the future. Most of risk-based methodologies aim at modelling the cause-and-effect chain. The most accepted and most generally formulated among them is the Failure Mode Effect Analysis (FMEA).

Human factors

The ITE *Traffic Engineering Handbook* (Pline, 1999) cites a definition of "traffic engineering" as "that branch of engineering which applies technology, science, and human factors to the planning, design, operation and management of roads, streets, bikeways, highways, their networks, terminals, and abutting lands." Thus the discipline of human factors is recognized as an integral contribution to traffic engineering practice.

However, many highway designers and traffic engineers do not have a clear understanding of what human factors is and how its principles are relevant to their work.

Human factors is the scientific discipline that studies how people interact with devices, products, and systems. It is an applied field where behavioural science, engineering, and other disciplines come together to develop the principles that help assure that devices and systems are usable by the people who are meant to use them. The field approaches design with the "user" as its focal point. Human factors practitioners bring expert knowledge concerning the characteristics of human beings that are important for the design of devices and systems of many kinds. The discipline contributes to endeavours as complex as space exploration and to products as simple as a toothbrush. In the field of transportation engineering, there have been numerous important contributions from human factors, but these are not always self-evident. Sight distance requirements, work zone layouts, sign placement and spacing criteria, dimensions for road markings, colour specifications, sign letter fonts and icons, signal timing – these and many more standards and practices have been shaped by human factors evaluation.

Driver behaviour aims at describing and analysing driver behaviour in situ (as safe or unsafe, legal or deviant,…), to identify the internal factors (relating to the driver himself, such as his experience) and the external factors (the technical and social environment of driving) that account for this behaviour, and to reveal the psychological processes (perceptual, cognitive, motivational,…) that govern drivers´activity.

In the research, there raise the requirement of distiguishing between two different types of chain: chain of actions based on time order, and chain of driver behaviour.

Chain of actions can be defined as a chain of activities that a normal driver usually conducts in the proceed of traffic participation. For exmaple, when conducting left-turning maneuvre at intersections, the driver has to approach the intersection, signalize his desire to turn, wait (if needed), enter the intersection area, move inside the intersection area and leave the intersection. In other words, "chain of actions" describe "which activities do drivers conducts"

Bald (1991) describes chain of driver behaviour as follows: *The driver obtains information by processing optical pictures which he receives within his "driving space". Driver behaviour therefore depends a lot on his driving space (including infrastructure, traffic flow, traffic control and bound* *conditions). In some specific cases, driver behaviour depends much more on traffic control and operation.*

Driver behaviour is obviously the results from consideration to balance between acceptable risks (probability of accidents/conflicts) and urgent need to reach destination. Acceptable risk is higher, faster goes the driver. Otherwise, the driver will ride the vehicle slower but safer.

Briefly speaking, ***chain of driver behaviour*** describes "which type of reaction does a specific driver conduct in order to respond to a specific traffic situation".

3.2. Risk-based Methodology

3.2.1. General Overview

As mentioned from Chapter 2, in the field of traffic safety, there are two trends of analysing the past and forecasting future events.

Firstly, the simplest methodology to conduct diagnosis of traffic (un)safety situation is determining frequency of traffic accidents/conflicts in the past. This methodology does not pay attention to practical reasons as well as interactive relationship among parameters in black box. With such inputs as traffic infrastructure (visibility, type of roads, number of lanes, etc.), traffic environments (rainy or sunny weather), traffic flow conditions (average speed, density, headway, etc.), percentage of accidents/conflicts is statistically reported. This methodology uses statistical tools of linear/non-linear regression, analysis of variance, etc. to obtain relationship among input parameters and output.

Secondly, risk-based methodologies start also from statistical data. However, they aim not only at simple relationships between input and output, but try to analyze deeply the process (chain) of causes and effects. The final goal is sophisticated probability distribution of damages with interacting relationships (multi-dimensional) among parameters. Bayes theory of conditional probability distribution is the important tool in this approach.

Firstly applied by the U.S. Nuclear Regulatory Commission, risk analysis has quickly become an efficient methodology to apply in many industries, which have to deal with uncertainty. The nuclear industry, and more recently transportation (land and air), space, and food safety industries promote a greater use of risk analysis in their operations, and policy decision making.

As defined from the above part, risk is the combination of the likelihood and consequences of an undesirable event. To calculate ris level, situations must be evaluated to answer the following questions: (i) what can go wrong? (ii) how often it can happen? (iii) what are the impacts?

The first question involves creation of a risk scenario (driver behaviours in specific scenarios); the second, determination of likelihood; and the third, specification of consequences. The process for answering these three questions is called "risk analysis", and the answers derived, for all possible scenarios, are a complete expression of the risk being assessed.

Traditional methodologies normally focus on single effects of causing parameters to traffic unsafety situations. For examples, "young and inexperienced drivers" seems to be involved more in speeding behaviours. Speeding behaviour has the highest percentage in all causes of traffic conflicts and/or accidents.

However, there is the fact that traffic accidents in most cases are not the result of just a single reason. If a driver rides at a very high speed, but he concentrates very much in his task of driving, if there is no unexpected obstacle, then the probability of a traffic conflict or accident is rather low (may be equal to zero). Analysing impacts of different parameters to traffic safety as well as their interacting effects can be clarified just by the modular structural approach of risk-based methodologies.

The following figure summarises the difference between traditional forecasting methods and risk analysis methodologies.

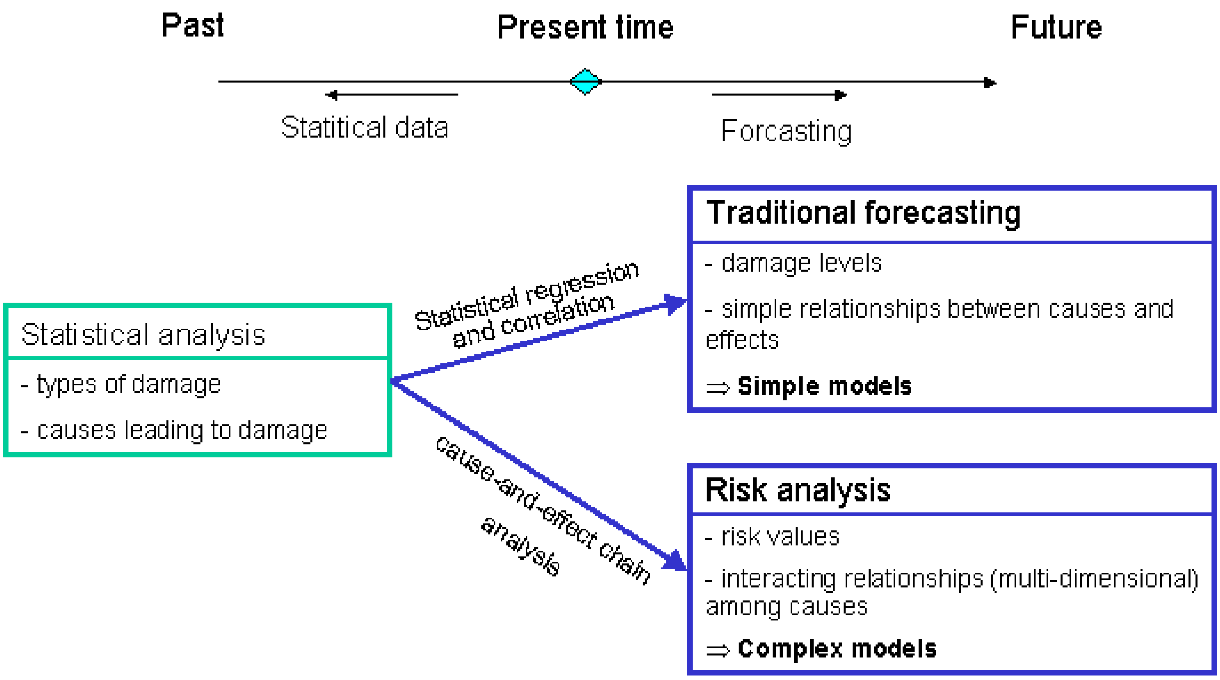


Figure 5. Risk analysis methodologies and traditional forecasting

In order to construct a model to quantify the risk of (some) specified events, it is required such a huge amount of data. However, data on traffic accidents and/or conflicts are scaterred without systematical statistics. Risk analysis with the driver behaviour chain provides an efficient tool in determining and using all available data.

3.2.2. DRAM Methodology

3.2.2.1. General Overview

Darmstadt Risk Analysis Methodology (DRAM) with its Darmstadt Risk Analysis Tool (DRAT) is mainly based on the FMEA-based risk analysis method developed in Darmstadt 15 years ago.

DRAM provides possibillty to model the cause-and-effect chain in different areas and to use this model by varying input parameters as well as modules of driver (road user) behaviour chain. In this research, DRAM is applied to construct driver behaviour chain of violating traffic regulations.

The methodology aims at five objectives, which can be described in the following figure.

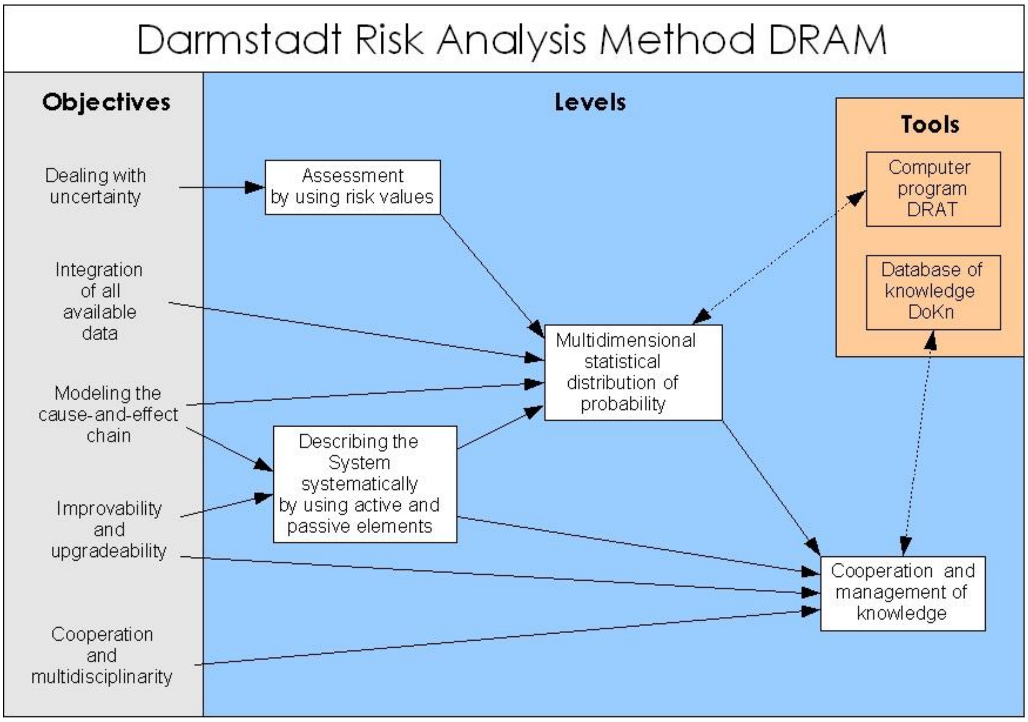


Figure 6. Structure of Darmstadt Risk Analysis Method DRAM

In summary, working with DRAM methodology needs to determine:

- The cause-and-effect chain (from every possible causes to expected effects);
- Parameters described by risk values with their probability distributions; and
- The relationships among parameters.

3.2.2.2. Risk values and probability distributions

As mentioned ablove, risk is explained as the product of the probability and the extend of a possible damage. More generally, it can be described as the integral of this product for all possible extend values of damage.

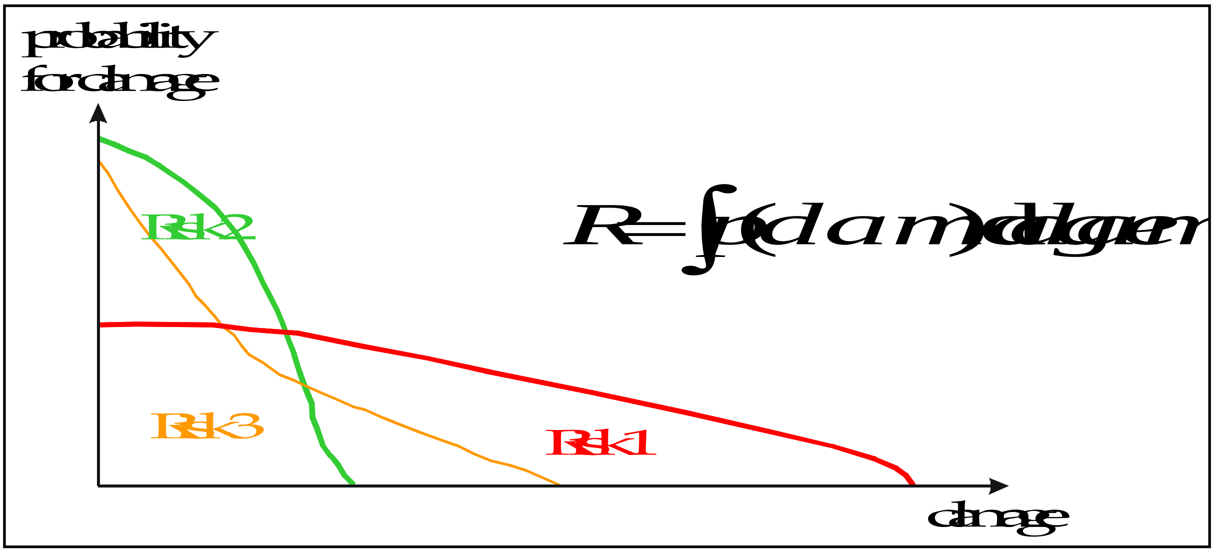


Figure 7. Description of risk

[Bald 1991]

It is important to mention, that the risk has to be related to time, place and referenced group (only one person or a more or less specific group of persons). Using risk values offers the opportunity to eleminate units of different variables (different terminologies). Therefore, it will be very much helpful when calculating the probability leading to different situations (normal situations or critical situations or harzards, etc.). Risk values help also in classifying different groups as well as summing up variables and their probability when needed. By regarding the risk of larger groups, it is possible to assess the total loss of the whole traffic system.

In methodology, interfaces and modules describe whole classes of states and actions, called “situations” and “developments”. They are tainted with uncertainties resulting from the statistical nature and the influence of human behaviour in road traffic. It seems to be appropriate to describe most variables, representing the values of situations and the relations of developments, as probability distributions.

Additionally, the values of most situations and the relations of most developments depend on other variables (which themselves may be described by probability distributions and may be dependent on other variables), giving the need to describe them as a function of themselves. For that reason, the DRAM uses multidimensional probability distributions (see example in Figure 8), which means hierarchically organized sets of distributions.

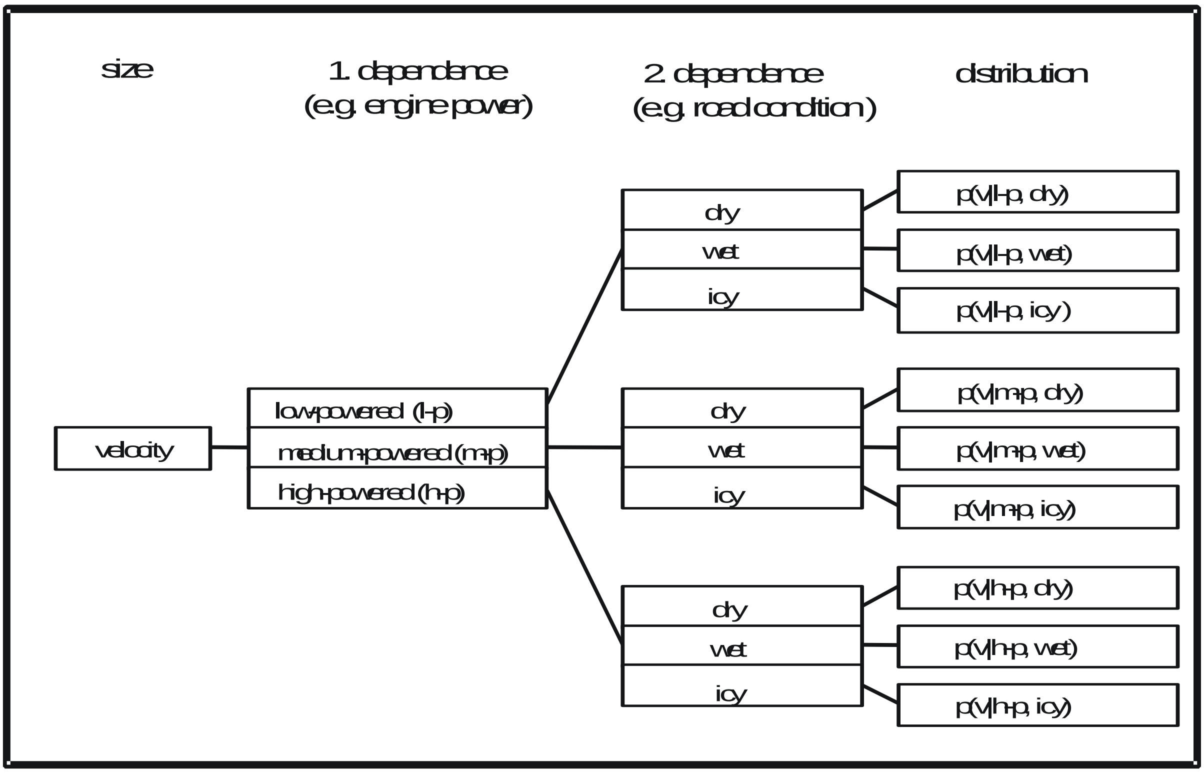


Figure 8. Example of a multidimensional probability distribution

[Bald 1991]

The distributions themselves are given numerically, allowing to describe every form of distribution (not only the standard ones). The reason is, that the complex and non-linear relations are only rarely comparable to standard distributions and that the used data, which are currently used, are mostly empiric higher. Accuracy is only a question of the number of values (and dependent upon it, the computing power of the analysing machine)

3.2.2.3. Describing the System Systematically by Cause-and-Effect Chain

As mentioned from above, the DRAM is using probabilities to describe the states and situations of the systems. For all parameters, it is essential to obtain a reliable estimate of their value. Unfortunately, those estimates are based on relatively scarce information. In recent years, interest in the Bayesian approach to data analysis has increased significantly in many areas of application, including traffic safety. Traffic safety engineers are among the early adopters of Bayesian statistical tools for analysing crash data.

The Darmstadt Risk Analysis Method follows a modular approach by trying to describe the cause-and-effect-chain from the influencing parameters to possible damage with active and passive elements (“developments” and “situations”; see Figure 4). “Development” and “situation” are more general terms for “action” or “event” and “state”, which are often used to describe technical or organizational processes. These more general terms and thinking are necessary, because whole sets of actions/ states are analysed.

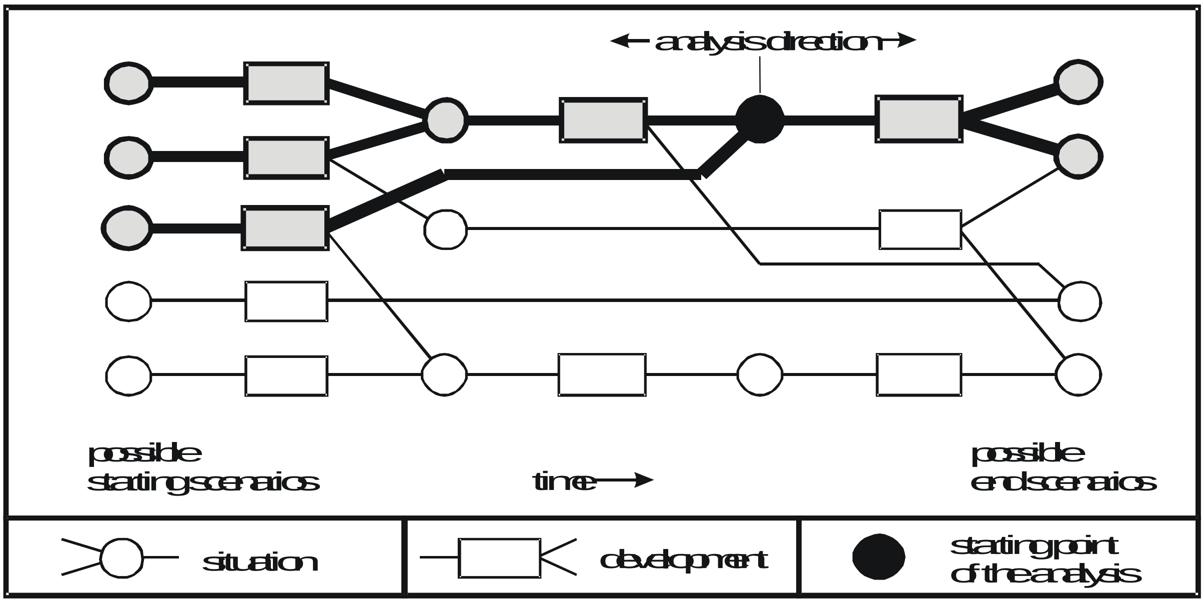


Figure 9. Describing a system with "situations" and "developments"

[Durth, Bald 1988]

The use of a whole network of passive (interfaces) and, especially, active elements (modules) offers many advantages:

- very complex systems can be cut into independent modules, which may be analysed by different researcher groups (even from different disciplines) with different methods (e.g. theoretically, by simulator experiments, by observation of the process);
- every module may be improved and substituted as long as the interfaces and its basic functionality is not changed;
- every module may be refined by regarding it as a sub-process (Figure 10); it is also possible to analyse non-linear relations.

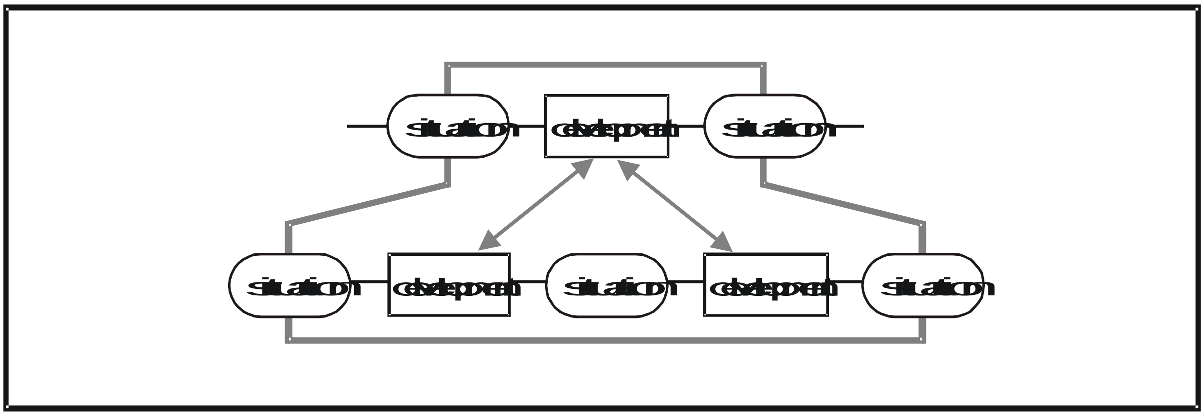


Figure 10. Refining the description by analysing an active element as a sub-process

[Durth, Bald 1988]

Every research group can concentrate on the modules they are especially interested in. For their analysis they can use generalized results of other groups. For the analysis of other research groups they can give away a generalized description of their own findings. In the same manner, the whole cause-and-effect chain may be assembled from the findings of many research groups. This approach is very similar to a Finite-Element-Method (FEM), where stiffness data of many elements are combined systematically to one big system stiffness for analysing the whole system with knowledge only of the single elements.

3.3. Modelling Progress

3.3.1. Driver Behaviour Chain

The cause-and-effect-chain may be described as a continuous chain from influencing parameters to dangerous situations and/or accidents. The basis discussion is that most hazards are the result of numerous negative events and it is possible to analyse the whole chain and network of relevant facts in single (independent) modules, even by different research groups and by different disciplines.

As mentioned from above, when considering traffic system as a consistent and complete system, then traffic accidents can be considered as an error of the whole system. That means, accident cause(s) are error(s) of one or some elements in the system, or error(s) of interactions among the system elements. The analysis process of finding system errors can be performed by many different approaches. When considering the driver as the centre of the whole system, all other elements must aim at serving the driver convenience and safety. We then consider the driver behaviour as an internal factor of the model and all other elements are external factors (including driver personal characteristics as age, education, etc.).

It is possible to consider traffic system as a complete system with the interacting relationship among those elements of human being – infrastructe – vehicle – traffic flow - bound conditions. Occurance of conflicts and/or traffic accidents must be consequence of some factor(s)´ error. Driver errors happens when the driver cannot perform neccessary prescribed tasks for a safe maneuvre.

General information/suggestion to detemine the chain of ***prescribed tasks*** includes:

- Perception of demanding to change the current driving maneuvre: demand for changing driving direction/trajectory (lane changing or turning movement) or optical perception of current situation in the road (sharp bends, intersections, pedestrian,…): ***perception task***
- Deciding tasks that he may perform, balancing (negotiating) between demand for destination and demand for safety: ***decision task***
- Performing his decision: swerving, accelerating/decelerating urgently/comfortably, keeping speeds: ***action task***

Determining ***critical situations*** includes the following tasks:

- Critical situations are defined as the situations which have the high probability to lead to conflicts and/or accidents. Critical situations are determined by (historical) statistics data (accident causes: single/multi vehicle crash, crash angles, transportation modes involved: pedestrian, light/heavy vehicles, motorcycles)
- Determining distribution probability of different critical situations (depending on external factors) and their probability of leading to conflicts (depending on driver behaviours)

Road traffic is the result of the interaction between humans, vehicles and road infrastructure, subject to traffic regulations. Safety issues concern the means of transport (like vehicles) and the infrastructure of transport (e.g., roads), as well as human beings involved directly or indirectly in any transport operation. In this process, the human is a key element, but also the weakest link.

The ***driver behaviour*** can be defined as a continuous chain of decision including activities to reach his desired destination and his reactions to events in his “driving space”. Recently, there have been researches determining different impacts of road traffic system´s elements on driver behaviour.

Michon (1985) proposed a hierarchical control model of car driving, where car driving is seen as occurring at three different levels. At the strategic level, trip decisions are made regarding route to drive, and general goals are set, such as “minimise time” or “avoid traffic jams”. Actual manoeuvring takes place at the tactical level: overtaking, negotiating intersections; at the operational level, immediate vehicle control occurs, such as change of gear, braking, steering. Each level is associated with a time scale: at the strategic level, decisions take minutes, driving manoeuvres are measured in seconds, whereas operational control actions take less than one second.

The same argument can be applied into motorcycle driving. The difference from car traffic flow can be observed at operational level depending on the distinguishing between car and motorcycle characteristics.

3.3.2. Simulation and Modelling in Motorcycle-dominated Traffic Flow

The applications of traffic simulation programs can be classified in several ways. Some basic classifications are the division between microscopic, mesoscopic and macroscopic, and between continuous and discrete time approach. According to the problem area we can separate intersection, road section and network simulations. Special areas are traffic safety and the effects of advanced traffic information and control systems. A newly emerged area is that of demand estimation through microscopic simulation.

3.3.2.1. Macroscopic and Microscopic Simulation

Dynamic, meaning time-variant, modelling of the traffic flows has become common nowadays. The common term for simulations that model traffic as flows is *macroscopic* simulation. The use of these tools has grown extensively, and been facilitated by the development of extensive traffic measurement systems that have been installed in major urban areas and motorways. An additional factor that helped especially macroscopic models gain popularity is the fact that the data needed for such models (flow counts, speeds) is at the same level of aggregation as the data supplied by the measurements.

While dynamic assignment in general can be studied using the macroscopic simulators, the need has arisen to understand at least part of the traffic system at a more detailed level. It has been found that ‘details’ at the macroscopic level, such as the length of an on-ramp or the settings of signal control, are often constraining when it comes to the maximum (capacity) and nominal flows through such sections, and the study of the vehicular interactions is needed to discover and understand such constraining factors.

Whereas the macroscopic models often exhibit a minimalist approach, so that an efficient solution can be reached, because the new generation of models aim at modelling the process of vehicular traffic in detail. This type of models, that try to describe the actions and reactions of the particles that make up the traffic as accurately as possible, are called *microscopic models*.

In microscopic models, traffic is described at the level of individual vehicles and their interaction with each other and the road infrastructure. Normally this behaviour is captured in some set of rules of behaviour which determine when a vehicle accelerates, decelerates, changes lane, but also how and when vehicles choose and change their routes to their destinations. The models that govern the vehicle's behaviour can often be divided into a car-following model, a lane-change model, and a route-choice model. The car-following model describes the breaking and accelerating patterns that result from interaction of the driver with the vehicle in front as well as other objects (such as speed limits, road curvature, etc.). The lane-changing model describes the decisions when to change lanes, based on the driver's preferences and the situation in both the current lane and other lanes (speed of vehicle in front, sufficiently large gap in adjacent lane, etc.) The routechoice model describes how drivers determine which path to take from their starting location (origin) to their destination, and how they react to traffic and route information along the way.

In traffic engineering, micro-simulation has proved to be a particularly useful tool for studying the traffic system where the behaviour of the system as an entirely object is largely dependent on the behaviour and interactions of entities, ie. Road-users (in car traffic flow). The use of micro-simulation of the traffic system enables new and sometimes controversial measures to be tested without disrupting existing traffic networks, or putting people at risk. Through its ability to indicate the potential of alternative system designs at an early point in project planning, it can also provide a useful and cost-effective platform for establishing a balance between the different, and often opposing system objectives of efficiency, safety, and environmental concerns.

Most traffic system simulation applications today are based on the simulation of vehicle-vehicle interactions and are microscopic in nature. Traffic flow analysis is one of the few areas, where macroscopic (or continuous flow) simulation has also been in use. Most of the well known macroscopic applications in this area originate from the late 1960's or the early 1970's. The British TRANSYT-program (Byrne *et al*. 1982) is an example of macroscopic simulation of urban arterial signal control coordination and the American FREQ- and FREFLO-programs (Byrne *et al*. 1982; Payne 1971) plus the corresponding German analysis tool (Cremer 1979) are related to motorway applications. A mesoscopic approach with groups of vehicles is used in CONTRAM (Leonard *et al*. 1978), a tool for analysis of street networks with signalized and non-signalized intersections.

The two above mentioned methodology have their own advantages and disadvantages.

3.3.2.2. Mesoscopic Simulation

A third 'class' of traffic simulation models is gaining popularity. So-called mesoscopic models fill the gap between the aggregate level approach of macroscopic models and the individual interactions of the microscopic ones. Mesoscopic models normally describe the traffic entities at a high level of detail, but their behaviour and interactions are described at a lower level of detail.

These models can take varying forms. One form is vehicles grouped into packets, which are routed through the network (CONTRAM, (Leonard, Power et al. 1989)). The packet of vehicles acts as one entity and its speed on each road (link) is derived from a speed-density function defined for that link, and the density on the link at the moment of entry.

The density on a link is defined as the number of vehicles per kilometre per lane. A speed-density function relates the speed of vehicles on the link to the density. If there is a lot of traffic on the link (the density is high), the speed-density function will give a low speed to the vehicles, whereas a low density will result in high speeds. The lane changes and acceleration/deceleration of vehicles is not modelled.

Another mesoscopic paradigm is that of individual vehicles that are grouped into cells which control their behaviour. The cells traverse the link and vehicles can enter and leave cells when needed, but not overtake. The speed of the vehicles is determined by the cell, not the individual drivers' decisions (DYNAMIT (Ben-Akiva 1996)).

Alternatively, a queue-server approach is used in some models (DYNASMART (Jayakrishnan, Mahmassani et al. 1994), FASTLANE (Gawron 1998), DTASQ (Mahut 2001)), where the roadway is modelled as a queuing and a running part. The lanes can be modelled individually, but usually they are not. Although the vehicles are represented individually and maintain their individual speeds, their behaviour is not modelled in detail. The vehicles traverse the running part of the roadway with a speed that is determined using a macroscopic speed-density function, and at the downstream end a queue-server is transferring the vehicles to connecting roads. This last approach combines the advantages of dynamic disaggregated traffic stream modelling (since the vehicles are modelled individually), with the ease of calibration and use of macroscopic speed/density relationships. The capacities at the node servers follow from saturation flows and their variance (measured or calculated). Signal controlled intersections can be modelled by replacing the queue servers with gates that open and close according to the states of the signal control (green / amber / red). Adaptive signal control is harder to model since the positions of the vehicles on the link are not known, and therefore it is difficult to know when they pass detectors connected to the signal control. Another advantage of the representation of individual vehicles is the possibility of modelling disaggregated route-choice. This is important when en-route changes of routes need to be modelled, for instance when evaluating ITS systems that help drivers decide their routes.

Another type of mesoscopic model uses cellular automata. In these models the road is discretised into cells that can either be empty or occupied by a vehicle. The vehicles follow a minimalist set of behaviour rules (most notably the Nagel-Schreckenberg rules (Nagel and Schreckenberg 1992)), which determine for each time step the number of cells that are traversed by the vehicle (TRANSIMS (Bush 2000)).

The main application area of mesoscopic models is where the detail of microscopic simulation might be desirable but infeasible due to a large network, or limited resources available to be spent on the coding and debugging of the network.

The problem raising is that the motorcycle traffic flow, with its flexibility and maneuvrability is a so-called ant-crawling traffic flow. That means, there is no individual two-wheeled vehicle which can typically represent for the movement of the whole traffic flow. In order to apply techniques of traditional micro and macro simulation, it is necessary to provide a new concept of a typical representative object.

The research aims at breaking new ground in road traffic micro-simulation for safety assessment, particularly applying in MD traffic flow. The new method is supposed to be constructed with the co-operation of micro and macro simulation methods. That means, in a MD traffic flow, each group of motorcycles (classifying into groups based on specific driver behaviours) will be treated as an independent object. Relationship and interaction of such objects with surrounding and with each other follows micro simulation. Charactersistics of each group will be calculated with macro simulation measure.

Classifying object vehicles in the traffic flow can be applied not only in motorcycle traffic flow. In fact, from emperical observation, it is obvious to see that in specific conditions, based on different criteria of driver behaviours, we can determine different groups of moving vehicles on roads. For example, traffic flow moving in the tunnel, or car flow in large areas, with low density of vehicles, without fixed lane markings, etc.

DRAM method is applied in order to conduct micro research, based on the independent movements of vehicles in the traffic flow. Then, it is possible to calculate characteristics of the traffic flow such as average speed, flow volume and density. This process do not vague detailed characters of micro simulation but still take full advantages of macro simulation.

3.3.3. Progress of Modelling the Cause-and-effect Chain

One method to analyse and assess the internal cause-and-effect structure and interactions of a complex system is modelling. The (theoretical) modell helps a lot in simulate natural situations in a more or less theoretical world. The traffic system can be treated as a comprehensive system with interacting relationships among factors of human being – roads –vehicles – traffic flow – bound conditions. Occurrence of traffic conflicts and/or accidents (traffic unsafety) are results of some factor(s)´ error. There are several methodologies to analyse causes leading to traffic unsafety.

In the approach of human behaviour analysis, driver behaviour chain is taken as a focus to construct modelling of the traffic system. When conducting modelling, man should pay attention to the most important characteristics of models:

- There exists a theoretical world, which describes the real world (inside simulacrum or symbols of outside objects).
- The theoretical world has to be adjusted with observed data, and results calculated from the constructed model must be examined with the reality.
- Modelling allows to conduct analysis general characteristics in the theoretical world.

Constructed models must faithfully illustrate the real world and economical in being constructed, as well as logically consistent and mathematically precise:

- The faithful description is essential, as the model results can help in estimating the activity consequence in practice.
- The model must be so economical that there is no need to provide to much effort to realise the model.
- The model must be so logically consistent and mathematically correct that it is reviewable and is able to give out the conclusion about the internal cause-and-effect structure.

The model, based on risk analysis process, can simulate the cause-and-effect relationship of drivers in road traffic. By modelling those relationships between cause and effects, it is possible to do research on the reason for an accident happening.

There are many different approaches to do research on reasons for traffic unsafety. With the approach of analysing driver behaviour, the chain of driver behaviours are considered and treated as the central object to construct risk analysis models.

The process of constructing the risk analysis model can be described as follows:

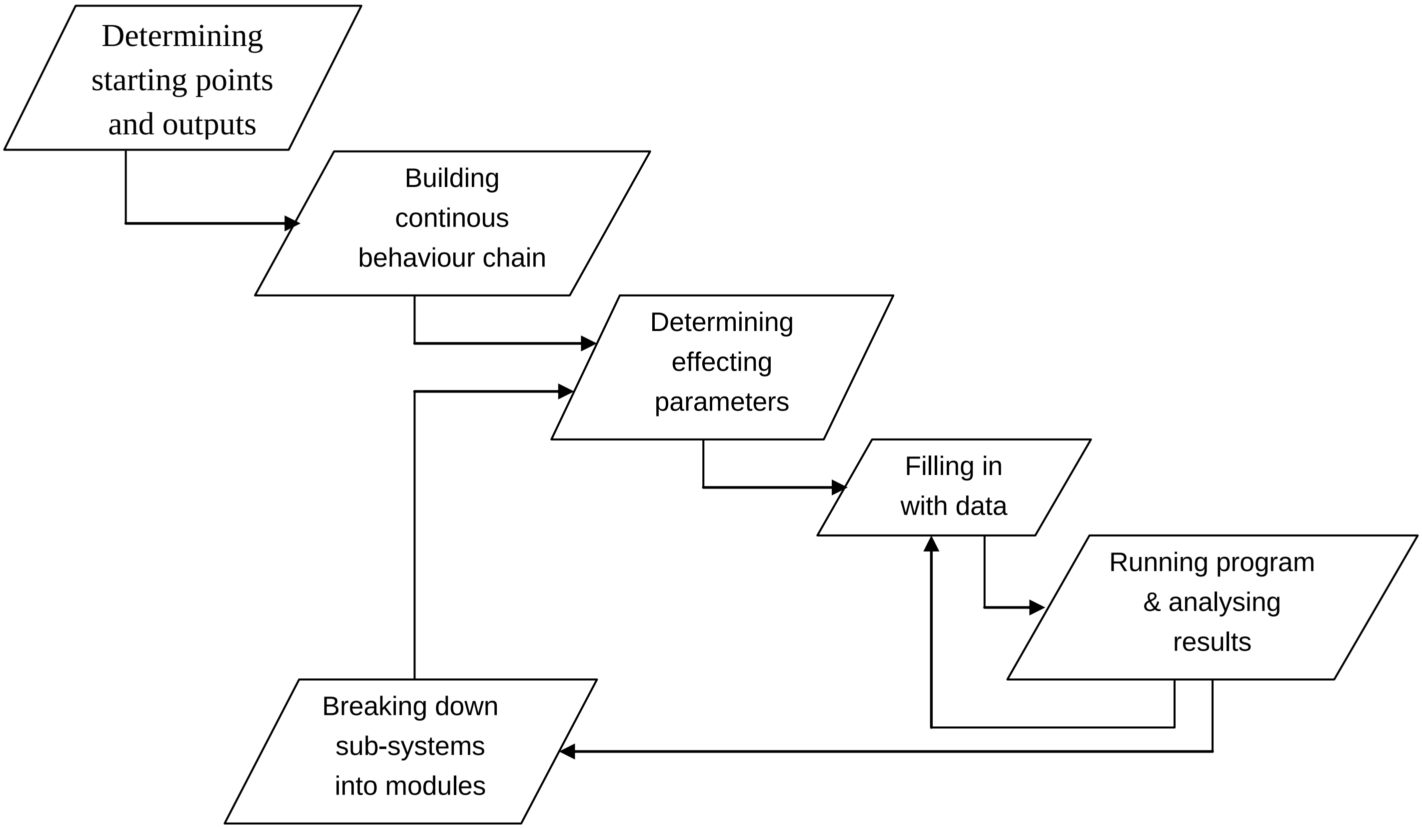


Figure 11. Process of constructing the risk analysis model

Step 1. Determining starting points and outputs of the model

There may be several targets and objectives to build the risk analysis model:

- Analysing risks from an existing situation to evaluate the level of dangers and give out the solutions if needed;
- Determining effects in reducing risks of the new traffic safety measures (in the trade-off with measures´ costs and expenditure);
- Determining risks for a new project of infrastructure;
- etc.

Depending on the target, it is required to clarify: starting points, objective output; the scenario description (including assumptions if needed); scope and scale of the model.

As mentioned above, DRAM methodology allows users to construct a risk analysis model based on the cause-and-effect chain of driver behaviour in a specific situation. There is also a computerized program available, with which it is possible to obtain risk values in the form of probability values. The program conducts calculation based on relationships among dependent and independent parameters, values of independent parameters which are provided bye users. There is also the possibility of calculating dependent parameters at any point of the model which is very helpful in validating and verifying the model. The user then has the duty of interpreting the model results and giving out suggestion and recommendation in the situation.

The characteristics of DRAM (especially its modularity) allow to describe the system systematically and selectively refine (parts of) the model according to the needs and available knowledge. Therefore, it is possible to start at any point of behaviour chain.

Risk analysis models can have such outputs as:

- Accidents (frequency, rates, level of damages,…)
- Risks or failures (damages and probability distribution, conflicts and probability distribution, etc.)
- Driving activities: speed, acceleration/deceleration rates, lane changing (yes/no), etc.

Step 2. Building continuous behaviour chain

This step requires to determine chain of events as well as chain of behaviour (from driver and the system) leading to traffic risks (conflicts or accidents).

The research of Grundlagen für die Anwendung von Risikoanalysen im Straßenwesen (Bald 1991) provides the following illustration process in traffic and/or traffic accident progress:

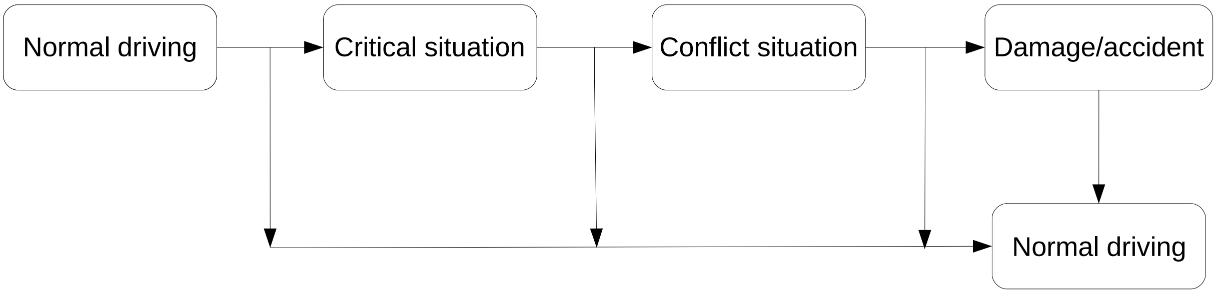


Figure 12. Accident progress

The progress of bulding continuous behaviour chain proceeding to accidents consists of determining “normal driving” and “critical situation” as well as driver behaviours reacting to those critical situation.

For the first step the basic structure of the system has to be found. The following figure shows the basic structure of the system “road traffic”. The structure starts with the “regular situation” as situation. It is followed by the sequence of driving (development). As result there is no change (the regular situation is back) or the consequence of driving is a damage.

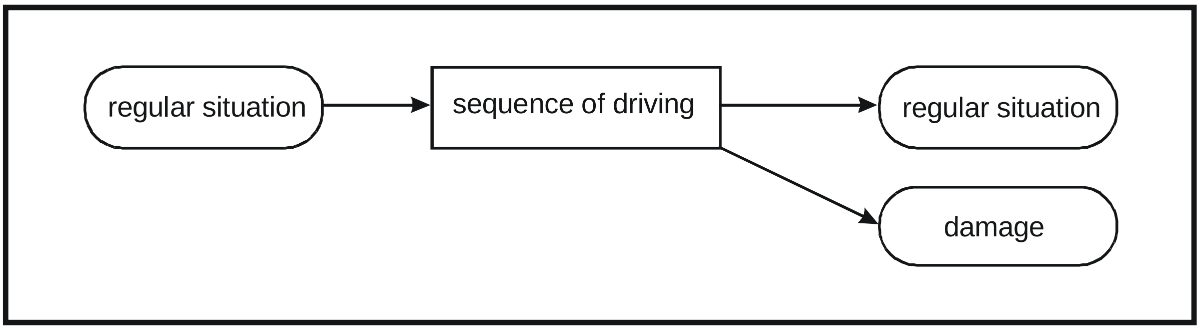


Figure 13. Basic structure of the system "road traffic"

[Durth, Bald 1988]

The development "sequence of driving" has to be differentiated into smaller developments with situations between. The system is composed of several situations (rounded boxes) and developments (rectangular boxes). All developments can lead to two different situations. On the one hand to the regular situation and on the other hand to a new situation to potential damage. The complex system is composed of independent modules, which can be analysed independently by different researcher groups.

There are some regulations when building continuous chain of behaviour:

- Modelling chain of behaviour is a model describing relationships among active and passive elements, where as active elements are actions of drivers (the system) and passive elements are situations of the system.
- Action (active elements/development) lead to the new situations
- After a situation is always an action and vice versa
- There may be several actions leading to one situation, however, in order to have the optimal capacity of the computing system, maximum input for one situation should be 4 actions (3 inputs are recommended). In the case of much more inputs, it is suggested to breaking the situation into sub-modules.

Step 3. Determining causing parameters:

Accident risk and accident consequence are here defined as stochastic variables, while the terms accident frequency and accident severity are defined as the actual outcomes, where obviously frequency is related to risk, and severity to consequence. In the research, the two components (further named factors) risk and consequence, are influenced by technical variables, further named determinants.

The guiding principles for identifying these factors and determinants are:

- to cover all traffic safety related situations;
- to avoid overlaps (as much as possible) between determinants;
- to provide a convenient and transparent framework for comparative analysis

In the research, only risk is studied, and not consequence. This applies, e.g. in cases where only numbers of accidents are known and no information on consequence is available.

Based on specific scenarios of modelling to determine impacting elemenst which may lead to risks. In the risk-analysed models of road traffic systems, impacting parameters belong to 5 groups such as: infrastructure, vehicle, human being, traffic flow and border circumstances.

In the methodology of DRAM, there is no requirement to take all parameters into consideration at the same time. Depending on the availability of knowledge and data, the method allows to conduct analysing each parameter´s influence gradually.

Step 4. Collecting data

Planning the schedule of collecting data, including the following steps.

- Determining input parameters required.
- Determining characteristics of each parameter (in order to quantify parameters´ values as well as their probability distribution).
- Determining relationships among parameters (developments of the model)
- Determining data source and methods of collecting data

Step 5. Running program and analysing results

Step 6. Breaking down sub-systems into modules

3.4. Data Collecting and Processing

3.4.1. Data Requirements

In order to quantify risk level, the first requirement is to provide the model with input data in the numerical form. Unfortunately, this requirement is not always possible, especially in the case of risk analysis and driver behaviour, which relate too much with such types of psychological and logical data (normally expressed in a verbal/text data format). Moreover, data on accidents are normally not sufficient and lack of information.

Using DRAM methodology, the research can start at any point in the whole process (the whole chain of behaviour).

Working in the context of lacking of numerical input data, it is possible to apply some available techniques and tools to convert from verbal/text data into numerical one:

(i) With the data available in statistical database.

(ii) With the required data but not available:

<u>Expertise´ opinion</u>

❖ Interviewees: Transportation managers and operators, Engineering/professional researchers, Policeman, Hospital.

❖ Contents:

  - VN law, regulation & standards dealing with traffic safety in intersections and left-turning movement: infrastructures, technical support (lane-marking, traffic signal and signs, etc.)
  - Database and statistics on traffic and traffic accidents: structural organization of management, traffic accident reports in all types.

- Driver behaviour in left-turning movement:
    - logical thinking (cause-and-effect chain of wrong left-turning movement ⇒ conflicts ⇒ accidents)
    - common errors and their causes, effects;
    - other characteristics
- Measurement (already applied/suggested and comment):
  - ✓ Enforcement: Law, regulation and standards
  - ✓ Engineering: Infrastructure
  - ✓ Education and training

Current situation (statistics)

- General overview on traffic and traffic safety:
  - ✓ Traffic situation: classification by:
    - Transportation mode
    - Location (urban or rural)
    - Road types (national roads, urban roads: main and small road, rural roads)
    - Road users´characteristics (dealing with transportation mode)
  - ✓ Traffic safety situation: statistics data through years with classification by:
    - Transportation mode
    - Location (urban or rural)
    - Road types (national roads, urban roads: main and small road, rural roads)
    - Road users´characteristics (dealing with transportation mode)
    - Accident causes
- Statistics data on traffic safety in urban intersections: number of accidents, location of accidents, damage level, involved party, direct causes, people who make errors (characteristics: age, gender, experience, occupation, transportation mode, …), etc.
- Traffic and traffic safety in left-turning movement in specific urban intersections: (video camera, photograph, field observation and counting): traffic flow, conflicts, accidents, etc.

3.4.2. Data Collection

An intersection can be regarded as a zone of transition along the road where the driver may have to adjust his speed and/or trajectory so as to comply with the regulatory and/or functional requirements resulting in a change from the previous driving situation. In the viewpoint of risk analysis, an intersection can be defined as a zone of high likelihood interaction with one or several other road users.

A number of researches have shown that when crossing intersections, driver display a certain inertia in the regulating actions they take or take time to become aware of conflicts with other drivers, and these are factors that can lead to accidents.

In order to do analysis on road traffic dealing with human behaviour, it is required a great amount of data. There are common methodologies to collect data related to traffic system such as observations, interviews, experts (police, policy makers, road engineers, etc). In-depth analysis normally requires experimental observations or field observations with specific supporting equipments.

The three most frequent types of data collecting methods applied in transport and traffic engineering are field counting, statistics and surveys. Statistical data give out historical information in available database. Field observation involve direct observation of traffic activity at fixed locations, such as crosswalks or intersections. Interviews indirectly capture mobility demand in a geographic area by gathering travel data from a sample, as well as obtaining experts´ knowledge.

3.4.2.1. Statistical data

In Vietnam situation, the Staff Bureau, under the Traffic Police Department, is responsible for collecting road traffic accident data. This bureau is responsible for data processing and reporting accident statistics; accident data are collected on a bureau-provided form.

Traffic police investigators at accident locations will collect accident data and make reports using the form daily, weekly, and monthly. Completed forms are then sent to the Staff Bureau. For a serious accident, a report will be sent to the Staff Bureau immediately. The accident data reported will be computerized. Reports made by the Staff Bureau are sent to the Ministry of Public Security, National Traffic Safety Committee (NTSC), and Office of the Government, for their further action. Reports on road traffic accidents by the Staff Bureau are very useful in helping these agencies direct road safety work. Accident reports by local traffic police are merely statistical reports. Deaths after a certain number of days after an accident are not fully reported. There is no definition for reporting the deaths of victims that occur within 30 days of accidents. Viet Nam should define the period for fatal reports.

In accordance with the Decree No. 14/2003/ND-CP dated 19 February 2003, Road and Railway Traffic Police Bureau of MOPS is responsible for reporting of road traffic accidents.

The present road accident reporting system begins with the traffic police accomplishing a two-sided form “Form-45GT” at the accident scene that is then forwarded to the national office of the Traffic Police, usually within one month after accident. The road traffic accident report form covers accident times, accident locations, fatalities or injuries, vehicle damage, weather conditions, collision types, and accident sketch maps. Information from “Form-45GT” is manually totaled at provincial Traffic Police headquarters to give a one or two page summary on the number of reported accidents, fatalities and injuries, as well as a simple analysis on the cause, type of vehicle and type or road. The summary report is forwarded to the Traffic Police central office where it is consolidated and sent to NTSC. For accidents involving one or more fatalities, a “Hot Report” (“Form-44GT”), which is a summarized “Form-45GT”, is sent to Traffic Police central office immediately in order to give factual information to police management.

The traffic accident reporting system is described as follows:

i) When an accident occurs, people report either to the nearest police station or to the police on the road. In a number of cases, however, they settle the matter without involving the police.

ii) At the accident scene, traffic police are responsible for giving emergency aid to victims, securing the scene and easing traffic congestion.

iii) Accident information is relayed to the district or town traffic police or sometimes, directly to the city/ provincial police.

iv) After being notified, the investigating police proceed to the traffic accident scene to collect, investigate and compete the accident record. In traffic accident cases with no criminal liabilities, the investigating police send the records to the traffic police office. However, for serious traffic accidents which may result to criminal cases where the punishment is more than 15 years, the completed report will be sent to the provincial/city investigating police.

v) The city/provincial traffic police office is responsible for dealing with accidents involving senior cadres and foreigners.

vi) The city/provincial traffic police office is responsible for relaying information on serious accidents with criminal evidence to the city/ provincial traffic police.

vii) The provincial traffic police office reports the accident data to the traffic police national office.

viii) Reports are archieved by the originating office of the traffic police or investigating police.

No close coordination in road accident reporting exists between the Traffic Police Department and hospitals. This needs to be improved. Not all road accidents are fully reported, particularly minor accidents.

Such situation of statistical data approves of the urgent demand for standardizing accident data and accident report form. In order to conduct researches in the area of risk analysis, it is also required to have such statistics data of: infrastructures, traffic conditions, vehicles, driver skills and characteristics, other surrounding elements. An intended database is therefore also needed. This database will also help much in historical data, where we can follow the way to enlarge experience of a driver in driving skills.

3.4.2.2. Field observation

Traffic volumes at intersections are usually collected directly using either (i) manual counts, taken by collectors in the field, or (ii) automated counts using specialized equipment. Although automated counting devices are very popular in developed countries, the technology for counting modes of transportation is not yet developed in developing countries such as Vietnam.

The accuracy of these counting methods directly affects the accuracy of the exposure estimate and thus the value of the risk analysis at an intersection.

Manual counting methods are frequently used to quantify all types of transportation activity, including vehicle, bicycle, and pedestrian volumes. Manual methods are the most frequently used method of counting pedestrians, particularly for studies that require small samples of data at specific locations, such as pedestrian crossings.

The two most common manual counting methods used to measure pedestrian flows at crossings are:

- Field observations: in which pedestrians are observed in the field and counted by hand.
- Video-recordings: in which camera recordings of pedestrian crossings are taken and then processed through playback and manual recording.

Field observations are typically used for periods of less than a day. The normal intervals for counting are 15, 30 or 60 minutes. The counts are recorded with tally sheets. Tally sheets can include an individual line for each pedestrian and his or her characteristics and/or behaviour can be recorded, due to the desired information.

Manual-video recording uses cameras to record images of traffic flow which are later reviewed by an observer. The observer records the number of vehicles as well as driver characteristics and behaviour, if needed. Detailed review of behaviours, or crowded traffic flow conditions, may require that the observer review the video in variable time (e.g. slowing and speeding the video as needed). Specialized video-playback tools may be used to facilitate review of the videos. Howver, such kinds of tools has not been very common in Vietnam so far. The central issues with the manual-video method of counting pedestrians are the need for a good camera angle and resolution and the long time required to review the video tapes, estimated to be three times the tape length (Diogenes et al., 2007).

In general, automated counting of vehicles is advantageous because it can reduce the labor costs associated with manual methods. It also has the potential to record vehicle activity for long periods of time that are currently difficult to capture through traditional methods.

Automated methods are commonly used to count motorized vehicles in developed countries, but are not used in Vietnam at this time. The reason of the situation may be that there is lack of appropriate attention to the urgent case from authorities.

3.4.2.3. Interviews

Hurworth (1996) classified interviews into 4 types of informal conversation, semi-structured, standard structured and focus group interviews.

Informal conversation are spontanous and take place in corridors or over coffee. They have the advantage of allowing free-ranging responses, and “natural” conversations. The disadvantage is taking time. They also require a lot of skill in order to obtain useful data and the data collected is hard to analyse because it has been informally expressed. There are also ethical issues that may prevent the use of such interviews for formal research projects.

Semi-structured interviews use a general guide and a list of topics and questions. They have the advantage of allowing an interviewer to concentrate on specific topics and issues and it is more focussed than informal conversations. Like informal conversations, however, they have the disadvantage of requiring great skill to keep focussed on the intended topics and minimising extraneous material. This type of interviews is suitable with getting opinions from experts when interviewees may have their own opinion and knowledge that the questionairs cannot cover all.

Standard structured interview involve setting precise questions. They have the advantage of consistency and more efficiency in conducting (requiring less time). Data collected is more focused and easier to analyse as the questions have been designed carefully.

Focus group and group interviews use a selected group of representative people in order to collect data about a larger population. A focus group interview starts with broad general questions, then move to focus question which are the target of the interview. In a group interview, the order and arrangement of questions are less important.

3.4.3. Hypothesis Testing

Normally, data needed for transportation and traffic engineering are in large amount and continuously. It is impossible to obtain, as well as processing, such amount of data. In order to figure out input data for the risk analysis model, the research has to work with samples. From empirical samples´ characteristics, required data will be obtained with the technology of hypothesis testing.

From theory of statistics (e.g., Introduction to the Theory of Statistics (McGraw-Hill Series in Probability and Statistics)), we can see some main points related to hypothesis testing as follows.

A ***Hypothesis*** is a statement or assertation about the state of nature (about the true value of an unknown population parameter). For example: “The accused is innocent”.

One may be faced with the problem of making a definite decision with respect to an uncertain Hypothesis which is known only through its observable consequences. A ***statistical Hypothesis test***, or more briefly, *Hypothesis testing*, is an algorithm to state the alternative (for or against the Hypothesis) which minimizes certain risks.

Every Hypothesis implies its contradiction or alternative. A ***null Hypothesis***, denoted by H_0, is an assertation about one or more population parameters. This is the assertation we hold to be true until we have sufficient statistical evidence to conclude otherwise.

The ***alternative Hypothesis***, denoted by H_1, is the assertation of all situation *not* covered by the null Hypothesis. It is required that H_0 and H_1 are mutual exclusive (which mean that only one can be true) and exhaustive (meaning that together they cover all possibilities, so one or the other *must* be true).

The null Hypothesis:

- often represents the status quo situation or an existing belief.
- is maintained, or held to be true, until a test leads to its rejection in favor of the alternative Hypothesis.
- is accepted as true or rejected as false on the basis of a consideration of a test statistic.

A ***test statistic*** is a sample statistic computed from sample data. The value of the test statistic is used in determining whether or not we may reject the null Hypothesis.

The ***decision rule*** of a statistical Hypothesis test is a rule that specifies the conditions under which the null Hypothesis may be rejected.

A Hypothesis testing is conducted in order to give out a decision. Generally speaking, there are two possible states of nature that H_0 is true or H_0 is false. Then a decision may be incorrect in two ways: (i) a true H_0 is rejected (Type I Error) with the probability denoted by α (α is called the ***level of significance*** of the test); (ii) a false H_0 is failed to be rejected (Type II Error) with the probability denoted by β ($1 - \beta$ is called ***the power of the test***).

The ***p-value*** is the smallest level of significance, α, at which the null Hypothesis may be rejected using the obtained value of the test statistic.

The ***rejection region*** of a statistical Hypothesis test is the range of numbers that will lead us to reject the null Hypothesis in case the test statistic falls within this range. The rejection region, also called the critical region, is defined by the critical points. The rejection region is defined so that, before the sampling takes place, our test statistic will have a probability ***P*** of falling within the rejection region if the null Hypothesis is true.

The ***non-rejection region*** is the range of values (also determined by the critical points) that will lead us not to reject the null Hypothesis if the test statistic should fall within this region. The non-rejection region is designed so that, before the sampling takes place, our test statistic will have a probability 1-***P*** of falling within the non-rejection region if the null Hypothesis is true

In the progress of Hypothesis testing, a Hypothesis is considered as a scientific Hypothesis when the Hypothesis has falsifiability (or so-called falsibility). Empirical falsification is the method to conduct experiments in order to find out evidence to approve or falsify a state of the nature. It is able to consider the falsification progress as a learning progress from try and errors. Then doing scientific research is the progress of Hypothesis testing which consists of the following steps:

- Determining the null Hypothesis
- Determining the alternative Hypothesis
- Examining the correctness of the null Hypothesis (calculating α, β, and *p*-value)
- Deciding to accept or reject the null Hypothesis.
- If the null Hypothesis is rejected, then the alternative Hypothesis is accepted by default.

Let´s take an example of speed of motorcycles in the traffic flow.

Speed of motorcycle traffic was measured from two different locations with the following characteristics.

Table 1. Average speed of motorcycles (examples)

Location	Motorcycle volume	Number of sampling	Observed speed				
			Mean (km/h)	Max (km/h)	Min (km/h)	Standard deviation	
						(km/h)	%
1	3.240	582	32,3	55,2	14,3	5,7	17
2	2.621	270	32,7	56,3	20,9	5,2	15
Average			32,5				

Assuming that speed of motorcycle traffic is a variable (called X) which follows Normal distribution.

From the above mentioned empirical observation, there may be different types of Hypothesis testing to determine mean and standard deviation of variable X such as:

- Testing μ_x (when σ_x unknown)
- Testing σ_x
- Comparing characteristics of motorcycle mean speed and deviation among the two selective locations.

Solution: (to test μ_x for the location 1)

With location 1, we have:

Hypothesis for two-tailed test:

H_0: $\mu = \mu_0 = 32{,}5$ H_1: $\mu \neq \mu_0$ For $\alpha = 0{,}05$, critical values of z are $\pm$ 1,96 (based on the table of z for Normal distribution)

The test statistic is: $t = \dfrac{\bar{x} - \mu_0}{\dfrac{s}{\sqrt{n}}}$

Decision making will be:

- Do not reject H_0 if $(-1{,}96 \leq z \leq 1{,}96)$
- Reject H_0 if $(z < -1{,}96)$ or $(z > 1{,}96)$

In the example of location 1, we have:

n = 582

$\bar{x} = 32{,}3$

s = 5,7

Done, it is calculated that:

$$t = \frac{\bar{x} - \mu_0}{\dfrac{s}{\sqrt{n}}} = \frac{32{,}3 - 32{,}5}{\dfrac{5{,}7}{\sqrt{582}}} = \frac{0{,}2}{\dfrac{5{,}7}{24{,}12}} \approx 0{,}85$$

Then, we can ***conclude*** with the confidential level of 95% that motorcycle mean speed is 32,5km/h.

4. Traffic Safety in Motorcycle-dominated Traffic Flow

4.0. Introduction

The major aim of the research is to conduct risk analysis on driver behaviours at intersections in motorcycle-dominated traffic flow. In order to apply the methodology of DRAM, it is essential to comprehensively understand the current situation of traffic flow as well as the driver behaviour in specific cases (so-called critical situations, which have the high percentage of leading to traffic conflicts and/or accidents).

The very first step of the methodology will be constructing the cause-and-effect chain. Description on the scenario of left-turning movement as well as different approaches to conduct risk analysis at intersections in motorcycle dominated traffic flow in big cities in Vietnam is provided. The first approach is the accident progress, which deals with the gap between normal driving and reaction to critical situations. The second will be the approach of conflict analysis. There are arguments on two concepts of “conflict zones” and “conflict time segments” which can be further developed to determine the hazard that drivers have to face with in their left-turning movement at intersections in motorcycle-dominated traffic flow. Both concepts are developed from the physolophy of Conflict Technique in car traffic flow, with the modification in order to be relevant in case of the distinguishing characteristics of non-lane based movement of motorcycles. The other possibility of starting from a known psychological model will be discussed in the next chapter.

4.1. Driver Behaviour and Traffic Safety

4.1.1. Current Situation in Vietnam

From police reports, driver errors are the main reason for traffic accidents in urban areas. In the area of Ho Chi Minh City, only in the first three months in 2008, there are 146 accidents caused by driver lane misuse, leading to the death of 145 people. The policemen argue that "High traffic volume along with bad road conditions leads to the capacity decrease of the whole traffic system. After the bottleneck (congestion), vehicles, especially motorcycles, always accelerate, using the wrong lane, which is very dangerous and may cause traffic accidents”.

In the whole country, there have been a survey conducting to study the major causes to accidens. From the report of NTSC (National Traffic Safety Committee, 2006), there are the list of major causes to accidents (only a sampling amount of accidents is analysed) as follows.

Table 2. Major causes to road traffic accidents

Causes		2001		2003		2005	
		%	Quantity	%	Quantity	%	Quantity
Total number of accidents			25.040		19.852		14.711
Number of sampling analysed accidents		100	14.332	100	771	100	8.485
1	**Road user´s error**	76	10.896	83,9	647	66,4	5.629
	Speeding	32,7	4.686	27,5	212	31,3	2.656
	Dangerous overtaking	25,7	3.686	20,1	155	15,5	1.317
	Drunk driving	5,9	841	5,4	42	6,0	506
	Poor road observation	8,3	1.183	13,4	103	12,0	1.015
	Misuse of lanes	-	-	14,1	109	1,6	134
	Pedestrian	3,5	500	3,4	26	4,4	371
2	**Unsafe vehicle conditions**	1,3	191	0,4	3	0,7	56
3	**Infrastructure**	0,2	33	0,3	2	0,2	12
4	**Others**	22,4	3.212	15,4	119	28,5	2.418

(Source: NTSC report, 2006)

Causes to accident are listed also as high increase of registered vehicles, irrelevant infrastructure (as the mobility demand increases at the high pace), dangerous mixed traffic flow, traffic safety education and training without expected results, irregular enforcement, etc. It is reported many serious accidents caused by the mixed traffic flow (with participants of different types of vehicles with different sizes) whereas drivers drive in the wrong lane, which cause delay in average traffic flow speed as well as reduce road traffic capacity.

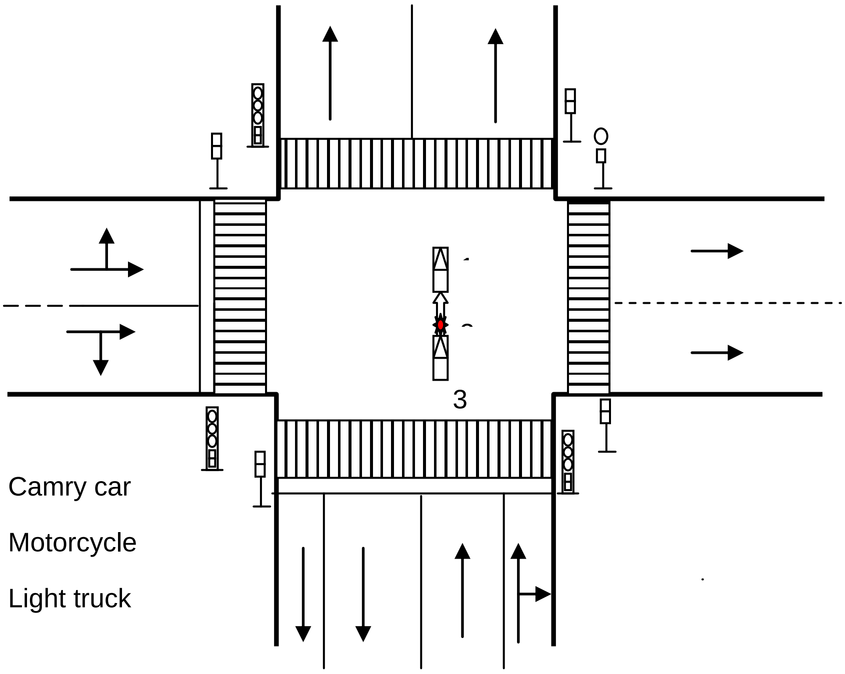
As mentioned from above (chapter 3), traditional statistical methods conduct only the analysis on simple relationships between causes and effects (speeding, poor observation, etc. with number of conflicts, accidents, etc.). In fact, the only cause of speeding, for example, normally cannot lead to a conflict or an accident. Let´s compare two drivers riding in the street. The first driver drives very fast, but he concentrates highly in driving, with good experience in driving, skilful and quick reaction, etc., therefore the probability that he cause an accident will be low. In contrary, the second driver rides at a lower speed, but he has a limited visibility when approaching the intersection, or he does not pay proper attention to his task of driving. Meanwhile, if a critical situation happens (for example, a red-light turning vehicle unexpectedly cross the vehicle trajectory), then the probability of inappropriate reaction is much higher, which is in turn may lead to the higher probability that an accident may happen.

Let´s considering one example of serious accident causing by violating traffic signals (red-light running). On February 11th, 2009, at 16:30pm in Hanoi, there happened a very serious accident in the intersection of Hung Vuong – Phan Dinh Phung, the reason of which was a red-light running car. At the accident site, the motorcycle of Future BKS 29N3-4350 laid under the car of Toyota Camry BKS

30K-0183. The motorcycle was hit from rear end by a light truck. Eyewitnesses at the site described that when the traffic signal was going to change from green to red light, the truck tried to enter the intersection, the driver could not control the speed and hit the motorcycle ahead (in the same moving direction). After being hit heavily, the motorcycle was pushed towards the leading Camry car. The patient was taken to an emergency hospital in a serious situation.

Figure 14. A red-light running accident

(Source: www.vnexpress.net)



Legend: 1. Camry car

2. Motorcycle

3. Light truck

Figure 15. Sketch of the red-light running accident

Argument: There is not enough information about the accident. However, it is obvious that there must be some conditions coming together in order to cause such a serious accident. For example, the causing elements may be: bad quality of vehicles (braking system of the truck, no traffic safety facility for the motorcycle), road conditions (sliding, wet surface), headway from the car of Camry and the motorcycle, current speed of the truck, driving skill and motivation of the truck driver (experience, visibility, perception skill in the near-to-dark time, the need to arrive at the destination in time, etc.), etc… Cases of causing an accident/conflict and running away are not very rare in Vietnam. There is no effective enforcement such as automatic camera to catch the violation behaviour. The policemen do not always have such facility as police car to catch violators.

The accident is rather a rare event. Causes leading to an accident are the composition of many different elements. Whereas analysing risks by constructing the chain of driver behaviour requires a lot of data as it would like to take into consideration all influencing factors and remove the over-lapping effects. Building a standard database of accident with clear and appropriate objectives for analysing risks is essential.

4.1.2. Accident Progress

The research of Foundation for applying risk analysis in road traffic (Bald 1991) provides the following describing process in traffic conflict and/or traffic accident progress:

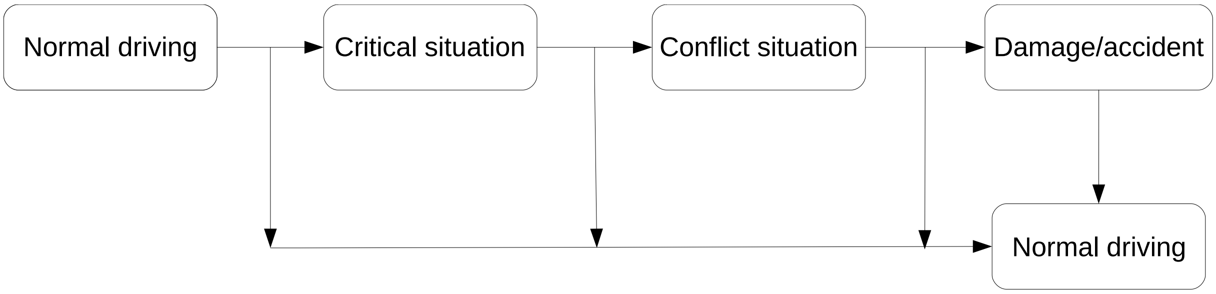


Figure 16. Accident progress

Such physolophy of accident progress has been applied in doing research on traffic safety in Europe (e.g. Risikoanalysen im Straßenwesen, Walter Durth, J.Stefan Bald, 1987, Grundlagen für die Anwendung von Risikoanalysen im Straßenwesen, J.Stefan Bald, 1991, Approaching curve, or IN-Safety project, 2008).

The accident progress clarifies that, in normal driving, the drivers may have the opportunity to meet critical situations, which may in turn lead to conflict situations, and then to traffic accidents (with or without damages). At every point of accident progress, we know that there are two possibilities, one of which is that the driver can appropriately cope up with the situation to continue his normal driving. In the other case, the worst combination of bad situations will lead to conflicts and/or accidents (as described in the above diagram).

Applying the methodology of cause-and-effect chain, it is required to determine the relationship from causes to effects. It depends on the research target to determine the expected "effect" (in fact it is the question of determining output parameter in the whole chain). For example, the result (output) of the driver behaviour chain may be conflicts, or accidents, or may be only some types of behaviours such as behaviour of violating road traffic regulations…

It is not necessary to construct the cause-and-effect behaviour chain based on accident progress in the only direction from the real cause to expected effects. We have three possibilities to conduct risk analysis in traffic safety:

(i) From the causes to effects: analysing from the normal driving to expected effects. For example, in case, the driver meets a critical situation (e.g. a red-light running crossing his trajectory), the whole procedure may be analysed as shown in Figure 17.

(ii) From the effects to the causes. Based on statistical data, we can see all the expected results (effects). Group causes (statistical data) based on determined criteria. Take different causes into consideration. In its turn, this object (parameter) will become a specific "effect" which is in need of determining their "cause(s)". The process will be repeated with all branches of the chain and will finish when all data and knowledge have been taken full use of.

(iii) Mixing the two above-mentioned possibilities.

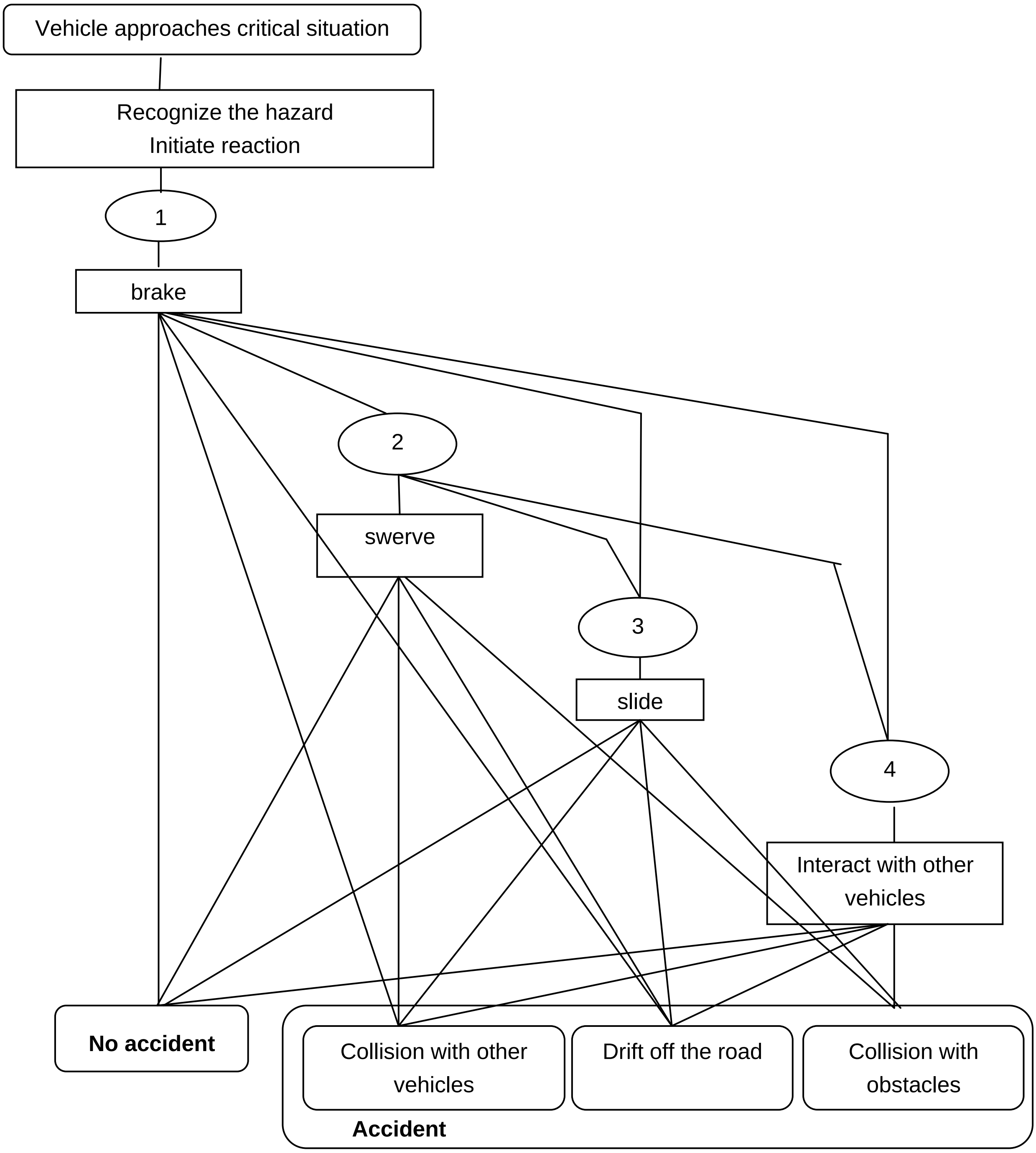


Figure 17. Chain of unfortunate events at intersections in MD traffic flow

This chain of unfortunate events has been applied into doing researches in European conditions of traffic flow (e.g. Lippold, Mattheß, Durth 1992). The above-mentioned behaviour chain has been adjusted in order to fit well with the accident situations at intersections in Vietnam.

4.2. Prescribed Tasks in Left-turning Movement

Driver behaviour aims at describing and analysing driver behaviour in situ (as safe or unsafe, legal or deviant,…), to identify the internal factors (relating to the driver himself, such as his experience, cognition, motivation, etc…) and the external factors (the technical and social environment of driving) that account for this behaviour, and to reveal the psychological processes (perceptual, cognitive, motivational,…) that govern drivers´ activity.

This approach, classic in Ergonomics and Work Psychology, thus calls for analysis of the prescribed task (what a driver has to do in a given situation) and the actual task (what a driver effectively does) with the aim of identifying the possible discrepancies between these tasks and their origins (see, for example, Leplat 1990). The prescribed (or formal) task is the task to be carried out as conceived by the designer of the system and/or the safety manager. It sets out (more or less explicitly) a number of prescriptions, which are supposed to influence and to some extent guide driver activity. In other words, the prescribed task defines the behaviour expected of the driver, what he should do (in terms of performance and/or procedures to follow). Analysing the prescribed task in a given situation thus involves identifying the demands and constraints imposed upon drivers' activity (formal rules for using the road and for managing interactions with other users, as defined by the highway code; design and layout of the infrastructure; traffic conditions; and so on).

The actual task consists of what the driver actually does, the demands and constraints that s/he effectively takes into account. Identifying the actual task calls for a detailed analysis of driver behaviour with the aim of determining exactly how drivers organise and perform the driving task: what their goals and intentions are, what information they select from the environment, what motives and criteria underlie their decision-making, and what regulating actions they take. Research in the field of driver behaviour is concerned with analysing drivers´ behaviour, taking into account their own characteristics as well as the characteristics of the task to be performed. The conflicts/accidents happen when the drivers cannot react appropriately with critical situations.

Understanding and analysing driver behaviours in road traffic is a rather complex duty which requires cooperation of many disciplines. The task becomes more difficult in the case of ant-crawling motorcycle-dominated traffic flow. Task Analysis of Intersection Driving Scenarios: Information Processing Bottlenecks (2006), provided the prescribed tasks in left-turning process, applied for car traffic flow. This part deals with driver prescribed tasks (tasks in normal driving) when proceeding left-turning manoeuvres at intersections with the modification to fit with motorcycle-dominated traffic flow (values of speed are extracted from previous surveys as mentioned in chapter 2).

There are two scenarios of complete stop or non-stop before traffic signals (as an individual driver). The first scenario involves the subject vehicle making a left turn on a green light.

Figure 18 shows the scenario partitioning based on driving objectives and speed characteristics by segment. Briefly described, this scenario involves the subject driver identifying the intersection as the turn location, then decelerating to a stop. Following the stop, the subject vehicle advances into the intersection and waits for an appropriate gap in oncoming traffic before making the turn.

Table 3. Left-turning prescribed tasks on green lights

Segment	Driving objectives	Speed characteristics
Approach	Indentify upcoming intersection as the location of the turn	Travelling at full speed
Deceleration	Stop at the intersection	Controlled deceleration until stopped
Intersection entry	Get into position to turn	Slowly advance into position
Prepare to turn	Wait for a safe gap in oncoming traffic	Stopped until clear to go
Execute turning	Make the turn	Turning and accelerating up to speed

An approximate timeline showing the key temporal milestones for scenario 1 was calculated based on vehicle kinematics (

Figure 18). These milestones were used to make judgments about the pacing of tasks within segments, and they also provide a basis for the overall sequencing of certain tasks. Most segments included an interval with a variable time component, which represented intervals that either were long enough to effectively provide unlimited time to perform tasks or of a duration that was determined external to vehicle kinematic factors (e.g., waiting for the leading vehicle to turn).

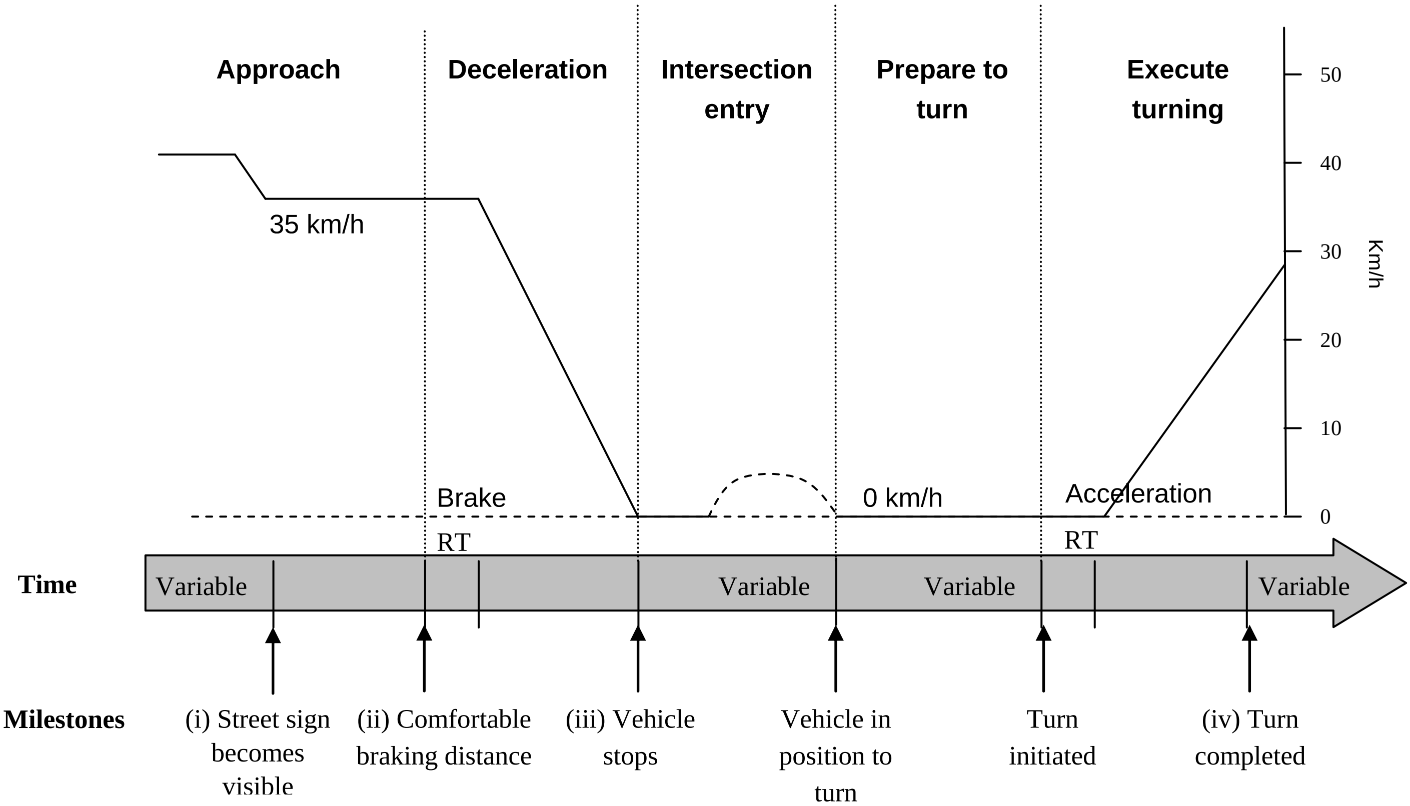


Figure 18. Time scale of left-turning movement with stopping

The second scenario involves a vehicle making a left turn on a yellow light. **Figure 19** shows the scenario diagram and provides additional details regarding the scenario. Briefly described, this scenario involves the subject driver identifying the intersection as the turn location, then decelerating. As the decelerating subject vehicle nears the intersection, the traffic light turns yellow. With no leading traffic and with the subject vehicle close enough to the intersection to go, the vehicle enters the intersection after determining that it is safe to do so and proceeds with the turn. The alternative scenario in which the traffic signal turns yellow while the driver is established in the intersection and waiting for a gap in traffic is probably more common because drivers spend more time in this phase; however, this situation was not investigated because it is nearly identical to scenario 1 with the exception that the onset of the yellow light simplifies the task by stopping oncoming traffic.

Table 4. Left-turning on yellow light

Segment	**Driving objectives**	**Speed characteristics**
Approach	Indentify upcoming intersection as the location of the turn	Travelling at full speed
Deceleration	Slow to turning speed/stop	Controlled deceleration until stopped
Intersection entry	Determine if there is sufficient time to turn and whether it is safe to do so	Slowly advance into position
Prepare to turn	Get into position to turn	Stopped until clear to go
Execute turning	Make the turn	Turning and accelerating up to speed

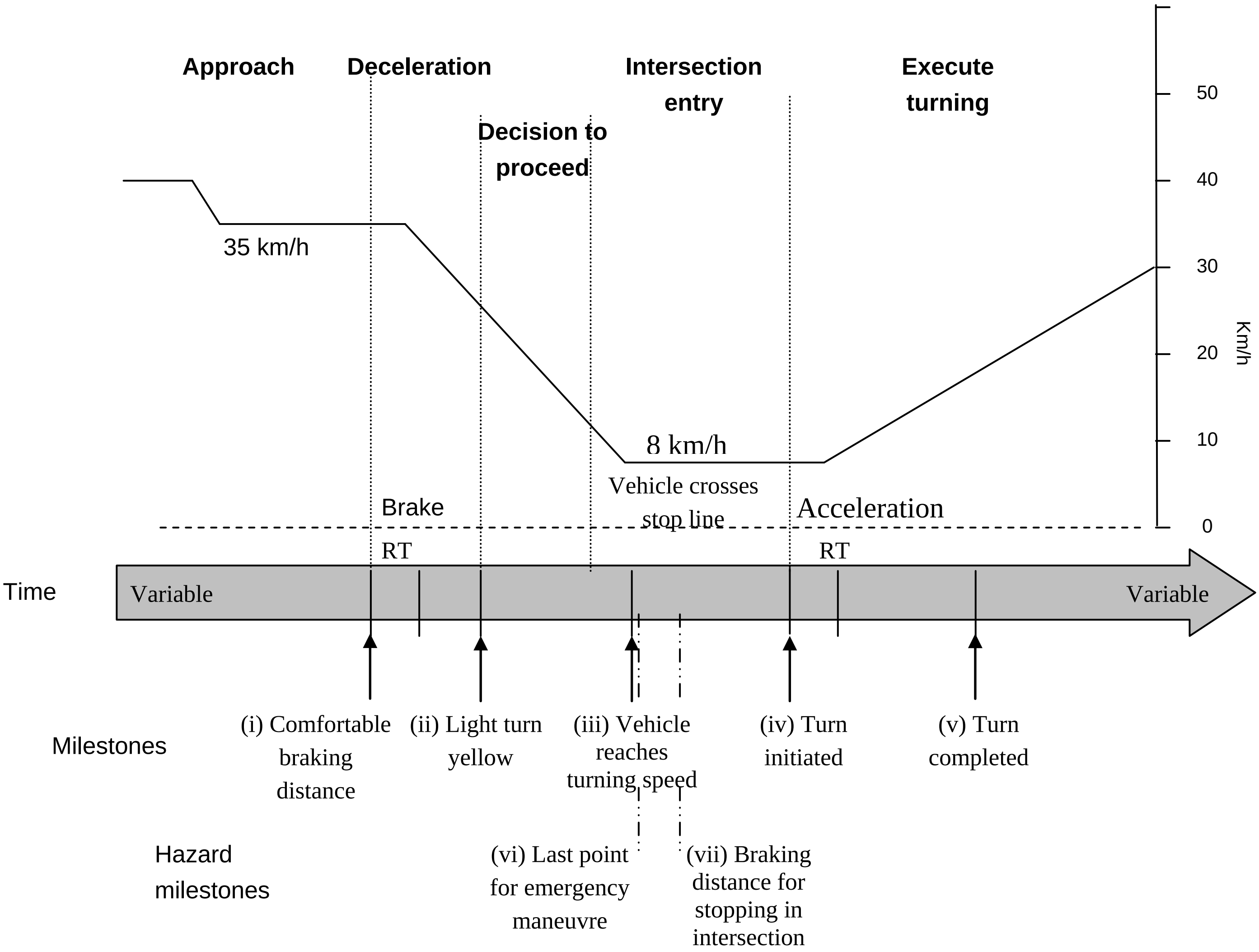


Figure 19. Time scale of left-turning movement without stopping

Then we can see, in the normal driving, if there is any critical situation happens, then it depends on the driver´s reaction. The conflict or accident can happen at any point during the driver´s normal driving. Let´s see what are critical situations that drivers may meet in left-turning movement at intersections. Critical in road situation may be linked to, among other things:

- Changes in the road infrastructure: a main road that passes through an urban area, a bend after a straight section of road, or an intersection;
- Changes induced by the behaviour of other users: a user arriving at or crossing an intersection, for instance, or a driver slowing down in front of the driver or cutting in on her or his lane.

For the driver, these variations may be more or less predictable, and more or less expected, depending on whether or not s/he has the knowledge and the information needed to detect and identify them as s/he drives along.

This suggests that there are two main types of driving problems and points to the approaches to be adopted for designing the road infrastructure and driving aids:

- One set of problems has to do with identifying infrastructure characteristics likely to facilitate the reading of road situations and the detection of changes in the situation, which can be grouped under heading of “the readability of the road”
- The second problem relates to the management of interactions between users and calls for the cues and modes of communication likely to facilitate the dynamic management of interactions to be identified.

Those studies have been conducted in developed countries, in which car drivers are large percentage in the whole traffic. In the case study in Vietnam, critical situations that motorcyclists may meet are totally distinguished. In this case, critical situations are defined as that situation which may lead to traffic conflicts, which is in turn defined as cases when one or more drivers have to adjust his/her speed and/or trajectory.

Critical situation which may lead to a traffic conflict and/or accident can be defined in other ways. In the approach of risk analysis, critical situations are such situations occurring beyond the driver´s expectancy. Those critical situations have such a high probability of leading to a conflict or accident. From empirical observation in the streets, there may be a list of critical situations that motorcyclists can meet during his /her left-turning manoeuvre.

When doing research on left-turners (excluding risks of internal conflicts, that means the risk of conflicts among vehicles in the same movement, left-turning in this case), then we can see the critical situation as the risk of being in a conflict with other movements. Taking into consideration a vehicle of left-turning from South to West, there are such critical situations to meet vehicles in other movement directions listing bellows:

1. On-coming traffic flow (North – South)
2. Red-light running crossing flow (West – East and East - West)
3. Red-light running left-turning from the right side (East – South)
4. Potential conflicts with vehicles in the same branch of roadway, including:
    a. U – turn vehicles from right side (South – South)
    b. Right – turning vehicle(s) from left side (South – East)
    c. Straight vehicle(s) from left side (South – North)
5. Conflicts with pedestrians who are crossing the streets disobeying the traffic signals.

There raises such research questions as follows:

- How often such kind of critical situations happen?
- How dangerous those situations are? (their probability in causing traffic conflicts and/or accidents)
- How to do influence on frequency of such situations?

Applying the approach of risk analysis into doing research on accident progress at intersections, we can also analyse the driver behaviour chain in the real time progress. From the prescribed task as mentioned above, when conduct the behaviour of crossing the intersection, normally the driver has to pass those actions of approaching, waiting (in the waiting line for green light, or inside the intersection area for other vehicles who have the higher priority in crossing the intersection), entering, and leaving. The critical situation can happen at any segment of the whole moving process. The worst case may be accidents with or without damage.

We have the time chain, which may lead to a traffic accident, describing critical situations which may happen during the normal driving as follows:

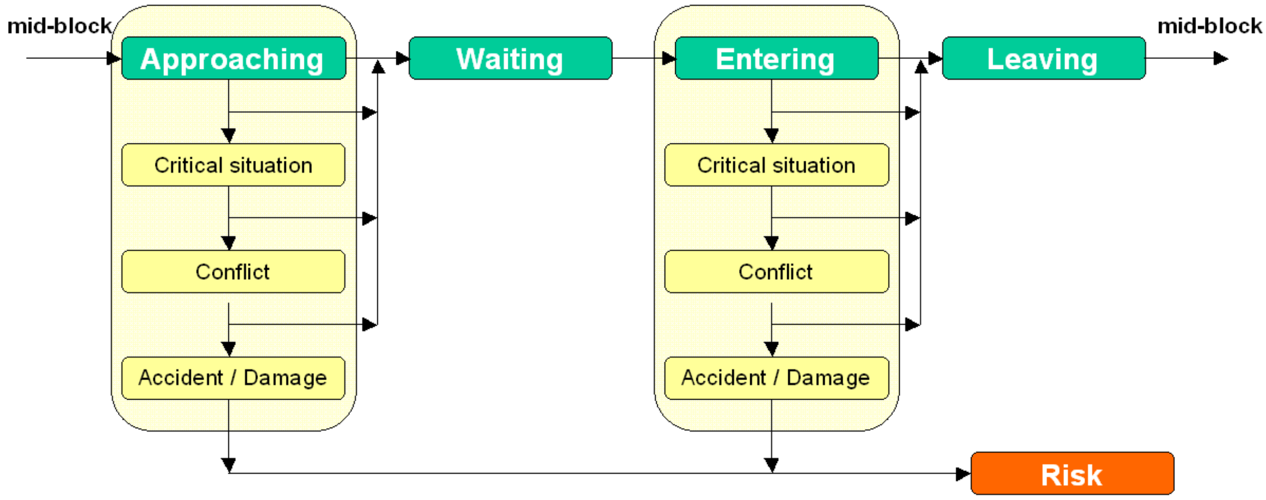


Figure 20. Chain of driver behaviour in time zones analysis

Calculation to determine the risk level in every segments of driver behaviour chain of crossing through intersections may apply also the approach of risk analysis with probability variables and Bayes formula.

4.3. Groups´ Behaviour in Motorcycle-dominated Traffic

It is obvious that behaviours of motorcyclists depend very much on people surrounding. The main reason is that motorcycles´ flexibility and manoeuvrability allow motorcyclists to adjust speed and trajectory rather easily while moving. Then, crowded traffic with small spacing (both lateral and longitude distance) among different vehicles will have such influences causing the motorcyclist impossibility to move in his own cognition and motion.

In other words, depending on the crowded and uncrowded status of traffic flow, driver behaviours can be considered as behaviours of an individual motorcyclist or a group of motorcyclists (meaning that following motorcycles are much dependent on the leading one). In the situation of uncrowded traffic flow, driver behaviours are taken into consideration as an independent subject vehicle. In crowded traffic flow, the research object will be the subject group of vehicles. In the second situation, there raise concepts of external conflicts (traffic conflicts among leading vehicles, representing for the subject group with other groups) and internal conflicts (traffic conflicts among vehicles in the subject group).

The question is now what are criteria to classify crowded and uncrowded traffic flow and how the traffic flow has influence on driver behaviour? We will come back to this question in the following chapter when discussing about the influence of an intersection layout and traffic flow density on driver attitude towards legislation.

Under mixed traffic and existing infra- and superstructures conditions, driver behaviours are particular. Motorbikes occupy any lateral position across the carriage ways instead of travelling on a particular lane. Traffic flow in Vietnam follows ant-crawling one. It is very crowded, especially in big cities such as Hochiminh and Hanoi. Drivers in the system have flocking behaviours (Reynolds, 1987). For instances, an individual avoids colliding with its neighbours, and tries to drive at the same (similar) speed as neighbours´. They tend to follow a leading driver, which form travelling groups on the road. The leader usually moves with free flow acceleration/deceleration manner. Besides, vehicles move in different velocities and accelerations/decelerations depending on drivers, vehicle's physical performances, and traffic situation. The system's complication rises at intersections where traffic flows intersect with each other. All types of vehicles mix together. They follow chaos-rules which mean that they are guided by traffic rules, but they travel in chaos ways. There is no priority for any type of vehicles, so they drive as they can. Some examples are illustrated as in Figure 20.

Figure 21. Congestion on road, and at an intersection

(Source: http://www.vnexpress.net)

All mentioned characteristics create the distinction between the mixed traffic system and the lane-based motorized traffic systems of developed countries.

Traffic behaviour at intersections follows all mentioned-above characteristics of normal traffic behaviours. However, due to the complex characteristics of the movements at intersection, there are a lot of potential conflicts in the area. As we can see from psychology, drivers are led to expect a particular operation condition based on information presented to them. Under conditions of complex traffic, driver expectancy will have larger variations. The potential errors of drivers (road users in some situations) may have higher probability.

From the field observations and statistical data, disregarding traffic lights and misuse of traffic lanes are typical at intersections, which can be partly illustrated in the following pictures.

Figure 22. Mixed traffic without lane-marking

(Source: http://www.vnexpress.net)

Figure 23. Disorderly traffic behaviors at intersections

(Source: http://www.vnexpress.net)

Emperical data (from field surveys) on red-light running and lane violation will be described more detailed in the next part.

In some literatures (e.g. Human Factors and driving, 2001), the influence of crowded situation in traffic system has also been mentioned. It is named as social factors of groups´ influence on individual driving. It is noted that groups tend to establish norms of behaviour amongst group members and to differentiate themselves from other groups. Most of human being like to fell accepted by significant others and to be part of a group. The threat of withdrawal of their approval or of rejection from the group can produce enormous pressure on us to conform to group norms. These social forces can work to enhance or undermine safety, depending on what those group norms are. If it is the norm in his group to obey the lane priority regulation, it is difficult for the driver not to conform.

In urban road traffic in Vietnam (especially in such a condensed city as Hanoi), motorcycles account for a large volume, while 4-wheel vehicle´s share is very small. Such composition has made urban traffic flow very unique. Motorcycles are so highly adaptable and manoeuvrable that they can easily fill up any road space available. Traffic flow in Hanoi is more like the flow of small particles rather than discrete objects. Therefore, the flow easily compresses and expands depending on the road and the traffic condition. Moreover, it occupies a much smaller space in comparison with the case of 4-wheel vehicles. While the general behaviour of motorcyclists minimizes delays and makes maximum use of the road space there are many undesirable aspects of motorcycle driving that reduce the effectiveness of the road system, including violation of regulations, decreased safety, and dangerous and inconsiderate driving, that interrupts the flow and results in additional stress for other road users. In developing any traffic improvement solutions a balance between the efficiency of the current situation and restrictive new practices that may result in less effective use of road space must be considered.

It is very common at intersections, whether signalized or not, that priority rules are mostly ignored. Left-turning vehicles and motorcycles proceed toward the lane intended for traffic going to the opposite direction even if there is oncoming traffic. Both flows fight for their way and motorcycles and vehicles squeeze through whatever space is available. If one is not skilfull enough or there is a disagreement between drivers on the problem that who can go first, accident happens. Normally, due to the slow movement, accidents are not severe and only minor injuries or damages to vehicles occur. However, intersection capacity is rather lower than the designed one. In Vietnam at the time being, there are many intersections having priority spaces for vehicles with different movements waiting before the traffic lights (with the aim of providing priority lanes along the whole road). However, obeying the lane priority seems to cause troubles to drivers.

Motorcycles do not follow the rule of “First in First out” as orderly as four-wheelers do. At a typical signalized intersection, during waiting time, motorcycles have the trend to creep as far as possible to the leading position of the waiting line. After the traffic signal changes from red to green, the motorcyclist starts moving and speeding up gradually. Very first motorcyclists leading the waiting queue, without any constraint from front vehicles would accelerate freely until attaining the desired speed. Moreover, when the space headway between the subject motorcycle and the leading vehicle is large, the motorcyclist would also accelerate freely. Following motorcycles would accelerate according to the action of the leading vehicles. Due to the characteristics of flexibility and manoeuvrability, as well as faster response to the change of traffic conditions, motorcycles are easier to manoeuvre ahead four-wheeled vehicles.

In a rather crowded intersection, in the green phase, vehicles (with the high percentage of motorcycles) have the trend to move within groups of vehicles with the similar behaviours. As mentioned from above, due to the moving characteristics of MD traffic flow, it is reasonable to classify motorcycles and other types of vehicles into groups, using criteria of behaviour manners. The main target is to determine why, how often and which behaviours are dangerous.

4.4. Conflict Zones vs. Conflict Time Segments in MD Traffic Flow

4.4.1. Conflict Techniques

Constructing the cause-and-effect chain can be conduted in the second approach with the physolophy of conflict analysis.

Intersection navigation is a particularly hazardous component of driving. Even though intersections comprise just a small amount of the total roadway surface area, they contribute to a relatively high proportion of crashes because they are the critical points in the roadway system where traffic movements are more frequently in conflict with each other. In addition to a greater frequency of conflicts, intersections generally are more complex and difficult to navigate than most other road segments. More specifically, intersections can be visually complex, requiring that drivers scan several different areas and keep track of several different elements to get the information they need to safely pass. Also, there are more hazards to deal with in terms of pedestrians and other traffic, such as turning and crossing vehicles that can encroach into a driver´s path. Intersections also represent action points in which drivers may frequently have to make a response based on emerging traffic conditions under time pressure (e.g., change lanes to continue past stopping vehicles or decide to stop on a yellow light). Thus intersection driving involves a multitude of different elements and hazards that can combine to increase the difficulty and workload that drivers face. When drivers are unable to meet these higher demands, their risk of making critical driving errors that can lead to conflicts wit other road users also increases.

As we have also seen in previous studies, the assessment of the effect of specific measures is often based on accident analyses. One of the main drawbacks of reactive traffic safety assessments (accident analyses) is that this approach only shows a fraction of the total number of events. Traffic (un-) safety is characterized by a much broader set of events than accidents alone, ranging from undisturbed passages, normal interactions, and conflicts to collisions. In experimental studies, driving behaviour is observed, being mostly undisturbed passages and normal interactions. This broad set of events is shown as a continuum of traffic events, which describe the traffic process (Figure 7.1; Hydén, 1987). Another drawback of accident analyses is that accidents are underrepresented in accident statistics, mostly showing the more serious accidents. And if they are represented in statistics, police reports do not always contain the information researchers are interested in from a traffic safety perspective and “objective” eyewitness testimonies are biased due to subjective interpretation.

In several projects, the limitations of accident analyses and statistics have been overcome by developing a method for investigating conflicts and traffic accidents in more detail.

A conflict point is commonly defined as the point at which a highway user crossing, merging with, or diverging from a road or driveway conflicts with another highway user using the same road or driveway. It is any point where the paths of two through or turning vehicles diverge, merge, or cross. Conflicts points are commonly used to explain the accident potential of a roadway. Access management strategies are typically designed to reduce the number and density of conflict points.

Conflict points are associated with increased levels of roadway accidents. A motorist can safely negotiate only so many conflict points within a given area. Studies have shown that when driveway access to arterial roadways is granted to too many property owners without considering future traffic volumes and roadway classifications, the extra driveways increase the rate of accidents and decrease the efficiency of the roadway.

Although this does not appear to be a simple, direct relationship, reducing conflict points has been shown to significantly reduce the accident rate at case study locations (T. J. Simodynes, The effects of reducing conflict points on reducing accident rates, October 1998).

Other safety-related factors include the type of conflict points that are reduced—different types of conflict points have different propensities for accidents. Studies of hundreds of crashes at more than 1,300 driveways in three different communities in Illinois found that left-turning vehicles (exiting and entering) are involved in the majority of driveway-related crashes (Paul Box and Associates, 1998).

Access management strategies can reduce traffic conflicts:

- by limiting the number of conflict points that a vehicle may experience in its travel
- by separating conflict points as much as possible (if they cannot be completely eliminated)
- by removing slower turning vehicles that require access to adjacent sites from the through traffic lanes as efficiently as possible

Common strategies include relocating, consolidating, and eliminating driveways; promoting shared driveways; increasing corner clearance; improving driveway geometrics (radius, width, grade, throat length); prohibiting left turns out of driveways; installing raised medians with left turn lanes; installing two-way left turn lanes; and providing alternative access roads.

However, Conflict Technique applied in motorcycle-dominated traffic flow has distinguished requirements. The reason is that motorcyclists do not move in a lane-based regulations. There may be different definitions of groups in motorcycle traffic flow. However, in this research of driver behaviours in left-turning movement at intersection, it is more reasonable to classify groups based on their different turning manoeuvring movement.

4.4.2. Conflict Zones

The above-mentioned controlling measurements at intersections as traffic signals aim at reducing the number of conflict points. However, motorcycle movement at intersections in fact shows very clearly the difference in traffic characteristics of motorcycles with four-wheelers.

It is observed that due to motorcycle characteristics of manoeuvrability, motorcyclists have the trend to occupy all the space ahead that they can recognize. However, when the traffic flow in the intersection become more crowded, then they seems to ride within groups, mostly affected by the flow approaching from the opposite direction (named as opposite direction vehicles - ODV). In the field, during the green interval and the green-amber-red transition, we observed a somewhat more complex set of turning patterns as drivers approached and entered an intersection to turn left.

Due to the relatively small size in comparison with four-wheelers, due to flexibility and manoeuvrability of movement, normally, when turning left at intersections, there is a large amount of vehicles moving in the zigzag trajectory (27% - 35% in the interrupted intersection and more than 50% in the uninterrupted but crowded intersection).

In the year 2007, a field survey was conducted at some intersections in Hanoi. The first survey was conducted on January 1, 2007. The second survey was conducted on February 8, 2007. Between these two surveys, there is a traffic safety campaign, in which traffic enforcement is proposed with several measurements such as lane-marking, policemen, etc. The main objective of the field survey is to collect data of driver manoeuvre at intersection left-turning movements. The field survey is conducted with the hypothesis that zigzag movement is the reason for traffic unsafe situation at intersections.

From the survey, on January 1, 2007, there is a diagram of zigzag movements at intersection as follows:

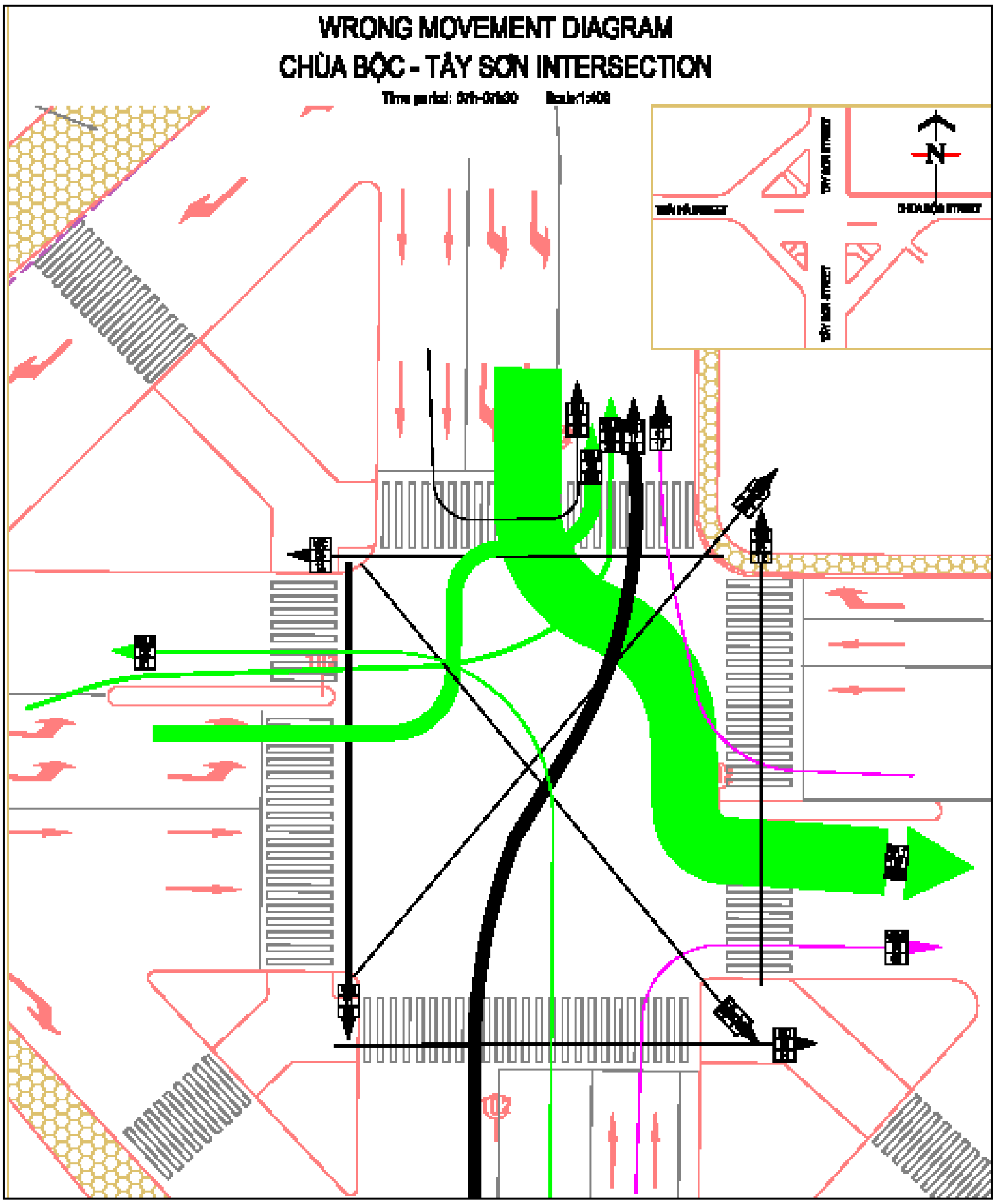


Figure 24. Current situation of left-turning movement at Chua Boc - Thai Ha intersection

The statistical data is shown in the following table.

Table 5. Numbers of zigzag movements in the first survey

Movements			Morning		Noon		Afternoon		Total	Percent	
			Quantity (veh.)	*Movement/ 10,000*	Quantity (veh.)	*Movement/ 10,000*	Quantity (veh.)	*Movement/ 10,000*		WM/ $Total_{WM}$	WM/ $Total_{d}$
	WL1	zigzag	129	*353*	118	*382*	134	*251*	**381**	67%	339
	WL2	zigzag	0	*0*	0	*0*	0	*0*	**0**	0%	0
	WL3		2	*5*	20	*65*	15	*28*	**37**	7%	33
	WL4		0	*0*	0	*0*	1	*2*	**1**	0%	1
Turn left	WL5	zigzag	3	*8*	9	*29*	15	*28*	**27**	5%	24
Straight	WS1		17	*17*	0	*0*	0	*0*	**17**	3%	5
	WR1		0	*0*	1	*3*	5	*10*	**6**	1%	5
Turn right	WR2		2	*6*	0	*0*	0	*0*	**2**	0%	2
U_Turn	WU		2	-	4	-	3	-	**9**	2%	-
Cross	WC		21	*20*	36	*44*	22	*17*	**79**	14%	25
Diagonal	WD		2	-	1	-	4	-	**7**	1%	-
Total			**178**	***104***	**189**	***132***	**199**	***87***	**566**	100%	**106**

With the concept of conflict is the situation in which, one or more drivers have to adjust his/her speed and/or path, the conflict observed is listed in the following table.

Table 6. Number of conflicts in the first survey

	Code	Morning		Noon		Afternoon		Total	Conflicts/ $Total_{conflicts}$	Conflicts/ 10,000 movements
		Number of conflicts	*Number of conflicts/ 10,000*	Number of conflicts	*Number of conflicts/ 10,000*	Number of conflicts	*Number of conflicts/ 10,000*			
Rear-end	A1	2	*1,16*	1	*0,70*	1	*0,44*	**4**	17%	*0,75*
Head-on	A2	0	*0,00*	0	*0,00*	0	*0,00*	**0**	0%	*0,00*
Right-angle	A3	2	*1,16*	3	*2,10*	3	*1,31*	**8**	33%	*1,49*
Head-angle	A4	2	*1,16*	4	*2,80*	2	*0,87*	**8**	33%	*1,49*
Rear-angle	A5	1	*0,58*	1	*0,70*	0	*0,00*	**2**	8%	*0,37*
On-flowside-swip	A6	2	*1,16*	0	*0,00*	0	*0,00*	**2**	8%	*0,37*
Counter-flow side-swip	A7	0	*0,00*	0	*0,00*	0	*0,00*	**0**	0%	*0,00*
Total		**9**	***5,24***	**9**	***6,30***	**6**	***2,61***	**24**	100%	***4,48***

In the survey of February 8, 2007, the number of zigzag movement (as well as other types of wrong movement) has been decresed considerably.

Table 7. Number of zigzag movements in the second survey

Movements			Morning		Noon		Afternoon		Total	Percent	
			Quantity (veh.)	*Number movements/ 10,000*	Quantity (veh.)	*Number movements/ 10,000*	Quantity (veh.)	*Number movements/ 10,000*		WM/ $Total_{WM}$	WM/ $Total_d$
Turn left	WL1	zigzag	1	*3*	0	*0*	0	*0*	**1**	6%	1
	WL2	zigzag	0	*0*	0	*0*	0	*0*	**0**	0%	0
	WL3		1	*3*	1	*3*	1	*2*	**3**	18%	3
	WL4		2	*5*	1	*3*	0	*0*	**3**	18%	3
	WL5	zigzag	0	*0*	0	*0*	0	*0*	**0**	0%	0
Straight	WS1		0	*0*	0	*0*	0	*0*	**0**	0%	0
Turn right	WR1		0	*0*	0	*0*	0	*0*	**0**	0%	0
	WR2		0	*0*	0	*0*	1	*2*	**1**	6%	1
U_Turn	WU		1	-	0	-	0	-	**1**	6%	-
Cross	WC		2	*2*	1	*1*	2	*2*	**5**	29%	2
Diagonal	WD		0	-	3	-	0	-	**3**	18%	-
Total			**7**	***4***	**6**	***4***	**4**	***2***	**17**	100%	**3**

In this survey, number of conflicts at all three intersections chosen for survey have been reduced to zero. Therefore, there may be an initial conclusion (Hypothesis) that zigzag movement (as one of wrong movements) of the left-turning vehicles has an influence on conflicts at intersections.

However, it is very difficult to determine the reason why the number of drivers conducting the zigzag movement decreased totally to 0. One reason to reduce this number may be due to the measurement of traffic operation and management. In the campaign of traffic safety, in this intersection, the measurement of lane separation (figure), new traffic signals of 4 phases (with priority for left-turning movement), etc. have been conducted. With such engineering measurements, the potential conflicting movement has been eliminated. Then the conflict number will be reduced. The problem raised up now will be the fact that the cycle time of traffic signal lasts too long (120s). When the traffic is not so crowded, then the driver do not feel that he or she will have to wait too long. However, if the traffic is too crowded (the actual volume exceeds the intersection capacity), the driver with the (high) experience of getting stuck seems to have the fear for congestion. If he or she cannot pass through the intersection in one traffic signal cycle, then he or she may try to break the rule somehow, especially when he or she does not have the fear for being punished under the law. When such situation happens to a large number of road users, then the probability of drivers (as the whole population at this specific intersection). At that point, the engineering measurements (lane marks, traffic signal, priority rules for left-turning, etc.) will no longer have expected effects on the driver behaviour, as well as traffic safety and disciplinary at the intersections.

Coming back to the questions: what are critical situations may happen during drivers´ turning to lead his normal movement to potential conflicts or accidents? The research proposed a methodology to determine the position and areas of the conflict zone in the intersection in order to be able to calculate the distance that the driver can cope with the critical situation based on his/her experience, skills and motivation (available distance).

Here comes out the concept of “conflict zone” in MD traffic flow. It is a development of a new concept in comparison with the concept of conflict point (in the traditional approach of Conflict Technique). In the car traffic flow, with lane-based traffic, conflict points are commonly used to explain the accident potential of a road way. Access management strategies are typically designed to reduce the number and density of conflict points. In a car traffic flow, a conflict point is the point at which a highway user crossing, merging with, or diverging from a road or driveway conflicts with another highway user using the same road or driveway. In other words, a conflict point of car traffic flows is the same with a conflict point of road lanes.

In the motorcycle traffic flow, due to non-lane based traffic characteristics of motorcycles, motorcycle movement does not follow the lane discipline. Especially, in conditions of crowded and complex traffic flow, (as in the case of intersection), in order to save the total time of proceeding a moving manoeuvre, a motorcycle has the trend to move around an obstruction rather than following the fixed trajectory. The conflict point is therefore expanded as a conflict zone.

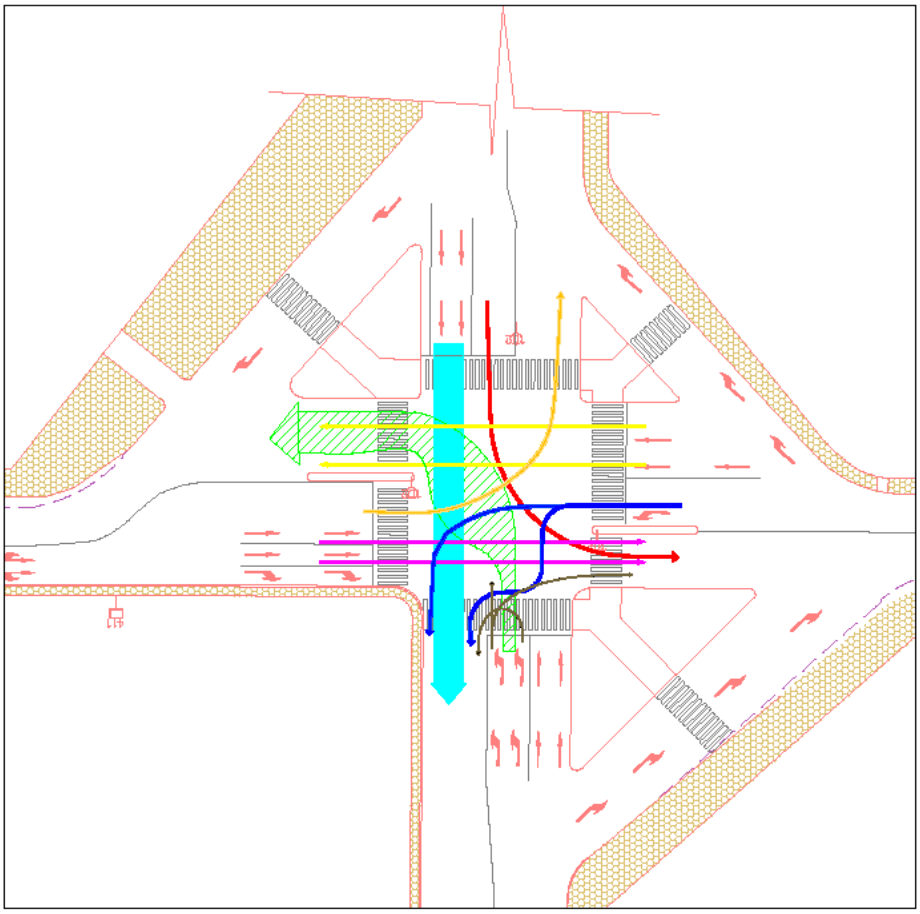


Figure 25. Conflicts in case of no traffic signal

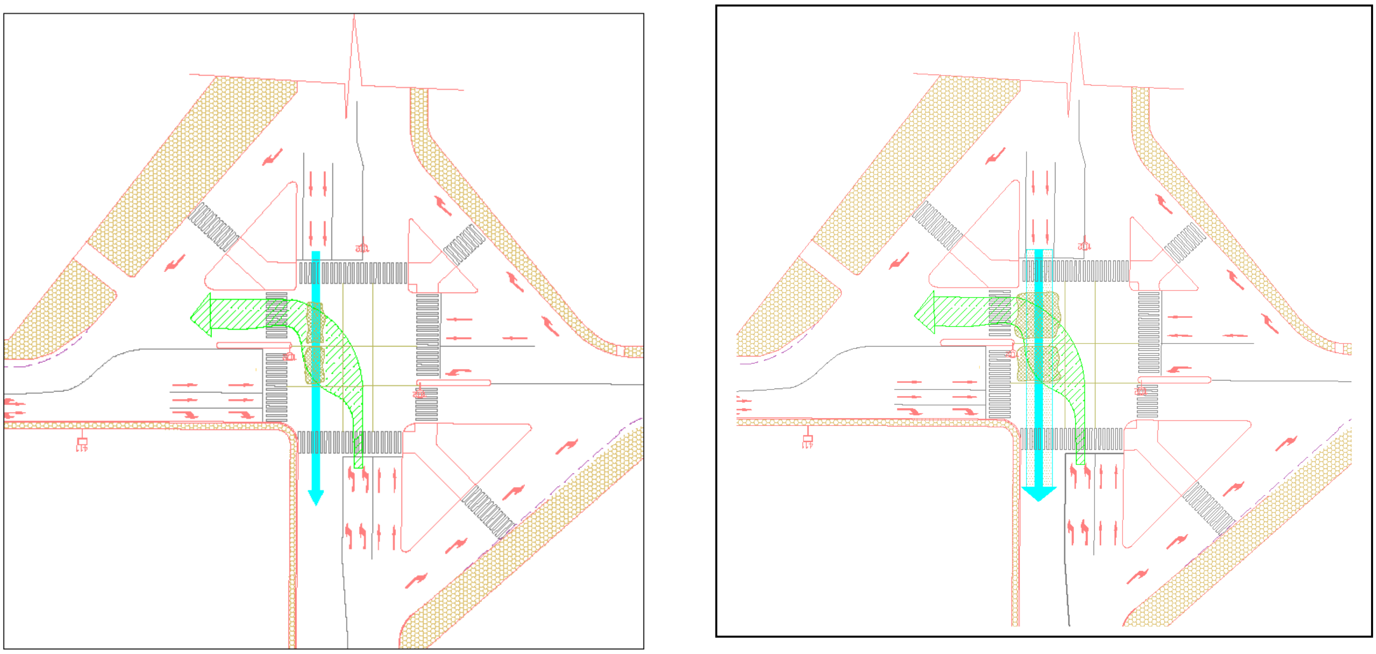


Figure 26. Conflict zones with traffic signals

There is a hypothesis that the square area of conflict zone has close relationship with numbers of potential conflicts. The square area of conflict zone depends on the following elements:

- Intersection square area, layout
- traffic flow volume, density
- trajectory of vehicles/groups of vehicles
- traffic management and operation

4.4.3. Conflict Time Segments

From field observation in the signalized intersection, it is remarks of "sub-phases" in a traffic cycle as described in the following figures.

Table 8. Time segments in one traffic signal cycle

Traffic signals (for left-turners)	Red	Green						Yellow	Red
Group 1	waiting in the waiting line	starting	conflicting with NS						
Group 2				waiting	turning		keep going		conflicting with WE
Opposite flow (NS)		starting	continously moving		slowing	avoiding			
Other flow (WE)		waiting in the waiting line							starting

Group 1 or 2 are separated due to their selected trajectories as shown in the

Figure 27.

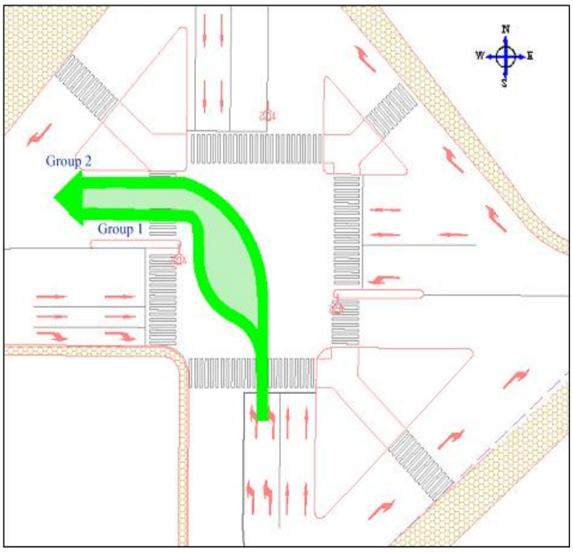


Figure 27. Vehicle classification due to turning trajectories

The 1st group (Group 1) of left-turners are those who initialize their vehicles at the very first seconds of the green phase. They are mostly those who stand in the first positions in the waiting queue. There is a common psychological trend that those drivers would like to avoid the potential conflict with ODV, then they choose the zigzag trajectory (further discussed in the next chapter)

Almost vehicles in group 1 can deliberate before the 1st group of ODV arrive at the potential conflict area (90% as counting from video camera). A few left vehicles in group 1 will continue the zigzag trajectory or change their moving trajectory to the 2nd size.

The 2nd group enters the intersection when ODV has occupied their whole moving area. They will wait as a waiting line in the area of intersection, looking for a gap in the flow of ODV. Normally, in the case of irrelevant traffic signals (ineffective signal cycle, which mean that the traffic flow can not be released within one cycle), vehicles waiting inside the intersection will cause obstacle for other vehicle flows when they arrive. Moreover, when waiting too long in this position (more than 30s, for assumption), the 2nd group shows their willingness to complete their turning at every manner.

This manner may be the basic difference between motorcycle and car traffic flow. In most of the cases of homogenous car traffic flow (or cars dominate the highest percentage of transportation mode in the flow), normally there are not many cars waiting inside the intersection area and there are space among waiting vehicles. With the characteristics of particles (as mentioned above), motorcyclists have the trend to move along any direction, just for occupy any available space ahead. Therefore, at the peak hour (when the mobility demand is rather high in comparison with the intersection capacity), it is very common to observe a group of vehicles waiting in the internal area of the intersection.

It is remarked that vehicles move as groups (of similar behaviours) in a crowded traffic flow (normally in peak-hours: 7-8am and 17-18pm). In the uncrowded condition, vehicles drive more freely (relatively independently).

We can see that despite the traffic signals, there are still critical situations for left-turners to have to negotiate with road users from other directions. The following figures are taken from the field survey, illustrating conflicts among different flows of road users.

Figure 28. Left-turners avoid POV (on-coming flow)

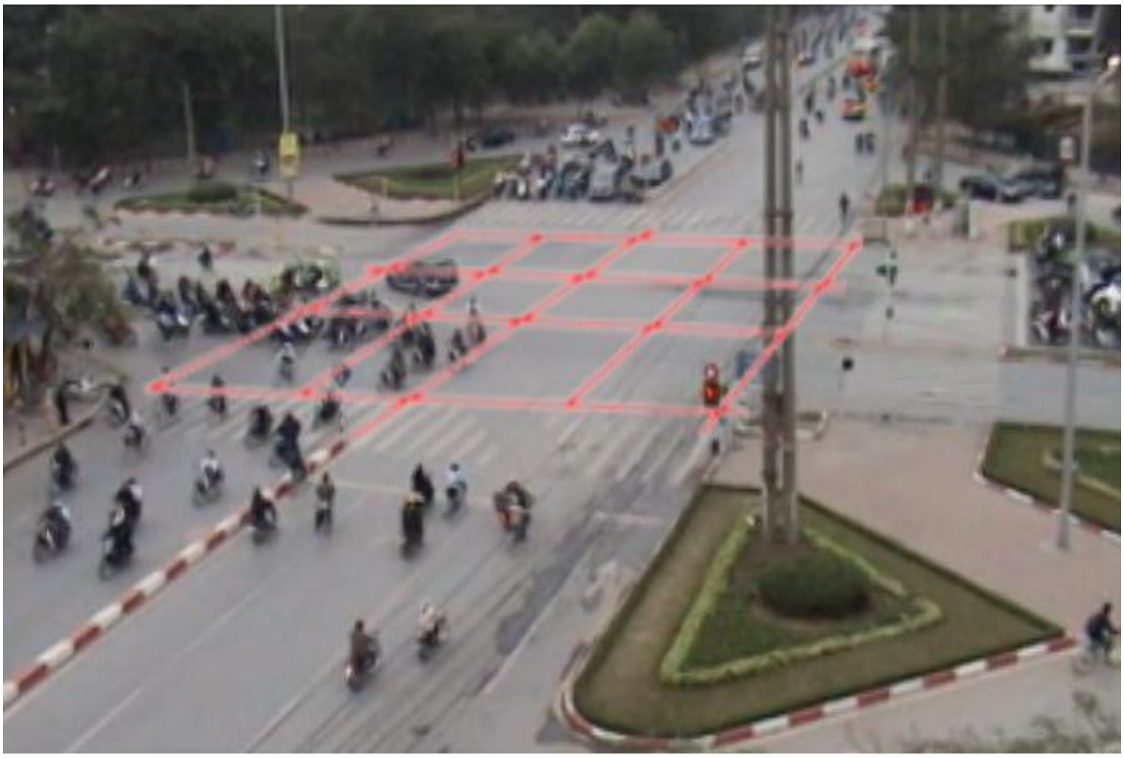


Figure 29. WE group entering the intersection while the last left-turner leaving

(Source: from video camera file with modification)

There have been remarked that we can divide a traffic signal cycle into time segments as follows:

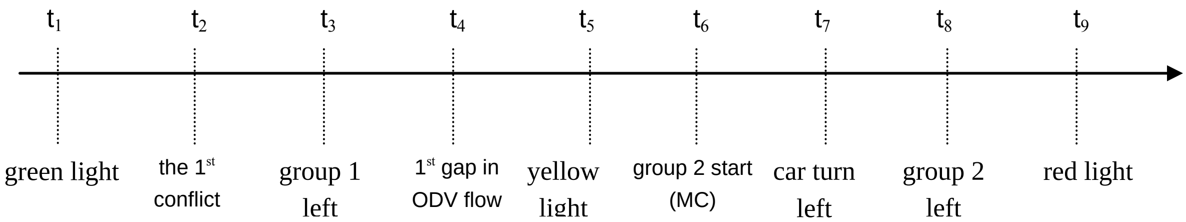


Figure 30. Different time segments in one cycle

Some times, t_9 may even appear before t_7, and t_8, which means that even when the signal becomes red, there are still some vehicles waiting inside the intersection inner area. That lead to the conflict situation between left-turners and the group from west to east.

However, it is remarks that there are not only risks to get involved into conflicts from other groups of road users, but also risk to be crashed from vehicles in the same group. It can be suggestion to determine external risks (to get involved in conflicts with other groups) and internal risks (with the same group). If the leading vehicle in the group have some actions which are unexpected by his followers, and the followers cannot react in time, then the conflict or accident may happen.

From the video camera, it is noticed that, at the very first seconds in the green phase, (from t_1 to t_2) whereas group 1 can ride faster than the on-coming flow. There are almost no external risk. From t_3 to t_4 when the on-coming flow block almost the straight way, group 2 of left-turners have to wait, there are almost no external risks as well. Then, the conflict time segments can be determined as such segments when group 2 tries to turn crossing the movement of on-coming vehicles. The situation will be more dangerous and disordered if the vehicles cannot finish their desired movement (completely leaving the intersection) within the signal cycle, so that they will have conflicts also with vehicles from other directions.

There is a hypothesis that the length of conflict time segments has close relationship with numbers of potential conflicts. The conflict time segments depend on the following elements:

- Intersection capacity
- traffic flow volume in each moving direction
- speed of vehicles/groups of vehicles
- traffic signals (cycle time and priority rules)
- reaction-perception time of drivers

At the time being, the most common methodology to do research in the traffic flow in Vietnam is the combination of video camera and manual counting. The above remarks on Conflict Zones and Conflict Time Segments are also extracted from video camera files. It is recommended that there are several available computer soft-wares, which allows us to modify the video camera (e.g., Ulead soft-wares). The author also suggests dividing the intersection inner area into small zones in order to figure out the most hazardous zone(s) (with the highest probability of conflict occurrence).

4.5. Driver Behaviour Chain in MD Traffic Flow: Recommendation

In this chapter, the study has described different approaches of risk analysis based on analysing the accident progress in the direction from causes to effects (from influencing parameters to the results of conflicts or accidents). These approaches work with normal situation (in the case, with those prescribed tasks of drivers in left-turning movement), determine critical situations which can happen, evaluate gaps between normal situations and critical situations to see (i) why do critical situations happen; (ii) how often do critical situations happen; (iii) how dangerous are they.

However, in such a complex system as the traffic system, with so many random and unpredictable parameters which are difficult to be quantified, working systematically with the whole structure at once is really impossible. DRAM methodology provides us the tool to conduct analysis in the opposite direction from effects to the causes. Firstly, it seems to be relevant to focus on any point which comes out to be the most critical (hazard point) in the whole system. Moreover, we can also expand our model whenever we obtain more knowledge and data in the related field. The next chapter will discuss on the driver behaviours of violating road traffic regulations which are at the first rank in the list of main causes to traffic accidents in Vietnam currently.

5. Road Traffic Regulation and Driver Behaviours

5.0. Introduction

The previous chapter has provided with different approaches to conduct risk analysis in motorcycle-dominated traffic flow. This chapter focuses more on the driver behaviour of violating road traffic regulations. The chain of “Driver behaviours of violating traffic regulations” based on “General attitudes towards road traffic regulations” and “Specific-scenario acceptance of rules” is then constructed. This chapter would like to analyse the influence of external parameters on the behaviour of violating traffic regulations. Enforcement and its effects on driver attitudes towards driver behaviour is the very first topic. Congestion and “fear of getting stuck” are mentioned the next. New concepts of “conflict zones” in motorcycle (two-wheeled vehicles) traffic flow is clarified. The other interested parameters are those of traffic signals, infrastructure and rules of priority at intersections.

5.1. Current Situation in Vietnam

From the above discussion, we can see different possibilities to conduct risk analysis of driver behaviours at intersections in MD traffic flow in general. However, it is needed to emphasize that the main research objective is analysing reasons of unsafe situation in MD traffic flow. From analysing the current situation, the research aims at evaluating traffic measurements to improve such unsafe situation.

From the current situation in Vietnam, many experts in traffic safety (e.g. JICA) agree with the argument that behaviours of violating traffic regulations now are the most serious problem in Vietnam.

Based on statistical data from policemen, reports and researches on current situation of traffic safety in Vietnam, dangerous behaviours classified by the criteria of violating traffic regulations are listed as below.

Table 9. Main Causes of Traffic Accidents (causing heavy accidents)

	Poor observation	Misuse of lanes	Turning	Dangerous overtaking	Over speeding	Other causes	Pedestrian
1999	25.59%	19.69%	5.51%	11.81%	26.77%	5.12%	5.51%
2000	28.05%	13.31%	4.82%	11.61%	27.76%	6.80%	7.65%
2001	29.81%	13.70%	4.81%	10.82%	26.92%	5.05%	8.89%
2002	20.84%	12.65%	7.26%	11.94%	30.44%	8.43%	8.43%
2003	22.89%	9.94%	7.53%	8.73%	33.13%	11.45%	6.33%

Source: National Traffic Safety Committee

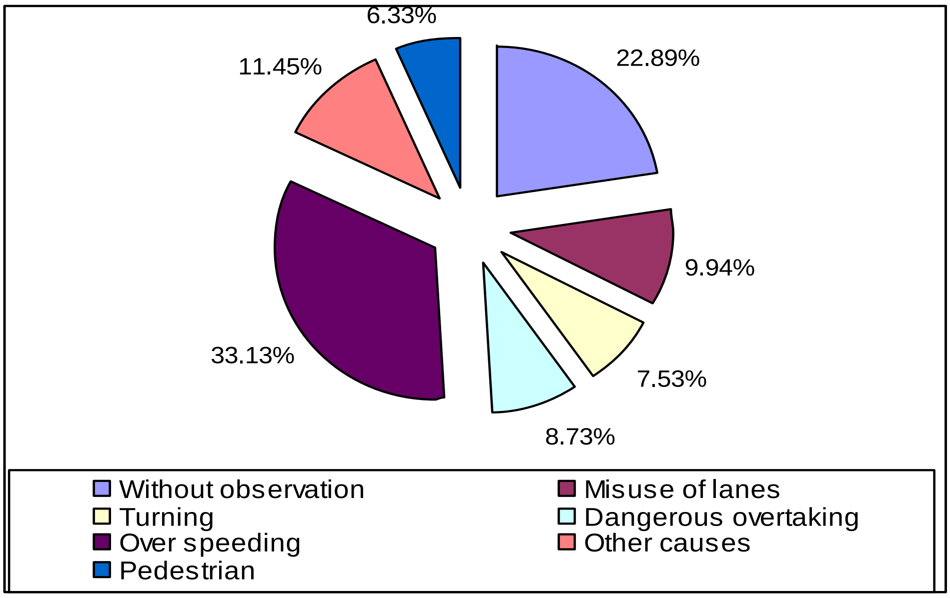


Figure 31. Traffic accident causes in 2003

The target of traffic signals are distinguishing traffic flows with potential dangerous conflicts. However, at intersections with traffic signals, naturally drivers expect that they will not have potential conflicts from crossing flows. In that case, red-light running may lead to the higher level of risk.

The first priority of the research is analysing driver behaviour of traffic regulation violations. Constructing the model to conduct prediction of "violating traffic regulations" behaviors with regards to external elements such as infrastructure traffic flow, traffic management, traffic enforcement,… Applying the model to evaluate impacts of suggested methods to improve the situation and possibility to apply in specific intersections.

In order to construct the model to evaluate risk levels based on analysing driver behaviors, it n is required such a large amount of empirical data. From the field survey of traffic situation and behaviors of road users, it is obvious that in Vietnam traffic situation that there are problems of driver awareness and attitude towards legislation. Violating traffic regulation become so common that road users accept it as informal rules. Many dangerous conflicts have been caused from such violations.

In recent years, many researches have been conducted in order to answer the question "why do road users violate traffic regulations?" Many measurements of education and enforcement have been implemented. However, their effects are still in doubt, though traffic safety measurements normally require a lot of time and efforts, as well as investment.

One problem is raised: how dangerous are those behaviours of violating traffic regulations. This part deals firstly with the problem of traffic regulation violating behaviours at intersections with traffic signals.

In the reports of National Committee of Traffic safety (2008), it is concluded that the major cause leading to traffic accidents are the fact that traffic participants disobey the traffic rules and regulations especially on the aspect of traffic safety and operation management. Number of accidents due to technical safety of vehicles is under 1%, due to infrastructure is approximately 1,8%. Bad behaviours of traffic participants cause nearly 97%, whereas 73% from motorcyclists. Automobile drivers cause 24% of accident cases but mostly particularly serious ones (from interprovincial buses, container trucks, etc.).

From empirical field in Vietnam, there are distinguishing problems in driver behaviours of violating road traffic regulations in different locations. The difference is in both percentage/frequency of violation behaviours and their dangerous levels.

In details, we have different types of violation behaviors in different locations as follows (Source: research of JBIC SAPFOR, 2003, 2006, 2007):

(i) In the major corridors coming into the cities (9 stations in the major corridors)): survey in 6/2004: (statistics from reports) Over speeding, Dangerous overtaking, right-side overtaking, Dangerous dodge, Over people loading, Bulk loading, dangerous, Running contrariwise, misuse of lanes, Walker crosses over road misuse of lanes, Walker crosses over median, Misuse of stopping and parking, Misuse of motorized lane by vehicle, Running in 3, 4 parallel line by bicycle, Misuse of motorized lane by xichlo

(ii) In national highway (NH3, NH5, NH10, NH18), from 2003- 2005 (statistics from reports): Over speeding, Reckless driving, Careless overtaking, Poor observation, Drunk driving, Misuse of lanes, Drowsy driving, Overloading, Disregarding rules, Mechanical failure, etc.

(iii) In urban areas: major errors include red-light running, misuse of lane (when overtaking and in the waiting line, etc.), which are those details of stopping (waiting) in the wrong priority lanes, stopping or waiting on the carriage way of the opposite traffic, weaving over the continuous lane separation marks, etc.

Many measurements to improve the situation have been applied. However, such measurements are not useful in all the cases. Using the approach of risk analysis applying in conducting research on driver behaviour, this research will analyse the driver behaviour chain in order to find out the reason "why do drivers at MD traffic flow violate the traffic regulations?" The objective is to determine influencing levels of external parameters (influencing parameters) to driver violation behaviors.

It is the next task to find out the answer for the question: "why and how many percent of drivers behave in such a way of violating traffic rules".

5.2. Process of Decision Making

5.2.1. Theory of Planned Behaviour

Theory of planned behaviours (TPB) is explained in the above chapter. This theory has been successfully applied in car traffic flow (e.g. in Europe). From analysing the current situation in Vietnam, in the study on National Road Traffic safety Master plan in the Socialist Republic of Vietnam (March 2009), experts gave out the suggestion to apply this theory in studying road user behaviour.

The Theory of Planned Behaviour from intentions to actions has been applied to studies of the relations among beliefs, attitudes, behavioural intentions and actual behaviour in various fields including traffic safety particularly driving behaviour.

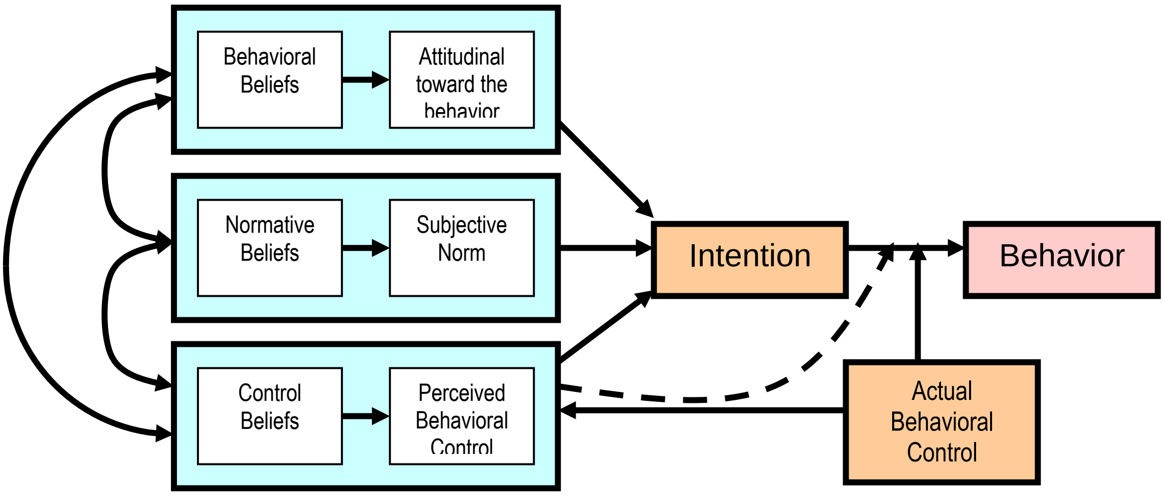


Figure 32. Theory of Planned Behaviour (Icek Ajzen, 1985, ver. 2006)

Theory of planned behaviour suggests that behavioural belief and attitude toward behaviour are related, normative beliefs has influenced over subject norm, perceived behavioural control is determined by the total set of accessible control beliefs and behaviour is a compatible intentions of perception of behavioural control and actual behavioural control.

For explanation:

Behavioural beliefs-

e.g., if I drive fast I will not be stuck by the traffic or

I believe crossing the road here is much safer.

Attitude toward behaviour

e.g., I do drive fast (because I don't like to get stuck in the traffic) or

I cross the road here (because it is much safer than crossing near intersection).

Normative beliefs-

e.g., my parents told me if I drive slowly I will not have an accident or

my friend told me wearing helmet while riding the bike is much safer.

Subjective norm-

e.g., I should driver slowly (otherwise my parents will never allow me to drive again….) or

I should wear helmet while riding bike (otherwise no friend will talk to me…..)

Control belief and perceived behavioural control

e.g., I believe I can run red light without causing the accident or

I believe I can cross the road while it is red light).

Behavioural intention and behaviour

e.g., I decide to drive safely for my own sake and for everyone concerned… or

I decide to drive opposite the traffic direction to shorten distance and travel time

Note that sometimes behavioural intention and actual behaviour are not always appeared to be as they intended to behave. This may depend also upon actual behavioural control like this situation below.

e.g., I was about to run red light but I saw a car came from opposite direction so I stopped.

Changes in such cultural factors may prove to be a prerequisite for effectively promoting safety with a culture. The modification of belief and social structures through the provision of information, social norm referents, and incentive or penalty schemes can significantly improve safety behaviours and acceptance of safety interventions.

The author of the study on National Road Traffic safety Master plan confirm that this theory of planned behaviour is suitably applicable to study road user behaviour in both urban and rural or remote areas in Vietnam.

[Study on National Road Traffic safety Master plan, TRAHUD project, March 2009]

5.2.2. Cognition and Motivation for High-risk Taking Behaviours

For the purpose of analysing the causes of driver behaviours of violating traffic regulations, let us take as a working Hypothesis the idea that most of the time, drivers drive so as to achieve their mobility, their travel goals, while ensuring the difficulty of the task remains within acceptable limits. For example, if things seems to get too hectic (too demanding) on the road, the driver slows down. If the task is boringly easy, the driver speeds up, making it more challenging. (Ref. Human factors for highway engineers by Ruller, Jorge A. Santos, 2001). In other words, when driving, the driver has to balance between two demands for mobility (achieving their travel destination in time) and the demand for safety.

In fact, the final target of the driver is approaching his destination in the most appropriate time (in most of the trips). Therefore, it can be said that every risk that he can meet in the way, such as the risk of traffic conflicts or accidents, etc., may have the risk (probability) of influencing to the whole trip. In the approach of risk analysis, to one individual driver, there is the negotiation between the risk of being punished by traffic rules and the risk of getting stuck (failure of reaching his destination in time).

When the driver feels the higher risk of getting stuck (failure of reaching the travel destination in time), saving the time becomes a priority when journey delays may have arisen. Thus driving in such a way that may save time become potentially rewarding options, motivating potentially risky behaviour. Examples of such tactics are driving faster, accepting shorter gaps in stream entry or stream crossing, overtaking recklessly and running red lights. The situation seems to be more serious to motorcyclists as they drive such a flexible and manoeuvrable vehicle that they can take full use of any space they have in their visual pattern.

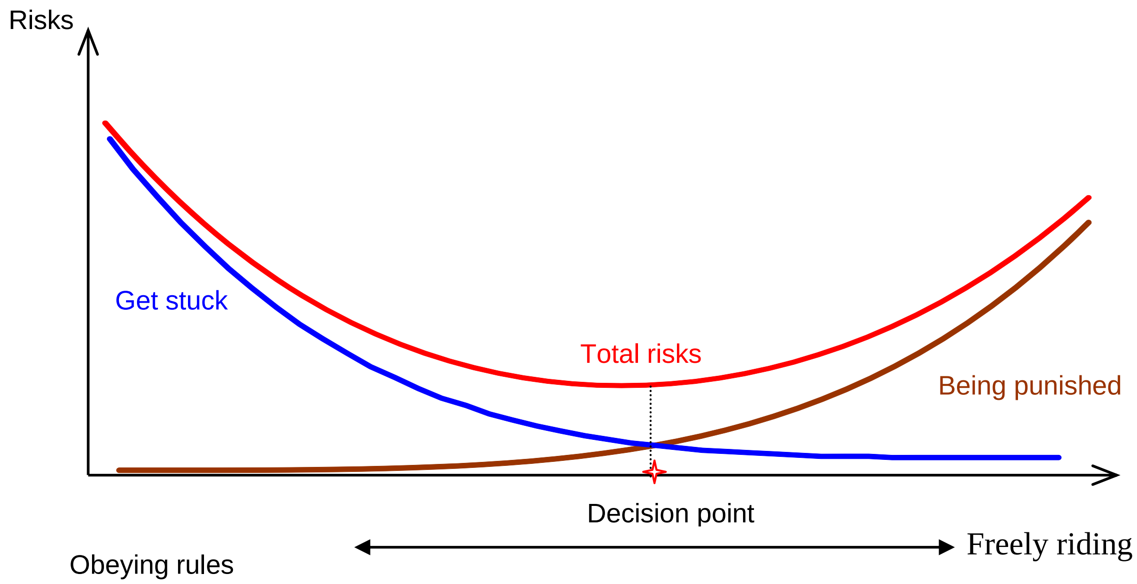


Figure 33. Flow chart of negotiating attitude between risks

Briefly speaking, a driver decides (with intention or not) to violate traffic regulations when s/he supposes that s/he can gain more than losing with such behaviours.

The implications of this conceptualisation which should be of immediate relevance to the highway safety engineering are that:

- safety may be challenged if there is a discrepancy between the driver´s perceived task difficulty and objective task difficulty, as the driver underestimates real task difficulty
- when shortening journey time has a value, if a driver can increase speed without increasing perceived task difficulty, he/she will do so;
- where conditions are such that the demands of the task exceed his or her capability, and the driver can do nothing to reduce those demands or enhance his or her capability, the driver will choose to avoid those conditions.

Like many activities performed in dynamic environments (Amalberti, 1996; Hoc, 1996), driving is characterised as:

- A complex task, subject to temporal constraints and calling for a continuous adjustment to evolving road situations.
- A task that implies the organisation and performance of multiple inter-related sub-tasks associated with the control of the vehicle, on one hand, and the control of road events on the other (Allen et al., op.cit.);
- A task in which the driver is facing uncertainty and has to take decisions that involve risks, given the number of interactions to be negotiated (with his vehicle, with the road infrastructure, with other road users, and so on)

Driving may also be defined as a relatively in structured task (Saad, 1975) in that:

- The formal task, such as prescribed by the “highway code”, only partially defines the conditions to be taken into account and the procedures to be followed in a given situation. This is due to the very complexity of the driving task and the difficulty of defining a system of rules of a fully operational nature (Leplat, 1998)
- Most of the information required for driving is informal;
- Driving experience is mostly acquired “by doing”, i.e. through practice and experience of road situations. Thus drivers essentially acquire knowledge and develop strategies in a rather “unsupervised” manner.

Drivers´ capacity to learn from experience is a measure of their ability to find heuristic solutions to the dynamic problems they are faced with in managing their journeys. This ability to adapt may be regarded as the result of a “structuring of the task” (Saad, op.cit.) based on:

- The acquisition and organisation of knowledge about the structure of the road space, the (formal and informal) rules governing its use and interactions with other road users, and the dynamics of different road situations
- The development of strategies for information gathering and processing and of rules of action.

Some research shows that when crossing intersections, drivers may take undue time to become aware of conflicts with other drivers, or display certain inertia in the regulating actions they take (Saad et al., 1990). Factors connected with the features of the road environment (disparity between the functional characteristics of an intersection and the regulations governing it, or the visual aspect of the intersection), as well as factors related to driver characteristics (general experience or specific experience of the site).

Ruller, Jorge A. Santos (2001) affirmed that one of the human factors which make for variability in performance is motivation. When considering driving performance, motivation may be expressed as the level of effort you are prepared to make to do the task effectively, efficiently and safely. We behave in particular ways to obtain pleasant consequences or to avoid unpleasant ones. In this sense behaviour is “controlled” by its consequences. Thus we might take a short-cut when turning in order to save time (rewarding consequences) and stop before red lights to avoid censure from a policeman (punishing consequence). However, for consequences to control behaviour, other conditions usually have to be met. Particular conditions can become triggers for particular behaviours. In this sense, behaviour is activated by these conditions, a process known as stimulus control. Thus we can say that behaviour is under the control of two events – both activating conditions and consequences.

The consequences of behaviour also provide a mechanism for learning. The “rewarding” of a particular behaviour (with a pleasant consequence) makes it more likely to occur again under similar circumstances. The “punishing” of a particular behaviour (with an unpleasant consequence) makes it less likely. This analysis provides a framework for incorporating the processes of motivation and learning in understanding the causes of risk-taking. A person may engage in a risky behaviour because it has rewarding consequences.

So the question will be: what consequences can motivate risky behaviour (in this case, the behaviour of violating road traffic regulations)? Although accidents are usually triggered by one final act or failure to act, they nevertheless have multiple causes. When all of those causes occur together in the right pattern – an accident is inevitable. The fact that a pattern of events is typically necessary for an accident to happen means that the driver can sometimes (or often) get away with mistakes. Such a forgiving system can enable the driver to get away with unsafe practices for a long time. In this way, the driver can unwittingly learn unsafe behaviour. In similar ways, if the driver can drive when violating traffic signals or lane markings without being punished with the “feeling” that s/he can drive much faster, then the violation behaviours become more common.

Briefly speaking, general attitudes towards legislations as well as specific reaction in a special situ (involving experience about the site/intersection and his/her own compromise of risks) lead to behaviors of violating traffic regulation.

5.3. General Attitudes towards Rules

Applying the theory of planned behaviours in analysing the data collected from an interview in Vietnam (Consumer Behaviour & Insight, Happy Street, 2008). The questions for road users´ opinion are those such as:

1. Almost everyday I see traffic regulation violators without being punished
2. Sometimes, I also violate the rules
3. With such traffic situation, it is impossible to ride without violating traffic regulations
4. At this time, in traffic participation, everybody breaks traffic rules
5. In the traffic conflicts, errors belong to the "big" vehicles
6. Sometimes, it is understandable to driver a little bit faster.
7. The policemen often do not punish bicyclists
8. Sometimes, it is understandable to have a small violation in order to drive faster
9. Normally I do not pay attention to lane markings when stopping before red lights
10. Sometimes, I cannot recognize (in time) traffic signs when driving (turning forbidden, unique streets...)
11. In the last one month, I was not punished by the police
12. I think that the traffic situation is improved day by day.
13. I always feel the difficult atmosphere when getting outside
14. I feel very difficult to get out in the peak hours
15. Now everybody have to try to drive, there is no orderly traffic flow
16. I have to use wrong lane/wait in the wrong position to avoid congestion
17. When there is congestion, if we give other the priority (yield others), then we can get stuck
18. I always get delay due to congestion
19. Congestion cause angry to road users
20. The environment seems to get more and more polluted due to congestion
21. In some cases, it is understandable to conduct red-light running

In the interview asking for their opinion when participating in traffic system, mostly drivers agree that "in such a traffic condition, it is difficult to ride without violating traffic rules" (Q11.3: 68% agree). Other explain that "I have to use a wrong lane/wait in the wrong position to avoid congestion" (Q11.16: 58% agree) and "In a traffic congestion, if we yield others then we will get stuck immediately" (Q11.17: 68% agree). Those reasons for violating traffic regulations are put in the group of "congestion fear".

Vietnam is now in the progress of amazing increase in economics. Social and economical living standards have very high achievement. Demand for people and goods transportation has the significant increase in both quantity and quality.

At the same time, it is eye-witnessed the amazing increase in traffic accidents, both in number and damage rate. Statistics data reveal that number of people died and injured by traffic accident is much higher than any of the most serious diseases. The very high occurrence frequency of traffic accidents in Vietnam has become one of the country's major social issues.

There are several reasons leading to traffic accidents. Inadequate infrastructure network is currently considered as one of the biggest reason for traffic accidents. However, the problem is to find out whether it is worth investing in constructing and/or upgrading roads network. Sometimes, in newly-built roads, as drivers can ride at the very high speed, traffic accidents can occur much more times with much more seriousness.

The tendency for the non-regulation of transport construction activities provides a free selection of the approaches for risk assessment for safety and health in the stage of project design. This freedom assumes that a search for appropriate engineering approaches for their prediction and minimization will be performed.

In order to be able to control traffic accidents, it is required to quantify the driver of a risk and its impacts to traffic safety. Many measurements can be applied to fulfil the objectives. However, in Vietnam, up to now, there is an urgent need of building consensus on priorities for regulation and standardisation process. The cost to spend for safety measures are also the very important things to take into consideration.

There are many characteristics causing the distinction between Vietnamese traffic system and those of other developed countries. The most distinct characteristics consist of transportation infrastructure and superstructure, traffic participants, driver behaviours, and traffic flow.

In the aspects of transportation infrastructure, it is easy to see that long, narrow, and interlacing roads in poor quality are particularities of road systems in urban areas. Big cities such as Hanoi, Ho Chi Minh City, etc. have a monocentric urban form, which also mean that almost the mobility demand focuses in the area. The uncontrolled urbanisation and the explosion of motorcycle usage at the same time create many "two-wheeler accessed only" blocks in the conurbation. The main issue of this unique urban form is the isolation from the public transport service and emergency services (e.g. ambulance, fire fighter).

Generally, there are no dedicated paths for pedestrians and cyclists. Therefore, all participants have to negotiate traffic. Traffic control systems are operated by traffic regulations, traffic light systems, and policemen.

Traffic system in Vietnam is a mixed one. This terminology is used when the traffic flow comprises both motorized and non-motorized vehicles, in which motorbikes occupy a large proportion. According to Vietnam General Statistics Office (2007), the number of motorbikes having registered until 2007 reached about 21.72 million in a population of 81 million while the number of cars was only 1.11 million. The widespread use of motorbike has its rational of the vehicle’s flexibility and economy, citizen’s income, roads’ conditions, and et cetera. Public transports such as bus and taxi are also in use, but they cannot compare with motorbikes in terms of flexibility, convenience (especially in the characteristics of narrow and long road inside urban areas), as well as time and money saving. The number of private owned cars has increased continuously in recent years but just within a limitation. High price, taxes, traffic congestion are some of main reasons for unpopularity of cars. Trucks and heavy trucks are used for freight transport because cities are normally economic centers where industries parks and ports are also located. Besides bicycles, other transport modes such as tri-cycle also participate in traffic system.

Researches (e.g. Human factors for highway engineers by Ruller, Jorge A. Santos, 2001) have led to the identification of the main characteristics of the driving task, which may serve as a general framework for analysing driver behaviour. In this section, we will emphasise the main features that characterise the driving task and the nature of certain behaviours of violating traffic regulations identified through observation and interviews on experts and drivers´ opinion.

The main question to ask from the behavioural viewpoint is why you behaved in a particular way, why you responded by answering your phone, at the particular moment you did. After all, in your repertoire of possible behaviours, you could have simply carried on with what you were doing, you could have lit a cigarette, and you could have turned a somersault or enacted a myriad of possible alternative behaviours. To get at this question, let's ask a further question. What might have happened if, in all of your previous experiences with this particular phone, attempting to answer it had resulted in failure - there was always no-one there at the other end of the call? Would you then have responded to the telephone? The simple answer is no you probably wouldn't.

Say every time you answered the phone you received a painful electric shock from the instrument. You would soon stop using it. A punishing consequence to behaviour has the effect of lowering its probability, of suppressing it and sometimes eliminating it altogether. So rewarding consequences strengthen behaviour, punishing consequences weaken it. Consequences therefore provide a powerful mechanism in the process of learning what to do or not to do. Translating this into the language of human motivation and *intention* (which will perhaps be more satisfying for the more cognitively inclined reader), it may be said that we behave in such-and-such a way in order to obtain pleasant or rewarding consequences or to avoid or escape from unpleasant or punishing consequences. Thus we drive faster (response) in order to get somewhere more quickly (rewarding consequence). Correspondingly we stop before the red light at an intersection (response) in order to avoid getting captured by the policemen (punishing consequence).

Many literatures (e.g., Human Factor Guidelines of AASHTO - HFG, 2007) prove that, driving behaviour consists of two components:

(i) perception – reaction time (PRT) required to initiate a manoeuvre (pre-manoeuvre phase), and

(ii) Manoeuvre time (MT) required completing a manoeuvre.

The PRT component includes the time needed to see/perceive the roadway element, time needed to complete relevant cognitive operations (e.g., recognize hazard, read sign, decide how to respond etc.), and time needed to initiate a manoeuvre (e.g., take foot off accelerator and step on brake pedal). MT includes actions and time required to safely coordinate and complete a required driving manoeuvre (e.g., stop at intersection, pass a vehicle, etc). Typically, a vehicle maintains its current speed and trajectory during the PRT phase, while changing its speed and/or path during the MT phase.

Applying the guidelines in motorcycle traffic flow in Vietnam, it is argued that the cause-and-effect chain of violating traffic regulations can also divided into two phases of perception and reaction. The Hypothesis will be proved through opinion and judgement of experts and driver as well as residential.

In Vietnam, there is the trend of applying the behavioural model of 4E (see reference of JBIC/ALMEC project) which consists of education, engineering, enforcement and emergency. In order to understand the cause-and-effect behaviour chain of violating traffic regulations, the research focuses firstly on the expert opinions on Vietnam driver behaviours. (Ref. The workshop on the topic of “Situation and solutions of education and training on traffic culture for Hanoi residents” on March 22, 2008)

Policemen say that it is possible to realize driver poor attitudes towards legislation through the fact of behaviours against traffic policemen when participating into the traffic. In the year 2007, inside the city (Hanoi) there are reports of 16 cases when traffic participants intentionally heat policemen or run away from traffic regulation violation and attack policemen afterwards. From reports of Hanoi police, in 11 months in 2007, more than 0,5 million people received punishment from behaviours of violating traffic regulations. Cases of violation behaviours, which the traffic police had to deal with, increased by 136% in comparison with the last year.

Mr. Takagi Michimasa, a traffic expert from Japan, the chief technical advisor of the project Traffic Safety Human Resources Development in Ha Noi (TRAHUD), a long with other experts agree that beside infrastructure and vehicles, driver attitudes towards legislation is one of the most important “link” in order to reduce the number of accidents and traffic congestion. He said "When travelling on the road, Vietnamese people use their experience instead of following the instruction of the law."

A survey conducted by Nguyen Van Du, an expert from TRAHUD, indicated there were more than ten traffic hot spots in the city. "But the leading cause is the people" the survey pointed out. Du described road behaviour as "uncultured."This behaviour has become a "bad habit" for quite a number of people. There exists a mix between the two concepts of “you cannot drive” and “you’re not allowed to drive”. The researcher also discusses that "During the rush hours some riders suddenly pull over to the roadside to buy something from street vendors or listen to their cell phones. They’re not bothered about the consequences of their actions: traffic jams." In Du’s opinion, it is imperative to build a civilised traffic culture, as a part of the city’s civilisation. In order to have a transport culture we need to have the support from people involved in the traffic as well as the devotion and fairness of law enforcement officials.

In the TRAHUD project, Ha Noi has selected some road portions as models, including the Thai Ha-Chua Boc, Thai Ha-Lang Ha, Nguyen Chi Thanh-La Thanh, Cau Giay-Xuan Thuy-Pham Van Dong roads, in hopes that by the end of 2008 Ha Noi would become a forefront in traffic safety.

Do Kim Tuyen, deputy director of the Ha Noi Police Department and deputy director of the 197 Steering Committee on Traffic Safety, said the committee had launched a campaign to build a civilised traffic culture among the Hanoians ahead of the 1000th founding anniversary of Thang Long-Ha Noi in 2010. "In 2008, we want all Hanoians to become law-obeying citizens. In order to reach this target we will introduce tough measures, including the adjustment of the volumes of vehicles operating on a certain routes and the temporary seizure or confiscation of vehicles engaged in illegal races"

Based on analysing current situation and collecting experts´ opinions (as mentioned above), aiming at finding out the causes to such violations to traffic rules, the above-mentioned project (so-called Happy Street) has the main findings as discussed follows.

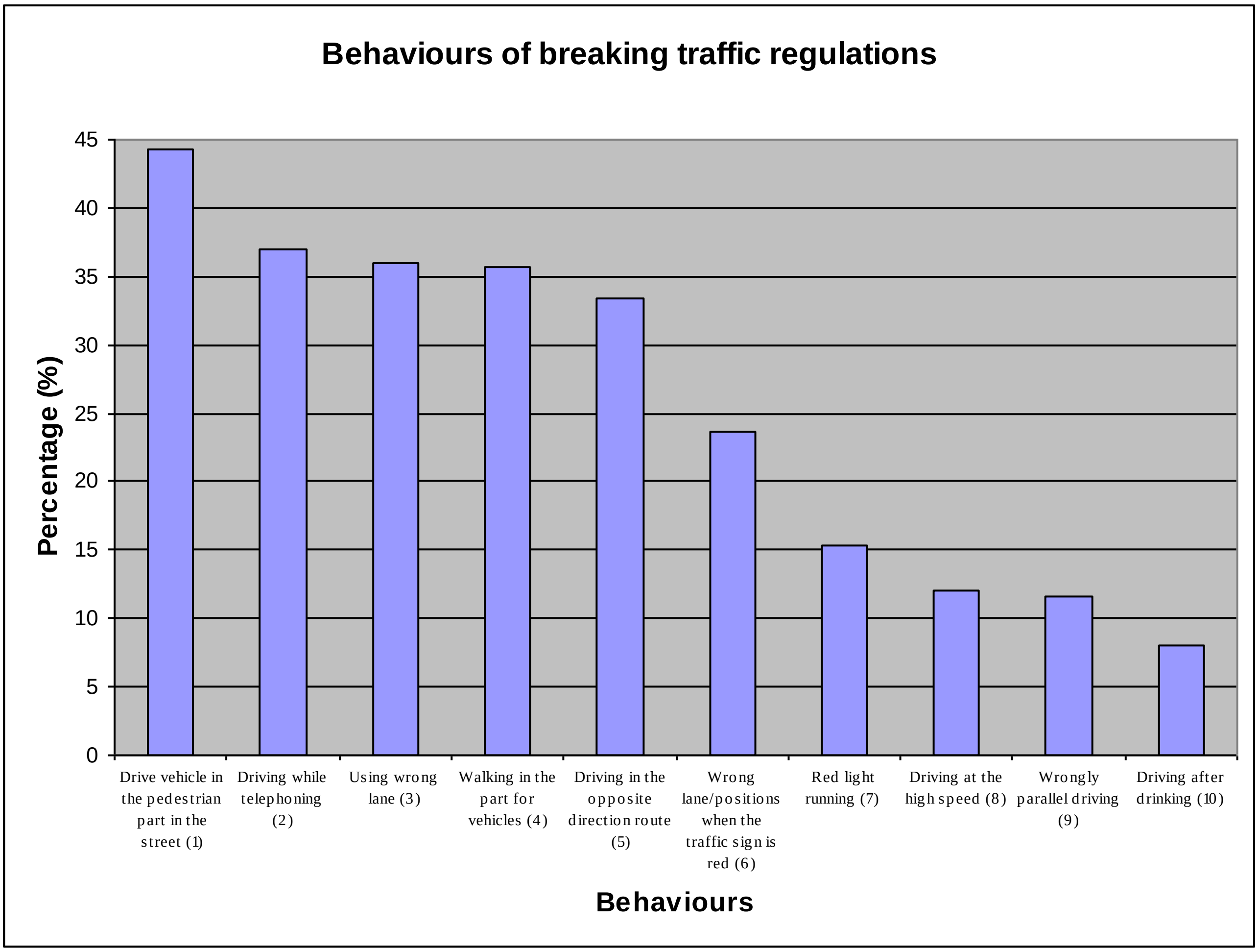


Figure 34. Driver behaviours of violating traffic regulaltions

Though interviewees also perceive the danger of such behaviours as they grade their dangerous level.

Table 10. Driver evaluation on critical situations

No.	Behaviours	Acceptable	Very dangerous
1	Drive vehicle in the pedestrian part in the street	46%	54%
2	Driving while telephoning	31%	69%
3	Using wrong lane	22%	78%
4	Walking in the part for vehicles	40%	60%
5	Driving in the opposite direction route	45%	55%
6	Wrong lane/positions when the traffic sign is red	25%	75%
7	Red light running	7%	93%
8	Driving at the high speed	7%	93%
9	Wrongly parallel driving	8%	92%
10	Driving after drinking	4%	96%

From the interview, it is shown that there are two attitudes of imitation and the trend to avoid congestions.

Immitation and the attitude of ”disobey = no damage/punishment”

- Almost everyday I saw people breaking traffic rules without being punished: 71%
- In the last one month, I was not punished by the police: 82%
- Sometimes, I also break the rules: 72 %
- In the current traffic status, it is impossible to drive without breaking traffic rules: 68%
- At this time, in traffic participation, everybody breaks traffic rules: 52%
- In the traffic conflict, errors belong to the "big" vehicles: 33%
- The policemen often do not punish bicyclists: 69%

Attitude “It is impossible to ride in such a crowded traffic without breaking the rules” and “traffic rules obey = damage”.

- When there is congestion, if we yield others, we can get stuck immediately: 68%
- I have to use a wrong lane/wait in the wrong position to avoid congestion: 58%
- Now everybody have to try to drive in his own desire, there is no orderly traffic flow in the city: 85%

Attitude “sometimes it is understandable to violate the traffic regulations”

- Sometimes it is understandable to drive at a higher speed than the regulation: 64%
- Sometimes it is understandable to have a small violation behaviour to ride faster: 60%
- Sometimes it is understandable to drive over red lights: 44%

In conclusions, from theoretical and empirical aspects in Vietnam, it is assumed that driver behaviours of violating traffic regulations are the result of a continuous chain from attitudes towards legislation with the influence of such following parameters:

- Driver personality characteristics: Attitudes towards legislation, Perception capacity, Cognitive elements, Motivation in specific cases
- External parameters: Infrastructure; Traffic legislation, operation and management regulations; Traffic flow conditions (and other road users´ behaviour); Other surrounding parameters.

Now we can have the chain of driver behaviours (focusing on the driver internal characteristics) illustrated as follows:

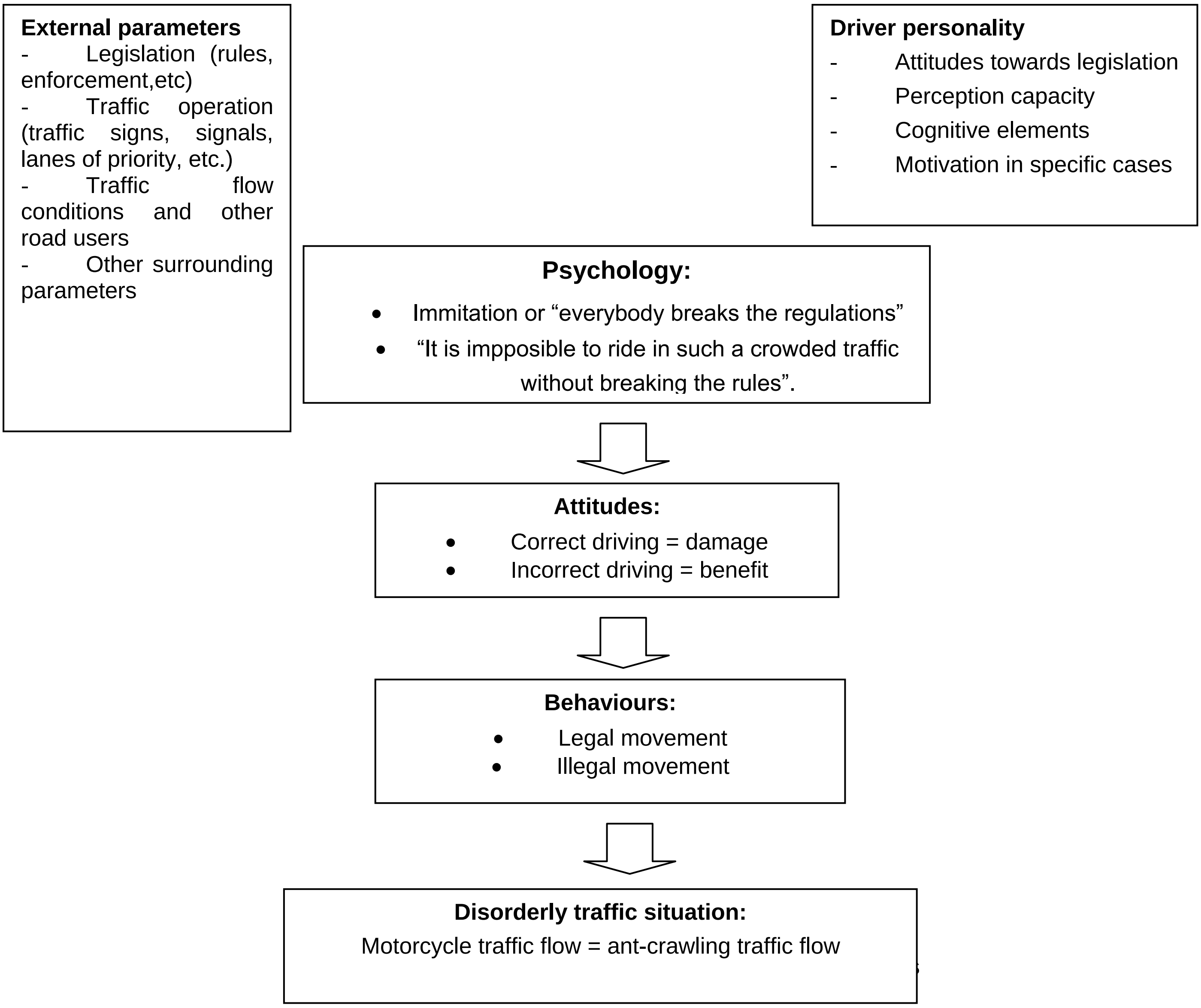


Figure 36. Driver behaviour chain of violating traffic regulations

5.4. Specific-scenario Acceptance of Rules

5.4.1. Balancing between Two Risks

As mentioned from above, driving task is the negotiation between two risks. The level (hard or not) of enforcement have influences on driver attitude towards legislation, shifting the curve of "being punished" to the left. The optimum point of "total acceptable risk" will also be shifted to the left, causing the driver behaviour to be more likely to "obey the rules".

From the chapter 3 of methodology, the definition of risk (Bald, 1991) is mentioned as the product of the probability and the extent of a possible damage. With such definition, all units are reduced, then it is possible to calculate the probability for any case (good or bad), from the causes (independent parameters, such as driver age, education level, intersection level of service, traffic environment, etc.), through all internal elements (dependent parameters, such as general attitudes towards legislation, fear for congestions, etc.) to come to the expected results. The physolophy of DRAM also provides the opportunity to come up with the probability of population of drivers from individuals.

For example, when we have two different drivers with different personal characteristics, in different trip motivation and cognition, then we can obtain two different curves of fear for “getting stuck”. We can then sum up the two curves, with the participating of the curve of “being punished” to get the total risks. The same procedure may be conducted for the whole population.

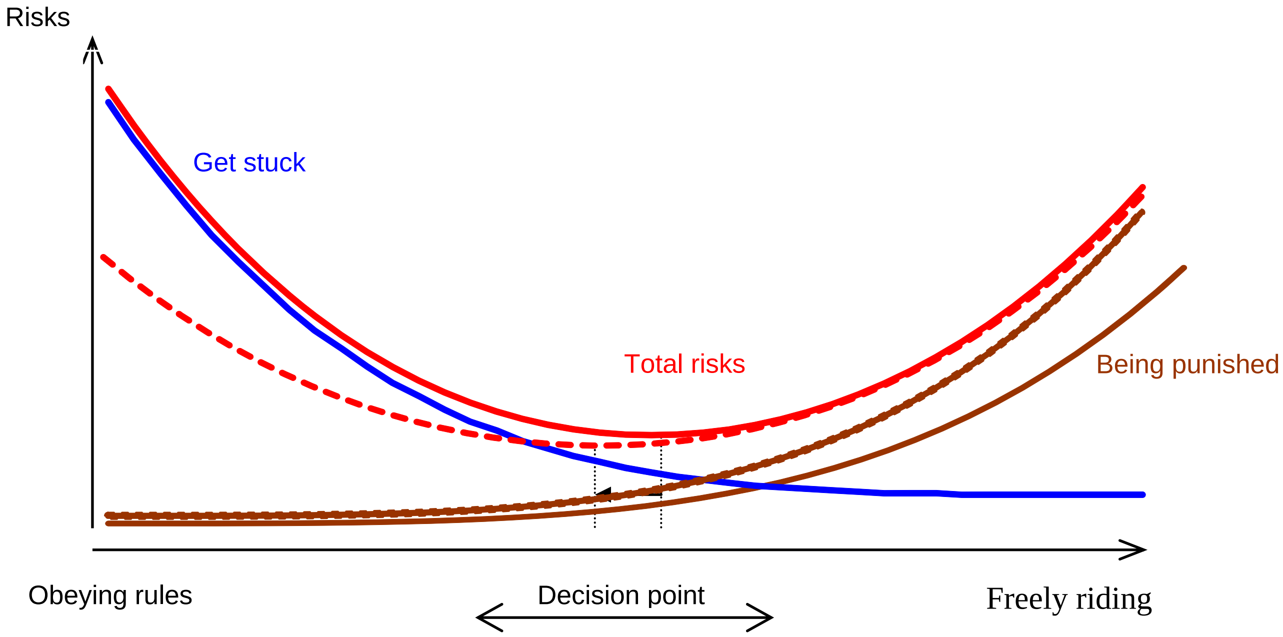


Figure 37. Total risk from different individuals

It is important to emphasize that the external parameters will affect two curves of “getting stuck” and “being riding” and then it influences the curve of “total risk”. Then the decision point will be the answer for the question “why do drivers behave that way”. Classifying drivers into groups will help simplifying the task of calculating influences from different external parameters.

5.4.2. Enforcement and its Long-term Influence

Thus far we have been talking in terms of external controls on behaviour, controls out there in the environment. An alternative is provided by the internal control of 'rule-following'. Rules may be described as statements of contingencies. For example the rule "do not overtake on a blind corner" may be translated as a statement of the contingency "if there is a blind corner (discriminative stimulus) and you overtake (response) you may crash into an oncoming vehicle (punishing consequence)". Rules of the road and rules of good driving practice in a road-user's head may be thought of as internalised statements of contingencies. When made explicit, they not only provide a useful method for transmitting knowledge about contingencies, but they do so without the learner having to experience them directly. They are also of particular use in those situations in which the naturally occurring contingency, i.e. what actually happens, is not very effective at maintaining the desired behaviour. An example would be in the control of slow speeds through a built-up area. Seeing a clear run ahead, drivers may drive over the speed limit without experiencing any punishing consequence such as a collision. But just so long as the road user follows the correct rule for the conditions, even if on many occasions following the rule is experienced to be unnecessary, a safe outcome is more likely to occur. As amply demonstrated in the commercial aviation sector, in which rules are expressed as Standard Operating Procedures for most routine actions performed by air, ground and maintenance personnel, control by rules is a strategy with a remarkably safe record. Unfortunately there is evidence that where rule-following is not supported by the natural contingencies, the control of behaviour may transfer from the rule to those contingencies. If a driver sees that s/he can break the speed limit without punishing consequences, and is motivated to go faster, then the control of behaviour by the rule may be suspended. Because of this problem, Skinner (1988) emphasised the role *of enforcement* in the maintenance of rule-following behaviour that is the addition of consequences other than naturally occurring ones to the behaviour in question. Although rewards for rule-following have been tried out successfully in only a few contexts, punishment for failure to follow a rule has been the more prevalent procedure. This is exemplified by police speed-traps and more generally the detection and penalisation of traffic law violations (see review by Evans 1991). Creating a perception amongst road users of an enhanced enforcement of traffic regulations can produce remarkable changes in behaviour leading to significant decreases in accident statistics (see Epperlein 1987).

In the report of project funded by the European commission with the topic of “Traffic enforcement in Europe: effects, measures, needs and future” (Escape Project, 2003), they released a model of describing compliance of traffic laws based on research into the effects of legislation and enforcement.

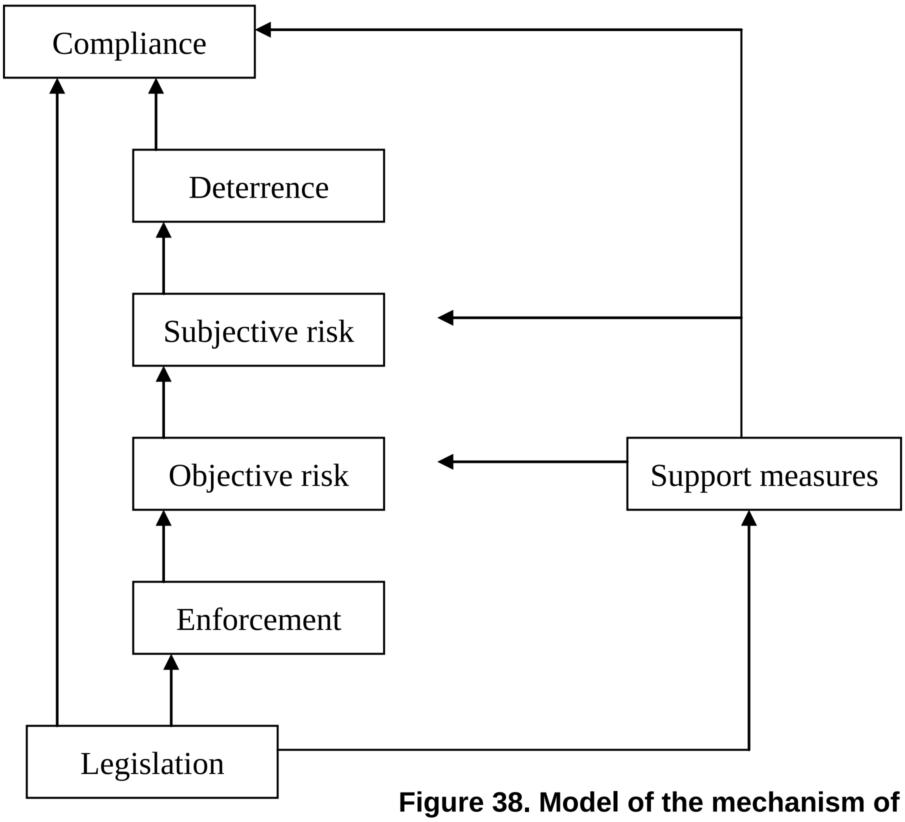


Figure 38. Model of the mechanism of traffic law

According to the model, legislation forms a framework for traffic enforcement. Legislation may influence drivers in three ways. First, enforcement including surveillance, catching the offender, possible prosecution and adjudication creates an objective risk of detection for traffic offences. This, again, has an impact on drivers' perceptions of possibilities of getting caught for infringements. Subjective risk of detection is the drivers' own more or less conscious and less explicit judgment on possibilities of getting caught for violations. Moreover, supportive measures such as media or word of mouth (e.g. communication among professional drivers) may either increase or decrease the subjective risk of detection. Thirdly, the effects of legislation and other sources of information often directly influence behaviour just by making road users aware of the norms or the codes of correct behaviour. This is simply because usually the majority of road users *want* to comply with the rules, not in order to avoid fines, but simply to behave as prescribed by law. For some road users, however, it is their concepts and experiences of the enforcement system in the last phase that create the deterrence effect of enforcement and make them comply with regulations.

As a guide to TLE policy the model is, however, fairly general and explains only a part of driver behaviour. As the model suggests, there is a direct 'line' from legislation to compliance, suggesting that for some road users the mere existence of a traffic code reinforced by observations of the behaviour of others is sufficient for compliance. Moreover, it is unlikely that compliance is determined mainly by what police do about detection and on the private translation of these actions into subjective risk of detection. The model does not consider other likely determinants of compliance such as how sensible or how fair a regulation may seem to people.

There is an example in enforcement effectiveness in traffic flow in Table 11.

Table 11. Effects of conventional and fixed camera enforcement on speeds

Type of enforcement	Effect in space	Effect in time
Conventional = the police monitoring the same site at intervals	Speeds decrease in the vicinity of the surveillance source	Speeds increase after the removal of a surveillance source
Fixed camera = surveillance facilities continuously monitoring at the same site	Speeds decrease in the vicinity of the surveillance source	Speeds do not essentially increase over time

5.4.3. Fear for Congestion

As mentioned from above, driver behaviour of violating traffic regulations have a lot of effects from "fear of congestions" (or "failure of reaching the destination in time").. The external parameters influencing "congestion situation" at a specific intersection are such of infrastructure (intersection layout, dimension, etc.), policy of traffic operation and management (traffic signal cycle, rules of priority, etc.), and traffic flow (critical volume, average density, etc.).

The current situation of congestion in Vietnam traffic system cause such "fear for congestion" to normal drivers. The most update statistical data (from NTSC) shows that in Hanoi, there are 76 intersections with the potential risk of congestion, especially at peak hours (7-8am and 17-18pm). Congestion now is a rather serious problem in traffic system in urban areas in Vietnam, also because it reduces the whole traffic system effects, wasting a lot of time and expenditure, polluting the environment, etc.

The research would like to make a definition of "congestion" and the qualitative evaluation of congestion level in an intersection.

From the literature review, there is also another possibility to define "congestion" with the average waiting time". However, as mentioned from above (chapter 4), it is observed in crowded situations in mixed traffic flow that left-turners do not only wait in the waiting line (when there is a red-light) but a percentage of them have to wait inside the intersection area (to wait for an acceptable gap)

Applying the approach of risk analysis, it is reasonable to give out the concept of congestion in mixed traffic regulations. To one driver, congestion means "he/she has to wait in the waiting line for more than one traffic signal cycle and/or wait inside the intersection". To the whole system (in a specific intersection), there will be such following classification:

- "congestion is high" when more than 30% of drivers are in "congestion"
- "congestion is moderate" when 0 – 30% of drivers are in "congestion"
- "no congestion" means there is no driver is in "congestion"

From the interview of driver opinion (Happy street project) in Vietnam, it is possible to take into consideration the influence of congestion (so-called "situation of crowded traffic flow") on attitude and behaviour of traffic rule violation. Interviewees explain that congestion situation is one reason for their behaviour of violating traffic regulations

1. When there is congestion, if we yield others, we can get stuck immediately (Q11.17: 68%).

2. I have to use a wrong lane/wait in the wrong position to avoid congestion (Q11.16: 58%).

3. Now everybody has to try to drive in his own desire, there is no orderly traffic flow in the city (Q11.15: 85%).

The Hypothesis raised here is that the crowded traffic flow has a closed relationship with behaviours of traffic rule violation of road users (especially with the behaviour of red-light running, wrong lane usage and driving/walking in the opposite lane). It is of course the question of confidence level of the interview results before possibility to use such statistical data (percentage) in the model.

In Vietnam, especially in the condensed population of urban area, with high vehicle density, there are the distinguishing parameters of volumes in different period of time during a day. The average speed of vehicles is also very much different.

Being different from four-wheelers, motorcycles do not follow lane disciplines. When the spacing to the front vehicle is very far, the motorcyclist rides without any constraint from the front vehicle. When the spacing to the front vehicle is close sufficiently, the subject rider in accelerates/decelerates with constraints from the front vehicles.

In the first case, risks that drivers have to cope with are the potential conflict between the subject vehicle and critical situations (including other vehicles in the other moving direction or other obstruction). In the second case, all the vehicles moving under the same constraint of one vehicle (the leading vehicle) form one travelling group of vehicles. Therefore, there are two different types of risk. One is the risk of the whole group to meet the conflict with critical situation (as in the first case of one single driver). The other is the risk of internal conflict in the same group, which may happen when the following vehicle(s) can not react appropriately with the leading vehicle´s riding manoeuvre. In comparison between two cases, it is obvious that the amount of conflicts in the second case is larger than one in the first case. However, accidents (conflicts with damage of property and/or human being) are mostly more serious than those in the first case. This fact one more time approves the above-mentioned Hypothesis that there is the linear connection between travelling speed and seriousness of accidents.

From empirical pilot observation in the field, it is obvious that there are a big gap among driver behaviours in two different situations of uncrowded traffic (in which case, there are sufficient spacing among travelling vehicles, which provide conditions for vehicles to drive at their designed/technical speed) and crowded traffic.

Variables illustrating the congestion level of an intersection can be classified into two groups of time and space variables. Time variables include average crossing time, average delay time (lost time) of vehicles crossing the intersection, time headway between vehicles in the traffic flow, etc. Space variables include vehicle density, average occupancy in the intersection area, space headway between vehicles in the traffic flow, etc.

There is a common situation in urban traffic in Vietnam that during the peak hour in the morning and in the evening, the traffic flow has a considerable increase in volume.

5.5. External Parameters

5.5.1. Intersection Level of Service

From literature review, there is no linear relationship between conflict quantity and risk level (which is described with the accident seriousness and frequency of accidents at different risk levels). This research raises a Hypothesis that accident is a function of conflict (with or without conflict), travelling speed of the vehicle(s) at the moment of conflict, and conflicting angle. This argument also can explain the reason for the fact that in many cases, in locations, or time periods (in the whole day), there is a crowded traffic, the conflict frequency is higher. However, such conflicts do not lead to the serious results (fatal, injury or property damages). Normally, road users can only process simultaneously limited amount ò information during their driving. Meanwhile, the pace at which information is encountered increases with their travel speed. That means, when the speed is higher, the amount of information they have to deal with increase quickly. In fact, many researches (Englund, Gregersen, Hyden et al. 1998, Karin F. M. Aronsson, 2006) show that there is a close relationship between travelling speed and the seriousness of accident.

Another requirement for applying in the model is a variable that can illustrate “congestion level” of the traffic flow. Following are some documents that we can take as a reference.

HBS 2007 classifies the quality of an intersection traffic flows into 6 levels based on the average waiting time of vehicles as follows (Table 6.2 page 6-9, HBS 2007):

Table 12. Intersection quality levels

Quality level	Average waiting time (s)				Percentage of vehicles passing without stop (%)
	Public transportation	Bicycle	Pedestrian	Car	Car
A	≤ 5	≤ 15	≤ 15	≤ 20	≥ 95
B	≤ 15	≤ 25	≤ 20	≤ 35	≥ 85
C	≤ 25	≤ 35	≤ 25	≤ 50	≥ 75
D	≤ 40	≤ 45	≤ 30	≤70	≥ 65
E	≤ 60	≤ 60	≤ 35	≤ 100	≥ 50
F	> 60	> 60	> 35	> 100	< 50

From Merkblatt für die Austattung von Verkehrsrechner zentralen und Unterzentralen (MARKZ 99), Ausgabe 1999, we have the evaluation of traffic flow situation as follows:

Table 13. Quality of traffic flow

		1 lane		2 lane		3 lane	
Traffic flow		V (km/h)	D (veh/km)	V (km/h)	D (veh/km)	V (km/h)	D (veh/km)
Z_1	Free flow	≥ 80	0 ÷ 20	≥ 80	0 ÷ 30	≥ 80	0 ÷ 40
Z_2	Crowded flow	≥ 80	20 ÷ 50	≥ 80	30 ÷ 60	≥ 80	40 ÷ 70
Z_3	Slow flow	30 ÷ 80	≤ 50	30 ÷ 80	≤ 60	30 ÷ 80	≤ 70
Z_4	Congestion	< 30	> 50	< 30	> 60	< 30	> 70

In the practical traffic flow in Vietnam, due to the road traffic regulations, in urban roads area (as the concept of the area with high population density), the maximum speed allowed is the value of 40-50km/h. From field surveys, average speed in urban areas (JBIC, project SAPFOR, 2006) can be summarized as follows:

Table 14. Current situation in urban traffic flow

Type of vehicles	**Speed in urban area (km/h)**		**Speed in outskirt area (km/h)**	
	Peak hour	Off-peak hour	Peak hour	Off-peak hour
Motorcycles	25	30	40	50
Car	25	35	40	60-70

The average speed when crossing intersections are not surveyed yet. It is also rather difficult to clarify “temporary speeds” of motorcycles in left-turning movements. Especially when we would like to do research with macro view-point. In order to apply such standards in motorcycle-dominated traffic flow, it is required to understand the theoretical fundamental of classifying quality levels of traffic flow. Let´s take a look on the principle of classifying 6 different levels of service of an intersection from HBS. The quality of the traffic flow ranges from level A (with the highest quality) to level F (with the lowest quality). Characteristics of different levels are described as follows:

- Level A: Road users are seldom affected by others. They conduct their expected freedom of movement to the extension of the infrastructure design. The traffic flow is free.
- Level B: The presence of other road users is considerable, but has rather low impact. The traffic flow is almost free.
- Level C: The individual movement depends much on other road users. The moving freedom is considerably limited. The traffic flow is stable.
- Level D: The traffic flow is characterized with high loading, in which the moving freedom of all road users are very much limited and affected by other road users. The interaction among road users appears. The traffic flow is still stable.
- Level E: There must be a negotiation among vehicles to move in the traffic flow. The movement freedom has just a very limited sense. The intersection capacity has been reached. The traffic flow is in between stable and unstable.
- Level F: The demand is larger than the capacity. The traffic is very much congested.

The similar principle can also be applied to MD traffic flow. As mentioned from above, in the urban area, it is very common situation (in many places) when the traffic is very much crowded in the peak hours. Below are results of counting vehicles in a continuous period of time of 16h at 9 locations in Hanoi. Selected stations chosen for conducting the survey are all located on main routes (normally in the major entrance to the city) with high traffic volume.

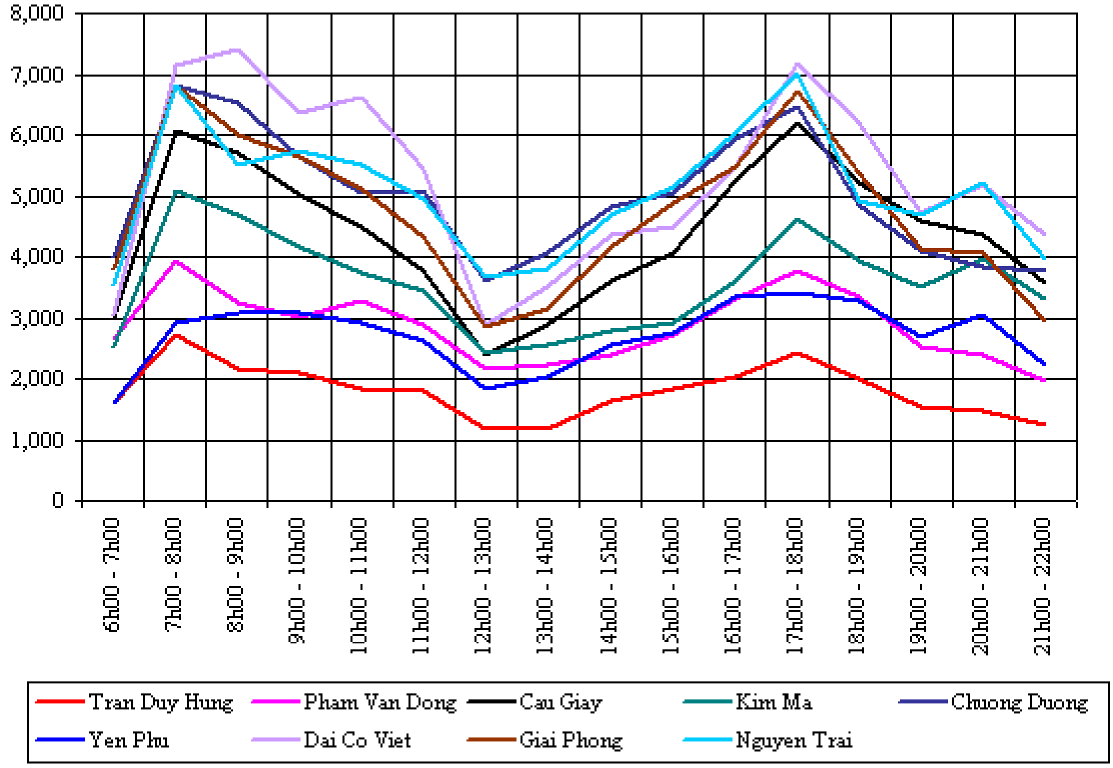


Figure 39. Traffic Volume at 9 Counted Stations (Passenger car unit: PCU)

It is remarkable that the peak hour of traffic flow is in the morning (7:00am to 8:00am) and in the afternoon (17pm – 18pm). Applying the physolophy of intersection quality of service, we can relate the congestion situation with the peak-hour or off-peak hours in a day. From now on, the research focuses only on driver behaviours (of violating traffic regulation) in such congested period of time (peak hours).

5.5.2. Infrastructure

In research of *Ergonomics of driver interface with the road environment: the contribution of psychological research*, (Human Factors for highway engineers) (2001) Farida Saad argues, that the road infrastructure conveys a wealth of information that guides drivers´ activity and their interactions with others in situ (explicitly through devices such as road signs and road markings, and implicitly by means of the environmental context and road layout, for example). The design of the infrastructure and the formulation of the rules determining its use result from choices made by the designers of the road system in the broadest sense (including in particular road and traffic engineers and the legislators of the Highway Code), so one can regard the road infrastructure as an interface between road designers and drivers. This concept is also described by Hale and Stoop (1988), who position road design problems in terms of communication between road designers and road users and of compatibility between the formal rules of use underlying the design of the road and the effective rules applied by drivers when using the road.

Concepts that have emerged in the 1980s, such as “positive guidance” (Allen and Lunenfeld, 1986), “road readability” (Mazet, Dubois and Fleury, 1987), “self-explaining roads” (Theeuwes and Godthelp, 1995b) and “forgiving road” (IN-safety project), all raise the question of how the road infrastructure could support drivers’ activity. What these different approaches have in common is to stress the need to structure the road network by adopting homogenous and consistent design principles that take account of the different tasks to be performed by the various road users and the constraints on their execution. They seek to identify the relevant infrastructure features likely to provide a clear picture of the functionality of the road space: how to cross a complex intersection, who has the priority at a specific location; what kind of information can be expected; what kind of road events could happen, and so on.

Such an approach involves helping drivers to detect, identify and interpret current situations and, given the dynamic nature of driving and the associated temporal constraints, facilitating their anticipation of on-coming situations and the events that could occur. Given the collective nature of driving, it also involves facilitating interactions between drivers by enabling each driver to be prepared for their occurrence and ensuring that the rules to be applied for solving potential conflicts are clear and easily understandable. Lastly, and in the long-term, reducing the variability of road infrastructure design should make it easier for drivers to learn its functionality and its use.

The questions raised from this perspective have led researchers to

- Propose diagnostic methods for spotting critical situations from a safety viewpoint (e.g., the Expectation Violation Analysis approach advanced by Allen and Lunenfeld (op. cit.) or the itinerary approaches and global safety approaches. These diagnostic approaches suggest that action should be taken at the level of the information to be conveyed to drivers, and indeed are an invitation to make profound changes in the road infrastructure.
- Stress the need for improving the design process by bridging the communication gap between road system designers and traffic psychologists, suggesting that the former should spell out the rules of use induced by the design of the road and that the latter should formulate the results of their research in terms of the driver´s effective rules of use (Hale and Stoop, op.cit)
- Lastly, in terms of psychological research to focus work on the knowledge and strategies that drivers apply in controlling different driving situations and the tasks to be performed.

Many researches on road traffic safety have considered the relationship between infrastructures with road users´ behaviours. In order to quantify “driver behaviour, researchers try to choose a variable which can describe and/or characterize driver behaviours. Drivers´ visibility is an example. Some values are suggested to be qualitative and quantified values for driver visibility such as “failed to see”, “sight of distance”, etc. From that, the main aim will be to determine the quantified value of driver´s PRT (perception-reaction time), driver´s stopping distance, or verbal rules of “when driver´s visibility is poor, which means that the distance of sight is short (not long enough), then the driver cannot stop the vehicle before the hazard, and conflicts/accidents will happen”. Such relationships (influences) are mainly direct relationship between infrastructure and conflicts/accidents due to driver behaviours (mostly due to driver errors when proceeding normal driving).

Some other researches pay attention to road based hazards and try to reduce the frequency of such hazards. Road based hazards can be categorised as permanent characteristics of the road surface (e.g. roughness, being an unsealed or gravel road), temporary characteristics of the road surface (e.g., potholes, surface irregularities), visual obstructions (e.g., stationary vehicles, vegetation), and characteristics of the road alignment (e.g., horizontal and vertical curves).

Other approaches take behaviour of speed reduction into consideration (Human factor). They argue that when crossing the intersections located on the main road, drivers' speed adjustment appeared to be a function of the characteristics of the intersection and of traffic conditions.

This research takes into consideration influences of infrastructure on road users´ behaviour of violating road traffic rules. From empirical research on the motorcycle-dominated traffic flow at intersections, as analysed from above, crowded and uncrowded traffic flow have direct influences on driver behaviours of violating road traffic regulations.

In the crowded traffic, there is a high risk of congestion, intersection space is limited, then the general attitudes of road users will be trying to take full advantage of every space he may have in order to ride further (reach his trip destination) despite the fact that he has to violate the traffic regulations. The infrastructure will have effect on the “driver fear for congestions” (fear to get stuck).

In the field survey in two big cities in Vietnam, Hanoi and Ho Chi Minh City, there is a situation that the traffic problem in intersections is rather serious. The problem is not only traffic safety to road users but also bad effects to road traffic system capacity, especially at intersections.

General situation in intersection area and traffic operation at intersections in Vietnam urban areas is the inconsistence in managing and operating as well as positioning at intersections irrelevantly.

In Vietnam, the general situation in urban traffic is that congestion situation is very common, especially in peak hours. The reason is that our infrastructure cannot meet up with the mobility demand.

Let´s take two big cities of Hanoi and Hochiminh city as an example.

Approximately 6.500 automobiles and motorcycles share every 1 km length of road. Based on Hanoi police, recently there happens much traffic congestion everywhere inside the city, especially at peak hours. In almost road segments and intersections inside the city, the frequency of traffic flow is 200% over the capacity. Hanoi police also provide that after removing the regulation that each person can only make registration for one motorcycle, the number of registered motorcycle has increased amazingly. Since the end of 2006 to June, 2007, there are new registered vehicles of 223.000 motorcycles and 21.000 autos, then the total registered vehicles come up to 193.000 autos and 1.930.000 motorcycles. In the current situation of 530 km of urban roads and more than 1.000 km of suburban roads. Then on average, there are 540 autos and 5.900 motorcycles in each km in Hanoi.

In Hochiminh city, there are statistics on registered vehicles as follows:

Table 15. Statistics on vehicles in Hochiminh city

Type of vehicles	2001	8/2002	Increasing rate
Truck (including container truck)	50.000	65.200	30%
Car	129.000	300.000	132%
Motorcycle	1.900.000	2.500.000	31%
Bicycle	2.000.000	2.000.000	-
Others	96.000	120.000	25%

(Source. Statistics data from policemen in 2007)

With such number of vehicles, if there are only 60% vehicles operating in the city at one moment, then the required space will be approximately of 4.010.512 m^2. Whereas, there are only 1.713 roads, with the total length of 1.685 km, road surface is approximately of 12.800.000 m^2. Besides, there are many narrow major corridors which also have inappropriate layout of intersections, where are black spots in traffic safety and bottleneck spots in traffic flow status.

In fact, the intersection layout and the current situation of traffic flow do not have the direct influence on driver general attitudes towards legislation, but they will impact in advance the congestion situation (temporary) at intersections. From that, along with experience of getting stuck (in the past), the fear for congestion is affected, then along with general attitudes towards rules will raise driver intention showing by the probability of violating traffic regulations.

Other important elements must be the driver perception skill. If the driver cannot recognize in such an appropriate time the traffic signal or rules of priority, then s/he may violate the traffic rules. Infrastructure itself may also have the influence on this personality. For example, the driver rides in the minor road, with a narrow approaching angle, limited visibility, etc.

Before having the data on relationship between infrastructure and drivers´ specific-scenario acceptance of rules, there is a possibility to apply the methodology of expert system to evaluate the reasonable and appropriate level of infrastructure at a specific intersection and its measurements of traffic operation. Each intersection may be ranked as high relevant, medium and low relevant.

5.5.3. Transportation Management and Operation

From interview on expert opinion as well as driver, the system of traffic signal in urban areas has some problems as:

- percentage of traffic signals is low
- the whole system in the city is inconsistent and irrelevant
- can not keep up with the high increase of traffic volume
- deficiency
- road users have some reaction to new advanced techniques: new traffic signal system in the highway, backward traffic signals, traffic signals for pedestrians, etc.

There come out the hypothesis that „when traffic signal and/or rules of priority is unreasonable then road users´ specific-scenario acceptance of rules will reduce“as they are driven by the fear to be unable to get to the destination in an expected time.

6. Case Study: Effectiveness of Traffic Safety Measures

6.0. Introduction

After analysing influences of external parameters in the traffic environment and personal mechanism of the driver in performing the task of driving at intersections from the above chapters, this chapter will provide the model of risk analysis applying in driver behaviour of violating road traffic regulations. All the parameters and assumption will be clarified. A case study is conducted in order to evaluate the effectiveness of traffic safety measures in motorcycle dominated traffic flow at urban intersections.

6.1. Traffic Safety Measurements: Evaluating Effectiveness

6.1.1. Evaluation Model

As the conclusion from the above chapters, based on fundamental theory of human factors and driver behaviors, along with empirical data from field survey (manual counting and interviews), we can then describe the driver behaviour chain of violating road traffic regulations.

Talking briefly, it is concluded that the violation behaviour are caused from general attitudes towards regulations (long-term) and specific-scenario acceptance of rules (short-term). Those influencing parameters which have effects to the probability of violating traffic regulations can be categorized into two groups of:

- internal elements which are mainly related to driver personality (e.g. age, education, driving experience, etc.);
- external elements which are related to traffic environment (egg. Infrastructures, traffic flow, traffic rules and regulations, traffic operation and management elements, etc.)

In order to construct the model of risk analysis in the approach of driver behaviour, all above-mentioned elements will be treated as independent parameters of the whole system. Those process from normal situation to critical situations (which means driver behaviour chain, in the definition from the aspect of accident progress) consists of driver natural logics such as attitudes, perceptions, experience, skill, etc.

We then have the risk analysis model of driver behaviour of violating road traffic regulations (the figure can be seen in Annex A. The model parameters (situations and developments) are clarified in the Annex A. Summarization can be seen as follows:

A. Independent parameters.

1. Parameters have influence on general attitudes towards rules (long-term)
    - Education level
    - Age of driver
    - Experience of enforcement: are those experiences of getting punishment at the intersection when violating traffic rules (his/her own experience/observation on spot/ from other relatives, friends, etc…). In fact, this parameter is also influenced by enforcement level after a long period of time.
2. Parameters have influence on specific-scenario acceptance of rules (short-term)

- Enforcement level. In reality, an effective enforcement level in cooperation with some other measurements such as education, promotion, etc., will effect the driver experience of enforcement (as mentioned in chapter 5), which in its turn will have effects on (long-term) general attitudes towards road traffic regulations. However, in this research, we temporarily take into consideration the enforcement level´s influence on driver specific-scenario acceptance of rules. Enforcement level is defined as the enforcement punishment fee and effectiveness of monitoring works (automatic monitoring tools, or the presence of policemen).
- Perception skill: describe the driver knowledge on the specific situation of the intersection, including its entire layout, its traffic management and operation (whether there is a traffic signal or not, whether there is any priority rules for left-turning movement or any other rules, etc.) and the driver concentration level of recognizing the status of traffic signal, etc.
- Those parameters have impact on "fear for congestion":
  - ✓ Experience of getting stuck: are those experiences of getting stuck even in the local area (city, this crowded area, etc.) or at the specific intersection (his/her own experience/ from other relatives, friends, etc…).
  - ✓ Intersection level of service (LOS): including intersection capacity and traffic volume
  - ✓ Trip motivation: in this specific scenario, how urgent is the trip.

B. Dependent parameters

- "Fear for congestion" is result from "intersection LOS", "experience of getting stuck" and "trip motivation". From this position, the parameter of "fear for congestion" goes along with "enforcement level" and "perception skill" to create a "specific-scenario acceptance of rules" inside the driver´s mind.
- The dependent parameters of "general attitudes towards rules" and "specific-scenario acceptance of rules" come together to lead to the driver behaviour of violating traffic regulation (so-called violation behaviors in the model).

In order to calculate the risk level (how many percentage/ probability for the driver to violate the traffic regulations), it is required to quantify all above-mentioned parameters and their relationships. The methodology of risk analysis DRAM is constructed based on distribution probability of variables. Required data will be:

- data on probability distribution of parameters ´value
- data on relationship (also in probability distribution) among parameters in the model

In the approach of risk analysis, parameters´ values and relationships among them can be firstly determined as assumptions (the assumption may be verified and adjusted afterwards). When the knowledge is improved, the model can be developed and expanded later on. The important thing is that collected data to be further analysed must be consistent (comparable).

Relationships among parameters are described in the following assumption table.

Table 16. Describing relationships among parameters

number	development	number of relations	input situations			output situation
I	gaining attitude towards legislation	3	aod	eoe	eod	etl
II	calculating intersection level of service	2	ic	tcv		ilos
III	gaining attitude towards congestion	3	ilos	mot	eogt	ffc
IV	balancing between two risks	2	el	ffc		misc
V	deciding to violate traffic regulations	2	atl	misc		vb

Assumption related to developments:

I. High experience of enforcement leads to higher percentage of high attitude towards legislation

People having higher education have higher attitudes towards legislation

Old people have higher attitude towards legislation than the young people

II. Calculating LOS by comparing intersection capacity (Cc) and traffic volume (Vc)

III. The high motivation of driver leads to higher fear for congestion

More often of getting stuck in the intersection cause to higher fear for congestion

Intersection level of service decrease means higher fear for congestion

IV. High enforcement leading to lower motivation in scenario to violate the traffic regulations

High fear for congestion leading to higher motivation in scenario to violate the traffic regulations

V. High attitude towards legislation leads to lower percentage of violating traffic regulations

High motivation in scenario leads to higher percentage of violating traffic regulations

Applying the methodology of risk analysis, parameters are displayed in the form of probability distribution. Relationships among them are therefore such fomulars which can apply Bayes formular for conditional probability distribution.

Just take one relationship as an example: In the first relationship (I) from independent parameters of "education level" (el), "age of driver" (aod), "experience of enforcement" (eoe), and the dependent parameter of "general attitudes towards traffic rules" (ga).

We have (from the above mentioned table the probability values of independent parameters as follows:

P(eof = high) means the probability for the driver to have the high experience of enforcement.

$\Rightarrow$ P(eof = high) + P (eof = medium) + P (eof = low) = 1

The probability for the driver to have the high "general attitude towards traffic rules" is the probability of every cases:

P(ga = high| eoe = high, el = high, eod = old)

+ P(ga = high| eoe = high, el = high, eod = young)

+ P(ga = high| eoe = high, el = medium, eod = old)

+ ….

+ P(ga = low| eoe = low, el = low, eod = young)

In the specific case study, assumptions will be adjusted step by step, based on empirical data (knowledge), as well as data from field survey (observation and interview).

6.1.2. Vietnam Experiences

So far, guidelines to conduct traffic safety measurements, such as AASHTO (NHCRP report 500, 2004), often classify measurements into groups based on their oriented objectives (due to elements of the whole traffic system). Such system of 3E (Engineering, enforcement, and education) to evaluate traffic measurements are applied now in Vietnam (Source: JICA, ALMEC, TRAHUD projects).

In fact, when applying such measurements of traffic management and operation, they are not conducted separately. More often, such traffic safety measurements are conducted in the broad scope (in the whole route or some routes, in one or some local areas, etc.). Moreover, influences of traffic safety measurements on driver awareness and behaviors are very essential to take into consideration, even before applying. Evaluating effectiveness of such measurements is important but not very simple.

There is a fact that many traffic safety measurements, which have been successfully applied in developed countries with considerable results in removing traffic accidents, require a rather long time to have the initial results when being applied in Vietnam. The first result mentioned here is the high probability of road users to obey such regulations though they are very useful in traffic safety. Many measurements need the procedure to be adjusted and come into effects (see examples in the next part). The problem is that, almost measurements of traffic management and operation in general and traffic safety in particular are very costly, with the large social effects.

In order to improve the current situation, the research suggests using the risk analysis model to evaluate effectiveness of traffic safety measurement before, during and after applying into the reality. The first criteria to evaluate are influencing level of the measurement to driver behaviours of violating traffic regulations. Recommend using expert methodology to evaluate the influence before applying. During the process of operating the measurement in the reality, other evaluation criteria will be determined and calculated (by collecting and processing data appropriately with the standard forms).

Traffic safety measurements are evaluated based on the objective-oriented fundamental. The expert opinion may be collected in the form of ranking (grades) as the following table.

Applying the model in order to evaluate the traffic safety measurement before conducting in the reality.

Table 17. Influencing elements of traffic safety measurement

Name of measurement	Measurement´s main elements	Percentage (%)	Measurement´s objectives	Influencing level (%)	Results (%)
	Enforcement				
			Enforcement level		
			Experience of enforcement		
	Egineering				
			Infrastructure LOS		
			Experience of getting stuck		
			Fear for congestion		
	Education				
			Education level		
			Perception skill		
Total influence					

This evaluation table can be more precious when knowledge on influencing parameters and their influence levels increase and are accumulated through periods of time. It is also possible to use the evaluation criteria of the time required for the measurement to be effect (long-term or short-term), the criteria of finance (applying costs), etc.

Briefly speaking, the model of driver behaviour of violating traffic regulations is useful to evaluate the effectiveness of the new measurement, particularly its impacts on the road users´ behaviors.

6.2. Case Study: Enforcement and its Effects to Driver Behaviours

In this case study, the research focuses just in one link in the whole model, which is the influence of enforcement level on driver behaviour of violating the traffic regulations. With the assumption that when the probability of obeying the rules increase in the traffic, then the chaotic situation in the traffic flow will be reduced. Due to the physolophy from accident progress, the probability of accidents caused by driver behaviour of violating traffic regulations will reduce. This also means that risk of violation behaviors reduces.

In the current situation of Vietnam traffic system, the research shows that enforcement has different influences on driver behaviour of “obeying the rule” based on different policy (the process of applying the policy in real traffic conditions). The reason for this practical situation fits well with the conclusion that enforcement has influence on driver behaviour through the role of driver attitudes towards legislation.

Let´s take an example from two traffic safety policies of "wearing safety helmet when driving motorcycles" and "lane separation".

6.2.1. Scenario Description

Policy 1. "Wearing safety helmet when driving motorcycles".

- In 1995, there is the first regulation of "wearing safety helmets when driving motorcycles" in Decision 36/CP of the government. There is no regulation on punishment of violation behaviors.
- In 2001, the Ministry of Transportation releases "Guidance to wear safety helmets when driving motorcycles".
- In 2002, there is an article in Road traffic law stating that "wearing safety helmets when driving motorcycles is regulated by the government".
- In Feb., 2003, the government released an Instruction under Road traffic law stating some road segments which are obligated to "wear safety helmets when driving motorcycles".
- In Dec. 2005, they issue the Decision regulating the punishment of "driving motorcycles without a safety helmet" (punishment by cash and motorcycle captures).
- In 2006, starting to examine and conduct punishments.
- During the time (from 1995), they release education and training on the policy.
- On June 29th, 2007, the government issues Decision 32/2007/NQ-CP. There is a regulation that "From September 15, 2007, it is obligated to wear safety helmets when driving motorcycles in all national roads" and "From December 15, 2007, it is obligated to wear safety helmets when driving motorcycles in all types of roads".

Policy 2. "Lane separations for different types of vehicles". The policy is applied firstly at specific intersections (in one road line), then in some specific road lines (so-called standard traffic roads). In schedule, it is supposed to conduct in several roads in the whole city. However, standard roads still do not have good results then the policy needs some adjustments.

- In early 2005: The first road of Kim Ma - Cau Giay started to conduct lane separation for different types of vehicles. The separation was conducted by continuous lane marks in some obligated segments. Other segments in the road are marked just by dash marks.
- Feb. 4, 2007: The road of Chua Boc – Thai Ha applies lane separation in the area of intersections and their approaching roads. The infrastructure is improved by reducing the area of roadside to broaden the road area for vehicles, and intersection areas; lane marking; changing traffic signals from two-phase cycles into three-phase cycle (one intersection got the four-phase cycle to completely separate potential conflicting movements); promotion in mass media; one month of high enforcement with the appearance of policemen (no punishment by cash).
- March 2007: the four-phase cycle at the intersection of Chua Boc - Thai Ha was removed.
- Jan. 20, 2008: applying lane separation in the whole road of Dai Co Viet - Tran Khat Chan: traffic signals, hard lane separation (in some segments), lane markings (with symbols and writing on the road surface), and promotion in mass media and traffic signs.
- Feb. 28, 2008: starting to make punishment on violation behaviors with money.

- August 2008: lane separation by painting columns (instead of lane markings only).
- Feb. 2009: providing five additional locations of policemen (near intersections) to instruct drivers obeying the regulation of lane separating and punish those road users violating the regulations.

Evaluation and assessment

In October 2006, Project Management Committee (PMC) of Traffic Safety Human Resource Development project in Hanoi (TRAHUD) was full-fledged formed by Ha Noi People Committee (HPC). This project is exertion of cooperation between Japan International Cooperation Agency (JICA), and Ha Noi city's administration in order to improve the Hanoians social awareness of traffic safety.

In Feb 2007, the model road project of Thai Ha-Chua Boc, which the first phase of the program had done, the improvement was carried out wholly in cooperation of traffic safety equipments, traffic safety constructions, traffic safety policies, and traffic safety educations. After nearly one year of new assignment, Vietnamese and especially Hanoians were impressed by the well-done improvement of society awareness, driving skills and traffic participating behaviours shown by series of transport safety data. The result of this phase strongly expresses the active effects and the need to widen the model program in the next phase applied on three National Roads, and Thai Ha-Chua Boc street.

Based on the purposes of survey locations, one field survey has been released to have quantitative data in each location in three periods of time: before, during, and after new assignment (See details from field survey location in the Annex).

The results of two surveys can be summarized as follows (based on the report of Traffic Engineering Evaluation, by TRAHUD study system, 2008).

Policy of wearing helmet (Policy 1)

- Before the last Decision in December 2007, the percentage of drivers wearing safety helmets are low in national highways (the lowest percentage of 9,75% is in National highway No.1 in the afternoon). Motorcyclists give out many reasons for their violation behaviours such as inconvenience, limitation of visibility, hot weather, inconvenience to keep the helmet after reaching the destination, there are only obligation in some roads that they do not know where; low and irregular punishment, etc.
- After the Decision issues, the percentage increase up to 95% motorcyclists wearing safety helmets on average. The lowest percentage can be found also in the afternoon at the rank of 92,12% (also in National highway No.1).
- The percentage of obeying the policy is even higher after the enforcement campaign than those during the campaign.

Policy 2 of lane separation has obtained initial achievements.

In the road segment:

- Separation activity increase the average travel speed in Dai Co Viet-Tran Khat Chan corridor so that decrease the travel time and make road users more comfortable when drive in this corridor;
- Lane separating make the traffic flow more stable due to decrease of traffic vehicle lane changing percentage, this is a positive effect to traffic safety;

- Separating by type of traffic vehicle make the traffic flow more uniform, the traffic flow is prevented from harmful factors due to the reaction between different type of vehicle with different traffic characteristic within the traffic flow;
- Increase the road capacity due to increase the travel speed and making the traffic flow more uniform.

Issue:

- Drivers just obey the lane separation when there are policemen.
- Lane separating by type of vehicle increase the number of conflict at intersection area so increase the risk of local congestion at intersection area; lane separating by type of vehicle could be use in a case of low traffic volume;
- The increase the number of conflict at intersection increase waiting time and travel time at intersection;
- High density of connections with main corridor decrease the effect of lane separation;
- Unbalanced traffic volume distribution on lanes in peak hour sometimes “forces” road users make lane violation.

After a period of applying the policy of hard lane separation (in order to encourage road users to obey road traffic rules), we can see the following situations such as:

Figure 40. Illustration for behaviours of violating the regulation of „lane separation”

At intersections:

- The violation rate (number of violations/total volume of movements) seems to reduce during the campaign, then raise up again after the campaign.
- The campaign seems to have different effects on different types of violation (lane/traffic signal violation). Speaking clearer, after the campaign, the rate of traffic signal violation has a significant reduction, while rate of lane violation has the increasing trend after the campaign.
- The influence depends on different time during a day (peak and off-peak hours, morning and afternoon- peak hours)

[TRAHUD study team, 2008, Traffic Engineering Evaluation]

However, as we can see from the field survey (manual counting), it is obvious that the effects of enforcement (policemen´s campaign) and engineering measurements are not the same (or at least similar trend) to the violation behaviours of all groups of drivers (motorcycles, car, bicycles, etc.). Risk analysis approach with the help of the model describing the driver behaviour chain provide a supporting tool to analyse more deeply different aspects of enforcement effectiveness.

6.2.2. Risk Analysis Approach

It is obvious that the above-mentioned field surveys on driver behaviour of violating road traffic rules follow the traditional method of conducting survey to collect and process data. From the survey, experts just tried to evaluate (qualitatively) the effect of traffic safety campaign to behaviour of road users. Such kind of method (as clarified in chapter 3) pay attention only to the simple (two-way) relationships from input parameter (enforcement campaign in this case) and the output (violation behaviours). The field survey of video camera were conducted in such a Hypothesis that all other elements in traffic environment do not change except for the element of enforcement. In fact, it is not only enforcement itself which has an influence on the changes in driver violation behaviours, but the whole campaign of traffic safety have been conducted in this area in such period of time.

In order to better evaluate the effectiveness of the traffic safety campaign, it is better to take a look on the long-term influence of the whole campaign.

Those two policies aim at improving current situations of traffic system in the urban areas. The first objective is influencing driver awareness of traffic safety and their behaviours of obeying traffic regulations (especially those relating to traffic safety). However, the influence of enforcement in two policies gets different results in driver behaviour of obeying traffic regulations (the opposite side of violating traffic rules).

Policy 1 has been applied in such a long time (from 1995) with different types of measurements (such as promotion bands, education at schools, exhibitions of traffic safety, etc.). The last result of high percentage of driver obeying the rule even increases after the campaign of enforcement. Policy 2 can just observe the driver obey only during the campaign, which means that the campaign has only the effect with the presence of policemen (in that case, their presence also means the presence of monitoring measurement). It can be conclude that enforcement do not have direct influence on driver behaviours but only on their attitudes of safe and unsafe behaviours. Combining enforcement with education and training will have long-term effects on driver attitudes towards legislation.

In the view of risk analysis, it can be seen that Policy 1 has effects on driver decision of obeying rules just by shifting the curve of „risk of being punished" without any influence on the curve of "risk of getting stuck" (see Figure 5.1). Policy 2 shifts both curves of „risk of getting stuck" and „risk of being punished" at the same time then its effects on driver attitudes are reduced.

Taking policy 2 into consideration, when analysing more detailed data from the field survey (before, during and after the campaign), we can see that the campaign have different influences on different types of violation behaviours (lane violations and traffic signal violations). The result proves that beside influences of the enforcement campaign, driver attitudes towards legislation are also influenced by other elements of traffic environments such as infrastructure, traffic operation and management, congestion in traffic flow, etc.

Moreover, it is important to pay attention that two traffic safety campaigns conducted at two field sites of national highway and urban roads are different from each other under the light of risk analysis approach. At the national highway, besides the policemen presence, punishment level is clearly regulated if the driver does not wear the safety helmet. Whereas, in urban roads, the measurement of enforcement (with policemen's´ presence) are conducted along with other traffic management and operation measurements such as lane marking, changing traffic signal´s cycle, etc.

However, based on the theory of long-term and short-term effect of elements (see chapter 5), it is obvious that, elements related to the policemen presence and punishment fees are belong to the group of enforcement. Enforcement level has the temporary influence when the driver perceives that he has some percentage of ability to be monitored and punished. However, in the long term, the driver can obtain experience of enforcement (due to subjective norm, for example). Then his general attitudes towards traffic rules will increase. Whereas, measurements of traffic management and operation will effect the intersection level service. In its turn, LOS has its influence on specific-scenario acceptance of road users.

From such arguments, risk analysis model will be useful in detailed analysing multi-direction effects of influencing parameters on the output of violation behaviours. Of course, with the current available data, the task of constructing practical quantified parameters and relationships is still impossible. The next part will describe the way to calculate and verify a small part in the risk analysis model of driver behaviour of violating road traffic regulations.

Another point should be paid attention into is the fact that policies and measurements of traffic safety are conducted in campaigns at urban intersections and national highway (NH) (December, 2007) are those policies of "traffic enforcement with the only main point". That means, the policemen presence on site have the enforcement objectives, aiming at some main (expected) behaviors of violating traffic regulations. In this specific case, enforcement aims at the behavior of "no helmet" in the NH, and traffic signal violation, as well as lane violation in urban intersections. Besides, target group of strict enforcement level is mobile drivers (automobiles or motorcycles).

6.2.3. Enforcement Effects on Driver Behaviour

In general, the difference in enforcement influence on driver behavior in two cases of policy 1 and 2 is due to the influences of experience of enforcement (long-term) as well as enforcement level. Basically, policemen presence on site is just one factor of enforcement level. Enforcement level includes punishment level and monitoring mechanism. In case of policy 2, the regulation of punishment fees have posed the awareness of drivers, leading them to higher general attitudes towards regulations.

The other factors in applying policy 1 can be seen in the history of its progress of applying since 1995, before the regulation of administrative punishment, there have been applied a lot measures of education, promotion in mass media, etc. Those measurements belong to the group of traffic safety education, increasing driver education level. Moreover, the perception skill of wearing helmet when using motorcycle is improved.

Meanwhile, in case of policy 2, there is simultaneous application of enforcement along with measures of improving level of service in the intersection (by adjusting the traffic signal´ cycle and lane separation. The difference in comparison to policy 1 is at enforcement level, general attitude towards regulations and perception skill.

Analysing in details, we can see the influences of traffic safety campaign (with such measurements of policemen presence, punishment on violation behaviour, increasing intersection capacity with adjusting traffic signal cycle, etc.) are different to different types of violation behaviors. This can explain that driver experience of enforcement obtains different influences or enforcement levels are different in different types of violation behaviors. Similarly, influences of enforcement levels are different in different types of vehicles, which can be explained with the difference in enforcement level and perception skill.

It is important to highlight that comparing two different policies is a difficult task. Each policy (and its relevant measurements of traffic management and operation) has different objectives in influencing driver behaviour. We can see that, in different field surveys with object´s direction, statistics data on the number of violation behaviors may be different (due to different definitions of violation behaviors). For example, in the case of considering zigzag movement as a wrong movement (in the field survey at the intersection of Chua Boc – Thai Ha on January, 2007), the number of violation behaviors reaches to 30%. In the field survey of August 24, 2007 the number of violation behaviors reduces to the level of 12 –14%. The reason is not because road users follow the traffic rules better, but the definition of violation behaviors have changed. Similarly, the research in the national highway focuses on the violation behaviors of “driving without safety helmets”, whereas in urban area, traffic signal and lane violations are considered as violation behaviors.

Before applying the risk analysis model into two policies, it is required to quantify all variables. The main target will be to evaluate the effectiveness of measurement 1, and 2 in practice, to see whether it has the high influence in violation behaviour or not. The whole application process follows the process of constructing the driver´s behaviour chain (see theoretical process in Chapter 3).

(i) Determining starting points and output

(ii) Building continuous behaviour chain

The first two stages have been conducted as analysed above. The constructed behaviour chain of violating road traffic regulations is used to analyse the influence of traffic measurements on driver behaviour.

(iii) Determining influencing parameters.

This stage has also been finished from the behaviour chain. However, in this case study, it is required to determine, which influencing parameters (independent parameters) have changes. Such changes in the influencing parameters mean changes in their risk values (probability distributions of different classes). Some changes may also change relationships among independent and dependent parameters.

- Measurement 1 (to support the policy of “wearing the safety helmet when driving motorcycles”):
    - punishment on those drivers who do not wear helmet + policemen presence (more often and effectively) → increasing enforcement level
    - educations → increasing experience of enforcement, perception skill, changing the relationship among general attitude towards rules, specific-scenario acceptance of rules and violation behaviours.
- Measurement 2 (to support the policy of “lane separation”):

- policemen presence (more often and effectively) → enforcement level
- engineering measurement of new (more visualized) lane separation, adjusting the traffic signal cycle → perception skill, intersection LOS. This measurement has also effects on fear for congestion, and the relationship among enforcement level, fear for congestion and specific-scenario acceptance of rules.

Such changes need to be quantified in the standardized forms of data and distribution probability to fit and adaptable into the model of risk analysis.

(iv) Collecting data.

Data is collected from the field survey (3 periods of time as described above). The data which can be collected are those of violating behaviour rate (how many percent of driver violate traffic regulations (in this case, they are specific regulations of “wearing safety helmets when driving motorcycles” and “lane separation”).

(v) Running program and analysing results

After applying the model to evaluate, we can see that “enforcement level” only has long-term impacts when applying along with other measurements such as education, promotion (as they have impacts on driver general attitude towards traffic regulations), engineering (with the influence on intersection LOS). Enforcement level has only short-term effects on driver specific-scenario acceptance of rules.

We now have taken into consideration the results of helmet wearing survey in three National Highways.

Table 18. Changing of the rate of motorcycles without safety helmet before, during and after the traffic safety campaign

Direction A (outward from HN)				
Time Period	**Time of the survey**	**Bac Thang Long - Noi Bai**	**NH 1**	**NH 5**
Morning peak	before the campaign	14,26%	85,21%	53,82%
	during the campaign	6,45%	66,75%	27,65%
	after the campaign	2,62%	7,88%	4,61%
Noon peak	before the campaign	20,73%	77,37%	47,64%
	during the campaign	12,80%	63,06%	26,77%
	after the campaign	6,62%	5,24%	3,46%
Afternoon peak	before the campaign	18,06%	90,25%	23,26%
	during the campaign	19,19%	71,08%	32,40%
	after the campaign	1,84%	4,83%	1,84%
Average	*before*	*17,68%*	*84,28%*	*41,57%*
	during	*12,81%*	*66,96%*	*28,94%*
	after	*3,69%*	*5,98%*	*3,30%*
Direction B (inward to HN)				
Morning peak	before the campaign	45,15%	88,11%	56,43%
	during the campaign	27,79%	66,46%	31,93%
	after the campaign	4,69%	6,16%	4,20%
Noon peak	before the campaign	34,80%	88,46%	69,28%
	during the campaign	11,99%	67,46%	30,49%
	after the campaign	6,25%	1,02%	3,22%
Afternoon peak	before the campaign	17,25%	90,62%	58,38%
	during the campaign	4,90%	70,99%	40,65%
	after the campaign	3,80%	5,10%	6,30%
Average	*before*	*32,40%*	*89,06%*	*61,36%*
	during	*14,89%*	*68,30%*	*34,36%*
	after	*4,91%*	*4,09%*	*4,57%*

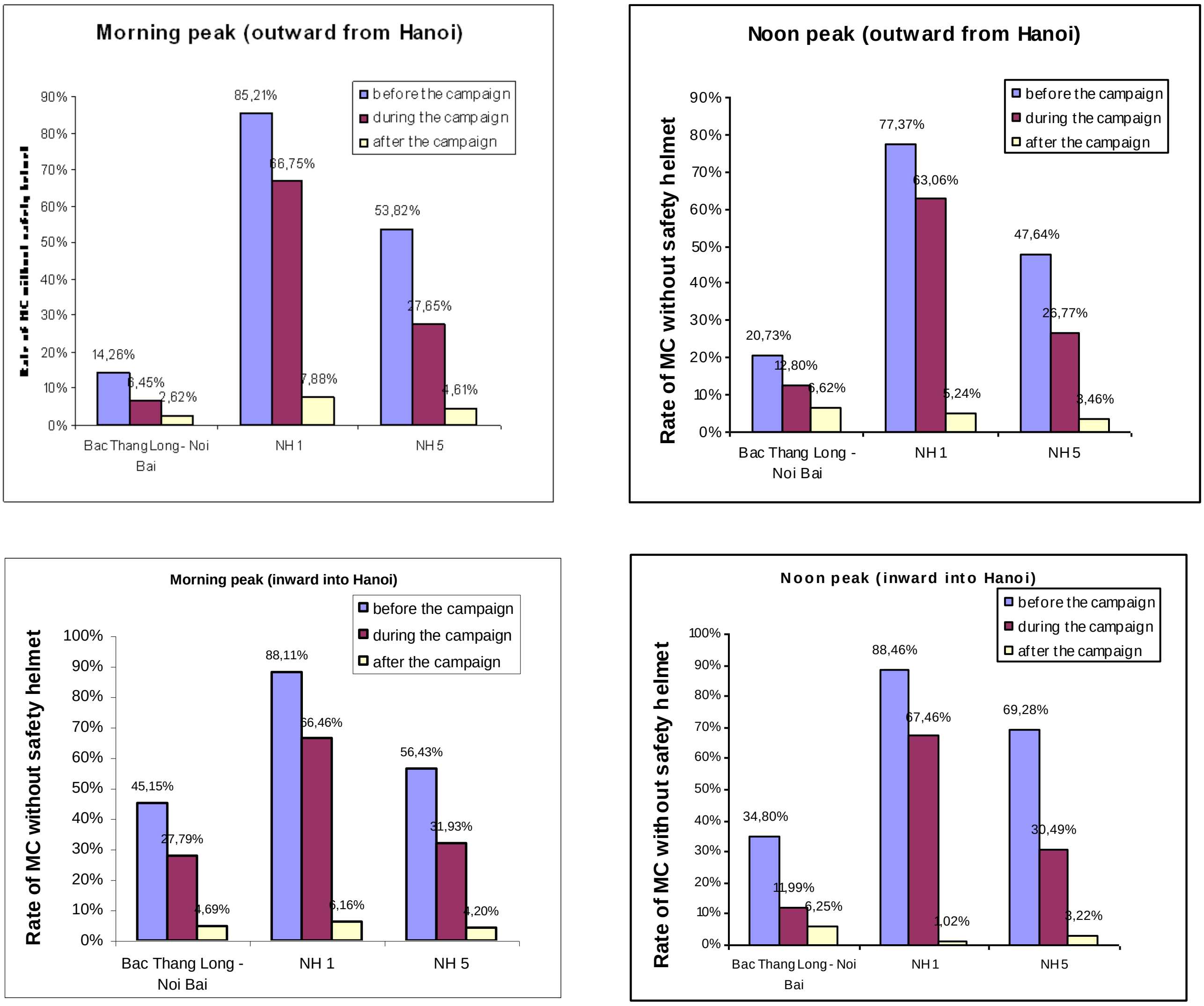


Figure 41. Violation behaviour rates in National highways

It is remarkable that the high enforcement (presenting by the policemen appearance on the spot and high punishment fee) have the same effects (the same trend) on the driver behaviour of wearing safety helmet when driving motorcycle. It does not depend on the time during the day (morning, noon or evening peak), the direction (inward or outward from the city/urban areas), or different national highway (which means different traffic environment).

Behaviours of violating traffic signal and lane separation at Thai Ha - Chua Boc intersection in comparison with BEFORE, DURING, and AFTER the campaign

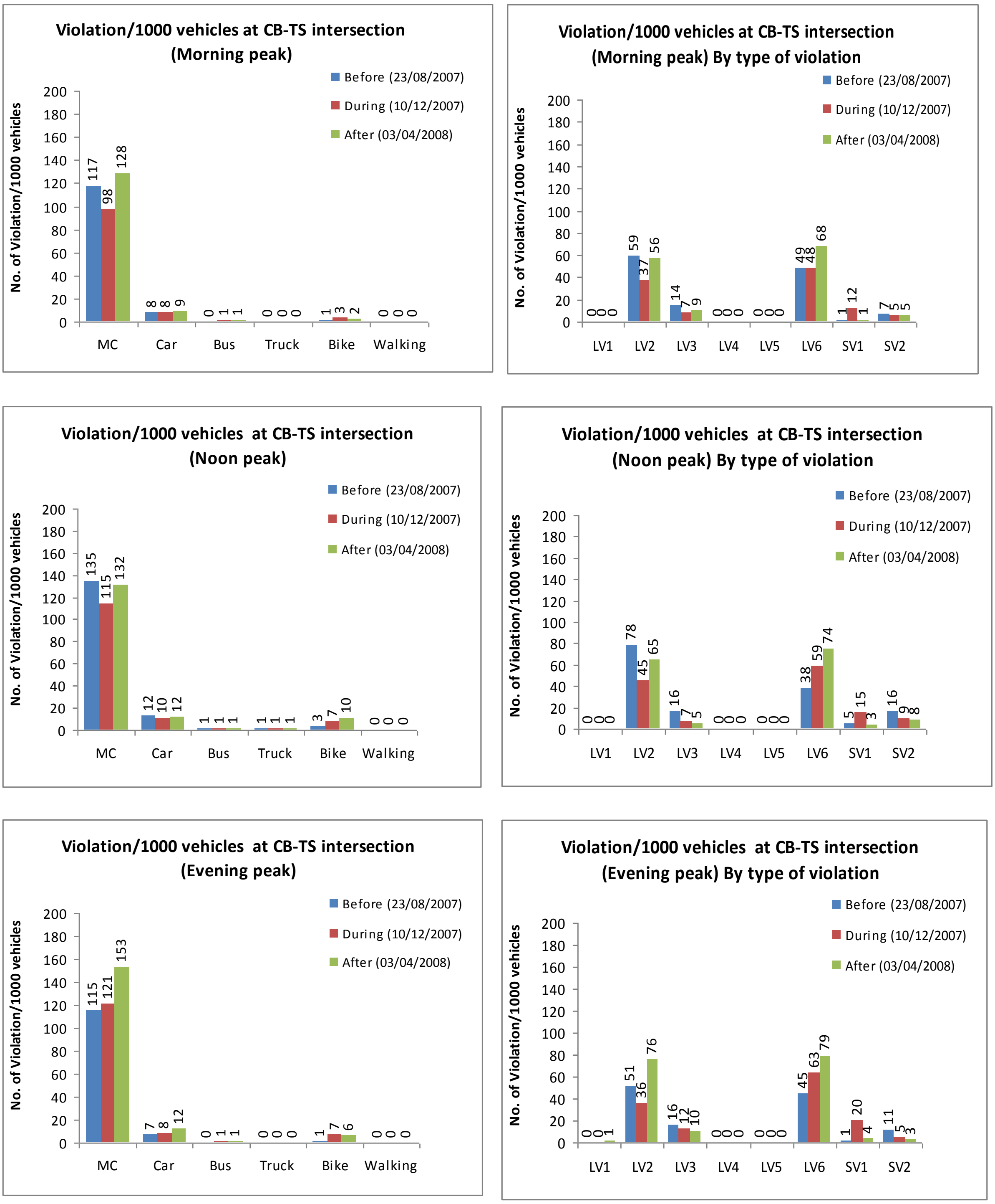
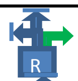
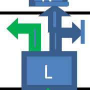
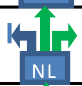
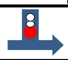
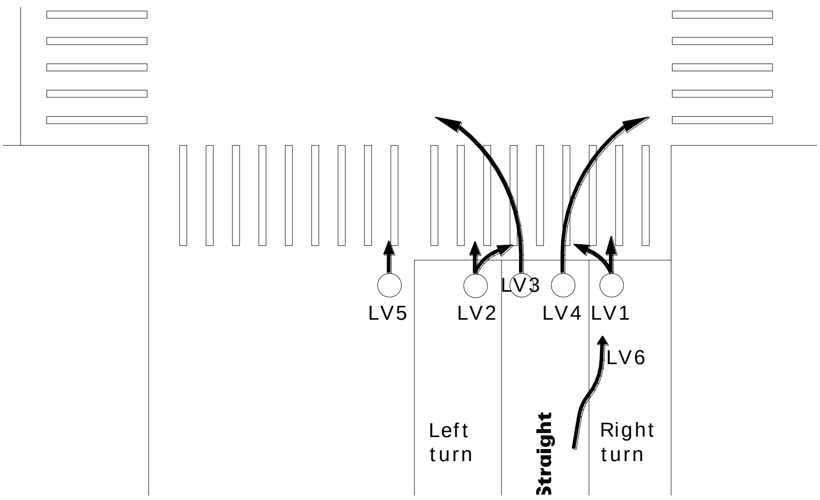


Figure 42. Behaviours of violating traffic signal and lane separation

Types of violation behaviours are clarified as follows:

Table 19. Description of Violation behaviors at urban intersections

Abbrev.	Symbol	Description
Group 1: Lane violation		
LV1		Non-right-turn vehicles stop on the Right-turn lane
LV2		Non-left-turn vehicles stop on the left-turn lane
LV3		Left-turning vehicles stop on the Non-Left-turn-lane
LV4		Right-turning vehicles stop on the Non-Right-turn-lane
LV5		Vehicles stop on the carriage way of the opposite traffic direction
LV6		Weaving over the continuous lane separation line
Group 2: Traffic signal violation		
SV1		Red light violation
SV2		Stop-line violation



Having different results than those from the policy 1, this survey on behaviours of violating traffic signals and lane separation shows that the enforcement campaign of policemen, as well as engineering measurements, seem to have results which do not meet the expectation as firstly designed. In general, the rate of violation behaviours seem to reduce during the period of enforcement campaign, and then rise up again (even more than before) afterwards.

The trend of changes in rate of violation behaviours is different in different time periods during a day, depending on different types of vehicles and types of violation behaviours. Using the model, it can be explained that, as the enforcement of the traffic safety campaign with the aim at lane separation has just the short-time effects. The road users do not have enough time to gain experience of enforcement, as well as perception skill. Then general attitudes towards traffic regulations have not been affected. The only influenced internal element is specific-scenario acceptance of rules. The effects on violation behaviours will therefore be removed when such external parameters disappear.

In summary, the case study can provide only qualitative remarks using the approach of risk analysis model to describe the mechanism of enforcement campaign and its effect in driver behaviours of violating road traffic regulations. There need more data and knowledge on the probability distribution of driver behaviours of violating traffic regulations, their probability to be involved in a traffic conflict/accidents, traffic environment, enforcement and congestion status, etc… After a period of time collecting and processing data in the standardized format in order to support the risk analysis model, requesting the amount of data large enough, then the quantitative method can be launched.

7. Conclusion and Recommendation

7.1. Conclusion

Briefly speaking, there are some large areas which have been mentioned in the study:

- Road traffic safety at motorcycle dominated traffic flow
- The new methodology of risk analysis and its application
- Driver behaviours of violating road traffic regulations: their causes and effects

The research aims at establishing a modular structure to conduct risk analysis of driver behaviours relating to violating traffic regulations at intersections in motorcycle dominated traffic flow. The final goal will be to obtain answers to the question: why and how often do drivers (in mixed traffic flow) violate traffic regulations at intersections, and what are the consequences of such violation behaviours. These questions have been organized systematically into discrete steps that involve identifying different behaviours of violating traffic regulations, determining the likelihood of their occurrence, and identifying their consequences.

So far, traffic accidents are of high importance to the public health spectrum in the world. In developing countries such as Vietnam, the mortality rate from road traffic accidents is rather high in comparison with other countries in this region.

The importance of human factors in transport policy discussion is growing. In recent years, understanding the serious effects of traffic accidents to the whole society, scientific researchers, traffic engineers and policy makers in Vietnam developed many projects and researches in the field of traffic safety. Human factor is considered as the central element in the whole system. The final target is to organize a traffic environment, which is convenient and safe for road users.

There is a distinguishing characteristic between traffic flow in Vietnam (and in many other Asian countries) and those in developed countries: two-wheeled vehicles (so-called motorcycles) consist a high percentage in the road traffic system.

Motorcycle dominated traffic flow is very much different from car traffic flow due to motorcycles´ distinguishing characteristics (which can be summarized as flexibility and manoeuvrability). Therefore, there appears the need to evaluate and verify such findings and measurements concluded from car traffic flow before applying in the MD traffic flow.

Risk analysis and driver behaviour is the modern and advanced trend in road traffic safety research (since 1980s). Risk analysis in general is a systematic, model orientated and modular approach to analyse safety issues and impacts on roads. Risk analysis aims at comprehensively analysing the chain of causes and effects, in order to answer three questions: (i) how (how often) do people behave in specific situations? (ii) Why do they behave that way? (iii) What are the results of such different behaviours?

From the above analysis on current situations in the field of road traffic safety (theoretically and practically), the study has fulfilled the following tasks of:

- Analyzing the current situation of traffic safety, motorcycle-dominated traffic flow, driver behaviours of violating road traffic regulations, their causes and effects at intersections in motorcycle-dominated traffic flow.

- Working with a new methodology of risk analysis, the progress of constructing cause-and-effect chain of driver behaviour based on the approach of accident progress, which deals with the gap between normal driving and reaction to critical situations.
- Developing two concepts of “conflict zones” and “conflict time segments” which can be further developed to determine the hazard that drivers have to face with in their left-turning movement at intersections in motorcycle-dominated traffic flow. Both concepts are developed from the physolophy of Conflict Technique in car traffic flow, with the modification in order to be relevant in case of the distinguishing characteristics of non-lane based movement of motorcycles.
- Constructing concepts and frame structure to conduct modelling of risk analysis on driver behaviours of violating road traffic regulations at intersections in motorcycle-dominated traffic flow. The chain of “Driver behaviours of violating traffic regulations” based on “General attitudes towards road traffic regulations” and “Specific-scenario acceptance of rules” was then constructed.
- Working with a case study in Vietnam to apply the model in evaluating measurements of traffic operation and management.
- More detailed results require more efficient tools as well as more data.

7.2. Recommendation

At the very first stage of study in the field, the risk analysis model of driver behaviour chain is just constructed in the qualitative approach. Many assumptions based on empirical and previous studies and researches are used. The disadvantage of the model is that in order to evaluate and verify it, it is required to have more and more data. However, it is also the advantage of risk analysis methodology to improve the model and integrate new knowledge from other disciplines whenever they are provided.

The next step to improve and apply the model into practice should be:

- Quantifying parameters in the model, with their probability distributions
- Evaluating and verifying relationships among parameters.
- Refining the model in specific areas, which have been identified in the prior analysis.

In additions, there are only independent parameters of “driver age”, “education level”, intersection capacity, traffic volume, trip motivation, perception skill, enforcement level are included in the model. Other parameters (including driver personality and traffic environment) and their influences can be added when they are available.

The constructed model has just stopped in the output of “violation behaviour” (which means the rate of drivers who violate road traffic regulations in the specific scenario). Working out the chain from such kind of behaviours leading to traffic conflicts and/or accidents should be further taken into consideration.

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Annexes

Annex A:

Model of Driver Behaviour Chain of Violating Road Traffic Regulation

Annex B:

Description of the Field Survey Location

Annex A: Model of Driver Behaviour Chain of Violating Road Traffic Regulation

Figure 1 gives out the general over view of the model describing relationships from traffic environment elements, their influences through personality of the driver to his “violation behaviour”.

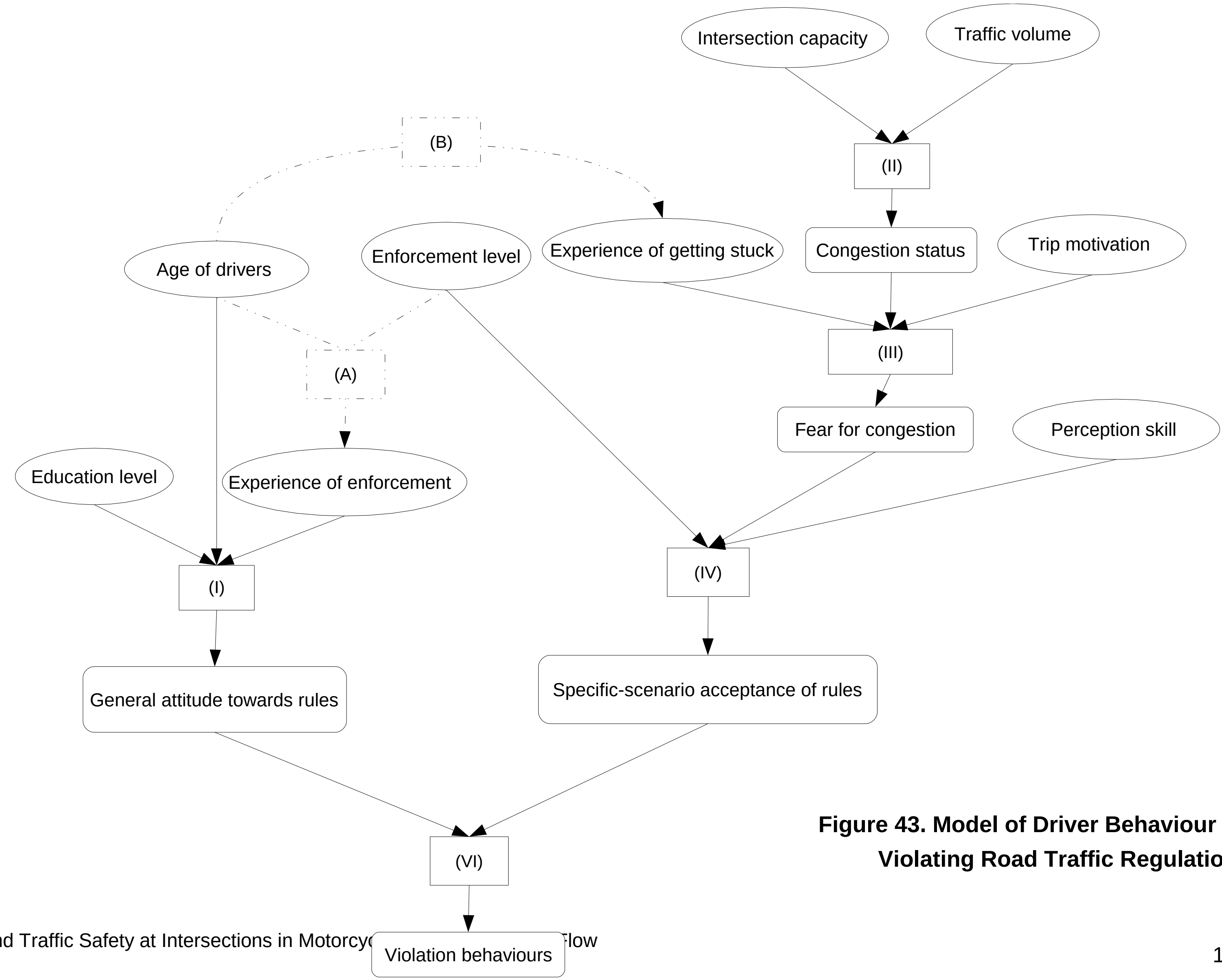

Figure 43. Model of Driver Behaviour chain of Violating Road Traffic Regulations

As explained in the methodology, all parameters (independent or dependent) are described at risk values, which means the extent and its probability distribution. The following table shows the explanation for the parameters in the model:

Table 20. Parameters explanation

number	situation	shortcut	Explanation	Classification	Criteria/Unit
1	education level	eod	education level of drivers in the intersection	high/medium/low	academic degree/professional training/ driver experience
2	age of driver	aod	age of drivers in the intersection	young/old	> 30 years old
3	experience of enforcement	eoe	experience of getting purnishment at the intersection (his own experience/observation/from other relatives/friends, etc.)	high/medium/low	high: his own experience (more than 2 times/ 1 time at the same intersection) - medium: his own experience (1 time/ more than 1 time at other location(s)) + experience from others (highly appreciated) low: the rest
4	enforcement level	el	many policemen, high purnishment,	high	heavy purnishment + regular monitoring
				medium	heavy purnishment + irregular monitoring
				low	light purnishment + irregularmonitoring
5	experience of getting stuck	eogt	experience of getting stuck at the intersection	high	very often get experience of getting stuck in the region/ sometimes (often) at the same intersection
				medium	very often get experience of getting stuck in the region/ at least one time at the same intersection + experience from others (highly appreciated)
				low	the rest
6	intersection capacity	ic		high/medium/low	vehicles/hours
7	traffic volume	tcv		high/medium/low	vehicles/hours

number	situation	shortcut	Explanation	Classification	Criteria/Unit
8	Congestion status	ilos	comparison intersection capacity and practical traffic volume (forecasting) to see whether the intersection capacity meet mobility demand or not	high/medium/low	high congestion: long waiting line, seems not moving;
					medium: moving slowly (average speed of 5km/h)
					low: moving normally (at the designed speed)
9	trip motivation	mot	says how urgent the driver needs to get to the destination	urgent/not urgent	
10	fear for congestion	ffc	say how high the driver feel afraid of getting stuck	high/medium/low	high: his own experience (more than 2 times/ 1 time at the same intersection) -
					medium: his own experience (1 time/ more than 1 time at other location(s)) + experience from others (highly appreciated)
					low: the rest
11	Perception skill	ps	driver´s skill and awareness in percepting traffic rules and regulations (at the specific scenario)	high/medium/low	
12	general attitudes towards rules	atl	how high do drivers accept to follow legislation	high/medium/low	high: follow the rules most of the time
					medium: in the middile (just violate the rules conditionally)
					low: violate the rules whenever he can
13	specific-scenario acceptance of rules	misc	say whether the driver decides to obey or violate the rules at the specific scenario	yes/no	
14	violation behaviours	vb		yes/no	

Among such parameters, there are independent parameters of:

- education level;
- age of driver;
- enforcement level;
- intersection capacity
- traffic volume;
- trip motivation; and
- perception skill.

Such independent parameters needs to be classified into classes with their relevant probability distribution.

There are two semi-independent parameters of “experience of enforcement” and “experience of getting stuck”. In fact, they are dependent parameters which the driver will get through the time. However, when there is still no available tool to determine such effects through the time, these two parameters can be considered as independent parameters to be treated with their assumed values and probability.

The other parameters are dependent parameters which the probability are calculated through the following developments:

number	**development**	**number of relations**	**input situations**			**output situation**
I	gaining attitude towards legislation	3	aod	eoe	eod	etl
II	determining congestion situation	2	ic	tcv		ilos
III	gaining attitude towards congestion	3	ilos	mot	eogt	ffc
IV	balancing between two risks	2	el	ffc		misc
V	deciding to violate traffic regulations	2	atl	misc		vb

For example, we have development describing how “general attitude towards rules” are affected by “experience of enforcement”, “education level”, “age of driver” as the following table:

Table 21. Relationship diagram

Experience of enforcement	Education level	Age	General Attitude towards rules		
Value	Value	Old	high	medium	Low
high	high	old	90%	10%	
		young	85%	10%	5%
	medium	Old	85%	10%	5%
		young	80%	12%	8%
	low	Old	80%	12%	8%
		young	75%	17%	8%
medium	high	old	80%	15%	5%
		young	75%	17%	8%
	medium	Old	70%	22%	8%
		young	65%	25%	10%
	low	Old	60%	28%	12%
		young	55%	30%	15%
low	high	old	60%	28%	12%
		young	55%	30%	15%
	medium	Old	50%	33%	17%
		young	45%	38%	17%
	low	Old	35%	40%	25%
		young	25%	45%	30%

Explaining for this table, it can be said that: “General Attitude towards Rules” are dependent output of three independent parameters of “Experience of enforcement” (eoe), “Education level” (el) and “Age” (aod). Repeting the assumption of this development (relationship), we have:

- High experience of enforcement leads to higher percentage of high attitude towards legislation
- People having higher education have higher attitudes towards legislation
- Old people have higher attitude towards legislation than the young people

Then, with the classification of 3 classes of “high, medium or low” for “eoe”, 3 classes for el and 2 classes for aod, we then have 18 different values with relevant probability distribution for “atl” (general attitude towards rules). Applying Bayes formula, we can calculate the probability of all dependent outputs, and the final results will be how many percent of driver will violate the traffic regulations in the specific scenario of this intersection.

Annex B: Description of the Field Survey Location

The data used in the case study of the thesis are extracted from the Project Traffic Engineering Evaluation, executed by TRAHUD study team (2008).

The objectives of this evaluation are to have quantitative data in each location in three periods of time: before, during, and after new assignment. These objectives can be specified as follow:

On Chua Boc-Thai Ha street, the objectives are focused on (1) Number and percentage of signal violations among total arrival and total discharge traffic volume at intersections (2) Number and percentage of lane and marking violations among total arrival and total discharge traffic volume at intersections under the transport police station No3 (TPS 3) enforcements .

Taking study on three National Highways, this evaluation focus on following up the (1) variation of every type of motorized vehicle spot speed BEFORE, DURING, and AFTER new assignment under east-coast TPS enforcements to have number and percentage of speed violations per total section volume on each period of surveying time; (2) variation of number and percentage of Helmet wearing per total motor-cycle volume BEFORE, DURING, and AFTER new assignment of TPS enforcement.

Digital cameras were used to record the traffic situation. Surveyors would do the counting of traffic volume and also the violations and spot speed under supervision of the lecturers of The Institute of Transport Planning and Management.

Following are description on the location of the field survey.

1. Chua boc street.

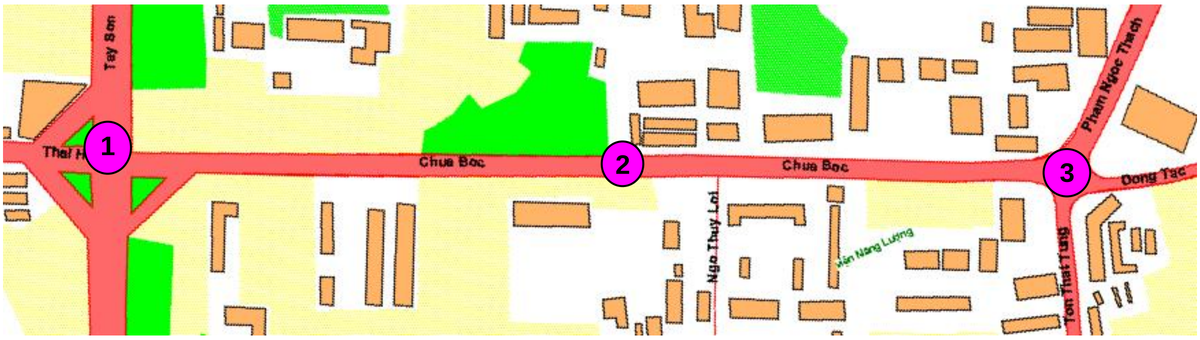

Figure 44: Survey location of Chua Boc street

Note: 1: Chua Boc – Thai Ha Intersection

2: Bank Academy

3: Chua Boc – Ton That Tung –Pham Ngoc Thach Intersection

The survey location on Chua Boc street is about 780 meters long from Chua Boc-Thai Ha intersection to Chua Boc-Ton That Tung-Pham Ngoc Thach intersection. The traffic engineering conditions on this corridor have been improved much for nearly 1 year according to the first step of the model project. This time being, the typical cross-section is about 14meters wide on average, which is divided in 4 lanes with dash painting (two lanes in each direction), and hard separator in the middle. Side walk is about 5 meters width for both side. There are three intersections in the segments, but the study takes only the intersection number 1, Thai Ha – Chua Boc, into consideration.

2. National Highway description

A. National highway No. 1A (former) and 1B (new)

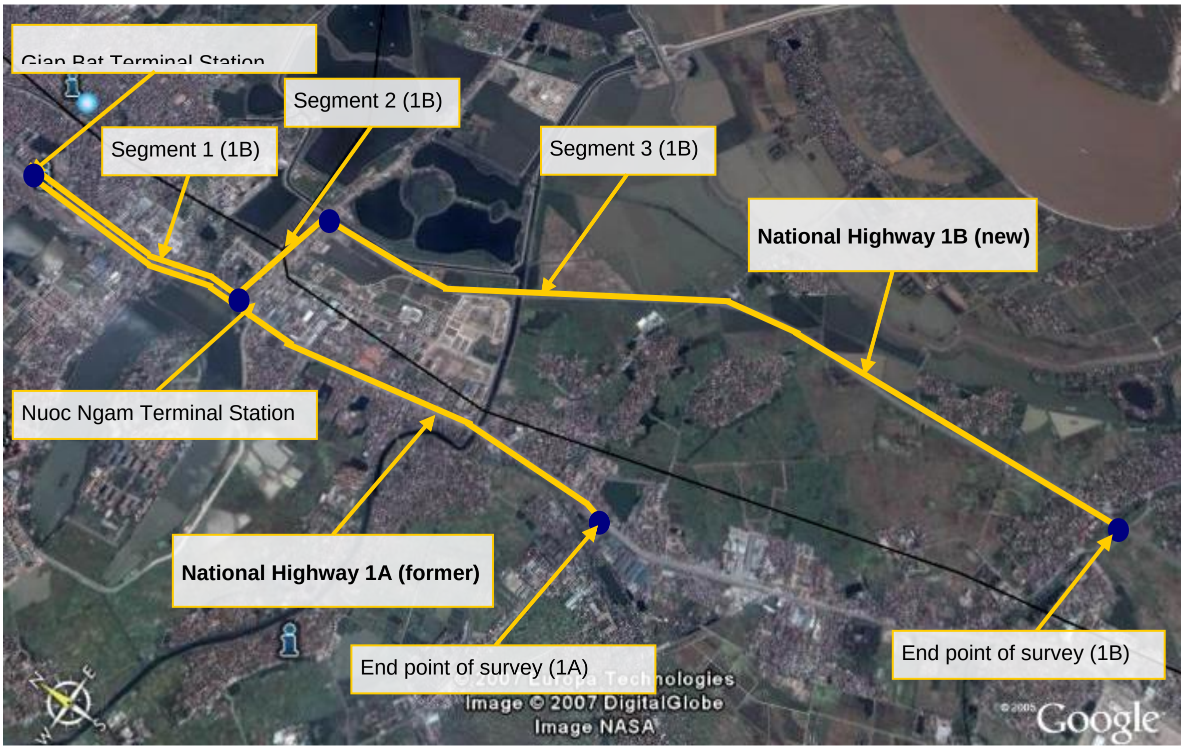

Figure 45: Survey location of National highway 1A and 1B

The survey team has carried out the survey on both National highway number 1A (former road) and 1B (new road) which coincide with each other in length of 1700 meters from Giap Bat terminal bus station to Nuoc Ngam terminal bus station.

These two routes are important in collection between Southern provinces of Ha Noi to the center of Ha Noi capital.

a. National highway No. 1A (former)

The survey section on National highway 1A is about 4180 meters long start from main gate of Giap Bat terminal bus station to a house number 36 Pho Ga. The hard separator with steel barrier in the middle is used to divide the typical cross-section into two separate directions. Three lanes in each direction including two 3.5meter-motorized traffic lanes, and one curbing-lane is 2 to 3 meters long for non-motorized traffic. Side walk in both side of this corridor is about 3 to 5 meters wide (see **Figure 45**).

b. National highway No. 1B (new)

The survey section on National highway 1B (see **Figure 45**) is about 7500 meters long from Giap Bat terminal bus station to the first over road bridge, which is divided in to three different segments with different traffic engineering characteristics.

The first segment is from Giap Bat terminal bus station to Nuoc Ngam terminal bus station coincides with the National highway 1A corridor, and has the same traffic engineering characteristics with this segment of National highway 1A.

The second segment of survey corridor is nearly 800 meters long, from Nuoc Ngam terminal bus station to Phap Van T-junction. Typical cross-section on this segment is 12 meters wide, the surface of road is seriously deteriorated.

The third segment of survey corridor is express way, 5,100 meters long, from Phap Van T-junction to the first over road bridge. The typical cross-section is 50 meters wide with steel barrier hard separator.

B. National highway No. 5

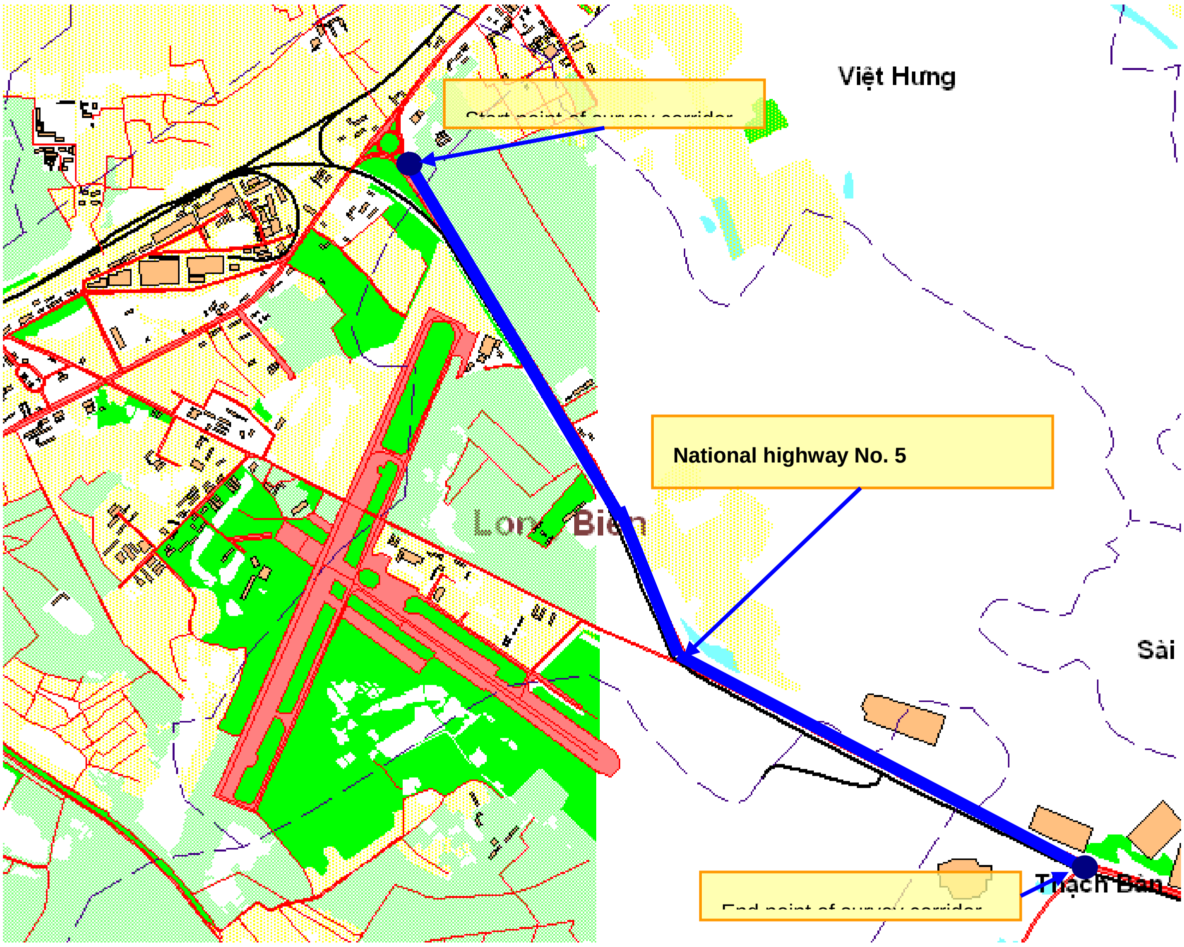

Figure 46: Survey location of National highway No. 5

The survey location, which is indicated in the National road 5, is shown in the **Figure 46**. This two-separated way is divided with hard separator in the middle all over 3,950 meters long of surveying. There are three motorized lanes in each direction of the survey section including two lanes for autos with 3.75meters wide each; one lane for motor-cycle with the width of 3.5meters. Beside three auto lanes in each direction, this road also has one non-motorized traffic lane in each direction with the width of 2 - 3 meters for pedestrians, bicycles,... The typical cross-section is about 35 meters width for total.

C. Bac Thang Long – Noi Bai

Figure 47: Survey location of Bac Thang Long – Noi Bai

The survey corridor is 4,600 meters long. Typical cross-section is divided in to three lanes in each direction, one lanes for autos, one for motor-cycles, and another for non-motorized traffic. There are still connections between this expressway and local road; No priority, separating lane for buses have been provided, neither bus bay design at bus stops.

The project aims at evaluating effects of the model program applied on Tran Khat Chan street, three National Roads, and Thai Ha-Chua Boc street. Only some results from this project are used to illustrate the ability to apply the constructed risk analysis model of driver behaviour in the context of violating road traffic regulations.

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