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# Identification of Factors in Road Accidents through In-Depth Accident Analysis

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# IDENTIFICATION OF FACTORS IN ROAD ACCIDENTS THROUGH IN-DEPTH ACCIDENT ANALYSIS

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The rising trend of motorization and improving socio-economic status of Thai people directly influences the aggravating road safety situation with fatalities and permanently disabled injuries of about 130,000 and 500,000 respectively over the past decades. An estimated annual cost from road crashes amounts to about US$2,500 million, 3.4 percent of Gross National Product (GNP), undoubtedly inflicts Thailand with a burning public health concern in the South East Asian region. This paper addresses an in-depth study through crash investigation and reconstruction which has not yet been practised in Thailand to identify the contributory factors in road crashes by the concerned authorities. This research attempts to establish the linkage between the causes and consequences with event classification of an investigated case by highlighting the dynamic driving situation with initial traveling speed, pre-impact and post-impact speed of the involved vehicles to describe the crash scenario. Moreover, inaccurate risk assessment and late evasive action, absence of street-light facilities, inadequate lane marking and visibility were also outlined as major risk factors increasing the severity of crash and injury in this investigated case.

**Key Words:** Investigation, Reconstruction, In-depth analysis, Event tree, Factors

## 1. INTRODUCTION

Road safety becomes a major public health concern when the statistics show that more than 3,000 people around the world succumb to death daily due to road traffic injury[1]. In addition, road crashes lead to the global economic losses as estimated in road traffic injury costs of US$518 billion per year[2]. The huge economic losses are an economic burden for developing countries. It is reflected that the road crash costs are estimated to be US$100 billion in developing countries which is twice the annual amount of development aid to such countries[2]. Considering within South East Asian countries, the economic growth rate of Thailand continues to move upward with an aggravating road traffic situation due to the heavy negative impact of a higher level of motorization. Over 130,000 fatalities and nearly 500,000 people were permanently disabled due to road crashes over past decades[3]. The economic losses due to the road crashes are; therefore, considerably high, costing approximately US$2,500 million per year (about US$0.3 million per hour), or 3.4 percent of the Gross National Product (GNP).

An Asian Development Bank country report[3] focused on the seriousness of the road accident problem which is shown in Figure 1 with an upward trend of injuries per accident whereas fatalities per accident remained constant with small fluctuations from 1993-2002. However, the fatality index declined to 16 percent in 2002 from 27 percent in 1993 over this period of time.

The collection and use of accurate and comprehensive data related to road accidents is very important to road safety management[4]. The road accident data are necessary not only for statistical analysis in setting priority targets but also for in-depth study in identifying the contributory factors to have a better understanding of the chain-of-events. Having the inconsistencies in the aims of the police and the road safety engineers, the data anal-

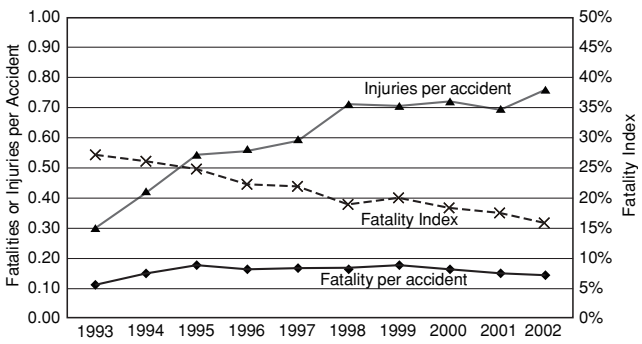



**Fig. 1 Trends in casualties per accident and fatality index (Tanaboriboon 2004)**

ysis and its interpretation usually does not result in proper countermeasures. Sometimes a lack of proper knowledge of crash and proper training of the police officers in charge on systematic data collection procedures from a crash scene adds to the diverging nature of the role of the police and the road safety professionals. These problems have become a burning issue for developing countries addressing road safety without completed crash data due to the negligence of the concerned authorities. A study[5] clearly indicates this limitation - "the reactions are mostly on major accidents, but the interests would fade away rapidly and the problem still remains".

## 2. BACKGROUND

The identification of factors affecting road crashes obtained from the crash investigation and reconstruction has not been conducted in practice in the Asian countries. The goal of this study was to initiate this road safety practice in Thailand by addressing the timely need for an in-depth study for road accidents.

The accident investigation involves the inspection of crash scenes and the documentation of all necessary and available information of each component (i.e. human, vehicle, and road-environment). Accident reconstruction is defined by Baker and Fricke[6] as "…the efforts to determine from whatever information is available, how the accident occurred". Accident reconstruction approach works backward from the evidence of the crash investigation and the remains of the crash to look into the scenario of before (pre crash), during (crash) and after the crash (post crash). The sequential analysis of end results to the initial condition of the events can establish "*how*" and "*why*" a particular type of crash occurs. Mathematics and Newtonian physics are applied in this analysis. It can be stated that crash reconstruction goes back to investigate the contributory factors and/or causes behind the crash event based on major and minor physical clues left behind at the crash scene.

The techniques of crash reconstruction, trajectory and damage based analysis by using physics simplifies the determination of many important parameters of crash events. Moreover, to obtain a reliable conclusion, detailed information encompassing the system components needs to be thoroughly investigated. The information necessary for reconstruction starts with the crash scene[7]. The answers to the questions of 'why', 'what', 'when' and 'how' should lead the reconstruction process to build up the real scenario of the pre-crash, crash, and post crash[7]. Photographing of important clues and videotaping of the crash scene plays a vital role for the reconstruction. Injury information from occupant medical reports can be verified with the trajectory of the occupants found inside the involved vehicles at the scene. Therefore, an "open mind" investigative attitude is very crucial to search for all the detailed information from the scene[7].

## 3. OBJECTIVES

The purpose of this study was to conduct an in-depth study focusing on the application of event analysis through crash investigation and reconstruction. The objectives of this study were the followings:

1. To identify the contributory factors based on the findings obtained from crash investigation and reconstruction by using a case study;
2. To apply an event analysis in establishing the links between the events to describe the crash scenario based on the available information.

This case was selected to conduct an in-depth analysis of the crash investigation and reconstruction because of the following reasons:

1. A fatal case between a bus and a pickup truck vehicle to understand the crash mechanism of two structurally different (incompatible) vehicles and crash and injury severity of the involved vehicles.
2. Good example for the evasive actions taken by the driver (i.e. bus driver) in the form of the skid marks on the road surface to calculate back the traveling speed of the bus.
3. The total number of buses and pickup truck vehicles combined involved in all crashes increased from 34,650 in 2003 to 36,816 in 2005[8]. But the severity of injury from an angled head-on collision like this case is very challenging to investigate the leading factors to prevent such crashes.

## 4. METHODOLOGY

The in-depth analysis for the contributory factors through event classification requires a scientific methodology to follow systematic research. The conceptual framework designed for this study is presented in Figure 2.

The investigation team was always on the alert for crash news. Independent News Network (INN) was considered a primary source of road accidents where the team was motivated to investigate the case. It should be noted that the safety precautions of the investigation team were maintained while conducting the investigation pro-

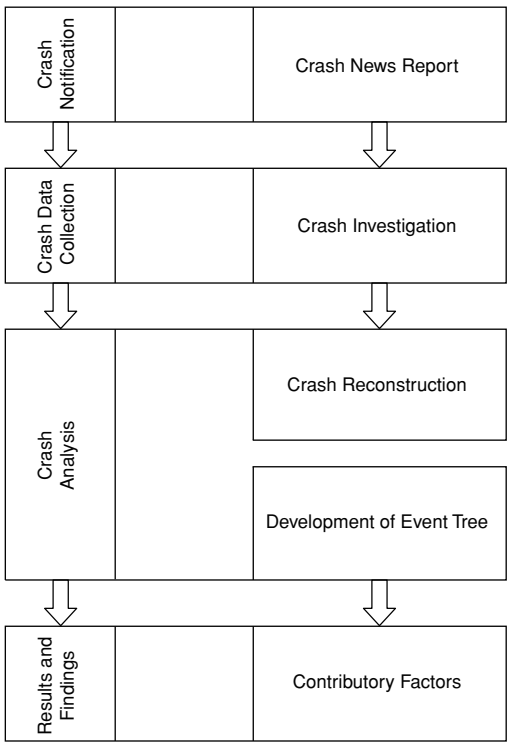



**Fig. 2 Conceptual framework for the study**

cess. After the arrival at the crash location, the necessary information was collected with field sketches, drawings, and photographs of the crash scene and damaged vehicles from different angles. The physical evidence (e.g. tire masks, broken glass, oil and blood spatter, etc) at the crash scene were carefully collected particularly for the skid marks that were measured according to direction and coordinates from a reference point. The roadside infrastructure was referenced and taken into consideration. In addition, the concerned police station was contacted and their reports were gathered. Damaged vehicles taken to the police station were also carefully investigated.

The evidence at the crash scene, interviews of eyewitnesses in the vicinity of the crash location, and the police reports were gathered and interpreted to visualize the events prior to the crash according to the available information. The trajectory based reconstruction was carried out to determine the traveling, pre-impact and post-impact speed including direction of force acting on the involved vehicles.

Based on the concept of Driving Reliability and Error Analysis Method (DREAM), the genotypes (i.e. cause) and phenotypes (i.e. consequences) of the case study were segregated. The inseparable driver behavior from the context was the main focus which encompassed the effects and the causes of the effects. The effects represent possible ways for a dysfunctional behavior to manifest itself in the dimensions of time, space and energy whereas the causes are interpreted from the reasoning[9]. To apply DREAM analysis in this study, the possible connections between factors behind the events were established which attempts to explain the observed consequences or the event phenotype[9]. Figure 2 shows the steps followed in this study to figure out the complete analysis.

## 5. ACCIDENT IN-DEPTH ANALYSIS - A CASE STUDY

### 5.1 General information of the case

The crash occurred between a bus and a pickup truck on an undivided 2-lane 2-way straight section of Chiang Rak-Bang sai Arts and Craft Center rural highway at about 9 p.m. A total of nine casualties, eight fatalities and one serious injury, were reported in this angled head-on crash between two vehicles. All of the causalities were the occupants of the pickup truck. The pickup truck truck was severely damaged with little deformation in the bus.

### 5.2 Pre-crash information

***Driver Information***

Pickup truck: The pickup truck driver was 37 year-old male. Nine passengers were inside the pickup truck. A seatbelt was used by the driver according to the evidence from the investigation process. He was traveling at about 55 kph outbound to Bangsai.

Bus: The bus driver was male (age not reported). He was trying to pass the motorcycle in front of him. He was traveling at about 65 kph inbound to Bangsai.

***Vehicle Information***

Pickup truck: The 4-wheel pickup truck was locally modified to provide a roof and seats for the passengers in the back. The seating rows were arranged along both sides of the vehicle for the convenience of passengers. The pickup truck was used for public transport. The body was silver color.

Bus: The body structure of the 6-wheel bus was locally modified. It was white and blue painted.

***Road-Environment Information***

Geometry: Chiang Rak-Bang sai Arts and Crafts Center Road is a 2-lane 2-way road in a rural setting. The lane width is 2.7 meters in each direction with 1.8 meter wide shoulders in both directions. The road was level.

Surface: The pavement surface was asphalt, and the surface condition was dry during the investigation.

Lane markings: The yellow marking (dashed) was a lane separating the two lanes, and the white marking

(solid) was a lane-shoulder separation in both directions. The lane markings were not clearly visible considering the road surface as a background.

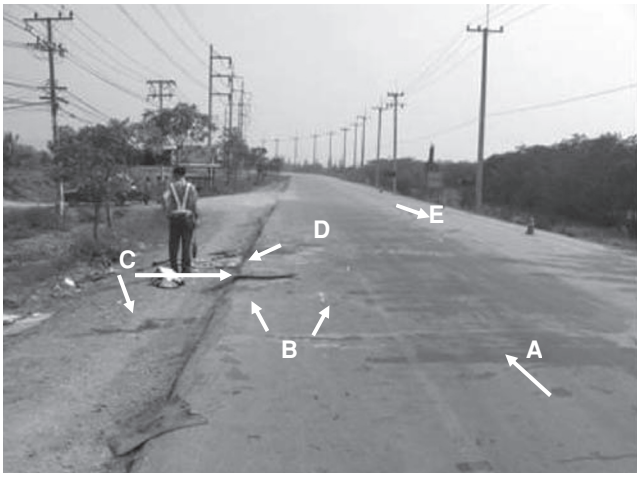
Roadside furniture and area: The small trees and electricity transmission poles were found along the straight section of the road. In addition, election campaign boards, information boards, and some traffic signs were observed along the road near the crash scene. There was a sheltered 'Bus Stop' on the opposite side of an election campaign board. No street light was found on the road. Two minor connecting roads (i.e. access road) were also observed on the opposite side of the road section at the crash scene. A cut-section was on both sides of the embankment of the road section.

### 5.3 In-crash information

***Driver Information***

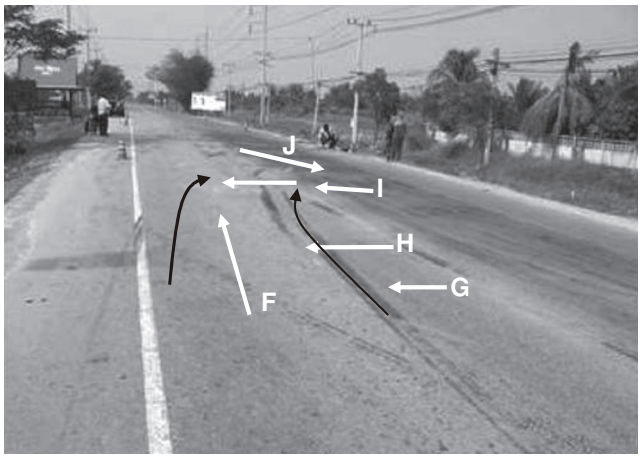
Pickup truck: As the pickup truck was traveling in its own lane, there was no sudden expectancy to slow down. Suddenly, the bus appeared into the right of way (lane) of the pickup truck. Due to 'sudden and unexpected' situation, the pickup truck did not have time to brake and avoid the collision (no skid marks by the pickup truck were found on the driving lane of the road). The pre-impact speed of the pickup truck was about 55 kph. The direction of force (PDOF) passing through the centriod of the damaged portion was 11.5 degree (clockwise) with respect to the longitudinal axis of the vehicle. Figure 3 shows the driving direction of the pickup truck.

Bus: Consequently, the bus was going to the right lane from its driving lane (left lane). Suddenly, the bus driver found that the pickup truck was approaching at a very close distance. Therefore, the bus driver applied the brakes in 0.63 seconds and made 9.8 meters of skid marks before the crash. However, the bus could not avoid the collision with the pickup truck. The bus was traveling at about 65 kph and slowed down to 47 kph within a very short time (i.e. 0.63 seconds). Figure 4 shows the driving direction of the bus.




Note: A: Initial Direction of Travel (pickup truck); B: Rear Right and Left Tire at Point of Rest (pickup truck); C: Blood; D: Debris and Oil Spatter and E: Initial Direction of Travel (bus).

**Fig. 3 Driving path of pickup truck (southeast bound)**




Note: F: Initial Direction of Travel (bus); G: Right Front Tire Mark (bus); H: Rear Right Tire Mark (bus); I: Rear Right and Left Tire Mark at Point of Rest (bus) and J: Initial Direction of Travel (pick-up).

**Fig. 4 Driving path of bus (northwest bound)**

### 5.4 Post-crash information

***Driver Information***

Pickup truck: The post-impact speed of the pickup truck was estimated to be about 37 kph. Due to severe intrusion and damage of the passenger compartment there were eight fatalities and one serious injury of the occupants.

Bus: The post-impact speed of the bus was estimated to be about 24 kph. Due to the geometry and mass incompatibility between the vehicles, the bus sustained minor damage compared to the pickup truck.

***Vehicle Information***

Pickup truck: Since pickup truck collided with the bus, the damage was very severe. The impact force of the bus was high enough to crush the major portion of crush zone and passenger compartment of the pickup truck. The measurements were not directly made due to the crash severity of the pickup truck. The external damage with internal intrusion of the damage resulted in eight fatalities out of nine passengers inside the pickup truck. The calculated delta-V for the pickup truck was about 89 kph. Figure 5 (a) shows the extent of damage of pickup truck from different angles.

Bus: The bus was higher than the pickup truck in terms of vehicle geometry and only the right side of the bus was damaged at the bumper and the right front fender. The direction of force (PDOF) passing through the centriod of the damaged portion was 8.4 degree (clockwise) with respect to the longitudinal axis of the vehicle. The extent of damage of bus was comparatively less. The calculated delta-V for the bus was about 24 kph. Figure 5 (b) shows the extent of damage of the bus from different angles.

***Road-Environment Information***

Pickup truck: The pickup truck was stopped after going backward on the left side for 6.8 meters from the point of impact. The rest position of the pickup truck was found at the crash scene on its driving lane but close to the shoulder.

Bus: The bus stopped after crossing 2.8 meters ahead from the point of impact on the opposing lane (right lane which is right-of-way of pick-up).

Figure 6 shows a schematic drawing of the crash scene when the vehicles were at their rest positions.

### 5.5 Reconstruction by simulation

The trajectory of the crash involved vehicles was determined by using hand calculations. The results were obtained and used as input in the reconstruction simulation software, PC-Crash, to simulate different events to demonstrate the consequences leading the crash. In the simulation package, 3D features were applied in the reconstruction process. The 100 meters-straight section of road following the curve was set as an input for the crash scene. Trees, electric poles, information sign boards, advertisement boards, two abutting roads, and the small sheltered 'Bus Stop' for the passengers were included as inputs for the crash scene data. Length of broken lines and gap between them were set as 3 meters and 6 meters, respectively. The plan view is illustrated in Figure 7.


**Fig. 5 a) Damaged pickup truck (left: front) and (right: right-corner), and b) Damaged bus (left: front) and (right: right-corner)**

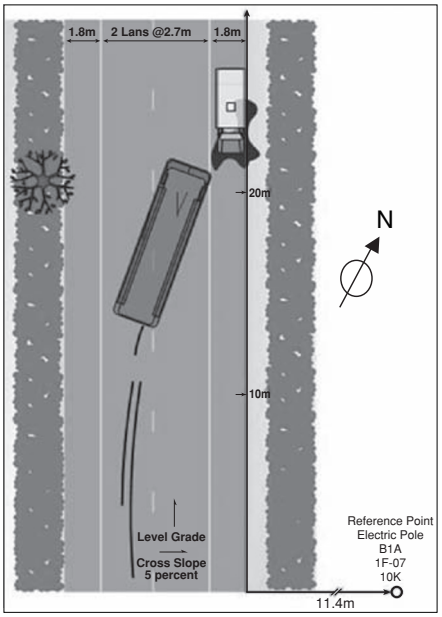
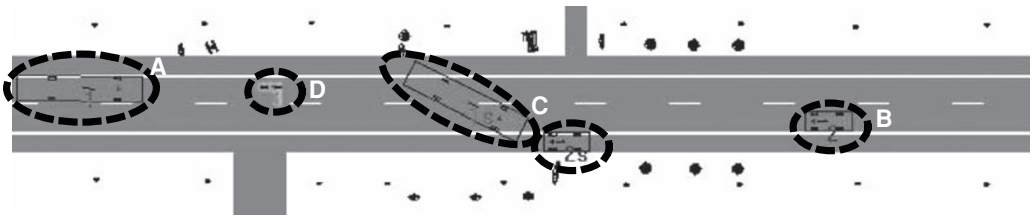



**Fig. 6 Schematic drawing of crash scene**




Note: A: Initial position of bus, B: Initial position of pickup truck, C: Point of rest, D: Initial position of motorcycle.

**Fig. 7 Plan view of crash scene input**

The traveling speed, path, direction, and relative positions of the vehicles (i.e. pickup truck, the bus and motorcycle) were set according to the investigation and values obtained from reconstruction. Figure 8 shows the snapshot of simulation when the bus was trying to start the passing maneuver. Figure 9 shows the separation of the bus and the pickup truck after full impact and both vehicles were starting to slow down to their respective rest positions. As shown in Figure 10, the speed vs. distance relationship of the bus shows the events for bus before collision (e.g. Perception-Identification-Emotion-Volition (PIEV) distance and pre-crash braking), at collision (e.g. point of impact) and after collision (e.g. point of rest).

Pickup truck: It was traveling at about 55 kph along the straight section of the undivided 2-lane 2-way rural road. The pickup truck driver was observing the oncoming vehicles in the opposite lane. There was a motorcycle coming in the opposite lane. During night time driving under no street light condition, the driver could have a glare problem to some extent. Consequently, the pickup truck driver paid less attention to the following vehicle (i.e. bus). The driver did not expect any opposing vehicle would enter the right-of-way of the pickup truck. However, the driver had little time (e.g. due to un-expectancy and glare) to react and no time to apply the brakes. Since no skid marks by the pickup truck were found during the investigation, the speed vs. distance profile of the pickup truck was not plotted.

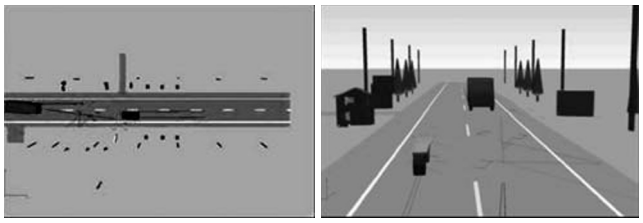


**Fig. 8 Snapshot of starting passing maneuver of bus (Left: Plan view, Right: Bus driver's view)**

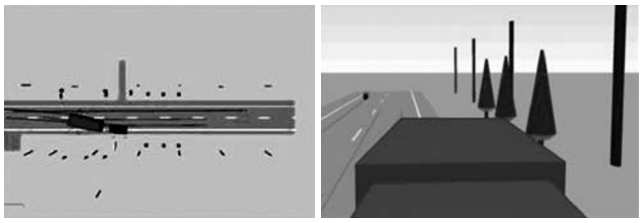
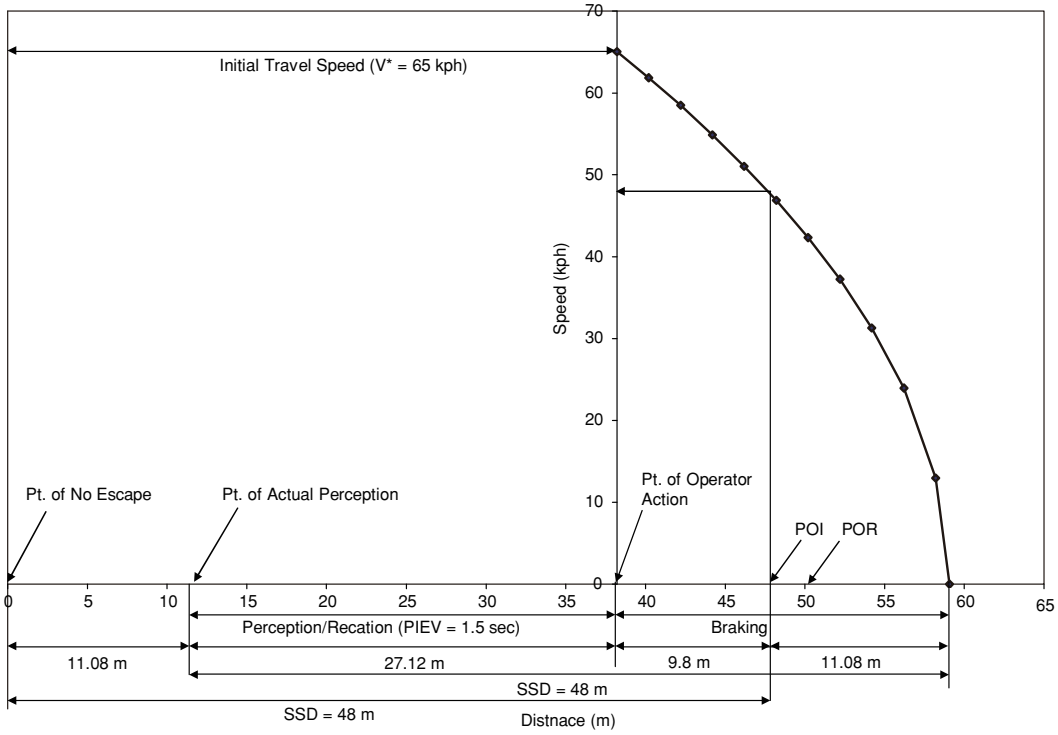


**Fig. 9 Snapshot of separation of the bus and pickup truck after full impact (Left: Plan view, Right: Bus driver's view)**




Note: PIEV: Perception-Identification-Emotion-Volition, POI: Point of Impact, POR: Point of Rest, SSD: Safe Stopping Distance.

**Fig. 10 Speed vs. distance profile for bus**

Bus: It was traveling at about 65 kph after crossing the curve upstream. The required safe Stopping Sight Distance (SSD) was 48 m. Considering PIEV time of 1.5 second, PIEV distance was about 27 m and pre-impact skidding took 9.8 m which made about 37 m in total with initial traveling speed of 65 kph. According to the calculations, the bus driver could avoid the crash if he started braking at about 11 m before the actual braking position as shown in Figure 10. At x = 38 m, the bus driver applied braking and collided with the pickup truck at x = 48 m with about 47 kph.

Due to the misjudgment of the bus driver to the pickup truck speed which was traveling (pickup truck: 55 kph) 10 kph lower than the bus (bus: 65 kph) and also with no street lighting resulted in too late decision making by the bus driver to pass the leading vehicle (i.e. motorcycle). The misjudgment of a gap between the vehicles (i.e. bus and motorcycle) and high traveling speed of the bus resulted in passing and entering to the opposing lane. The late decision of passing maneuver of the bus led to the collision with the oncoming pickup truck even though the bus was applying the brakes. All these factors influenced the bus driver to cross the point of no escape at x > 0 as shown in Figure 10.

### 5.6 Application of 'Event Tree' concept

The sequences of the events presented in Figure 11 (for Pickup truck) and 12 (for Bus) are based on the physical evidence found at the crash scene, damaged vehicles, information of the crash investigation, results of the crash reconstruction, interview of eye witnesses and local people, and police reports. Following the concept of DREAM analysis, possible factors and observable consequences were presented in Figures 11 and 12. The branching out of these consequences from their causes led to the collision.

Pickup truck: Lack of street light facilities, misjudgment of speed of oncoming vehicles, and normal driving expectancy on the straight road affected unclear vision of the pickup truck driver, less attention to following vehicles and unexpected state for the pickup truck driver. The later caused less time to react and literally no time to brake to avoid the oncoming bus from the opposite direction. All these factors and consequences are interlinked to one another. The event tree for the pickup truck is presented in Figure 11 with events prior to crash vs. time line.

Bus: Lack of street light facilities, together with misjudgment of speed of oncoming vehicles, and less attention in driving caused a faulty line of vision of the bus driver, misjudgment of gap between the leading and following vehicles, and temptation of higher speed. Consequently, the misjudgment of the gap caused improper plan of driving and temptation of higher speed to pass the leading vehicles causing a late decision for passing. This late decision of passing made the passing vehicle applied late braking to avoid the collision with the oncoming vehicle

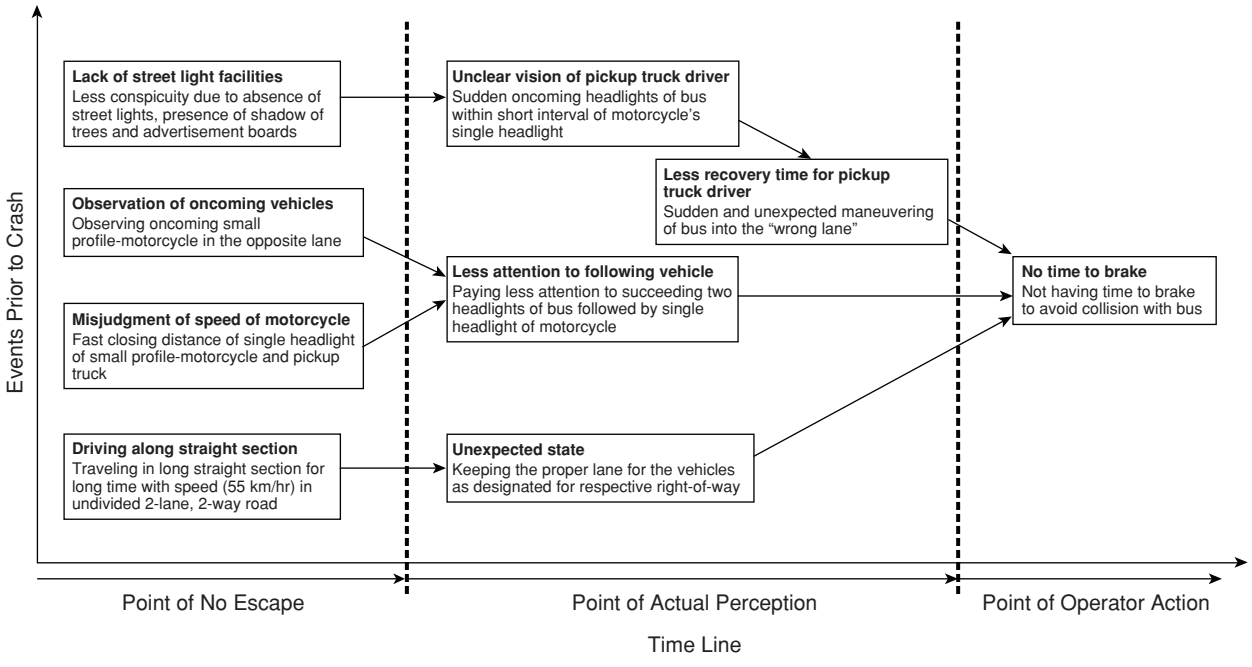



**Fig. 11 Event tree for pickup truck**

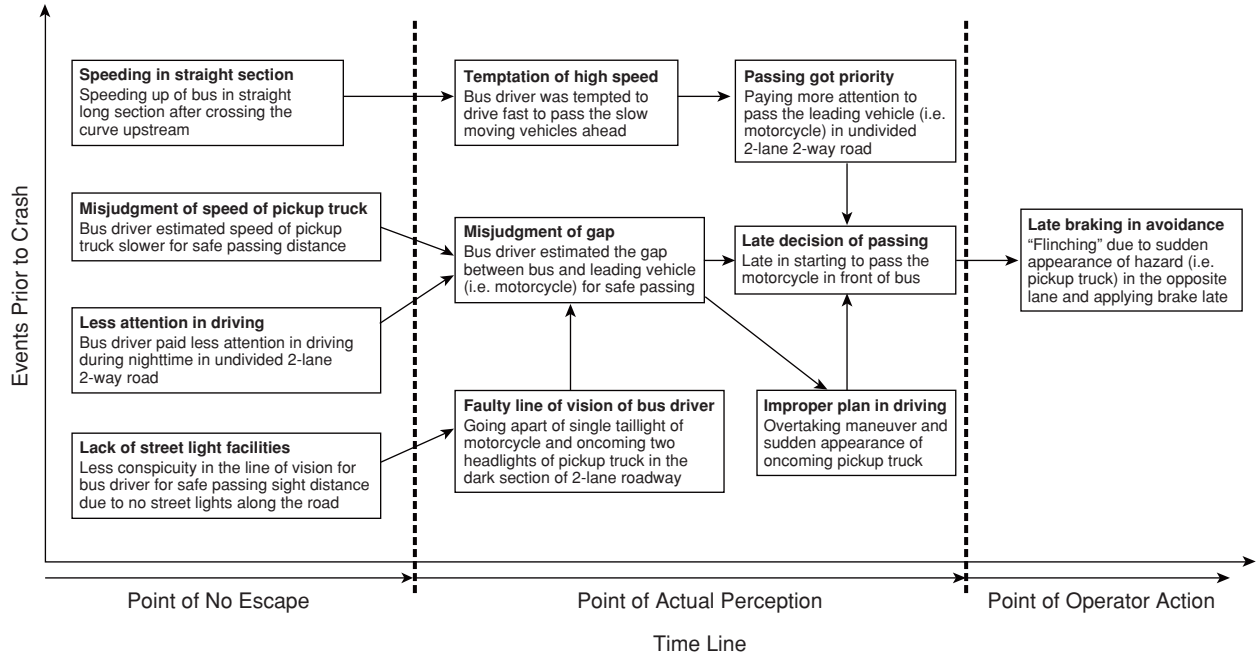



**Fig. 12 Event tree for bus**

from the opposite direction. The event tree for the bus is presented in Figure 12 with events prior to crash vs. time line.

## 6. SUMMARY OF FINDINGS

The summary of event analysis could lead to listing the factors of the system components. The human factor of the pickup truck, where the pickup truck driver could have braked as an evasive action (but actually he did not in the real situation) was influenced by the unexpectancy of the oncoming vehicle (i.e. bus) into its (i.e. pickup truck) own right of way. Less attentive driving on the undivided 2-lane 2-way highway at night in the absence of street light facilities is also added. For the bus driver, the misjudgment of a gap between bus and leading vehicle (i.e. motorcycle) together with late passing decision of the passing vehicle led to late braking to avoid the collision.

For the vehicle aspect, the compatibility of the bus and smaller vehicle such as a pickup truck in this case could be taken seriously in terms of mass and geometry of the vehicles. In addition, the locally modified body structure of the bus could possibly have late braking response due to the old age of the vehicle.

For the road and environment aspect, no street light facilities particularly during night time driving on the undivided 2-lane 2-way rural highway could lead to the difficulty in distinguishing the lane separation. Shadows of static objects (e.g. campaign boards, information boards) also contributed to the faulty decisions of the pickup truck and bus drivers. In addition, no speed limit signs along that road section were found during the investigation process.

Possible factors from the summary of event analysis could be listed as follows under system components (i.e. human, vehicle and road-environment):

***Human***

Pickup truck:

- Unexpected maneuvering of bus into "wrong lane" in 2-lane road
- Paying less attention to the oncoming vehicles in the opposite lane in undivided road during nighttime driving

Bus:

- Misjudgment of distance and speed of the leading vehicle (i.e. motorcycle)
- Late in overtaking for small profile vehicle (i.e. motorcycle)
- Inattentive driving for oncoming vehicles from the opposite lane in 2-lane-2-way undivided road

***Vehicle***

Bus:

- Complete stop by applying brakes did not occur due to having short braking time (0.63 sec)
- No "crash compatible design" between large vehicle

(i.e. bus) to smaller vehicle (i.e. pickup truck)

***Road and Environment***

Pickup truck:

- Lack of street lighting
- Lack of conspicuity of the static roadside objects during nighttime
- Difficulty in distinguishing the lane separation clearly due to lack of reflective devices for 2-lane road
- No "Speed Limit" sign along the roadside

Bus:

- Lack of street lighting
- Unclear vision due to shadow of small trees, advertisement boards, information sign along road
- No "Speed Limit" sign or warning sign of curvature ahead along the long straight section

## 7. CONCLUSIONS

The event analysis obtained from crash investigation and reconstruction can be applied to determine the possible contributory factors in the fatal road crash. These contributory factors are generalized according to the available information of the system components. The event tree analysis mainly deals with what were the events and factors that came to the drivers' attention and decision making to influence their behavior during driving in the pre-crash stage. The factors found based on the event analysis can be concluded as follows:

***Human Factor***

- Cognitive behavior particularly judgment and decision-making based on analytical aspects of reaction were found to be important particularly in this case. This behavior was highly dependent on the inaccurate risk assessment. Both drivers had other causes which influenced them to take the risk.
- Sensorimotor behavior includes experiences related to sensory and motor channels. This is another aspect of human behavior, which highly contributes to crashes. This effect was found to be important in this case where evasive action (i.e. braking action) was perceived later than required. In this case, the pick-up driver could not react in an appropriate time to avoid collision when there was a mistake in passing maneuver happened by the bus.

***Road and Environment Factor***

- It was found to have a potential effect on road crashes. The visibility, geometry, lane markings, surface condition, and street light facilities have a potential influence on the drivers to perceive and react in a dynamic driving condition. The interaction of road and environment is quite complex with driving behavior and performance. In this case, absence of street lights, unclear lane marking were found to increase the risk of crash and its severity.

The vehicle factor particularly the vehicular defects were not thoroughly investigated in this case. Nevertheless, the vehicle compatibility of bus and pickup truck focusing on a safer vehicle design is highlighted in this study. It is expected that more advanced vehicle investigation will be further analyzed in the future. Since this study was undertaken as a pilot study for future in-depth studies, the limitations and a more systematic way of analysis will be adopted to understand better about the pre-crash events and the contributory factors.

Human factors are supposed to be the leading contributory factor in any crash analysis including this case study. Nevertheless, vehicle and road-environment are also crucial in influencing driver behavior in pre-crash and the crash phase. These two factors require more attention in investigation and in-depth analysis in particular for developing countries where vehicle and road-environment are still not of the same standards as developed countries[10]. This in-depth analysis through a demonstrated case study eventually indicates the improvements in highway design and facilities need to be addressed to ensure safer roads in Thailand.

Since this study was initially conducted in Thailand, the findings and review of this study could play an important role as a pilot study for further research studies. Considering this pilot study, the objectives and scope of the research could be broadened to be implemented in other projects to establish a firm research base. The benefits of such in-depth study envisioned with better understanding of the interrelationship of the system components in road crashes eventually could be followed in other developing countries in Asia.

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