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Article

An In-Depth Investigation of Roadside Crashes on Thai National Highways

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Abstract. Road crashes in Thailand cause some 13,000 deaths each year. About 12% of these occur on national highways under the jurisdiction of the Department of Highways (DOH). For the past four years, 2007-2010, roadside crashes have constituted between 42.2 – 47.9 %, averaged 44% of the total crashes on the DOH's highways. This paper presents the result of in-depth roadside crash investigations with the aim of improving the roadside safety situation in Thailand. It was found that speeding was the main human error that contributed to the crashes, accounting for 57% of the causes. The cases involving vehicle hitting trees, the most common roadside hazard in Thailand, were found to be the most serious and common roadside crashes accounting for 72% with resulting 48 fatalities. The paper gives details of the investigation into the cause and consequences of these crashes. The authors urge DOH to take needed actions on the proposed strategies to deal with this immensely serious problem. The strategies are based on the DOH Roadside Safety Strategic Plan 2009-2013.

Keywords: Roadside crashes, roadside hazards, roadside safety strategies.

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1. Introduction

1.1. Background

Road safety is a global concern, particularly in low and middle income countries and among vulnerable road users. By 2030, road deaths as a proportion of all deaths will become the world's fifth cause of death rising from its present 9th position [1]. In such a scenario, Thailand is facing a challenging situation due to her having one of the highest road fatality rates in the world. Records for 2009 showed that, for one hundred thousand population, Thailand's road crash fatality rate stood at 17.0 (10,717 deaths), which was more than double the rate of Australia (6.9 or 1,507 deaths), while the number of injuries was close to one million [2]. The RISER project indicates that about 10% of all crashes are single vehicle accidents (SVA) that occur when the vehicles run off the road. When only fatal crashes are counted, ROR accidents account for a significant 45% of the tally. Crash investigations in the RISER project pointed to the fact that all fatal accidents involved impact speeds of 70 km/h or higher; roadside structures such as signs, concrete walls, fences, and so on, were struck in 11% of all fatal SVA. Safety barriers are the object most impacted in ROR crashes. Although few injuries sustained in safety barrier crashes are found to be severe, the safety barriers themselves can pose a major hazard if not properly designed and installed [3] In Great Britain over the past 15 years, while occurrences of other crash types have been declining, crashes involving collision with roadside objects have remained fairly constant, and accounted for around 20,000 injuries yearly, a high 24% of which proved to be serious or fatal. Trees, crash barriers, and lamp-posts are three most frequently struck objects; with trees being the most hazardous: 33 % of all tree crashes culminate in serious or fatal injuries. The collided object can be "unknown" as in cases involving a large group of some 7,000 collisions. [4]. In Thailand, despite the best of efforts by the Thai Government to reduce traffic accidents, the number of crashes still exceeds 13,000 resulting in more than one million injuries and several hundred thousand cases of disabilities every year [5].

One of the most overlooked causes of accidents has to do with roadside objects. Given its structure and placement, a fixed object by the side of the road, upon its being struck by a vehicle running off the carriageway, can cause, or is likely to cause, damage to vehicle, and/or injury or fatality to the occupant. Therefore, in order to reduce the severity of ROR accidents, more attention should be focused on hazardous roadside objects such as trees, utility poles, lamp-posts, sign posts, bridge rails and end treatments, fences, embankments and cuttings, ditches, guard rails (and guard rail end treatments), mail boxes and drainage structures [6]. This assumption is supported by findings in France, where the removal of trees closer than 2m from the traffic lane edge had contributed to significant reductions in crashes: the average number of accidents was halved, and the number of fatal collisions reduced by a factor of four. Current guidelines for most European countries recommend that a clear zone be established for 80 km/h roads, which is at least 4.5 m from the lane edge. No obstacles should be in this clear zone; if any exists, it should be properly removed or shielded [7]. The Michigan Tree Study reported that some 11% of tree crashes ended in fatalities. Such crashes often occurred on curved rural roads with narrow lane widths and high average daily traffic [8]. Tree crashes were also responsible for 25% of side-impact crashes with roadside hazards and produced 48% of side-impact-related fatalities [9]. Presented an interesting analysis of the relationship between the distance from trees to the travel lane and associated crash rates. [10]. Studies of highway bus crashes by the authors showed that more than 50% of these incidents were single bus accidents wherein the errant buses ran off the road and collided with roadside objects [11].

1.2. Purpose and Objectives

The purpose of this paper is to provide the concerned authorities with awareness and to take urgent actions in order to reduce the number of roadside crashes in Thailand. Three specific objectives of this paper are as follows:

- To understand the situation of roadside crashes on national highways in Thailand by using statistical information;
- To determine the contribution factors of roadside crashes by conducting in-depth crash investigations; and
- To highlight roadside safety strategies to the DOH for further actions.

2. Roadside Crash Situation in Thailand

Figure 1 shows the trends of total crashes and roadside crashes on the national highways from 1999 to 2010. On average, roadside crashes constitute 41.7% of total crashes on DOH highways over the past twelve years resulting in some 500 annual fatalities. However, for roadside crashes, the trend initially increases from the years 1999 to 2004. After that it decreases to a minimum of 5,425 cases in 2006 and become relative steady from 2007 to 2010, signifying the fact that it remains a big challenge to be addressed by DOH.

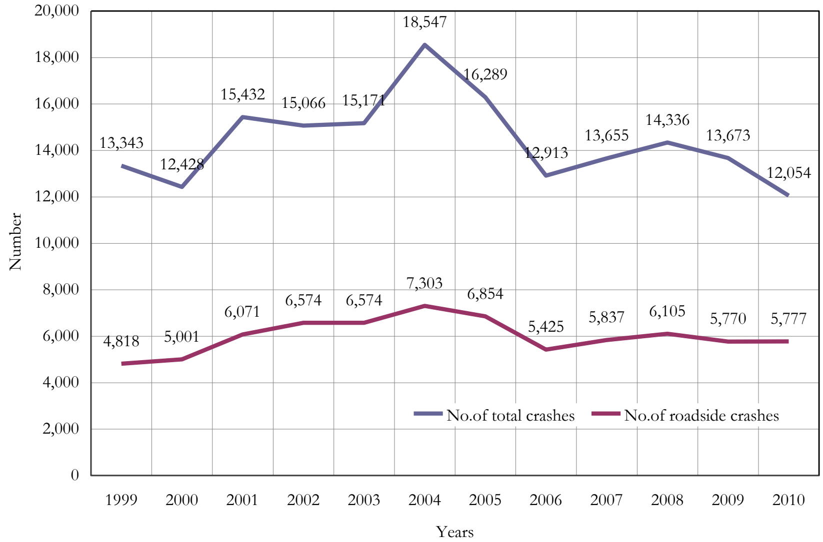

Fig. 1. Trends of total and roadside crashes on DOH national highways from 1999 – 2010 [12].

Table 1 shows the situation from roadside crashes on national highways for the past four years, 2007-2010. The roadside crashes constitute between 42.2 - 47.9 % of the total crashes on the DOH's highways or average of 44% over the 4-year period.

Table 1. Situation of roadside crashes on national highways.

Year	Total crashes	Roadside crashes	Percent
2007	13,655	5,837	42.75
2008	14,336	6,105	42.59
2009	13,673	5,770	42.20
2010	12,054	5,777	47.90
Average	13,430	5,872	44.00

Source: Bureau of Highway Safety, Department of Highways 2008-2011.

There have been earlier studies of roadside crashes using the annual data from crashes on national highways as reported by the DOH. However, these studies do not get into details of the cause of the crashes [13].

3. Principles of In-Depth Crash Analysis

3.1. General Concept

An in-depth crash analysis consists of two main procedures: investigation and reconstruction. An accident investigation is performed to determine the causes of as well as possible means of preventing an accident. The process would normally start with inspection of an accident site and gathering of evidence. The scenario would then be "played back" to enable investigators to figure out the cause of the crash. Such findings can lead to effective measures for preventing or minimizing injuries. A crash reconstruction is the process that all information, collected from the investigation step and other sources, are simulated to explain the chain of events, identify major causes, and to propose corrective/preventative measures [14].

3.2. Crash Investigation

The crash investigator must have fundamental knowledge of accidents, the road and its environment, and vehicles of all types, especially the dynamics of vehicular movement. The next subsections summarize the necessary data for the process [15].

3.2.1. Crash Scene Information

At the crash site, the investigator must choose a reference point (RP) as the origin for all measurements. From the RP, he proceeds to measure out the point of impact (POI), where the vehicles collided or where roadside obstacles were hit, and the point of rest (POR), where the vehicle stopped. Traces of debris or broken parts from the vehicles may be used to establish POI and POR which in turn would help to delineate the paths of the vehicles involved. In addition, skid marks and yaw marks can be used to explain the directions of movement, evasive action, or unlawful behaviour.

Sketches may be made to illustrate the crash configuration. Better still, photograph and video records should be taken to clearly explain the crash scene. General information, including date and time of a crash, weather, road surface condition, or previous accidents occurring at the current location, should also be recorded

3.2.2. Road User Information

Interviews of the driver and occupants should be performed to answer the question of what happened during the crash. Where possible, the injured person is also interviewed; as well as eye witnesses and those familiar with the location.

During the interview, allow the interviewees to describe their perception of events; avoid leading questions or implying. Moreover, identity and ownership documents (e.g. driver's license, ID card, and passport etc.) of driver and occupants must be checked.

3.2.3. Vehicular Information

Conditions of the crash vehicles are to be carefully examined. These include details of vehicle exterior (e.g. metal fold, wheel and tire, windshield, and wipers, etc.) and interior (e.g. instrument panel, steering columns, rear-view mirrors, seat cushion, and seatback, etc.) together with the age and condition of the vehicle part. Functioning of parts such as lights, brakes, and other safety restraining system should be tested out. The damages of different parts are to be noted. In addition, pictures of damages should be taken from different angles.

3.2.4. Road and Environment Information

General characteristics of the roadway at the crash site are to be observed; such as width, surface type, existing signs, markings, sidewalk, pedestrian crossing, speed limits, visibility, obstacles (e.g. utility poles, trees, and rocks), road name, and direction of travel. Layout of buildings can also be included, especially if the resting position of the vehicles is at or near buildings. Also look for signs of damage on the road surface or shoulder, large potholes, and on-going construction. Take note of features that might have caused loss of control; such as abrupt change in the surface of the carriageway/shoulder, poor lighting, water pooling on the surface, etc.

3.3. Crash Reconstruction

A crash reconstruction is the compilation of all items of evidence collected from the investigation process for a "playback" to illustrate the "how" and "why" of a crash. Knowledge of mathematics and Newtonian physics must be applied in order to establish the chain of events starting from Before (pre-crash), During (crash), and After (post-crash) stages. The process is essential for the examination and understanding of factors contributing to or causes behind the crash [16].

3.4. Benefits of In-Depth Crash Analysis

According to the Swedish Road Administration, a range of benefits can be gained from in-depth crash studies, as listed below:

- Lead to positive changes to the road and its environment.
- Provide data for long-term work in road design and vehicle development; and information for use by the police in traffic surveillance and other road safety efforts.
- Used in the study on effects of alcohol and drugs on driving.
- Help to heighten awareness of the role of seatbelts and other on-vehicle safety devices.
- Used as data for collaborations among authorities, agencies and companies to influence road safety.

Moreover, multi-disciplinary experts, such as vehicle mechanics, road designers, traffic engineers and behavioral scientists, should work together to analyze the result of chain-of-events reconstruction in order to gain better insight into the causes of, as well as means of preventing crashes. Experts in supporting areas, such as medical services, police, emergency services and local authorities, can also benefit from the insights gained from crash analyses [17].

4. Roadside Crash Investigation: Case Studies

In Thailand, crash data are not readily available and they are often kept in paper format. To do any analysis, researchers need to go back to the paper records and start to compile these data. In order to get the big picture view of the roadside crash situation as presented in Table 1, the first author who is DOH engineer working in the south of Thailand needed to access the crash records from DOH offices in this region. However, those records do not contain detailed crash information, therefore, to obtain this information, the authors have been conducting road crash investigations since 2008 with the support of the Office of Transport and Traffic Policy and Planning [18] and the Department of Land Transport [19] the crashes investigated include roadside crashes. The crashes reported in this paper were extracted from these reports plus the recent 16 cases which have been investigated by the authors. The investigated roadside crashes involve passenger vehicles, including cars, vans, pickups, and buses. The highway sections where these crashes occurred are: highway no.4, highway no.41, highway no.42, highway no.43, highway no.401, highway no.414, highway no.4028 and highway no. 4029 (see Fig. 2). A total of 21 crashes were investigated for highway sections in Chumphon, Surattani, Songkhla, Phuket and Narathiwat provinces as shown in Fig. 2.

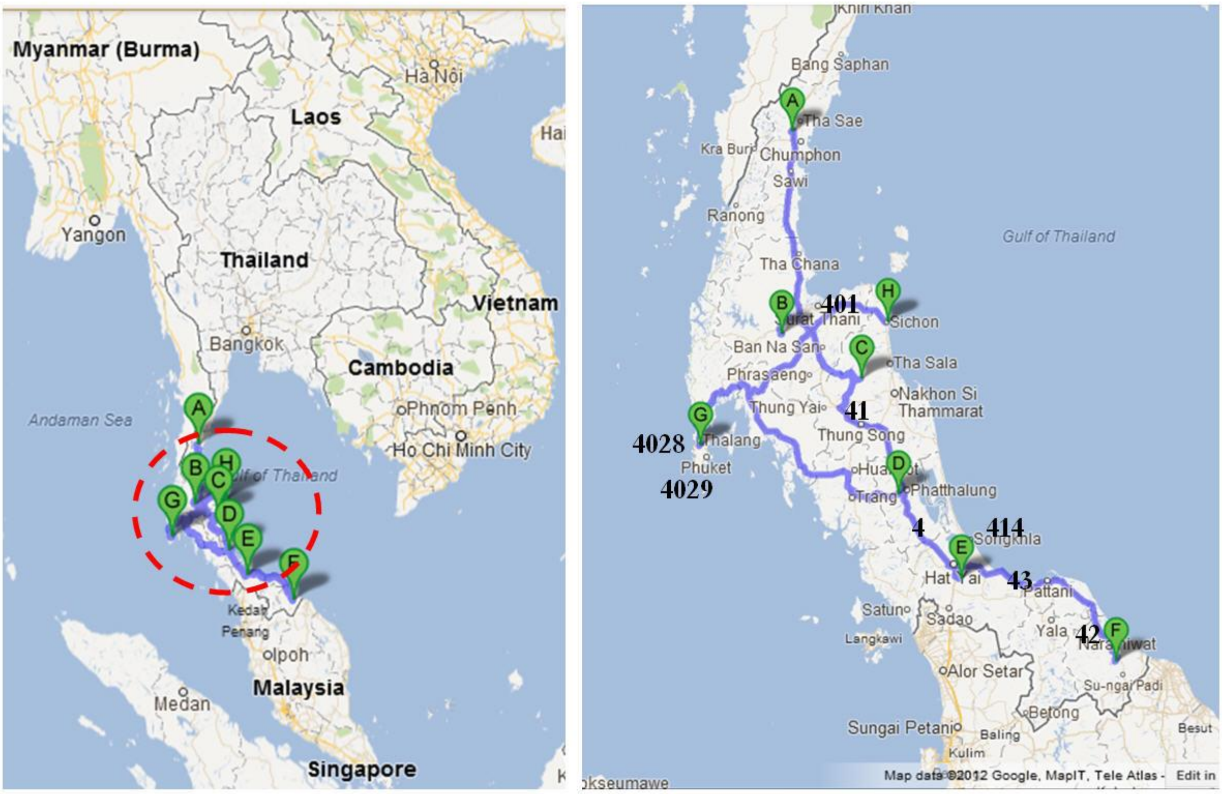

Fig. 2. Location of the roadside crashes on 8 national highway sections.

Summary of findings of the investigated roadside crashes are given in Tables 2 and 3. It is seen that out of the total 21 cases, 18 involve fatalities, while 3 involve serious injuries. The consequences of these crashes result in 63 fatalities, 85 serious injuries, and 142 slight injuries. The causes of these crashes are presented in Table 3. They are categorized into three main contributing factors, i.e. human errors, vehicle defects, and road and environment defects.

In general roadside crashes constitute a high proportion of all crashes on DOH highways, amount to more than 40%, as shown in Fig.1 and Table 1. However, for some highway sections, they can form a majority of all crashes on these highway sections. For example, on Highway no. 414, they make up 92% of the total crashes in 2011, and 100% in 2012 (up to September); for Highway no. 4, the percentage of road side crashes are 56 for 2011, and 100% in 2012 (up to September); and for Highway no.43, roadside crashes make up 83% of the total crashes in 2011.

4.1. Detailed Crash Analysis

Table 4 presents detailed analysis of roadside crashes and casualties. A total of 21 cases were investigated over the four-year period of crash investigation and reconstruction research. These cases include 63 fatalities, 85 serious injuries and 142 slight injuries. They cover the area of five main provinces in southern Thailand namely, Chumphon, Phuket, Songkhla, Surattani, and Narathiwas province. A total of 291 people and 21 vehicles were involved in the crashes. Of the total 21 vehicles, there are 6 passenger cars (29%), 6 buses (29%) 6 vans (29%) and 3 pickups (13%). In addition, it was found that the 6 van crashes caused the largest number of casualties and with the highest severities. In these crashes, 19 passengers were killed while 35 passengers and 13 passengers were seriously and slightly injured respectively. Moreover, a leading percentage of roadside crashes were caused by speeding, 13 out 21 crashes or 61.9% as show in the Table. As regards the type of roadside hazards hit by errant vehicles, it was found that tree is the most common, making up 62 % of the hazards.

Table 2. Summary of 21 roadside crash investigations on 8 southern highway sections.

No	Date/ Time of Crash	Location	Vehicles	Number of Victims		
				Fatalities	Serious Injuries	Slight Injuries
1	26 August 2008 1130 hr.	Highways no.42 Yi-ngo, Narathiwat	Van	5	5	-
2	31 August 2008 0820 hr.	Highways no.4 Bangklam, Songkhla	Van	1	5	5
3	28 September 2008 0450 hr.	Highways no.414 Hatyai, Songkhla	Car	1	-	-
4	8 October 2008 2210 hr.	Highways no.414 Hatyai, Songkhla	Car	1	2	-
5	11 January 2009 1630 hr.	Highways no.42 Yi-ngo,Narathiwat	Pickup	10	4	7
6	2 April 2010 1500 hr.	Highways no.43 Hatyai, Songkhla	Pickup	5	4	-
7	29 February 2011 1030 hr.	Highways no.414 Hatyai, Songkhla	Car	3	3	-
8	8 March 2011 0840 hr.	Highways no.4029 Kathu, Phuket	Bus	1	7	39
9	21 March 2011 1330 hr.	Highways no.4 Bangklam, Songkhla	Bus	-	2	20
10	15 July 2011 1845 hr.	Highways no.4 Ruttaphum, Songkhla	Bus	1	7	12
11	17 September 2011 0130 hr.	Highways no.414 Hatyai, Songkhla	Car	1	-	-
12	25 September 2011 1600 hr.	Highways no.4 Ruttaphum, Songkhla	Car	1	1	-
13	22 October 2011 0800 hr.	Highways no.4028 Chalong, Phuket	Bus	1	9	19
14	26 October 2011 1000 hr.	Highways no.4029 Kathu, Phuket	Bus	-	4	18
15	4 November 2011 1150 hr.	Highways no.43 Na- Mom, Songkhla	Van	1	2	1
16	6 November 2011 1550 hr.	Highways no.43 Hatyai, Songkhla	Pickup	3	2	2
17	23 January 2012 0900 hr.	Highways no.4 Lamae, Chumphon	Van	-	5	7
18	22 February 2012 0320 hr.	Highways no.414 Hatyai, Songkhla	Personal Car	6	-	-
19	29 June 2012 0640 hr.	Highways no.42 Yi-ngo, Narathiwat	Van	4	11	-
20	1July 2012 0515 hr.	Highways no.4 Lang-Suan,Chumphon	Van	8	7	-
21	3 June 2012 0520 hr.	Highways no.401 Kanchanadit,Surattani	Bus	10	5	12
				63	85	142

Source: Crash investigations by authors.

Table 3. Cause of crashes.

No.	Date of crash	Location	Causes				Age of driver
			Human errors	Vehicle defects	Road& environment defects	Roadside hazards	
1	26 Aug 2008	Highways no.42	Speeding	-	-	Tree	41
2	31 Aug 2008	Highways no.4	Drowsy	-	-	Tree	33
3	28 Sept 2008	Highways no.414	Drowsy	-	-	Tree	41
4	8 Oct 2008	Highways no.414	Speeding	Blown tire	-	Guardrail/ Tree	25
5	11 Jan 2009	Highways no.42	Speeding	-	-	Tree	33
6	2 Apr 2010	Highways no.43	-	-	Slippery surface	Tree	50
7	29 Feb 2011	Highways no.414	Speeding	-	-	Tree	21
8	8 Mar 2011	Highways no.4029	-	Brake failure	-	Guardrail	na
9	21 Mar 2011	Highways no.4	Drowsy	-	-	Tree	27
10	15 Jul 2011	Highways no.4	Unsafe driving maneuver	-	Slippery surface	Electric Pole/Curb /Tree/ Side slope	52
11	17 Sept 2011	Highways no.414	Speeding	-	-	Tree	31
12	25 Sept 2011	Highways no.4	Drowsy	-	-	Tree	26
13	22 Oct 2011	Highways no.4028	-	Brake failure	-	Guardrail /Tree	34
14	26 Oct 2011	Highways no.4029	-	Brake failure	-	Guardrail	na
15	4 Nov 2011	Highways no.42	Drowsy	-	-	Tree	33
16	6 Nov 2011	Highways no.43	Speeding	-	Slippery surface	Tree	22
17	23 Jan 2012	Highways no.4	Drowsy	-	-	Tree	24
18	22 Feb 2012	Highways no.414	Speeding	-	-	Tree	26
19	29 Jun 2012	Highways no.42	Drowsy	-	-	Tree	25
20	1 Jul 2012	Highways no.4	Drowsy	-	-	Tree	19
21	3 Jun 2012	Highways no.401	Speeding	-	-	Electric pole/Curb	58

Table 4. Detailed analysis of 21 roadside crashes and casualties.

Item	Number	Percentage	Item	Number	Percentage
Type of involved vehicle			*Hourly distribution*		
Passenger car	6	29	24.01-06.00	5	24
Van	6	29	06.01-12.00	8	38
Bus	6	29	12.01-18.00	6	29
Pick up	3	13	18.01-24.00	2	10
Causes			*Weekly distribution*		
Speeding	13	62	Sunday	3	14
Sleepy/Fatigue	5	22	Monday	2	10
Vehicle defects	3	13	Tuesday	6	29
Inclement weather	2	9	Wednesday	2	10
			Thursday	2	10
			Friday	2	10
			Saturday	4	19
Roadside objects hit			*Monthly Distribution*		
Tree	18	62	1-3	6	29
Guardrail	4	15	4-6	3	14
Electric pole	3	10	7-9	8	38
Curb	2	7	10-12	4	19
Traffic sign	1	3			
Guide post & KM post	1	3			
Crash location	15	71	*Weather condition*	14	67
Straight sections	6	29	Clear	3	14
Curve sections			Rain	4	19
			Cloudy		

4.2. Detailed Injury Analysis

The severity of injury resulting from of roadside crashes is often high because the hit object is mostly fixed and robust, especially large trees and utility poles. Moreover, these hazardous objects are often located close to the roadway and well within the clear zone. Table 5 presents the number of casualties resulting from these crashes categorized by level of severity, together with the estimated crash cost and cause of the crashes. From the table, it can be estimated that on average one roadside crash results in 3 fatalities, 4 serious injuries and 6.8 slight injuries, and costing 18.1 million baht.

Table 5. Type of roadside hazards hit by errant vehicles.

Roadside Hazard	No. of Roadside Hazards	Fatalities	Serious Injuries	Slight Injuries	Crash Cost (million baht)*	Cause of Crashes
Trees only	15	48	51	42	290,795,000	Speeding& Drowsy driving
Trees &Guardrail	2	2	11	19	13,926,500	Brake failure
Guardrail	2	2	11	57	9,613,500	Brake failure
Tree/Electric Pole/Curb & Side Slope	2	11	12	12	65,464,000	Speeding& inclement weather
Total	21	63	85	142	399,799,000	(US $ 12,251580)

*Note: * 5,738,000 baht per fatality, 158,000 baht per serious injury, and 37,500 baht per slight injury; modified from Bureau of Highway Safety, DOH. 2011; 1US$=31 Thai Baht.*

5. More Actions Needed To Improve Roadside Safety

It is clear from the analysis of DOH data and the in-depth investigations that the roadside crash situation is very serious as it constitutes an average of 42 % of all DOH crashes over the past 12 years, this average percentage rises to 44, when considered only figures for the past 4 years. This is despite the fact that DOH has put in place the Department of Highways Roadside Safety Strategic Plan 2009-2013 since 2009. To improve roadside safety situation in Thailand, and hence reduce the number of unnecessary road deaths which are the results of avoidable roadside hazards, the authors propose that more actions by DOH are urgently needed; this is in line with the UN's call for A Decade of Action for Road Safety 2011-2020. Even though reducing roadside hazard is a key action needed to reduce roadside casualties, there are other preventive strategies that require further actions by DOH as outlined in the DOH Roadside Safety Strategic Plan which the second author has contributed to its development.

5.1. Department of Highways Roadside Safety Strategic Plan 2009-2013

To improve roadside safety situation on national highways, the DOH needs to implement further actions in its Roadside Safety Strategic Plan 2009-2013. So far it has taken actions on strategy number 4 by putting guard rails and getting rid of some trees. Fig. 3 shows guard rails installed at curve section and Figs. 4 and 5 show the elimination of existing trees in the median when a 3 km. section of a highway in Songkhla was reconstructed. However, all strategies and actions in the plan need to be implemented. The plan consists of five strategies as follows:

Strategy 1: Increase the awareness for roadside safety;
Strategy 2: Increase knowledge on the cause, location, mechanism, costs and effective treatments of roadside crashes;
Strategy 3: Prevent vehicles from running off the highway;
Strategy 4: Protect errant vehicles from hitting roadside objects or rolling over;
Strategy 5: Reduce the severity of crash impact for the occupants of errant vehicles [20].

Fig. 3. Guard rails were installed to protect errant vehicles from impacting trees.

Fig. 4. Roadside crash in the median where trees were hit and safety improvement made during reconstruction and existing trees in the median removed.

Fig. 5. Improvement in roadside safety after treatment of median by removal of trees.

6. Conclusions

This practical paper addresses the roadside safety challenge in Thailand. It is clear from the analysis of DOH data and the in-depth investigations that the roadside crash situation is very serious as it constitutes an average of 42 % of all DOH crashes over the past 12 years, this average percentage rises to 44, when considered only the figures for the past 4 years. The number of fatalities from these crashes amount to some 500 annually; these occur despite the fact that DOH has in place the Department of Highways Roadside Safety Strategic Plan 2009-2013 since 2009. The in-depth investigations of 21 roadside crashes show that the main human errors causing a crash is speeding accounting for about 62 % of the crashes, followed by driving while drowsy 22%. The investigations also show that roadside trees, planted well within the clear zone are the object most impacted by errant drivers, accounting for 72 % of the total, and resulting in 48 deaths.

To improve roadside safety situation in Thailand, and hence reduce the number of unnecessary road deaths which are the results of avoidable roadside hazards; the authors has proposed that more actions by DOH are urgently needed; this is in line with the UN's call for A Decade of Action for Road Safety 2011-2020. Even though reducing roadside hazard is a key action needed to reduce roadside casualties, there are other strategies that require more actions as outlined in the DOH Roadside Safety Strategic Plan. The strategies for prevention of roadside crashes are no less important and need to be concurrently implemented. They include: increase the awareness for roadside safety; increase knowledge on the cause, location, mechanism, costs and effective treatments of roadside crashes; and prevent vehicles from running off the highway.

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