

The Application of Road Safety Audit on Motorways Thailand

Sakchai Rakkarn

Graduate School, Kasem Bundit University, Bangkok, Thailand

E-mail: sakchai.rak@kbu.ac.th

Tassana Boonyoo

Traffic and Transport Development and Research Center (TDRC),
King Mongkut's University of Technology Thonburi, Bangkok, Thailand

Email: tassana.booyoo@kmutt.ac.th

Bhawat Chaichannawatik

Department of Civil Engineering, Faculty of Engineering, Kasem Bundit University, Bangkok, Thailand

Email: bhawat.cha@kbu.ac.th

Chalat Tipakornkiat

Department of Civil Engineering, Faculty of Engineering, Rachamankala University of Technology Srivijaya,
Songkhla.

Email: chalat.t@rmutsv.ac.th

Pramuk Prabjabok

Autrans, Co.,Ltd. , Bangkok, Thailand

Email: pramuk.sut@gmail.com

Abstract— Road Safety Audit (RSA) is the formal process of assessment for a safer road by an independent, multidisciplinary experts. This article shows an application of RSA on Inter City Motorway Route No. 7 (Bangkok - Chonburi) and No. 9 (Outer Bangkok Ring Road from Bang Pa In to Bang Plee). Safety problems were found and grouped on 9 main topics. They were 1) Alignment and Cross-Section, 2) Drainage, 3) Signs, 4) Markings and delineation, 5) Roadside Hazards, 6) Pavement, 7) Lighting, 8) Auxiliary lanes and 9) Others. According to the problems, the Inter City Motorway Divisions, Department of Highways had pay attention and adopted the corrections to obtain a safer driving for motorway users.

Index Terms— road safety audit, inter city motorway, safer road, accident prevention

I. BACKGROUND

Thailand is ranked as the 2nd of road safety loss due to the road accidents as 24,237 fatalities in 2012 or 36.2 deaths/hundred-thousand population [1]. Even Thailand still doesn't have the regular inspections of existing road infrastructure but the Inter City Motorway Divisions, Department of Highways (DOH) has placed intention on road safety by setting up the RSA project on Inter City Motorway Route No. 7 (Bangkok – Chonburi) and No.9

(Outer Bangkok Ring Road from Bang Pa In to Bang Plee).

Austroroads define Road Safety Audit (RSA) as “A formal examination of a future road or traffic project or an existing road, in which an independent, qualified team reports on the project's crash potential and safety performance.” [2]. The proactive approach by Road Safety Audit is not only a check on compliance with (minimum) standards but aims to meet the “Safe Systems” for all road users.

According to the Office of the Commission for the Management of Land Traffic (OCMLT) report, The causes of the accident in Thailand come from three factors and can be simply represented in Venn diagram as shown in Fig. 1. [3]. Road Safety Audit can improve road safety by cut the chain of accident on the road and environmental factor. These can reduce the accident about 22 percent.

The RSA is widely accepted that can reduce the risk of road accident with very little cost [4] and benefit-cost ratio of 14-20 [5]. According to literature of RSA on motorway freeway or expressway, There are a lot of applications of RSA on these type of highway such as Vardaki, S. et, al. applied RSA and implemented some mitigations for road safety on Attica freeway [6] and H. B. Wu showed the current practice of RSA on

expressways and performed RSA on expressways in China [7].

This study is another adaptation of RSA by auditing on both motorway routes in Thailand in order to examine and dissipate the problems on road factor for ensuring safer road for motorway users.

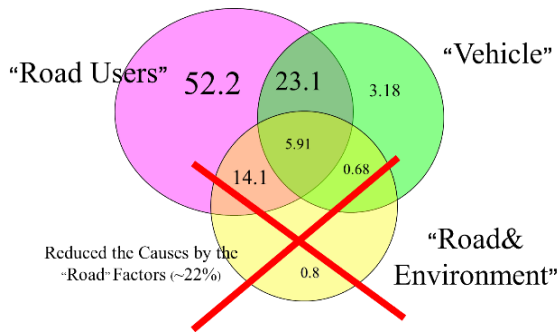


Figure 1. Cause of accidents in Thailand [3]

II. GENERAL INFORMATION OF STUDY AREA

A. General Data

Generally, motorway was built on a high standard with fully control access that the road users can travel up to speed limit of 120 kilometers per hour. The total traffic passing the tolled plaza on Inter City Motorways Route No. 7 and No.9 are 106,460,923 and 97,716,133 vehicles in 2016 [8].

Road safety audit (RSA) is conducted on two routes as follow:

1. Motorway Route No. 7 (Bangkok-Chonburi) is the eight-lane with shoulder starting from Srinakharin interchange (Sta. 0+000) to Bang Pra interchange (Sta. 78+850) and a porting of connecting spur from Bang Kwai Interchange to Bang Bo interchange for a distance of 4 km, which is total 165.750 km for both directions. However, the auditing distance on Motorway Route No. 7 in this project is 70.00 km from Sta. 0+000 to 70+000.

2. Motorway Route No. 9 (Bang Pa In – Bang Plee) is the eight lane with shoulder starting from Bang Pa In interchange (Sta. 0+000) to Wat Salut Interchange (Sta. 65+325) with total distance on both directions of 130.650 km. the auditing distance on Motorway Route No. 9 in this project is 65+325 km from Sta. 0+000 to 65+325.

B. Severity of Accident on Motorways

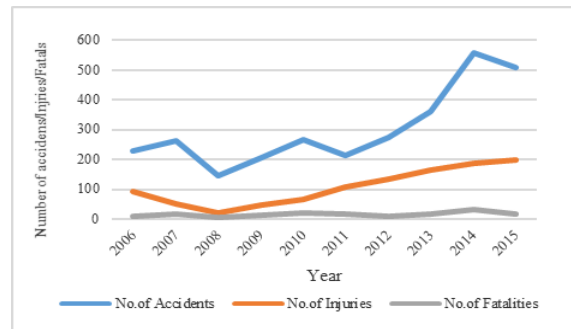
According to the report of Bureau of Highway Safety, Department of Highways, Thailand, the number of the road accident, injuries and fatalities on motorways are tended to increase during 2006 to 2015 as shown in Table I and Fig. 1 [9].

Moreover, the report also shows that motorways have very high rate of accident and severity compared to the other roads. The rate of accident, injuries and fatalities per 100 kilometer and per 100 Million vehicle-kilometers on motorways in 2015 are shown in Table II.

TABLE I. TRAFFIC ACCIDENTS ON MOTORWAYS IN 2006 - 2015

Year	No.of Accidents	No.of Injuries	No.of Fatalities
2006	229	94	10
2007	262	50	18
2008	147	22	6
2009	207	49	15
2010	267	66	21
2011	212	108	17
2012	273	133	11
2013	363	163	19
2014	556	186	34
2015	510	198	18

Source: Adapt from Bureau of Highway Safety, 2015 [9]



Source: Adapt from Bureau of Highway Safety, 2015 [9]

Figure 2. Trend of accidents on motorways, Thailand

TABLE II. NUMBER AND RATE OF ACCIDENTS ON MOTORWAYS IN 2015

Issue	Accidents	Injuries	Fatalities
Number	510	198	18
Rate per 100 kilometer	245.76	95.41	8.67
Rate per 100 M.Vehicle-km.	6.84	2.65	0.24

Source: Adapt from Bureau of Highway Safety, 2015 [9]

C. Causes of Accident on Motorways

Normally, all accidents on Motorways are recorded by the Inter City Motorway Divisions. Many studies of accidents on Motorways during 2004-2015 has shown that four of the fifth of accidents occurring on motorways (80-90%) was single vehicle accident and the causes were drowsiness and speeding [10, 11].

III. METHODOLOGY

A. Road Safety Audit Timing

Road Safety Audit on motorway route No.7 and No.9 had been conducted during December 22nd to 27th 2016 both daytime and nighttime.

B. Road Safety Audit Process

In order to understand more on motorway route No.7 and No.9 environment and general/physical characteristics, the selected audit team did the survey that conducted to collect all factors contributing to accident as is in operating condition both daytime and nighttime by auditing all factors involved with road safety, then dividing into many categories compliance with Thailand Road Safety Audit Guideline [12, 13]. On this audit stage, it was applied on the existing road.

1) Commencement meeting and assessing related documents

Before the site inspection, the RSA team and the Inter City Motorway Divisions have participated in a commencement meeting on Friday 25th, November, 2016 in order to acknowledge the general conditions and current situation in the project area, receive documents related to the project, contains historical accident statistics and discuss the schedule of the inspection.

2) Site inspection

Moreover, a survey was carried out by several techniques in order to be able to identify potential leading to the accident as follow;

a. Photograph and Video recording

Both photograph and video record along the routes especially where safety problems are issues. They were taken at driver eyes level (approximately 1 m. from roadway surface) at the location in both directions. All problems that might contribute to accidents were collected and can be reexamined after site inspection.

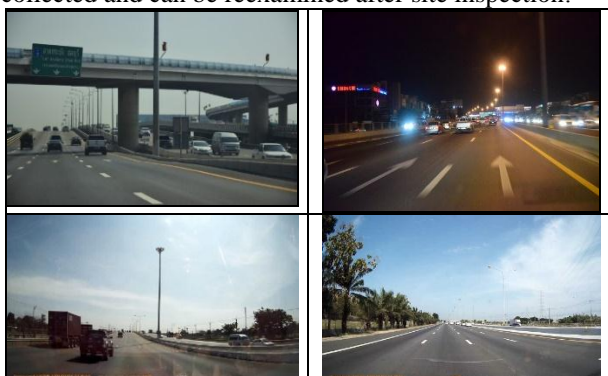


Figure 3. Examples of pictures and video taken from official cars

b. Drive through study scene

Driving through auditing routes by using a passenger car for test drive were carried out. Passenger car was selected due to its high proportion in traffic flow. By driving through the scene, an auditor was able to see deficiencies or obstruction in the same view as a road user and understand a road user decision and perception. Information gained from driving through was important as other traffic engineering information as well.

c. Behavioral study of road user at study location

Road users' behavioral study was conducted along study route via driving behavior and road surface usage observation. Collected information related to road users' erroneous give better understand road users' behavior on law disobedience, speeding, illegal parking of trucks etc.

d. Interview and Information Collection

Information by personnel interviewing highway police and rescue regarding the black spot and hazardous location was also collected

3) Road safety checklist for existing roads

According to Thailand Road Safety Audit Manual [12], Road Safety Audits Checklist for the existing roads is used to monitor road safety issues of both motorways.

4) Level of risk and treatment of each problem

The risk level of each problem was determined by the "Frequency" by considering likely to lead the crash and

"Severity" by considering the severity of the resulting accident. Then the treatment approach will be suggested. The level of risk and suggested treatment approach are shown in Table III and IV. [2, 12, 13]

TABLE III. RISK RANKING BY SEVERITY AND FREQUENCY CROSTAB [2]

Severity and Frequency	Frequent	Probable	Occasional	Improbable
Catastrophic	Intolerable	Intolerable	Intolerable	High
Serious	Intolerable	Intolerable	High	Medium
Minor	Intolerable	High	Medium	Low
Limited	High	Medium	Low	Low

TABLE IV. SUGGESTION OF TREATMENT APPROACH [2]

Risk	Suggested treatment approach
Intolerable	Must be corrected and dissipated
High	Should be corrected or the risk significantly reduced, even if the treatment cost is high.
Medium	Should be corrected or the risk significantly reduced, if the treatment cost is moderate, but not high.
Low	Should be corrected or the risk reduced, if the treatment cost is low.

IV. OVERVIEW OF ROAD SAFETY AUDIT FINDING

Results from Road Safety Audit along motorway route No.7 and No.9 were examined and reported together with the recommendations. The examples of problems are shown in Fig. 4 to Fig. 13. Moreover, all issues were concluded to 9 main topics with the risk ranking as summarized in Table V.



Figure 4. Problems on alignment, roadside hazards, markings and pavement



Figure 5. Problems on roadside hazards: height of concrete barrier



Figure 6. Problems on crash barrier: end treatments and connection



Figure 10. Problems on roadside hazards: crash barrier

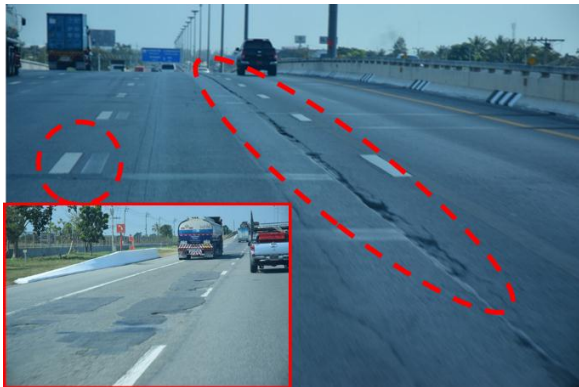


Figure 7. Problems on pavement and marking.



Figure 11. Problems on lighting.



Figure 8. Other problems: roadside activities and hazard.



Figure 12. Other problems: glared.



Figure 9. Other problems: roadside activities and hazard.



Figure 13. Other problems: parking

TABLE V. ROAD SAFETY AUDIT FINDING AND RECOMMENDATION

Topic	Safety issues	Recommendation	Ranking
1. Alignment and Cross-Section	- Vertical curve sight distance	- Reduce speed limit from 120 kph to 90 or 100 kph before the bridges.	High
	- Steep side slope	- Flatten the embankment - Shield it by install crash barrier and should be added Shoulder Rumble Strip to alert the drivers.	
2. Drainage	- General problems	- Install warning sign with the recommend speed during raining.	High
3. Signs	- General problems - Hidden Sign - Sign legibility	- Routine maintenance, repair, reinstalled and remove if not in use - Remove and reinstall traffic to suitable location	Low
4. Markings and delineation	- General issues - Centerlines, edge lines, lane lines - Guideposts and reflectors - Delineation	- Routine maintenance, repair, reinstalled and remove if not in use - Remove unwanted and reinstall new traffic line - Install additional Guideposts, reflectors and delineators	Low, Medium
5. Roadside Hazards	- Clear zone	- Remove roadside fix objects (Tree/light post, electric post/ kilometer post/ control box) out of clear zone - Change/select smaller type of tree - Use slip base type electric post to lessen severity of accident	Intolerable
	- Crash barriers	- Raise the height of concrete barrier at least minimum standard. - Improve end treatments and connection of guardrails to bridge rail and concrete barrier. - Repair and maintenance of damaged crash barriers - Install additional guard rail for the bridge approach	
6. Pavement	- Pavement condition	- Repair the damaged road surface to safer condition	Medium, High
7. Lighting	- General problems	- Routine maintenance of lighting	Medium
8. Auxiliary lanes	- General problems - Sight distance	- Inform the driver of the exit at proper distance - Install recommend speed sign or marking	High, Intolerable
9. Others	- Glare - Roadside activities-work zone - Illegal truck parking	- Install of anti-glare screen - Install additional traffic control device at work zone complying with safety standard - Speed control at work zone - Enforce on street parking prohibition on motorways	High, Intolerable

V. RSA RESPONSE AND IMPLEMENTATION

The detail of each finding from RSA and recommendation were reported and presented to Inter City Motorway Divisions. After the discussion meeting, all problems and recommendations were totally accepted. Moreover, the very quick respond on the low cost and easy improvement were done immediately by the Intercity Motorway Maintenance Districts. The safety responded implementations are summarized as follows,

- Remove confused traffic line and reinstall new traffic line.
- Repair the damaged road surface to suitable condition
- Install additional safety devices and repair the damages such as crash cushions, guardrails, reflectors, delineators, and anti-glare screen etc.
- Maintenance and repair road lighting.
- The height of median barriers were raised along both routes.

The examples of improvements are shown in Fig.14 to Fig. 15.



Figure 14. The replacement of damaged devices



Figure 15. Raising of concrete barrier height

VI. CONCLUSION

In order to enhance the safer motorways, this paper shows the application of Road Safety Audit (RSA) on the Motorway route No.7 and No.9, Thailand in late-2016. The results found that the roadway problems on both routes can be concluded into 9 main safety topics consisted of 1) Alignment and Cross-Section, 2) Drainage, 3) Signs, 4) Markings and delineation, 5) Roadside Hazards, 6) Pavement, 7) Lighting, 8) Auxiliary lanes and 9) Others.

In the meeting, the Inter City Motorway Divisions, responsible agency, acknowledged the problems and recommendations and decided to implement several countermeasures to reduce the potential of the road accident. The high and intolerable risk problems were shortly implementation after the RSA was finished such as raising the height of median barriers along routes, pavement treatment. While some recommendations are the general periodic maintenance such as traffic control and safety devices reparations.

ACKNOWLEDGMENT

Researchers express sincere thanks to the Inter City Motorway Divisions, Department of Highways, Thailand for the safer road funding support for this study.

REFERENCES

- [1] World Health Organization, "Global status report on road safety 2015," World Health Organization, Geneva, 2015.
- [2] Austroads, "Road Safety Audit," Pirie Printers Pty Limited, Canberra, 2002.
- [3] Office of the Commission for the Management of Land Traffic, "Final report on a project of study and analysis of traffic accidents causes in Thailand," Prime Minister's Office, Bangkok, 2002.
- [4] Federal Highway Administration, "FHWA road safety audits guidelines," U.S. Department of Transportation, 2006.
- [5] European Transport Safety Council, "Road safety audit," ETSC Fact Sheet, pp. 1-2, 05 July 2005.
- [6] S. Vardaki, F. Papadimitriou, and P. Kopelias, "Road safety audit on a major freeway: Implementing safety improvement," *European Transport Research Review*, vol. 6, no. 4, pp. 387-395, 2014.

- [7] H. B. Wu, "The application of road safety audit to expressway in China," *Applied Mechanics and Materials*, vol. 253-255, pp. 1586-1592, 2013.
- [8] Inter City Motorway Divisions, "Traffic Volume on Iner City Motorways Route No.7 and No.9," 23 11 2018. [Online]. Available: <http://www.motorway.go.th/2016/1072>.
- [9] Bureau of Highway Safety, "Traffic accident on national highways in 2015," Department of Highways, Bangkok, 2015.
- [10] B. Chaichannawatik, S. Leerakomsan, and S. Sattayamully, "The application of road safety audit on motorways during construction," in *Proc. International Scientific Meeting in EU-Asia Network in Competence of Road Safety, Weimar, Germany..*, 2008.
- [11] B. Chaichannawatik and T. Boonyoo, "the development of accident information system to enhance the management of rescue system on motorway No.7 and 9," in *Proc. the 20th National Conference on Civil Engineering, Pattaya, Thailand..*, 2015.
- [12] Ministry of transportation, "Thailand Road Safety Audit Manual," Bangkok, Thailand, 2003.
- [13] Bureau of Highway Safety, "Surveillance and troubleshooting of accidents on highways: Road safety audit," Department of Highways, Bangkok, 2006.



Sakchai Rakkarn is Director of Engineering Management program, Graduate School, Kasem Bundit University, Bangkok, Thailand. His research Interests are optimization, management, technology, safety systems and innovation. He has graduated in Ph.D. Systems and Control Engineering at Case Western Reserve University, U.S.A. since 2008.

Dr.Sakchai Rakkarn is registered professional engineering of Thailand (Industrial Engineering). He is also a member of the Engineering Institute of Thailand Under H.M.King's Patronage (Thailand).



Tassana Boonyoo is a researcher, at Traffic and Transport Development and Research Center (TDRC) at King Mongkut's University of Technology Thonburi (KMUTT), Bangkok, Thailand. He graduated in Master of Engineering (Transportation Engineering), from King Mongkut's University of Technology Thonburi, Thailand in 2005. His responsible are management & administration of several R&D and academic service projects

of TDRC, KMUTT since 2005. His research interest fields are the research of Traffic and transportation planning, Traffic management, Road safety, etc.

Mr. Tassana Boonyoo is registered professional engineering of Thailand (Civil Engineering). He is also a member of the Engineering Institute of Thailand Under H.M.King's Patronage (Thailand) in The Civil Engineering Fellow.



Bhawat Chaichannawatik is the Associate Dean for Research Affairs, Faculty of Engineering, and Director of Transportation Sustainability and Innovation of Technology Research Center (TranSIT) at Kasem Bundit University (KBU), Thailand. He graduated in Master of Engineering (Transportation Engineering) from King Mongkut's University of Technology Thonburi (KMUTT), Thailand

in 2004.

He works as Assistant Professor Lecturer at Civil Engineering Department responsible for highway engineering and transportation engineering subject for 12 years. His major responsibilities are management & administration of several R&D and academic service projects of TranSIT, KBU. His research interest fields are the research of Traffic and transportation Engineering, traffic planning and management, road safety, etc.

Asst.Prof.Bhawat Chaichannawatik is registered professional engineering of Thailand (Civil Engineering). He awarded the 2003 outstanding research award in traffic engineering on "Guideline for Road Accident Prevention during Festivals" of the Council of Engineering (COE), The 2nd runner up award for the best research in traffic engineering on "The Analysis of Factors Related to Road Crash Severity Level" of COE, Thailand in 2003, and the 2nd runner up award for the best paper on "Guideline for Road Safety Management on Intercity Motorway", National Road Safety Directing Center (RSDC), Thailand in 2007, etc.



Chalot Tipakornkiat was born in Narathiwat province, Thailand on 14 May 1980. He has graduated in bachelor degree of civil engineering from Prince of Songkla University Thailand in 2003 and master degree of civil engineering from Prince of Songkla University Thailand in 2005. He has graduated in the Work Zone management and safety, etc.

Mr.Pramuk prabjabok is registered professional engineering of Thailand (Civil Engineering), a member of the Engineering Institute of Thailand Under H.M.King's Patronage (Thailand) in The Civil Engineering Fellow, and a member of the Thairoads Foundation.

doctoral degree of transportation engineering from Asian Institute of Technology, Bangkok Thailand in 2013.

He is a lecturer in Faculty of Civil Engineering at the Rajamagala University of Technology Srivijaya in Thailand. He had experienced in civil and transportation for 13 years. He published papers at the international conference such as EASTS conference and APTE etc. Currently, he researches in the field of road safety design, road safety facilities, highway material, traffic and transportation planning and the use of waste material for the street.

Dr.Chalot Tipakornkiat is a member of the council of engineers. He received the first runner of 12th Thailand Road safety Seminar. He is a committee of the Thai Society for Transportation and Traffic Studies; a manager of an inspection body of Thai truck center; an expert and eminent of traffic, road safety and urban planning of Songkhla province government.



Pramuk Prabjabok is the Senior Traffic Engineering at Autrans Co.,Ltd. He graduated in Master of Engineering (Transportation Engineering) from Suranaree University of Technology (SUT) Thailand in 2011. His responsible are technical service in the area of traffic and transportation engineering & management, Transportation Planning, Road Safety,