TSTS

THAI SOCIETY FOR TRANSPORTATION AND TRAFFIC STUDIES

TRANSPORTATION FOR NATION-BUILDING

The 4th International Conference of TSTS

Chaopraya Park Hotel, Bangkok

April 2nd, 2015

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FOREWORD

Thai Society for Transportation and Traffic Studies (TSTS) was established in 1996 with the primary objectives of fostering and supporting excellence in transportation research and practice, and facilitating professional exchange in all aspects and modes of transportation. TSTS has worked in close cooperation with Eastern Asia Society for Transportation Studies (EASTS) and 17 other transportation societies in Eastern Asia and Australia to promote transport research and best practice in Thailand and Asia.

Following the success of the 3rd International Conference of the Thai Society for Traffic and Transportation Studies held in Songkhla in 2012, the society is pleased to announce "The 4th International Conference of Thai Society for Transportation and Traffic Studies". The theme of next year conference will be Transport for Nation-building. Thailand delayed the investment in Mega projects for Transport infrastructure more than five years. This fiscal year, the cabinet approval 2.4 trillion baht to alert the nation economic focus to transportation and logistics. The rail sector needs to catch up to connect the whole nation, and to connect with our ASEAN neighbors. Better connectivity among all ASEAN nations will enhance nation-building of all members. Myanmar is now embarking on her "nation-building" in a big way, and transport will play a key role, (note the development of Dawei port), and Vietnam is looking at her HSR to link the north and the south. For us, as Thailand is not Bangkok, so there is a need to systematically develop urban transport in regional cities so as to enhance their role as regional growth centers, this will help stem the flow of the rural poor to Bangkok, the capital city which is already over congested.

Thailand is trying to balance the distribution of budget between Bangkok and regional cities. The rail projects such as double track with high speed train is one of the dominant projects to promote not only better transport quality but also land development with the aim of increasing economic development and reducing regional income disparity.

PREFACE

Dear Delegates,

Welcome to the 4th TSTS International conference!

The Conference offers great opportunities for researchers, academics, policy makers and practitioners in transportation to exchange ideas and developments and to share knowledge for the common benefit of all.

The theme of this year conference is: Transport for Nation-building. We are happy to have Mr.Silpachai Jarukasemratana, the former Permanent Secretary of Ministry of Transport to give the keynote lecture on "Rail Development Impacts on Nation-Building", together with many distinguished speakers. The event promises to offer the best opportunity to interact and get intellectually stimulated on rail development impacts on nation-building.

I wish you all a Happy Conference.

Professor Pichai Taneerananon
Chair of Editorial Board

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SCHEDULE

The 4th International Conference of Thai Society for Transportation & Traffic Studies
"Transportation for Nation-Building"
April 2nd, 2015 Chaophay Park Hotel, Bamgkok

08.30 – 09.30 :	Registration
09.30 – 09.45 :	Opening and Welcome Speech Keynote Address: "Rail Development Impacts on Nation-Building" *Mr.SILPACHAI JARUKASEMRATANA,* *Former Permanent Secretary of Ministry of Transport*
09.45 – 10.30 :	Coffee Break
10.30 – 10.45 :	Panel Discussion : "Transportation Infrastructure in Thailand" *Dr. PICHET KUNADHAMRAKS,* *Office of Transport and Traffic Policy and Planning (OTP)* "Transportation Infrastructure Development in CLMV Countries" *Assoc. Prof. Dr. JITTICHAI RUDJANAKANOKNAD,* *Chulalongkorn University* "Rail Changes the City" *Assoc. Prof. Dr. VIROAT SRISURAPANON,* *King Mongkut's University of Technology Thonburi* "Could Greater Bangkok be Served Efficiently by the Newly Introduced MRT Network" *Dr. YIEMCHAI CHATKEO,* *Mass Rapid Transit Authority of Thailand (MRTA)* *"Common Ticket in Thailand"* *Dr.KERATI KIJMANAWAT,* *PSK Consultant CO., LTD.*
10.45 – 12.00 :	Lunch
12.00 – 16.00 :	Presentation of Academic and Practical Papers
16.00 – 18.00 :	Awarding Session
18.00 :	Welcome Party

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ACADEMIC PAPER

SITUATION REVIEW OF GOODS TRANSPORTATION ON LANCANG- MEKONG RIVER AFTER R3A COMPLETION

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ABSTRACT:

This paper reviews the situation of the use of Mekong-Lancang River for transports of goods after the R3A corridor, the main competing route, was completed since December 2013. Mekong is a trans-boundary river in Southeast Asia between Thailand, Myanmar, and Laos and has been used as a shipping route between Yunnan, PRC and Thailand for decades. The completion of R3A has induced infrastructure and transportation developments concentrated on the corridor, not the river, among four countries and could potentially curb the increase of transport volumes on the river. This paper will summarize key information to review the international shipping on the Lancang-Mekong River through existing condition, related development plans and obstacles. It will be followed by the preliminary analysis of challenge and opportunity on this route. The last section will summarize all key issues pertaining the trends of transport on the river versus R3A as well as future research recommendations.

KEYWORDS: River Transportation, Mekong River, Logistics Policy, North-South Economic Corridor

1. OVERVIEW OF TRANSPORT ON MEKONG RIVER

Mekong River has been an important channel for freight and passenger transportation for six countries. This paper will focus on only the upper part of the river defined as the upstream of the Chiang Saen port in Thailand. Narrower and turbulent water stream in the upper Mekong in China along with huge annual water level fluctuations present a challenge to navigation. The seasonal variations in water level directly affect trade in this section of the river as follows.

1) During low Season (January-April), the depth of Mekong River is in the range of 1.5-2.0 meters. Only small ship with less than 80 cargo tons can pass through.

2) During high season (July-September), the depth of Mekong River is above 7.0 meters. Large ship with 120-150 cargo tons can pass through.

3) In other season (May-June & November-December), the depth of Mekong River is in the range between 2.0-4.0 meters.

Despite these water level challenge, the Mekong River is already an important link in the transit chain between Kunming and Bangkok with about 300,000 tons of goods shipped via this route each year (Mekong River Commission, 2010). The volume of this trade is expected to increase by 8–11 percent per year. Port infrastructure is being expanded to accommodate the expected growth in traffic, with several new Chiang Saen ports.

The trade along Laos and China through Mekong River is mainly timber, agricultural products and construction materials with the use of 50 and 100 DWT vessels. These are mutual trades since Laos frequently needs construction materials from China to build major infrastructures and China needs agricultural products from Laos. For Thailand, the country has imported a variety of products from China. Major import goods are vegetables, fruit (apple), agricultural products and fertilizers. Simultaneously, but in lesser scale, China imports dry fruit (longan), fish oil, rubber products and consumer goods from Thailand. All goods are disembarked at one of Chiang Saen ports. All ships carrying cargo to and from China are 300 DWT Chinese flag vessels. For China-Myanmar transport, Chinese imports to Myanmar typically are steel and textile products, while Myanmar imports are raw wood. (Mekong River Commission, 2010)

There are approximately 100-200 vessels serving the transportation of goods on Mekong River. Almost all of them were registered in China. Myanmar vessels are very few due to lack of transport operators. There are a few Thai vessels but these were registered in China for easier access to China, Myanmar, and Laos ports. Laos vessels are smaller but it has gained more popularity recently due to lower transport cost.

According to the Quadripartite Agreement on Commercial Navigation on Lancang–Mekong River among the governments of China, Laos, Burma (Myanmar) and Thailand in 2000, four countries agreed to open a commercial inland waterway in Lancang-Mekong River between Simao, China to Luangprabang, Laos with no border passing fee and agreed to open 14 ports in Upper Mekong as follows.

1) China–Simao, Jinghong, Menghan and Guanlei
2) Laos–Ban Sai, Xiengkok, Muangmom, Ban Khouane, Huayxai and Luangprabang
3. Myanmar–Wan Seng and Wan Pong
4. Thailand–Chiang Saen and Chiang Kong

About 70% of all vessels load goods from China ports and unload at one of Chiang Saen ports, and 30% of them unload at Wan Pong port in Myanmar. It was found that no ships have been able to travel downstream of Chiang Saen to Chiang Kong, Huayxai and Luangprabang due to shallow water and numerous rocks between Chiang Saen and Chiang Kong. Important ports along Mekong River are:

• Simao Port – This port was opened since April 2001 and considered to be the most upstream location along Lancang River. It can serve two 120-DWT vessels. The port capacity is about 300,000 tons per year and can be used for transport up to 100,000 passengers per year.
• Jinghong Port – This old port was opened since 1994. It can serve two 100-DWT vessels. The port capacity is around 150,000 tons per year and can be used for tourist passenger transport from Yunnan to Luangprabang.
• Guanlei Port – This port can serve two 100-DWT vessels and serve passenger cruise transport along Mekong river. In addition, it was reported in 2014 that China is building the port city near Guanlei by building container ports.
• Wan Pong Port, Myanmar – This port serves as the main connection between Myanmar and Yunnan on Mekong River. However, since it is under Shan minority group area. Pirate attacks and freight vandalism were found around port area.
• Chiang Saen Port – Now, there are two Chiang Saen ports operated by the Port Authority of Thailand. The old one, opened in 2004, was replaced by the new one due to capacity limitation and close to historical town and the port will become a gateway for tourist passengers instead. The second (new) Chiang Saen Port, opened in 2012, is located on the bank of Mekong River, Chiang Saen District, Chiang Rai Province. This port is opposite to Laos, 10- km south of the old port. Behind the port is the road linking Chiang

Figure 1: Vessels on Mekong River

Figure 2: Simao Port (Yunnanadventure, 2014)

Figure 3: Jinghong Port

Figure 4: Guanlei Port

Figure 5: Wan Pong Port (Ecns.cn, 2012)

Figure 6: Old Chiang Saen Port

Figure 7: New Chiang Saen Port (Skyscrapercity, 2012)

Figure 8: Cargo throughput at Chiang Saen and Chiang Kong Ports (PAT, 2014)

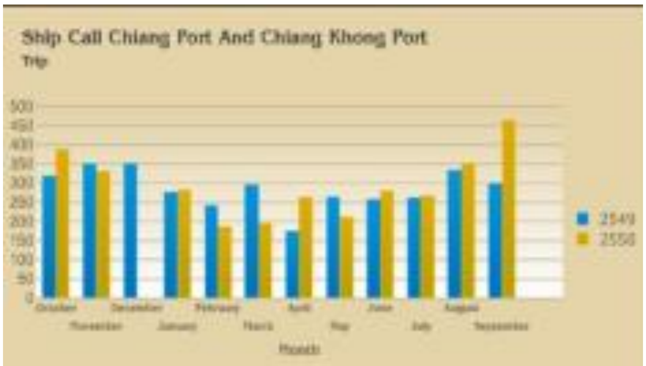

Figure 9: Ship Calls at Chiang Saen and Chiang Kong Ports (PAT, 2014)

Saen and Chiang Kong. Berth capacity can accommodate ship less than 200 Gross tonnage, 50 meters in length and 2 meters in depth. However, ship with 300 Gross tonnage can berth if the side of the berth is renovated. (Port Authority of Thailand, 2014)

2. EXISTING TRANSPORT CONDITION

2.1 Travel Time and Cost

Most of goods transportation along Mekong River are from Kunming through Guanlei port, via some Lao ports and take only two days in water. Some goods that depart from Jinghong or Simao take approximately three and four days, respectively. The distance between Chiang Saen and Chiang Khong is 70 km, and the distance between Chiang Khong and Jinghong is 380 km. and takes up to three days (or 40-50% longer time) due to travelling along reverse river stream.

The cost of transport varies depending on type of goods and season. In some season, with less transportation demand, cheaper cost can be negotiated. In addition, the labor cost of unloading and loading goods could be varied. In addition to ship operator and handling costs, shippers must pay other costs including:

- Laos pass fare- about 0.1% of goods value, or about 2,000-4,000THB per ship.
- China- import taxes are required for vegetable and fruits. Shippers of some Thai fruits like

Longan might have to pay taxes up to 30% of total value.

- Port fee- some ports, e.g., Jinghong port requires port maintenance charge up to 1-2% of goods value.

2.2 Recent Trade Values

The trade was disrupted from time to time. For example, in late 2002 to early 2003, China announced the order to stop all vessels on Mekong to maintain water draft and had more restricted policies in importing goods. In addition, in some year, the water level in Mekong was too low possible due to climate change and upstream dam construction. Some longan shippers then decided to use either highway or Laemchabang seaport to China instead. More recently in 2011, when two Chinese cargo ships were attacked on a stretch of the Mekong River in the Golden Triangle region on the borders of Burma and Thailand, China temporarily suspended all Chinese shipping on the Mekong. Nevertheless, the trade values on Mekong River have been resumed in 2013 (Prachachat, 2014). The total trade values (China-Chiang Saen) were 7,872.88 million baht, consisting of 4,788.82 million baht of exports and 3,084.16 million baht of imports. Of these values, the agricultural products were accounted for 84.68%.

According to the Office of Commerce, Chiang Rai (Prachachat, 2014), from January to June 2014, the trade value between Thailand and China through Mekong was up to 2,952,87 million Baht. The export value (Thailand to China) was 1,880.52 million Baht. Most exports were agricultural products, e.g. almond, dry macadamia walnut, fruit, rubber, rubber parts, agriculture processing products, fish, fuel, dry wood, etc. The import value (China to Thailand) was 1,072.35 million Baht. Most imports were equipment and parts, agriculture products, fresh fruits and vegetables, tea leaf, tobacco, consumer goods, metal, etc.

2.3 Challenges and Obstacles

This subsection presents main challenge and obstacles that occurs for transportation through upper Mekong River.

For physical challenges, seasonal variations in water level directly affect trade in this section of the river. Volumes of trade being shipped decrease by more than 50 per cent, primarily due to the reduced draughts available during the low water season (June–January). Figures 8 and 9 show the seasonality of trade values and number of ship calls at Chiang Saen ports in 2006 (BE2549) and 2007 (BE2550). The figures show that cargo throughput and trade value varied sharply depending on the season. The peak period is between July to December, while the low period is between March to May every year. This is due to the seasonal variations in Mekong water level.

To control the water draft and reduce seasonal variation, China had initiated a program of dredging and removal of rapids, reefs and shoals in conjunction with plans for construction of a cascade of hydroelectric dams in Yunnan Province since 1993, several of which are already in operation. The stated goal was to eventually enable vessels of 500 DWT to ply the route between Simao Port in Yunnan and Luangprabang, Laos, with some twelve other ports in between.

Initially, Chinese government supported the budget of 200 million Yuan. In November 2000, China government announced that the dredging program for navigation on Mekong River is unavoidable and three phases of 886-km dredging program. In addition, China initiated the Quadripartite Agreement on Commercial Navigation on Lancang–Mekong River among the governments to facilitate large vessels and not allowing all other activities that could obstruct river way. However, Phase 1 from China to Chiang Saen was the only phase that had been completed since Thailand and Laos were against downstream activities since they could affect national border and might ruin local citizens. Therefore, large vessels can be navigated to Chiang Saen only.

Besides dredging program, Yunnan Province has plans building more than 10 dams along Lancang River to produce hydroelectric power for Yunnan. Xiaowan, Manwan and other Lancang dams first and foremost aim to provide a cheap source of energy to fuel industry in Yunnan and elsewhere. In addition, officials argue that they will stabilize downstream water levels, decrease currents and increase depth of the river which will all improve navigability. These projects initially had a negative impact on water levels and decreased currents to the degree that silt accumulations blocked river channels, though China contends conditions will improve as the reservoirs reach capacity. (Stimson, 2008) These dams have brought both positive and negative effects to transport on Mekong-Lancang River depending on how water gates are managed. According to China announcement, water will be discharged from the dam every one day in three days. Therefore, the water level during dry seasons will be higher in general but sediments might be stored in several China dams that might affect the downstream river.

For non-physical challenge, since Mekong river flows through several developing countries without one legal entity, gangster and pirates have posed dangerous conditions for commercial navigation and transported goods. After leaving China the Mekong flows through the Golden Triangle area where the borders of Myanmar, Thailand, and Laos meet. As the Golden Triangle has been one of the most extensive opium- producing areas of Asia and of the world since the 1950s. Most of the world's heroin came from the Golden Triangle until the early 21st century when Afghanistan became the world's largest producer. An owner of one of the hijacked ships stated that almost every Chinese boat in the area had been robbed by river gangs with the recent attack on October 5, 2011. (BBC News, 2011) In response to the event, China temporarily suspended shipping on the Mekong, and reached agreement with Myanmar (Burma), Thailand, and Laos to jointly patrol the river. The event was also the impetus for the Naypyidaw Declaration and other anti-drug cooperation efforts in the region.

3. TRANSPORT DEVELOPMENT PLANS AND EFFECT TO MEKONG SHIPPING

Since the transportation development plans in four related countries are quite dynamic and uncertain due to government and economic uncertainly. We compiles the development plans

that are still active or being constructed in 2014. The summary of impact and relevance to Mekong shipping is shown in Table 1.

4. PRELIMINARY ANALYSIS

This section presents preliminary analysis on Mekong shipping. The first part presents the competing routes that might be substitutes of Mekong line for transportation of goods. The second parts presents benefits of each country along Upper Mekong from Mekong shipping.

4.1 Competing Routes (R3A/R3E, R3B, other modes)

Since Mekong shipping mainly uses for transport of bulk or agricultural goods from Yunnan to Chiang Saen port in Thailand (smaller percentage go to Laos and Myanmar), the analysis will focus on the pros/cons of competing routes if logistic providers select others. In fact, since railway projects are still uncertain in the near future, there are evidently three main ways of transport from Yunnan to Thailand as follows:

1) R3A/R3E: Kunming-Mohan-Boten-Huayxai-Chiang Khong-Chiang Rai-Bangkok, which was completed with the opening of 4th Thailand-Laos Friendship Bridge in December 2013. This route is quite popular among the shipments that require faster travel time to Thailand. Shipment from Sipsong Panna and south Yunnan can reach Chiang Khong,

Table 1: Effects of Development Plans and Projects on Mekong Shipping

Plan/Project	Range/Year	Type/Degree	Note
Dual-track railway project to Chiang Khong	Long-term (after 2020)	Affect Mekong shipping negatively Mekong shipping since R3A would be more convenient and easier for rail transfer.	The development of Chiang Khong by both government and private sectors mean less development in Chiang Saen port or Chiang Saen area.
Logistics Park at Chiang Khong	Long-term (after 2015)		
Laos Railway Project	Long-term (>5-10 years)	Affect Mekong shipping negatively since rail is more efficient for freight and containers shipping	This project is still on negotiation. It has lots of uncertainty esp. on financial deal.
Tonpheung International Airport	Long-term (after 2018)	Might not affect freight transport on Mekong since river transport is much cheaper for time-insensitive goods.	This project might slightly have negatively effect on Mekong cruise tourists since air travel from Kunming is faster
Lao - Burma Friendship Bridge	Long-term (after 2016)	Could affect freight volumes on Mekong for China-Myanmar trade.	This project paves a much easier connection from R3A to Myanmar (instead of rugged terrain R3B). Truck transport from China to Myanmar could use this route.
Kyaukphyu-Kunming Railway Project	Unlikely to happen before 2025	If happens, would decrease China-Myanmar volumes on Mekong shipping significantly.	Due to minority problem in Myanmar and conflict with central government, this project is unlikely to happen in next five years.
Lancang Airport	Long-term (after 2018)	Might not affect freight transport on Mekong since river transport is much cheaper for time-insensitive goods.	It would reduce tourists on Mekong and R3A route but no effect to freight transport on Mekong.
BCIM Corridor	Long-term (after 2020+)	If happens, would decrease China-Myanmar volumes on Mekong shipping significantly.	This project is at the start point and unlikely to come up with the construction plan soon. However, it would affect greatly to China-Myanmar trade.
Mekong joint military patrols	Short-term	This ongoing project might make Mekong shipping a bit safer but it could add delay and cost to regular lawful ships due to a lot of patrol.	Due to large scale of Mekong, the patrol is very difficult to catch the pirate and illegal goods. At the same time, regular lawful ships might be delayed from lots of investigation.

Chiang Rai within one day with the distance around 400 km. Due to logistics park and other facilities along the route, recent data show that the parts of trade volumes has been shift from Chiang Saen to Chiang Khong.

2) R3B: Chiang Tung-Thakilek(Myanmar)- Mae Sai-Chiang Rai-Bangkok. This highway connects with China at Daluo before joining R3A at Chiang Rung and continue to Kunming. However, this route is quite unusable due to poor road condition in Myanmar and unreliable of Mongla-Daluo border crossing point. Although the distance is almost similar to R3A, R3B has to pass through uncontrolled minority group (Shan State) in Myanmar and the road lacks maintenance. Therefore, the road might not be Mekong's competitor now.

the distance is almost similar to R3A, R3B has to pass through uncontrolled minority group (Shan State) in Myanmar and the road lacks maintenance. Therefore, the road might not be Mekong's competitor now.

3) Air Transport: A new international air terminal at Kunming was recently opened in 2011 while Tonpheung International Airport and Lancang Airport are being constructed and would be opened in the next five years. New available air transport routes in the Upper Mekong area are not expected to affect freight transport on Mekong River and R3A as much since goods shipped through air mode are very time-sensitive and expensive while goods shipped on land are bulk or agriculture products. However, it would affect passenger transport especially tourists on Mekong since it reduces travel time between cities. Travel by air from Kunming to Chiang Rai or Tonpheung would take only an hour comparing with 3 days through Mekong or 1-1.5 days on R3A.

From the analysis, the competing route of Mekong is only R3A as of now. The pros/cons of each route are as follows:

Advantage of Mekong Shipping vs R3A

1) Already well-established Transport on Mekong River has been in place a decade before R3A completion. Many transport and logistics operators are located along China ports and can handle goods well and conveniently.

2) Less problems on cross-border issues since ports along Mekong are large ones with legal government personnel from each country. Also, since most ships are registered in China and from the negotiation among government with China as a group leader, no trans-border tax has to pay Laos or Myanmar for Thailand bound shipment. This is opposite to truck transport on R3A that has to clear the customs for immediate country.

3) Generally cheaper for bulk items since inland water transport takes much less fuel, less labor than road transport given the same volumes. It is much cheaper for Mekong route (if goods can wait for a few more days en route.) Truck transport cost depends on the demand and supply of each season also but it is still more expensive than a vessel.

Disadvantage of Mekong Shipping vs R3A

1) Required Experienced Navigation Skill Navigate the vessel on Mekong River is not an easy task due to strong current and lots of bedrocks along the way. Although some guide signs and lighting are installed, they are incomplete. Only experienced captain that pass the route for many years can navigate the vessel through the path.

2) Risk from Drug Gangster and Robbery Since the area for Mekong shipping is Golden Triangle area with past drug trade and Myanmar Government cannot control Shan State. Therefore, the shipping route between Myanmar and Laos is almost no control except from the joint patrol. The risk remains for drug gangster and robbery.

3) Unreliable Water Draft in Dry Season Although China dams are expected to control Mekong draft along shipping route to be more stable, it is unreliable for some periods when China needs to store water for hydroelectric plants or irrigation purpose during the dry season.

4) Access to Mekong Ports is difficult Major China ports, i.e., Guanlei, Simao, are difficult to access from the main highway and large city or industrial zone in China. Due to rapid highway

development in China, most industrial estates are located near the railway line or expressway and they are quite more convenient nowadays to ship containers or goods through railroads or trucks from Yunnan to Guangzhou and then use Guangzhou port to ship goods to Bangkok or Laemchabang. Although this shipment take almost 10 days from Central China to Central Thailand, it costs cheaper due to economy of scale and proves to be a much safer and reliable route. The reverse direction (Central Thailand to Yunnan) is also similar.

4.2 Advantages of Transport on Mekong Rivers by Countries

Each country along Upper Mekong gets benefits from Mekong shipping as follows:

China

- Market & Trade Expansion Exported China goods from Yunnan would have lower transport costs so that Yunnan goods can be well popular in Thailand, Myanmar and Laos. In addition, Yunnan will enjoy cheaper and faster products from Northern Thailand shipping through this route.
- Route Control Since most vessels in Mekong are registered in China or belong to China's state enterprises and China is the only country with high experience in Mekong navigation, China can totally control trade and vessels along this route. Besides these, China dams can be used to control water level in the river.
- Expand Yunnan Economy Since Yunnan is the landlocked province, economy of Yunnan would depend on expansion of trade route to Lao, Myanmar, and Thailand in the south. Mekong shipping would add more jobs to Yunnan and bring shipbuilding industry and many industrial estates at Simao lively.

Laos

- Cheaper Import Goods from China Exported China goods from Yunnan can reach Bokaew with cheaper price.
- Revenue from Port Charge Since Laos is on the route and every ship must visit their ports and pay port charge to Lao government.

Myanmar

- Cheaper Import/Export Goods from/to China Exported China goods from Yunnan can travel to Shan State or lower Myanmar with cheaper price.
- Alternative to R3B Even with many uncertainty, Mekong transport is more reliable than R3B for connection between Myanmar and China until the Myanmar-Lao Friendship Bridge is opened.

Thailand

- Cheaper and faster Import/Export ways from/to China Exported China goods from Yunnan can travel to Northern Thailand (or Central Thailand) with cheaper price.
- Development of Chiang Saen Mekong shipping would induce the development at Chiang Saen area. Despite land and zonal limitation, many businesses were already established in Chiang Saen and enjoy the benefit of Mekong shipping route.

5. CONCLUDING REMARKS

Although the international shipping on the River has been growing for centuries and playing a more significant role in strengthening relationships and reinforcing exchanges of economy and trade among four nations. The importance of this route could change over time depending on government intervention and transportation development plans.

Normally, logistics providers will usually use the route with less cost. Since most trading goods between Thailand and Yunnan are time insensitive. Mekong transport, the cheaper mode, has been more popular except in the dry season or during occasional violent events. However, Thailand, China, and Laos development plans show more progress in improving R3A, e.g., logistics park, truck facility, industrial estate, and other developments at Chiang Khong and planned railroad line. On the other hand, at Chiang Khong, Chiang Rai, Thailand, development is quite limited since it is located in an ancient heritage town. In addition, in a foreseeable future, the conflict between Shan State and Myanmar government will not resolve soon. Therefore, the gangster problem on Mekong will remain from time to time. Based on these conditions, it is expected that R3A will gradually gain more market share for goods transport between Yunnan and Chiang Rai. The condition could be changed if the railway is successful opened. However, for adventurous tourists, Mekong would still be their way of sightseeing and travel between Chiang Rai and Sipsong Panna.

Keys from research investigation are as follows:

- Mekong Shipping will still be popular due to lowest cost of transport comparing with other modes. However, market share is decreasing to R3A after 2014.
- Most of the transportation developments among countries are not focusing on Mekong development as much as R3A development.
- Lots of air transport service and airport developments are recently initiated in the Upper Mekong area; however, it is not expected to draw Mekong shipping goods into air transport due to much higher cost
- Railway development is the latest trend in the upper Mekong region. If the railway project (passing Laos into Chiang Khong) is successful, it would negatively affect transport volumes on Mekong shipping. However, it is not expected to finish before 2020 or even begin construction in a few years due to lots of government involvement and high capital cost.

More researches would be done to compare the total logistic costs separated between types of goods (bulk and container) between along Mekong and on R3A and to analyze the effects of recent policy and technology such as new ship technology, joint military patrol, and railway development on river transport volumes.

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A COMPARISON OF TRIPS TO SCHOOLS IN SUBURBAN BANGKOK

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Abstract: In the morning peak hours, about 90% of the parents of students of School B used private cars to transport their children to school. This behavior can contribute to creating or increasing the severity of traffic jams during the morning rush hours. In contrast, only 3.78% take a school bus. We will look at another school to see if the findings are similar or different from those of School A. The objectives of this paper are to study and compare school bus management, and compare the key factors of School A and School B that influence parents' behaviors who allow their children to use their school buses. The methods used are an analysis of the factors that affect school bus management e.g., school bus cost, driver, assistance, and school bus operation. The results indicates that about 75.76% of the parents of students of School A send their children by private car. This is similar to School B and is the favorite mode of transportation for parents of School A students. However, it is found that the percentage of parents who decide to use a bus from School A (15.50%) is higher than the percentage of parents who use a bus from School B (3.78%). Furthermore, it is noticed that the school bus management of School A is more efficient than School B's in terms of assistance of School A buses by school staff who work at school, and their daily check of the number of children being transported. The school bus service of School A serves 2 trips; the first trip transports a group of pre-kindergarten and kindergarten students, and the second trip carries students of the primary school. However, the bus of School B serves one trip only. In addition, the school bus fare of School A is calculated based on distance, while the fare system of School B is dissimilar.

Key Words: school bus, private car, children, school bus management

1. INTRODUCTION

In Bangkok, the private car is favored more than other transportation modes; it is the most favorite method to send or pick up students from home to school and vice versa (Dissanayake & Morikawa, 2010). However, private cars are the main reason for traffic congestion around schools such as blockage of streets and areas around schools (La Vigne, 2007).

Parents who have high incomes choose private schools or selected schools for their children to attend, and they tend to drive their children by themselves in the morning and park their cars to wait for those students to finish class and get them home in the evening. That is the reason of traffic congestion around schools (Khan et al., 2011). And, School B has the same problems of traffic congestion like other private schools. About 90.22% of the parents of School B decide to send their children to school by private car and only 3.78% choose the school bus (Srisurapanon et al., 2014).

From the School B data, it shows that parents' decision to use a school bus is very low. However, if we change the location of schools, do we observe the same characteristics of parent behavior? If the results are similar to School B, then suburban schools display similar characteristics. If the results are not similar, it shows that suburban schools do not exhibit similar characteristics, and the characteristics of parents are influenced by other factors. That is the interesting reason why we should study this phenomenon.

The objectives of this study are to conduct a comparison of two schools and find the reasons. If we change our focus from School B to another school which is in the same location or same district, and the type of school is private school or selected school similar to School B, is the percentage of parents who decide to drive to school similar to School B or not? Table 1 shows that the tuition fees of School A and School B at kindergarten levels, primary school grades 1-3, and primary school grades 4-6 are similar.

Table 1. School A and School B Tuition Fees

Level	School A Tuition fee (Baht)	School B Tuition fee (Baht)
Pre-kindergarten	27,000	-
Kindergarten	30,000	26,500
Primary school grades 1-3	34,000	36,500
Primary school grades 4-6	36,000	36,500
Junior high school	-	41,500
Senior high school	-	41,500

2. BACKGROUND OF SCHOOLS

This part will discuss the issues about school bus use in Thailand, followed by two suburban school case studies, and finally a comparison of locations and facilities around the schools.

2.1 LITERATURE REVIEW

Thailand has a number of problems surrounding school bus use such as expensive school charges or fares, parents' level of awareness or consciousness about risks of school bus travel, and the discomfort of students waiting for a school bus at home or school (Department of Land Transport, non-specified year).

In Thailand, school buses can be divided into two groups based on their vehicle type such as minibus and van. The favorite type of school bus in Bangkok is a van because it is easier to negotiate in traffic congestions than a minibus, and the size of a van is smaller than a minibus. In Bangkok, parents who decide to use school buses are typically those who have occupations such as employees of businesses or business owners themselves, have a high level of education, have more than one child in a particular school, and have high incomes. The reasons that influence more parents to switch to school bus use are school bus fare and the development of school bus condition (Limmonthol et al., 2011).

Furthermore, additional interesting issues to analyze in this study consist of the following:

- Issues for comparison
  - School location, number of students/teacher
  - Methods of traveling to school
  - Mode selection to school
  - School bus provided
  - Factors influencing the decision of parents
- Composition of school bus systems
- School bus management
- Degree of importance of the management

2.2 METHODOLOGY

For this study, two different schools were selected which were analyzed by sending questionnaires to parents, conducting interviews, and observing physical facilities around the schools.

2.2.1 OBSERVATION BY SENDING QUESTIONNAIRES TO PARENTS

The questionnaires query the following information:

- Mode
- Trip length
- Trip cost
- Arrival time
- Perception or attitude of traffic

2.2.2 INTERVIEW

The details of the interviews are as follows:

- General issues e.g., starting time, types of school buses, number of school buses
- Tuition fees/entrance fees
- Bus fare system
- Management of school bus

2.2.3 OBSERVATION OF PHYSICAL FACILITIES AROUND SCHOOLS

The physical facilities observed around schools are the following:

- Sidewalks, public transportation, parking
- School bus operation
- Use of facilities in school bus e.g., safety belts

2.3 SCHOOL A

This section discusses school location, sidewalks around schools, types of public transport, and school parking.

2.3.1 SCHOOL LOCATION

School A is an alternative school and is located in suburban Bangkhuntian District on Rama II Road, which is the "Thonburi - Pakthor" Highway No. 35 that connects Suksawat Road to Phet Kasem Road. It has about 590 students and is divided into three subsections — Pre-kindergarten, Kindergarten Level 1 – Level 3, and Primary Level 1 – Level 6.

- Kindergarten students attend class in the morning before 0900.
- Primary students attend class starting at 0810.
- All levels of School A have about 20 students per class room.

School A has one type of school bus which picks up pupils from home to school. The direction of School A buses consist of 5 routes; the first route is Phetkasem, the second route is Tha Kham, the third route is Pracha Uthit, the fourth route is Phutthabucha, and the fifth route is Tha Phra.

Figure 1. School A

2.3.2 SIDEWALKS AROUND SCHOOLS

Sidewalks are pedestrian lanes that are paths along a roadway. The recommended width of a sidewalk is about five to six feet so two students can walk side by side (SRTS, 2014). The sidewalks of School A are wide and convenient with low numbers of street vendors along the roadway so students can walk or bike to school with ease, as shown in Figure 2.

Figure 2. Sidewalk of School A

2.3.3 TYPES OF PUBLIC TRANSPORT

Public transport will take you almost anywhere you want to go, and taxis are generally easy to catch, with door-to-door service, however, you must pay more money for taxis than for public transport (Vuchic, 2007). School A has varied types of public transport, as shown in Table 2, and paratransit.

Table 2. Types of public transport at School A

NO.	TYPES	ROUTES
1	Bus (BMTA)	No. 17, 68, 76, 85, 105, 140, 141, 142, 147, 169, 172, 173, 529, 558, 720
2	Van	- Ramkhamhaeng University - Central Plaza Ladprao - MBK Center - Central Plaza Pinklao

2.3.4 SCHOOL PARKING

School A has about 140 parking spaces, as shown in Figure 3. From the questionnaire data, it is found that 75.76% of parents drive private cars to school. School A is located near Rama 2 Road which is a main road with 3 lanes. An additional reason for increased private car use is that the school is not located in the same direction as the morning work traffic. So, School A does not have traffic congestion or points of conflict.

Figure 3. School A Parking

2.4 SCHOOL B

This section mentions location, sidewalks around school, types of public transport, and school parking.

2.4.1 SCHOOL LOCATION

School B is an alternative school and is located in suburban Bangkhuntian District. The school is sited in Soi Anamai Ngam Charoen 25 and the distance from the school to Rama II Road is about 2 km. It has about 1,192 students and is divided into three subsections — Kindergarten Level 1 - Level 3, Primary Level 1 - Level 6, Junior High School and Senior High School.

- Kindergarten students attend class in the morning before 0900.
- Primary school, junior high school and senior high school students attend class in the morning at 0750.
- All levels of School A have a student population of about 25 students per classroom.

School B has two types of school bus; the first type is a bus which transports pupils from home to school. The direction of the buses of School B consists of 4 routes — the first route is Sukhumvit, the second route is Bangbon, the third is Pracha-Uthit, and the fourth route is Phetkasem. School bus drivers serving each district must live in that district in order to pick up their pupils on time in the morning. In the evening, drivers pick up pupils from their school and take them to their homes. The second type, the shuttle bus, travels only one direction from the drop-off point at a Petronas fuel station where parents drop off their children only in the morning.

Figure 4. School B

2.4.2 SIDEWALK AROUND SCHOOL

The sidewalk of School B is not wide (narrow path) because it is controlled by the roadway. So, students cannot bike on the sidewalk which means they need to share the road with vehicles and that is harmful for children. The sidewalk of School A is better than that of School B because it is about 3 meters wide, not obstructed by trees, street signage and other obstructions, e.g. traffic signs, post boxes, phone boxes, streetlamps, traffic lights, and bus stops, as shown in Figure 5. Moreover, the sidewalk is a safe path because of traffic separation from Rama II Road.

Figure 5. Sidewalk of School B

2.4.3 TYPES OF PUBLIC TRANSPORT

School B is dissimilar to School A because School B doesn’t have any public transport; only taxis or motorcycles support travel to and from the school.

2.4.4 SCHOOL PARKING

School B has a total parking area limit of about 210 spaces, of which about 100 spaces are parking spots in the primary school section and about 110 spaces for parking in the high school section, as shown in Figure 6. However, parents from about 90% of 825 households, approximately 742 households, drive private cars to school. (Srisurapanon et al., 2014). Especially, it is the reason of traffic congestion in the morning in the School B area.

Figure 6. School B Parking

3. SCHOOL BUS MANAGEMENT

This section discusses school bus routes, school bus cost, and school bus operation.

3.1 SCHOOL BUS SERVICE TIME

In the morning, School A buses conduct delivery only one trip per direction. Whereas in the evening, the delivery is two trips per direction. The first trips are for groups of pre-kindergarten and kindergarten students who finish class at 2.50 p.m., and the second trips are for groups of primary school students who early than primary school at 03.50 p.m. The total number of students who take the school bus is approximately 89 students. The average per school bus is 18 students.

Figure 7. School Bus A

School B buses do deliveries only one trip per direction both in the morning and in the evening, and kindergartens finish class early and must wait for primary school students. These are some of the reasons why parents drive private cars to school. The total number of students who take the school bus is approximately 49 students. The average per school bus is 12 students.

The difference between School A buses and School B buses is that, in the evening, School A buses serve 2 trips and the first trips transport groups of pre-kindergarten and kindergarten students, and the second trips transport groups of primary school pupils. Whereas, School B buses serve one trip only. The similarity is in the morning trip — School A buses and School B buses both undertake only 1 trip.

Figure 8. School B buses

3.2 SCHOOL BUS FARES

In this section on rates, the school bus fare of School A is based on distances — if students live near school, they pay less money than students who live a long distance from school. For the round trips, the rates start at 0-5 km. and parents pay 1,300 baht. If the distance is more than 5 km. parents pay 200 baht for approximately 1 km. The price range of School A buses is between 1,500–3,800 baht. School B bus fares are based on distances, but no rates of distance are specified, and start at approximately 2,500 baht. While rates increase from distances to school, how much parents should pay based on range of distances is unclear. The range of fares of School B buses is between 2,500–3,800 baht.

For the one way trips, the rates of School A buses start at 0-5 km. for which parents pay 800 baht. If the distance is more than 5 km., parents pay approximately 200 baht per additional km. The rate range of School A buses is between 800–2,300 baht. While School B has no rates of distance and the fares are not clear, it appears to start up at approximately 1,500 baht. The rates increase based on distances to school.

This study found that, for School A, the school officials are responsible for maintaining the fare accounting system, so parents must pay money at the school or transfer money to the account of School A.

Whereas, for School B, parents must pay money by contacting a school official, or sometimes the parents contact the bus drivers

themselves to give money on an unofficial basis. The monthly salary of school bus drivers of School A is approximately 20,000 baht per month. However, for any excess money that students pay per route that amounts to more than 20,000 baht per month, drivers have an monthly bonus incentive in the following proportion — approximately 80 percent goes to the drivers and School A's proportion is approximately 20 percent. Whereas, School B bus drivers have a fixed salary rate of approximately 20,000 baht per month with no incentive bonus proportion.
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3.3 SCHOOL BUS ACCESSORY

The accessories of both School A and School B buses include seat belts and air conditioning. The specification of the student/seat ratio in a school bus is 1 seat per student. The capacity of a school bus is 14 seats — 12 seats for students, 1 seat for the driver, and 1 seat for an assistant.

3.4 SCHOOL BUS OPERATION

School A bus operation refers to school bus factors e.g., the driver is an outsider or a private contractor and is not a member of the school staff. The assistant is a member of the school staff and reports to the vehicle division every day the number of students who use the school bus, as shown in Figure 9.

School B bus operation refers to school bus factors e.g., the driver is an outsider or a private contractor and is not a member of the school staff. The assistant is an outsider, not working at the school. Sometimes, the assistant is absent, so the drivers must take care of additional children themselves, as shown in Figure 10.

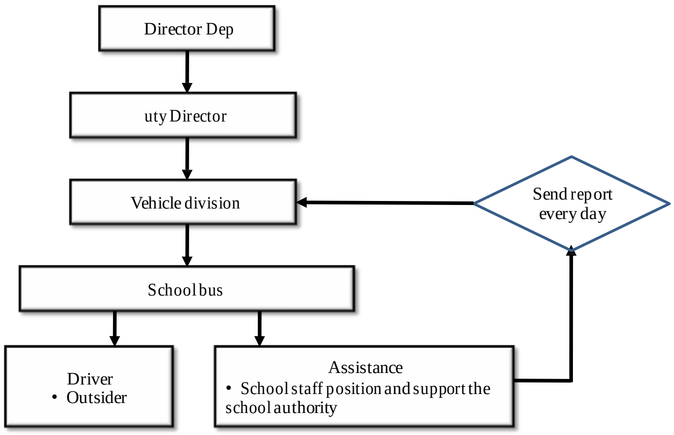


Figure 9. School A Bus Operations

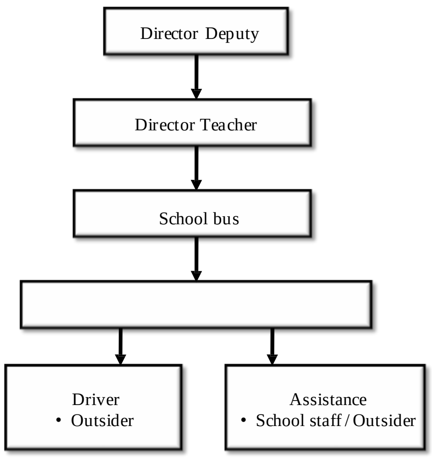


Figure 10. School B Bus Operations

4. CHARACTERISTICS OF PARENTS

The topics of parents' characteristics are data collection, travel behavior, and questions about traffic.

4.1 DATA COLLECTION

In this case study, data was collected through 583 questionnaire surveys which were distributed to several parents at School A with a return rate of 460 responses, which is a response rate of 78.90%. School B involved the dissemination of 825 questionnaires surveys with 450 responses received, which is a response rate of 54.54%, as shown in Table 3.

Table 3. School Bus Questionnaires

Level	School A		School B	
	Questionnaires		Questionnaires	
	Sent	Received	Sent	Received
Kindergarten	494	389	279	195
Primary school	89	71	320	219
Secondary school	-	-	226	36
TOTAL	583	460	825	450

4.2 TRAVEL BEHAVIOR

From the data, it is found that approximately 75.76% of the School A respondents drive private cars to school in the morning, while 15.50% transport their children on a school bus, as shown in Figure 11. For School B, approximately 90.22% of the respondents drive private cars to school in the morning, while 3.78% have their children take a school bus, as shown in Figure 12.

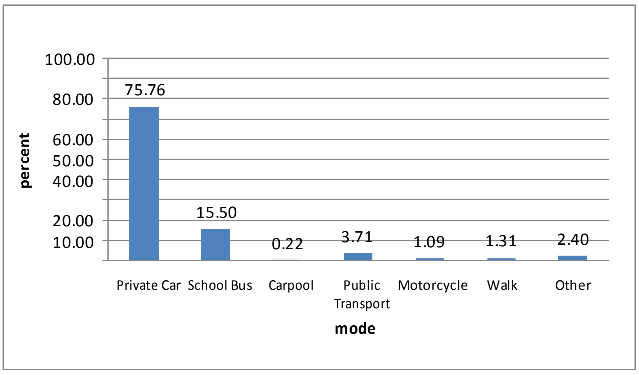


Figure 11. Mode of School A

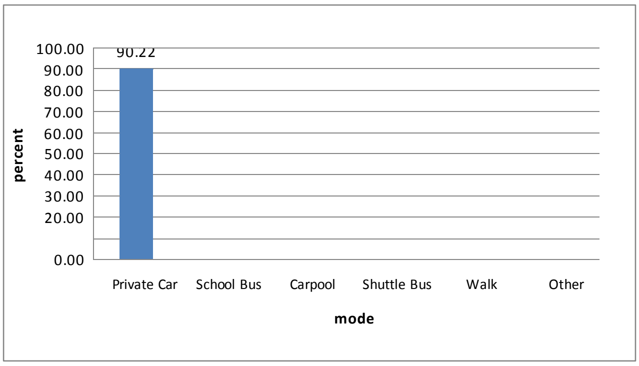


Figure 12. Mode of School B

out, ranging from 10 minutes to 60 minutes. Of the respondents, 46.32% stated that their children arrive at school between 7:31 a.m. and 8:00 a.m., and 26.84% arrive between 8:01 a.m. and 8:30 a.m. Some students, mostly at kindergarten level, arrive between 8:00 a.m. to 9.00 a.m., as shown in Figure 13. The arrival times to School B are also spread out, ranging from 10 minutes to 60 minutes. Of the respondents, 46.20% of the students arrive at school between 7:31 a.m. and 8:00 a.m., and 31.90% arrive between 7:01 a.m. and 7:30 a.m. Some students, mostly at kindergarten level, arrive between 8:00 a.m. to 9.00 a.m., as shown in Figure 14.

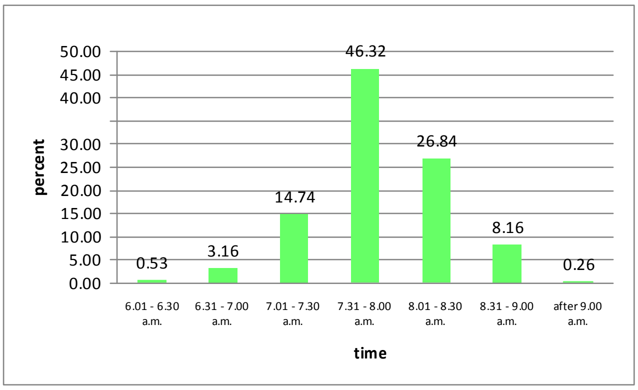


Figure 13. Morning Arrival Time of School A

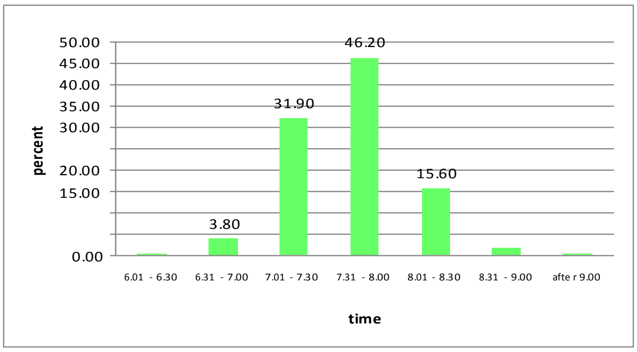
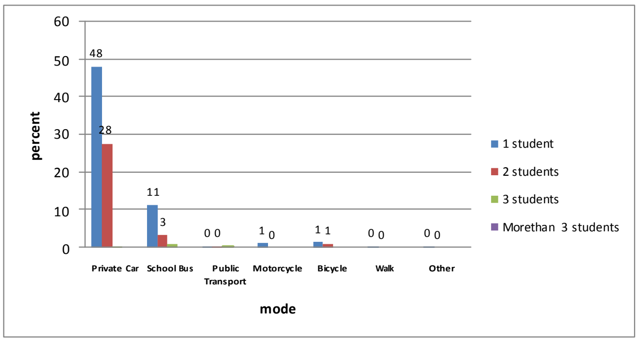


Figure 14. Morning Arrival Time of School B

From the data, regarding the relationship between the modes and numbers of students going to School A, it is found that most parents, approximately 48% of respondents, have 1 student who goes to school by private car, and approximately 28% of responding parents have 2 students who go to school by private car. Furthermore, approximately 11% of respondents have 1 student who takes the school bus to school, and approximately 3% of responding parents have 2 students who take the school bus to school, as shown in Figure 15.

School B data shows the relationship between modes and numbers of students who go to school. It is found that most parents who have 1 student, approximately 50% of respondents, take their child to school by private car, whereas parents who have 2 students, approximately 35% of respondents, transport their children to school by private car. Parents who have 1 student and send their child to school using a school bus are approximately 2% of respondents, whereas parents with 2 students who take the school bus to school are approximately 2% of respondents, as shown in Figure 16.



Number of Students at School A

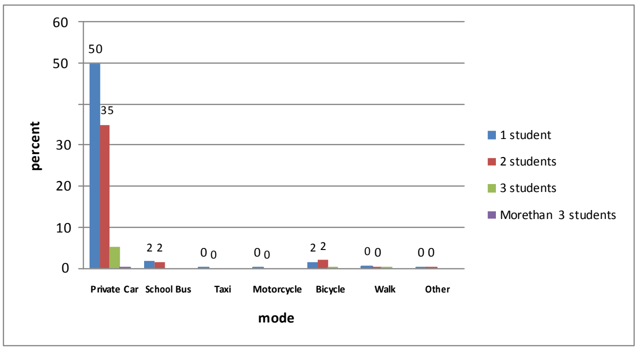


Figure 16. Relationship between Modes and Number of Students at School B

From the analysis of School A, it is observed that 43% of respondents return home after dropping off their children to school, and 42% continue on to work, as shown in Figure 17. From the analysis of School B, it is observed that 63% continue on to work, and 27% of respondents come back home, as shown in Figure 18.

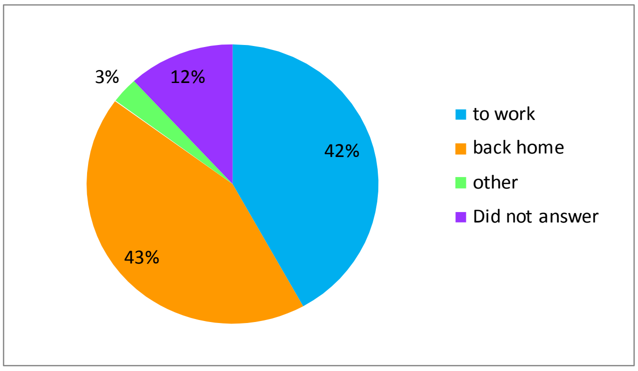


Figure 17. Activity after Transporting Children to School A

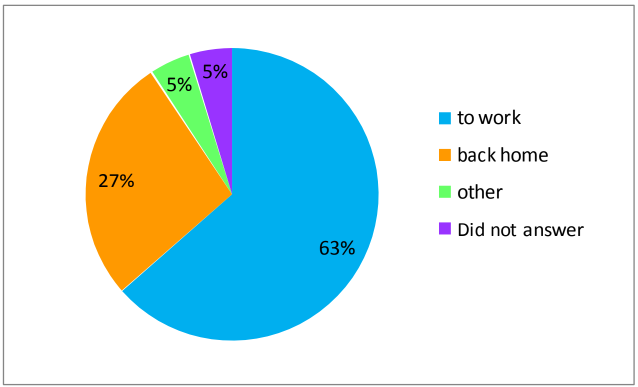


Figure 18. Activity after Transporting Children to School B

From the School A data in Table 4, it is observed that 41% of respondents choose driving to school due to the reasons relating to school bus issues. This is close to half of the total number of reasons and shows that the probability of their children using the school bus if the changing school bus system. While the School B data in Table 5 shows that 37% of respondents do so because of the reasons relating to school bus factors.

The first reason, a proportion of about 30%, why parents drive their children to School A is to be able to stay close to their children. Whereas, for School B, the first reason, a proportion of about 43%, why parents drive their children to school is due to the school being on the way to work or because the parents want to do other activities. Since a significant portion, about 43%, of the parents of School A children come back home without the restriction of outside work or obligations, it shows that several parents of School A students can spend more time to stay close to their children. However, most parents of School B students, about 63%, continue on to work places. This shows that several parents of School B students continue on to their work after taking their children to school.

The second reason, a proportion of about 22%, why parents drive their children to School A is the close proximity of their homes to the school, whereas for School B parents living close to the school, only 3% of the parents indicate the same reason. In terms of time spent driving to school, most parents of School A students take about 21-30 minutes, approximately 33.76%, and those driving for 11-20 minutes are approximately 29.64% of the total, as shown in Figure 19. For School B, several parents require about 21-30 minutes travel time, approximately 26.30%, while others, approximately 19.60% spend about 31-40 minutes, as shown in Figure 20. This indicates that several parents of School A students use less time to drive to school than do parents of School B students.

Table 4. Reasons why parents drive their children to School A.

Reason	Respondent	%
Be able to stay close to their children	117	30
Living nearby school	83	22
Not in the service area of school bus*	58	15
School bus cost is expensive*	52	14
Not assured school bus service*	32	8
the way to work/do other activities	17	4
Late school bus*	16	4
Others	9	2
Total	384	100

* Reasons relating to school bus.

Table 5. Reasons why parents drive their children to School B.

Reason	Respondent	%
the way to work/do other activities	130	43
Not in the service area of school bus*	51	17
Be able to stay close to their children	37	12
Inappropriate pick-up/drop-off station*	37	12
Not assured school bus service*	19	6
Living nearby school	10	3
A parent works at school	5	2
Late school bus*	5	2
Others	10	3
Total	308	100

* Reasons relating to school bus.

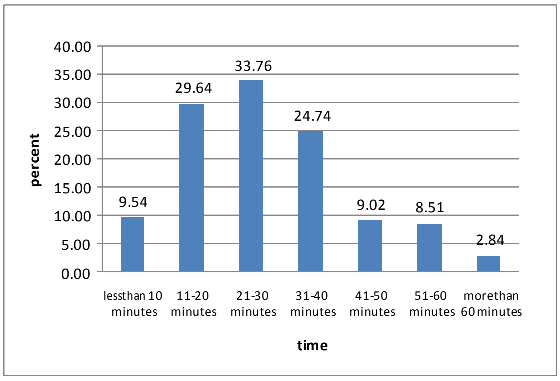


Figure 19. Travel Time from Home to School A

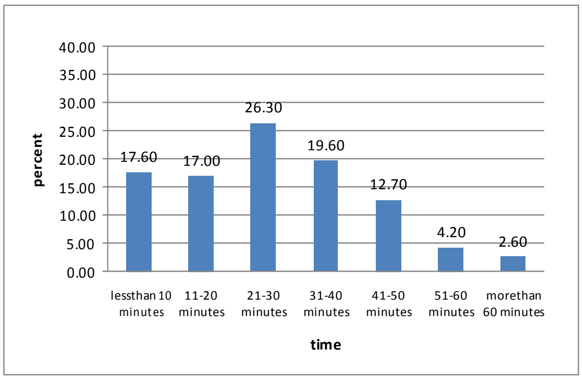


Figure 20. Travel Time from Home to School B

Most of the School A parents who travel to school must spend between 51-100 baht, while most of the School B parents who travel to school must spend money in the same range, as shown in Figures 23 and 24.

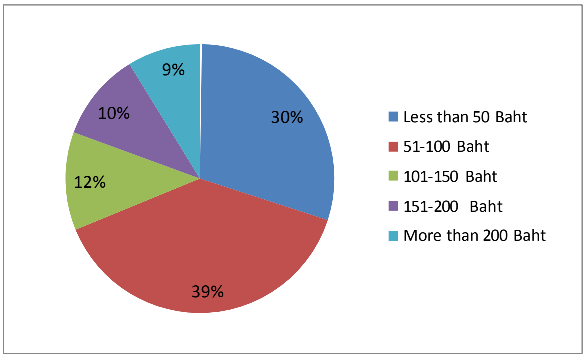


Figure 23. Travel Cost to School A

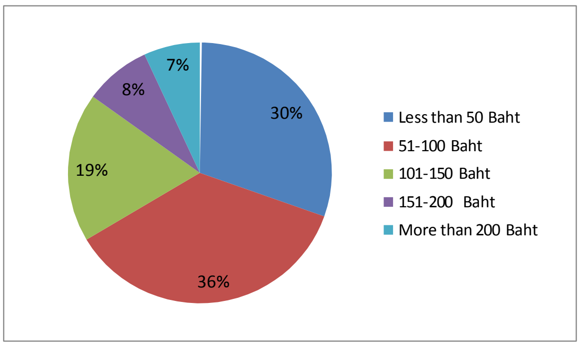


Figure 24. Travel Cost to School B

4.3 TRAFFIC DATA

From the questionnaire data inquiring about traffic being a problem in the morning related to sending students to School A, it is found that all respondents who go to school by private cars don't think traffic congestion is a problem, as shown in Figure 25. From the questionnaire data, related to morning traffic problem while transporting students to school B, it is found that 33% of respondents who go to school by private cars think traffic congestion is a problem between 7:31 a.m. and 8:00 a.m., and 10% of the respondents who go to school by private cars think traffic is problematic between 8:01 a.m. and 8:30 a.m., as shown in Figure 26.

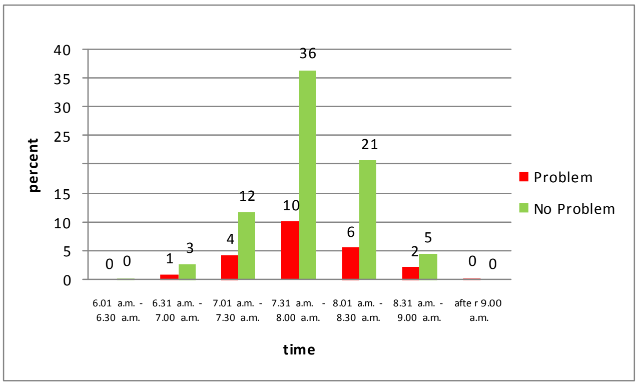


Figure 25. Traffic is a Problem in School A

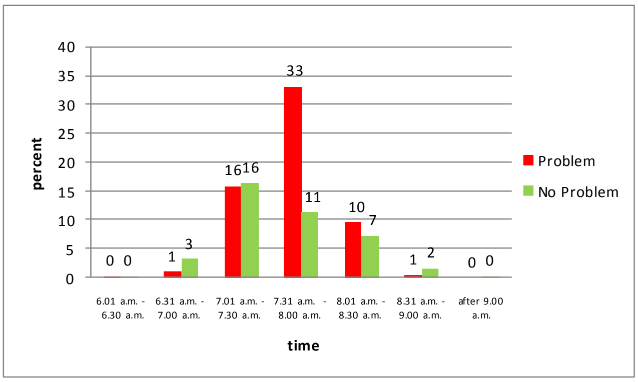


Figure 26. Traffic is a Problem in School B

From the analysis of School A data, it is observed that 42% of respondents believed school buses can reduce traffic congestion around school, as shown in Figure 27. From the analysis of School B data, it is observed that 33% believed shuttle buses can reduce traffic congestion around school, as shown in Figure 28.

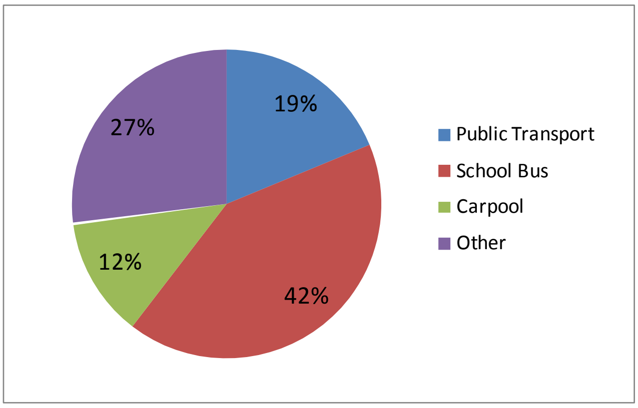


Figure 27. How to Reduce Traffic Congestion in School A

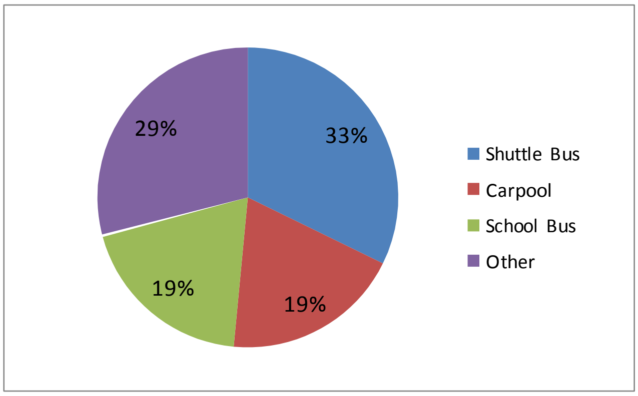


Figure 28. How to Reduce Traffic Congestion in School B

5. RESULTS

The results of this study of School A data found that 75.76% of households drive private cars to school, and the reasons why parents drive to school are, firstly, an inappropriate school bus system; secondly, a desire to stay closer to their children; and thirdly, living near the school, in the proportions of 41%, 30%, and 22%, respectively. Whereas, a study of the School B data found that 90% of households drive private cars to school, and the reasons why students are driven to school by their parents are, firstly, the convenience of ride-sharing with their parents as a household trip; secondly, an inappropriate school bus system; and, thirdly, the desire for parents to stay closer to their children, in the proportions of 43%, 37%, and 12%, respectively. It is notable hat several parents of both schools drive private cars.

As for school bus management, School A parents are interested in using the school bus, a proportion equal to 15.50% which is greater than the 3.78% of School B parents indicating the same interest. It shows that management of School A buses is more efficient than that of School B buses in terms of the following factors: rates of School B buses are based on real distances, and assistants of School A buses are school staff who work at the school and check the number of children every day. Additionally, there are incentives per month paid to drivers which makes it an attractive proposition to drive well. Finally, parents must pay money directly to School A or transfer money to a School A bank account.

The School A bus fares of round trips are calculated based on distances, and the rates start at 1,300 baht related to distances about 0-5 km. And the payment range of School A buses is between 1,500–3,800 baht. While School B calculates fares based on distances, there are no rates of distance and the payment scheme is not clear, it should be start up approximately 2,500 Thai baht. The payment range of School B buses is between 2,500–3,800 baht, which shows that the method to calculate fares of School A is greater than School B.

In addition, the school bus fares of a one-way trip for School A is calculated based on distances, and the rates start at 800 baht for distances about 0-5 km. Additionally, the payment rate of School A buses is between 800–2,300 baht. While School B calculates fares based on distances, no rates of distance are stated and not clear, it should be start up approximately 1,500 Thai baht, This shows that the method to calculate fares of School A is greater than School B that similar the fares of round trips.

From the first reason indicated by parents who drive their children to school, it shows that the behavior of School A and School B parents are different. School A parents are able to stay close to their children for a proportion of about 30%, while the reason of School B parents is that the school is on the way to work/other activities, a proportion of about 43%. Another reason is that most parents of School A students come back home and several of those parents can spend more time staying close to their children, whereas most parents of School B pupils continue on to work or to perform other activities outside the home.

From the physical data, it is apparent that the locations of the two schools are dissimilar. School A is located in an arterial road, the location is not in the same direction as parents' workplaces, and it can support high traffic volume in peak hours. School B is sited on a local road, the location is conveniently in the same direction as the workplaces of some parents, and there are traffic jams in morning peak hours. Notice that the location of School A is better than that of School B. It is recommended to improve the sidewalks around the two schools, and this enhancement would support non-motorized mode of travel, e.g., walking or biking to school.

From the traffic data, it is found that most parents of School A students think traffic congestion isn't a problem around their school, while most parents of School B think the traffic congestion is a problem. Regardless, 90% of them still drive to school which shows that a different perception exists about traffic congestion around these two schools despite School A and School B being located in the same district.

6. CONCLUSION

The results indicate that parents' decision to use school bus management for their children's transportation to school includes school bus service time, school bus fares, and school bus operation. Further work would be interesting and is recommended to construct the logit model for School A.

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FOUR TRIALS TO CRACK THE CHILD HELMET QUANDARY

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Abstract: Thailand has the second highest rate of road deaths per population in the world. Of those who die on Thailand's roads, 73% are motorcyclists. Despite a legal mandate, less than half of motorcyclists, and only 7% of children, wear helmets. To identify possible models to increase child helmet use, the Asia Injury Prevention (AIP) Foundation conducted four small-scale trials: (1) a helmet bank, (2) police enforcement, (3) petrol station retail, and (4) taxi stands. Trials 1, 2, and 4 resulted in increased child helmet use, but each had instructive challenges and strengths. Trial 3 presented a number of challenges leading to the conclusion that child helmet retail at petrol stations is not viable.

Key Words: injury prevention, helmet, motorcycle, school-based intervention, evaluation

1. INTRODUCTION

Road crashes are among the world's foremost public health issues with 1.24 million deaths and
20-50 million injuries per year. (World Health Organization, 2013) Thailand ranks second in road traffic deaths per population worldwide. (Michael Sivak and Brandon Schoettle, 2014) Motorcyclists account for 73% of Thailand's road deaths. (World Health Organization, 2013)

Helmets are proven to reduce the risk of head injury by 69% and death by 42% in a crash. (Liu et al., 2008) Even though Thai law has mandated helmet use for motorcycle drivers and passengers since 1996, fewer than half of motorcyclists, and only 7% of children wear helmets nationwide. (ThaiRoads Foundation et al., 2013) Road injury is the second leading cause of death among children aged 10-14 in Thailand. (Lozano et al., 2012)

To identify possible models to increase child helmet use, the Asia Injury Prevention (AIP) Foundation, in collaboration with Save the Children and the Road Safety Fund, conducted four small-scale trials (see Table 1) to pilot innovative ideas for increasing child helmet use in Thailand. The overall objective in conducting the trials was to identify initiatives that would be most suitable, in terms of sustainability and impact, for expansion.

From November 2013 to January 2014, AIP Foundation conducted four trials for two to three weeks each at locations throughout Bangkok.

Table 1. Four trials tested to increase child helmet use in Bangkok

	Name of Trial	Description
Trial 1	Helmet Bank	Loaning helmets to students from within schools
Trial 2	Police Enforcement	Law enforcement by police officers at school gates
Trial 3	Petrol Station Retail	Convenient accessibility through helmet retail kiosks at petrol stations
Trial 4	Taxi Stand	Motorcycle taxi drivers offer helmets to all child passengers

Trials 1, 2, and 4 were modeled on a pre-test, implementation, post-test design. The helmet wearing rate of children traveling to the school by motorcycle was measured before and after the trial based on AIP Foundation's helmet observation methodology. Focus group discussions and in-depth interviews were conducted with key stakeholders after the trials ended in order to gain their insights on the trials and on factors that motivate or hinder child helmet use.

Trial 3 was modeled on an implementation, investigation design. During the 2-3 week trial, customers completed a short questionnaire or were interviewed on-site about the trial, possible motivations, and barriers for helmet purchase and use.

This paper describes the methodology, findings, and recommendations of each trial.

2. TRIAL 1: HELMET BANK

In Thailand, child helmets are available through direct purchase or donation via educational schemes operated by government agencies, private corporations, and non-governmental organizations (NGOs). This trial aimed to test whether school-based helmet loans could increase child helmet use.

2.1 Methodology

Ban Nong Bon Primary School in Suan Luang, Bangkok was selected for the trial, because nearly half of its students travel by motorcycle, it is in close proximity to a major road, and helmet use is low. Students who traveled by motorcycle regularly, but did not regularly wear helmets when riding on motorcycles (making up about 30% of the school body), were targeted for the project. The trial was implemented from November 21 - December 12, 2013.

A "helmet bank" was established on the school grounds and operated each school day. The helmet bank stored 200 child helmets for students to borrow. Borrowers could keep helmets for a maximum of three days but could borrow helmets again if they wished.

Before implementation, AIP Foundation conducted a helmet observation and a training workshop. The observation took place at the school gate to assess baseline helmet use among students. The one-hour training workshop with 200 target students covered road safety, the importance of helmet wearing, and how to wear a helmet properly. It also introduced the helmet bank and how to access a helmet through the helmet bank.

During implementation, several activities aimed to increase awareness about the importance of child helmet use among parents and teachers. At the beginning of the trial, teachers informed parents about the helmet bank as they collected their children from school. Children informed their parents when they borrowed helmets from the helmet bank. Helmet observations assessed helmet use during and after the trial.

After implementation, AIP Foundation conducted two focus group discussions with students who borrowed helmets and one with teachers at the trial school about their perception of the helmet bank and insights on helmet use.

2.2 **Key Findings**

During the trial, a high proportion of students borrowed helmets at the bank. Daily borrowing rates ranged from 59% (with 117 out of 200 helmets borrowed) to 64% (128 helmets borrowed). On average, 60% of target students borrowed helmets during the trial.

Helmet use among students traveling on motorcycles at Ban Nong Bon Primary School increased from 8.8% prior to the trial, to 18.6% after the trial (see Figure 1). While a significant number of children borrowed helmets from the helmet bank, very few were wearing the borrowed helmets. The findings showed that child helmet use at the trial school more than doubled in only three weeks, but this increase did not parallel the rate of participation at the helmet bank. If all the children who borrowed helmets wore them, the rate of helmet use would be around 60%. The actual change in helmet use (of 9.8 percentage points) is equivalent to only 16additional children wearing helmets.

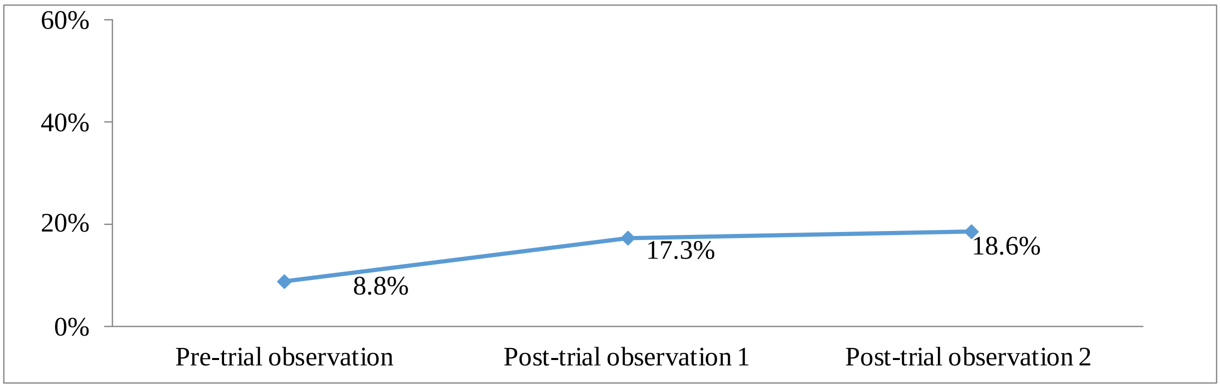

Figure 1. Helmet use before and after the “helmet bank” trial at Ban Nong Bon School

A focus group discussion among students borrowing helmets revealed that students did not have their own child-sized helmets. Before the trial, some students wore their parents’ helmets, but they expressed that they did not like wearing the adult helmets due to the size and weight. The students said that they borrowed helmets to protect them from road injury. However, the students reported borrowing helmets but not wearing them, because:

- Borrowed helmets were kept at home, and the students forgot to bring helmets to school
- Parents were afraid of helmet theft and having to pay for replacement helmets
- Some of the borrowed helmets were too small, and some had uncomfortable chin straps
- Students were uncomfortable wearing helmets in hot weather
- Helmets affected students’, especially girls’, hair styles

Many students responded that certain styles, based on helmet size, color selection, appealing designs, and windshields, would motivate them to wear helmets.

Teachers were very enthusiastic about continuing the helmet bank initiative beyond the trial period and suggested a cluster model expansion, in which a group of schools would each implement helmet banks, under the guidance of one lead school. Teachers emphasized the value of educational activities to inform children about the importance of correct helmet use. They suggested that further activities on road safety could be adapted and delivered by teachers in the classroom and that the involvement of police in delivering these activities would further engage the children.

2.3 **Discussion**

The helmet bank trial increased helmet use at the trial school and received enthusiastic support among teachers. That the helmets borrowed from the bank were free of charge created a perception of high value within the school, but due to concerns of hygiene, parents were also interested in purchasing helmets. The helmet bank's capacity to draw attention to the importance of helmet wearing is a valuable lesson. The school environment is an ideal setting to communicate messages to students, parents, and the wider community about child helmet wearing. The helmet bank, perhaps incorporating an element of helmet retail to meet demand from parents, can act as the focal point of these communications.

The greatest potential cost of implementing helmet banks at scale would be the acquisition and maintenance of the helmets. This trial was implemented at "no cost" to the school. To implement helmet banks at scale, there would need to be careful consideration of resourcing. If resources were more limited, requiring additional commitment from schools, this may impact schools' support and in turn reduce the effectiveness of the helmet

told to enforce the helmet wearing law.

bank itself.

Despite its benefits, the trial faced several barriers that prevented children from wearing helmets. These barriers indicate the need to invest more on behavior change if the trial is expanded. The trial could be improved upon by addressing the identified barriers, integrating comprehensive educational activities, and encouraging teachers to enforce child helmet use.

3. TRIAL 2: POLICE ENFORCEMENT

Although Thai law requires all motorcyclists to wear helmets, this mandate is not widely or consistently enforced by the police and, as a result, helmet use is low nationwide. Experience from road safety interventions around the world has shown that increased enforcement leads to an increase in helmet wearing. (Pervin, 2009; World Health Organization, 2009) This trial investigated the impact of increased police enforcement and its barriers.

3.1 Methodology

Sai Mai Police Station is located close to Thai Rath Wittaya 75 School in Sai Mai, Bangkok, which was selected for the trial based on proximity to the police station, high rates of students traveling by motorcycle, and low helmet use. Officers from the station were asked to patrol the school's entrance as children arrived and departed from the school for the duration of the trial. While patrolling, police officers were told to enforce the helmet wearing law.

Before the trial began on November 25, 2014, AIP Foundation conducted observations to assess baseline helmet use. For the first week, traffic police verbally warned parents whose children were traveling without helmets. In the second week of the trial, traffic police issued fines to parents whose children were traveling without helmets. In the third week, traffic police gave away rewards for children wearing helmets. The trial finished on December 14, 2013. On January 9, 2014, AIP Foundation conducted post-implementation helmet observations and focus group discussions with participating police, students, and teachers.

3.2 Key Findings

In the first week of the trial, only warnings, no fines, were issued. In the second week, a total of 16 fines were issued to parents who carried children without helmets.

Motorcycle helmet wearing rates among students at Thai Rath Witthaya 75 School increased from 7% before the trial to 14.4% afterward (see Figure 2).

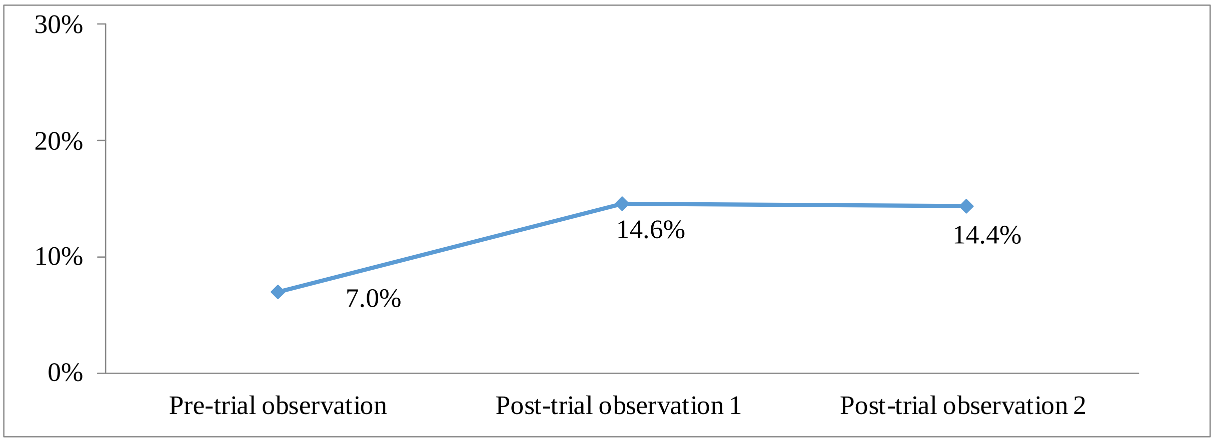

Figure 2. Child helmet wearing rates before, during, and after police enforcement trial at Thai Rath Witthaya 75 School

Students reported that their encounters with police patrols usually ended with warnings instead of fines and a few reported that their parents gave them adult helmets on the following days. Other students reported that they saw police officers infrequently, indicating that the police presence was inadequate as a visual deterrent. Students reported awareness of the importance of wearing helmets to protect themselves from injury in road crashes, and they said they felt good seeing police in front of the school.

Teachers reported that police enforcement is not a significant motivating factor for children to wear helmets and that police enforcement would instead impact the behavior of motorcycle taxi drivers, whose income would be directly affected by child passengers without helmets.

Despite the support of the head of traffic police at the Sai Mai Police Station, securing sufficient resources for the trial was challenging. Originally, police were asked to establish a checkpoint at the entrance of the school with many police officers to issue warnings and fines. A prominent checkpoint was hoped to be a visual deterrent to discourage children from riding motorcycles without helmets. At the time of the trial, there were significant demands on the Royal Thai Police throughout Bangkok. Ultimately, only one officer from the station was released to participate in the trial, so a prominent checkpoint was not possible.

In focus group discussions, traffic police explained their discomfort with enforcing the helmet law due to its potentially negative impact on their relationship with the local community. To fine children not wearing helmets seemed to them an inappropriate practice. The police officers also advised that, regardless of resources, it would not be possible to create a checkpoint outside a school as it would cause problems with traffic flow around the school.

Officers also mentioned a lack of resources for patrolling and enforcing the helmet law among children and suggested that efforts to increase enforcement should focus on negotiations with high levels of the Royal Thai Police. The police needed to protect its image due to demonstrations in Thailand during the trials. Any actions within the community had to be carefully managed. Successful advocacy with the leaders of the Royal Thai Police would hopefully provide the support for local police to increase enforcement of the helmet law.

When asked about the most effective way to increase child helmet use, the police officers felt that education or reminders, not increased enforcement, was the best option. They expressed that enforcement should be the final measure taken after education and awareness raising. If additional support was provided by the Royal Thai Police, the officers suggested that police could engage with and inform the community of the need to wear helmets.

3.3 Discussion

In this trial, the increase in children's helmet wearing was limited, possibly due to the police officers' unwillingness to issue fines for those who did not wear helmets. Insufficient police resources available for the trial were also a barrier to improved enforcement.

Future initiatives need to account for police sensitivities about community reaction and include components that allow police to address community concerns. The trial could be improved through continued high-level negotiations to increase police enforcement of the helmet law and supplemental activities to allowing local police officers to provide education about the importance of child helmet use, the helmet law, and law enforcement activities to combat negative reactions in the community.

4. TRIAL 3: PETROL STATION RETAIL

In Thailand, the primary distribution channels for adult and child helmets are motorcycle and related accessory shops. Supermarkets are a comparatively minor retail channel. Prior research with manufacturers indicated that helmets had never been sold in petrol stations. (Rubinyi,2013) This trial investigated if petrol stations could be viable helmet retail channels.

4.1 Methodology

Two temporary retail kiosks were set-up to sell children's helmets to customers of two petrol stations, selected in high traffic locations. One retail kiosk sold discounted children's helmets from November 29 - December 29, 2013, while the second kiosk sold helmets at market price January 6 - 19, 2014. The kiosks were located outside the petrol stations' offices with shelves to display the children's helmets and vinyl banners displaying customized advertisements.

Two retail assistants were recruited to staff the kiosks. The retail assistants were trained to assist customers with queries, process transactions, and conduct interviews with customers about reasons for buying or not buying a helmet.

4.2 Key Findings

During the trial, helmet sales were very low. An average of four helmets per day (55 total over the trial period) were sold at the discounted trial kiosk. Only two were sold at the market price kiosk over a period of 13 days. The reasons for low sales were investigated through customer interviews and observation.

In interviews with 40 customers at the discount kiosk and with 17 customers at the market price kiosk, cost and design were the most-cited reasons parents did not purchase helmets. Safety and the helmet law were the main reasons cited by parents who did purchase helmets. Although many more discounted helmets were sold than market price helmets, none of the customers who purchased helmets cited cost as their primary motivation for purchasing.

Increasing accessibility was insufficient to motivate customers to purchase. Customers whose children did not wear helmets cited the difficulty of finding child helmets as a reason for their children's behavior, but of those customers, only 20% proceeded to purchase helmets.

Although 73.7% of customers agreed that petrol stations would be convenient locations for helmet retail, most customers had limited time at the petrol station, and additional time would be required to ensure the helmets correctly fit their children. Adults often ride to the petrol station without their children, thus creating an additional barrier to purchasing helmets.

Furthermore, to establish helmet retail at a petrol station requires substantial investment of time and money to create a space to display and store helmets in a range of sizes and designs, in what is often a small retail environment.

4.3 Discussion

This trial has shown that accessibility and affordability were not sufficient to trigger high demand for child helmets. The petrol station environment presents a number of challenges for helmet retail in terms of customers' time and inventory management. The combination of these factors leads to the conclusion that child helmet retail at petrol stations is not viable.

Based on the small number of helmets sold at the trial petrol stations, we do not recommend further pursuit of petrol stations as a child helmet retail channel.

5. TRIAL 4: TAXI STANDS

Motorcycle taxis are a popular means of transport in Thailand, and many children take motorcycle taxis to and from school. This trial investigated whether child helmet use would increase if motorcycle taxi drivers offer helmets to child passengers.

5.1 Methodology

The trial was implemented from January 2 - 17, 2014. Two taxi stands located close to the Royal Thai Navy residential community and one taxi stand located close to Sanpawut Wittaya School in the Bang Na sub-district of Bangkok were selected for the trial. While the head of a motorcycle taxi drivers' association supported the trial, drivers at the proposed taxi stands were not eager. A number of stands were consulted before the three trial stands were finalized. Two of the three selected stands were located at a Royal Thai Navy residential complex. Consequently, the Royal Thai Navy oversaw the operation of the stands.

5.2 Key Findings

During the 16-day trial, taxi drivers offered helmets to 308 child passengers. Of those, 235 (76%) accepted the helmet (See Table 2). The number of drivers offering helmets to child passengers fluctuated throughout the trial and ultimately reduced over the period of the trial.

The finding of helmet observations in two locations (one near the community and one at the school) showed that rates significantly increased before and after the trial, from 0% prior to the trial, to more than 24% (See Figure 3).

The child passengers who did not accept helmets cited the short distance of the journey as the main reason for not wearing helmets. Others cited their dislike of helmets, size, and hygiene.

Although the Royal Thai Navy greatly facilitated the participation of two taxi stands, maintaining motorcycle taxi drivers' participation was challenging. Each taxi stand operated in isolation, moreover, the motorcycle taxi drivers at each taxi stand also acted with a degree of autonomy. Initiatives focusing on motorcycle taxi drivers will need to motivate and educate them about the importance of child helmet use, in order to secure their commitment.

5.3 Discussion

The trial showed that motorcycle taxi drivers can have an impact on children's helmet wearing behavior. While there could be positive ripple effects influencing other children to wear helmets, the impact of initiatives focusing on motorcycle taxi drivers alone may be limited in audience. Motorcycle taxi drivers can persuade their child passengers to wear helmets, but this may not directly impact children who ride motorcycles with their parents or other relatives. This model would be best implemented in combination with other educational and advocacy initiatives to reach children who ride non-taxi motorcycles.

The trial would be improved on with continued negotiations with motorcycle taxi associations to engage taxi stands and increased educational communications to promote the importance of child helmet wearing among drivers.

6. LIMITATIONS

The trials were conducted at a small scale, and the sites were chosen to fit the requirements of the project. Many factors impacted the results of the trials. Political protests in Bangkok affected implementation, particularly of Trial 2, which relies on the willingness of the police to enforce the law. The police officers were concerned that enforcement could increase tensions with the public during the protests. In addition, the replicability of the taxi stand trial depends on the cooperation offered by other autonomous taxi stands. It was not possible to exclude external factors to determine causality.

7. CONCLUSION

The helmet bank, police enforcement, and taxi stand trials resulted in increased child helmet wearing rates, but each trial had instructive challenges and strengths. The number of challenges presented by the petrol station retail trial in terms of customers' time and demand, as well as inventory management, led to the conclusion that child helmet retail at petrol stations is not viable.

The findings of all four trials indicate that

Table 2: Child passengers who accepted helmets offered by taxi drivers

Number of days in the trial	16
Number of child passengers carried by taxi drivers	308
Number of students who accepted helmets offered by taxi drivers	235
Students who accepted helmets as percentage of all carried	76%

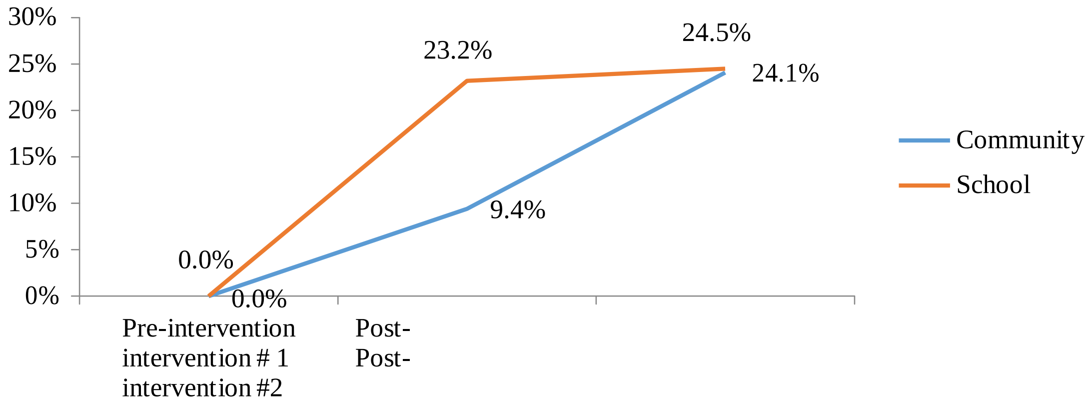

Figure 3. Child helmet wearing rates before, during and after the taxi stand trial

child helmet use could be increased through a combination of the following interventions:

1. High-level negotiations to increase police enforcement of the helmet law. Without high-level support, it is challenging for individual police stations and/or police officers to find the resources to enforce the helmet law.

2. Communications to convert helmet access into helmet wearing. Both the petrol station retail and the helmet loan bank results help demonstrate that access to helmets should not be the primary area of concern – in contrast, behavior change must be prioritized. Education, enforcement, and peer influence may motivate children to wear helmets, and encourage parents to acquire helmets.

3. Leveraging teachers as champions of helmet wearing. Teachers have significant influence on children's behavior and parents' attitudes. The helmet bank trial showed that teachers have the capacity to draw children's and parents' attention to helmet wearing.

4. Investigation of schools and taxi stands as channels for accessing helmets. The trials suggest that accessibility and cost of children's helmets are not the primary obstacles to child helmet use. However, while helmet retail at petrol stations was proven to be unviable, schools and taxi stands can be effective channels for helmet loans and retail.

5. Educational activities conducted by local police officers. Police are eager to inform the community about the helmet law and enforcement and raise awareness that police enforcement of the helmet law saves lives.

6. Customized child helmets in visually desirable designs. Based on students' feedback during the helmet bank trial, the range of helmet design choices should include new and trendy designs, popular cartoon characters, and various color options.

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PAVEMENT CONDITION RATING SCORE USING FUZZY LOGIC TECHNIQUE

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ABSTRACT:

This paper presents results of the study of the ultra-poor in the south of Thailand, revisited after 10 years since the original 2000 study. The objectives of the study were to assess the changes in the poverty situation after 10 years, and the impacts of the poverty reduction projects implemented by the government on the poor. The research methodology used both quantitative and qualitative methods. The same villages in the four provinces studied in 2000 were again chosen. The results show that the poverty situation of the ultra-poor groups has not changed much since they lacked the basic key factor to get themselves out of poverty: the ownership of land. Even though the government's projects have not reduced the poverty directly, the projects have significantly contributed to the improvement of the quality of life of the poor and the non-poor in the areas especially through better transport, mainly good roads which have significant impacts on the transport of agricultural produce, access to health and education, personal security, job opportunities and community participation.

KEYWORDS: Pavement management system, Fuzzy inference system, Distresses density, Severity level, Rating score

1. INTRODUCTION

Pavement performance modelling is an essential element of a pavement management system (PMS).The model developed plays a critical role in several aspects of the PMS including financial analysis. In developing countries like India, PMS is the needed approach for the optimum utilisation of the available scarce resources as it is concerned with optimal use of materials leading to cost optimization. A major problem faced by highway and transportation agencies especially in developing countries is insufficient funds to meet the expenses for repair and rehabilitations of deteriorated road sections. The problems becomes further complicated as these deteriorated highways are in use even though they are in poor condition. Lack of development of proper network process is to defer repair projects until conditions become unacceptable. Pavement deterioration takes place due to inevitable wear- tear, impact of environment and local conditions that occurs over a period of time. The gradual deterioration of a pavement occurs due to many factors including variations in weather, drainage, soil condition, and truck traffic. Further, lack of funds often inhibits timely repair and rehabilitation of transportation facilities. This aggravates the problem resulting on serious pavement defects and higher cost of rehabilitation. As the funds are often limited, the agencies tend to balance its programs between preventive maintenance activities and those projects requiring immediate corrective action. If preventive maintenance is neglected, then projects will be selected based on the extent of deterioration as observed by the road user. When the ride is extremely rough, vibrations may damage vehicles, crashes can occur and user costs increase significantly, these considerations are unacceptable by the road users. Usually preventive maintenance, carried out in an orderly and systematic way, will be the least expensive approach in the long run. However, when funds are limited, agencies often respond to the most pressing and severe problems or the ones that generate the most vocal complaints.

Pavement distress information is usually converted into a condition index. The condition index combines information from all types of the distresses, severities and quantities into a single number. This number can be used at network level to define the condition state, to identify when the treatments are needed, for ranking or prioritization and as the number used to forecast the condition. The condition index may be represent as a single distress such as fatigue cracking or a combination of many condition distresses which is usually referred as composite index. Condition surveys are made for the purpose of determining the condition of a pavement at a given time. This type of survey is not concerned with the evaluation of structural strength of pavement and generally no attempt is made to determine the reason for the pavement's condition. This type of survey is qualitative in nature in that subjective rating by individuals is made. Information obtained from condition surveys are used in setting up needs studies, priority rating and maintenance programs. However it is important to note the required type of maintenance is not indicated from the results of the condition survey.

The first step in the process of pavement management is to secure data about the condition of each pavement section in the system. The condition data were obtained by visual inspections that established the type, extent and severity of pavement condition. These inspections were subjective and relied heavily on judgment and experience for determining pavement condition and program priorities. Although such an approach can be appropriate under certain circumstances, possibilities exist for variations among inspectors and experience is not easily transferable. In more recent years, visual ratings have been supplemented with standardized testing equipment to measure surface condition. The pavement surface condition is affected by parameters like traffic axle loads, environmental conditions, moisture content etc. and are themselves uncertain in nature hence the rate of pavement deterioration is uncertain. Fuzzy mathematics offers a convenient tool to better represent the subjective assessment and uncertainty involved in pavement condition rating. Besides, it is common that the condition assessments of a given distress by different pavement experts are not the same. This is not surprising because there is an element of uncertainty concerning the 'true value' of the severity level of the pavement distress. The differences in distress assessments among experts and the uncertainty involved in their assessment can be easily incorporated into the analysis using fuzzy logic (FL) concepts.

The aim of this paper is to allocate the rating score against the normally existing types of distresses on bituminous topped road using Fuzzy Inference System approach.

2. FUZZY LOGIC

The idea of fuzzy logic was first advanced by Dr. Lotfi A. Zadeh in 1960. Fuzzy logic is an approach to computing based on degrees of truth rather than the usual true or false (1 or 0) Boolean logic on which the modern computer is based. Fuzzy logic is able to express any natural phenomenon especially related to human decision making efficiently using linguistic variables.

2.1 Fuzzy Inference System

The following discussion introduces the four-step fuzzy inference system employed in implementing FL efficiently viz. Fuzzifier, Fuzzy inference engine, Fuzzy rules and Defuzzifier as given in Figure 1.

2.1.1. Fuzzifier: The function of the fuzzifier is to convert a numerical value from the universe of discourse of the input variable into a linguistic variable and corresponding level of belief. This step takes the current value of a process state variable and gives levels of belief in input fuzzy sets, in order to make it compatible with the fuzzy set representation of the process state variables in the rule-antecedent. The level of belief is equal to the degree of membership in the qualifying linguistic set which can take any value from the closed interval (0, 1).

2.1.2. Inference Engine: The basic function of the inference engine is to compute level(s) of belief in output fuzzy sets from the levels of belief in the input fuzzy sets. The output is a single belief value for each output fuzzy set. In this stage, the fuzzy operator is applied in order to gain a single number that represents the result of the antecedent for that rule. The inference engine is mainly based on rule.

2.1.3. Fuzzy Rules: Rules determine the closed-loop behaviour of the system. The rules are based on expert opinion, operator experience, and system knowledge. The basic function of the rule base is to represent in a structured way the control policy of an experienced process operator and/or control engineer in the form of a set of production rules such as if (process state) and then (control output).The if-part of such a rule is called the rule-antecedent and is a description of a process state in terms of a logical combination of fuzzy propositions. Moreover, the then-part of the rule is called the 'rule consequent' and is again a description of the control output in terms of a logical combination of fuzzy propositions. These propositions state the linguistic values which the control output variables take whenever the current process state matches (at least to a certain degree) the process state description in the rule-antecedent. The inference process is divided into three phases, application of the fuzzy operator in the antecedent, implication from the antecedent to the consequent and aggregation of the consequents across the rules.

2.1.4. Deffuzifier: The function of defuzzifier is to convert the levels of belief in output fuzzy sets to a decision variable of some kind. In practice, the output of the defuzzifier process is a single value from the set. There are several built-in defuzzifier methods. The centre of gravity method is the most commonly used for extracting a crisp value from a fuzzy set.

3. METHODOLOGY

The methodology adopted in this paper is to identify the distresses which generally appear on the surface of bituminous topped highways. Further categorization of the density and severity level is done in fuzzy terms and their limiting value is assigned. Depute the Universe of discourse, membership function shape and function value range against the selected distresses. Apply the proper Fuzzy rules that consist of all possibility of if-then rules. All the above mentioned steps were carried out through commercial mathematical software MATLAB R2007b.

4. DATA COLLECTION

Distresses of seven types, their density and severity level has been obtained from the Ministry of road transport and highways(MORTH) 2004 guidelines and from the research carried out by Murlikrishna et al, 2011and Sandra et al, 2010 as mentioned in Table 1. & Table 2.Density of each distress types was categorise into three numbers of fuzzy language like light, average and heavy along with their limiting value in percentage as shown in Table 1.Similarly severity of each distress types was categorise into three fuzzy language like low, medium and high along with their limiting value either in numeric value or in logical form as shown in Table 2.

Table 1.Description of Pavement Distress Density Levels (MORTH 2004 & Murlikrishna et al 2011)

Sl.No.	Types of Distress	Density	Description
1	Cracking	Light	Less than 5 %
		Average	Between 5% to 30%
		Heavy	More than 30%
2	Potholes	Light	Less than 0.1 %
		Average	Between 0.1% to 1%
		Heavy	More than 01%
3	Raveling	Light	Less than 40%
		Average	Between 40% to 60%
		Heavy	More than 60%
4	Patching	Light	Less than 0.10%
		Average	Between 0.10% to 01%
		Heavy	More than 01%
5	Rutting	Light	Less than 10%
		Average	Between 10% to 20%
		Heavy	More than 20%
6	Edge Failure	Light	Less than 2%
		Average	Between 2% to 5%
		Heavy	More than 5%
7	Bleeding	Light	Less than 30%
		Average	Between 30% to 60%
		Heavy	More than 60%

Table 2.Description of Pavement distress severity levels (Sandra et al 2010)

Sl.No.	Types of Distress	Severity	Description
1	Cracking	Low	Width of the cracking is less than 3 mm
		Medium	Width of the cracking is greater than 3 mm and less than 6 mm
		High	Width of the cracking is more than 6 mm
2	Potholes	Low	Depth of the potholes is less than 25 mm
		Medium	Depth of the potholes is more than 25 mm and less than 50 mm
		High	Depth of the potholes is more than 50 mm
3	Raveling	Low	The aggregate or binder has started to wear away but has not progressed significantly. The pavement appears only slightly aged and slightly rough.
		Medium	The aggregate or binder has worn away and the surface texture is moderately rough and pitted. Loose particles may be present and fine aggregate is partially missing.

Table 2.Description of Pavement distress severity levels (Sandra et al 2010)

Sl.No.	Types of Distress	Severity	Description
		High	The aggregate and/or binder have worn away significantly, and the surface texture is deeply pitted and very rough. Fine aggregate is essentially missing from the surface, and pitting extends to a depth approaching one half (or more) of the coarse aggregate.
4	Patching	Low	Patch has low severity distress of any type including rutting < 6 mm; pumping is not evident
		Medium	Patch has moderate severity distress of any type or rutting from 6 mm to 12 mm; pumping is not evident.
		High	Patch has high severity distress of any type including rutting > 12 mm, or the patch has additional different patch material within it; pumping may be evident.
5	Rutting	Low	Barely noticeable, depth less than 6 mm
		Medium	Readily noticeable, depth more than 6 mm less than 25 mm
		High	Definite effect upon vehicle control, depth greater than 25 mm
6	Edge Failure	Low	Appearance of edge step with a few initial cracks on the bituminous surface along the edge portion of the carriageway.
		Medium	Appearance of edge step with a number of interconnected high intensity cracks on the bituminous surface along the edge portion of the carriageway.
		High	Permanent loss of part of carriageway and pothole formation along the edge portion.
7	Bleeding	Low	Percentage of bleeding is less than 25%
		Medium	Percentage of bleeding is in between 25% to 50%
		High	Percentage of bleeding is more than 50%

5. ANALYSIS OF DATA

In this study, a model was established which estimates the rating score of the bituminous topped road from density and severity level data using fuzzy inference system approach. The general structure of the model is shown in Figure 2.

In the established model, triangular membership functions were formed for each density and severity as inputs and for rating score as output whose function value range defined in three category namely left intercept, value equal to one and right intercept under the degree of discourse as mentioned in Table 3.Further these were trained using the tabulated data in the Table 3. Membership functions are given in Figures 3-5.

The If-then rule base was constituted for membership function whose details are available with Figures 3-5. Total number of firing rules used for the study is nine as indicated in section 5.1 and Figure 6.

The rule viewer is used for viewing the fuzzy inference system as shown in Figure 7. It enables to understand how each rule contributes towards the output or the role played by each rule. Each row of plots represents one rule. The three small plots across the top of the rule viewer window represent the antecedent and consequent of the first rule. Each rule is a row of plots and each column is a variable. The first two columns of plots show the membership functions representing the antecedent or the If part of each rule. The third column of plots shows the membership functions representing the consequent or the then part of each rule. The tenth plot in the third column of plots represents the aggregated fuzzy output of the fuzzy system.

Table 3. Fuzzy Logic and Membership function

Type of distress	Classification	Membership function shape	Fuzzy sets	Function value range			Universe of discourse
				Left intercept	Value equal 1	Right intercept	
Rutting	Density	Triangular	Light	0	0	20	0-100%
			Average	10	30	50	
			Heavy	40	100	100	
	Severity	Triangular	Low	0	0	10	0-30mm
			Medium	5	15	25	
			High	20	30	30	
	Rating Score	Triangular	Good	0	0	4	0-10 point scale
			Fair	1	5	9	
			Poor	6	10	10	
Raveling	Density	Triangular	Light	0	0	4	0-100%
			Average	30	50	70	
			Heavy	60	100	100	
	Severity	Triangular	Low	0	0	40	0-100%
			Medium	30	45	60	
			High	50	100	100	
	Rating Score	Triangular	Good	0	0	2	0-10 point scale
			Fair	1	3.5	6	
			Poor	5	10	10	
Bleeding	Density	Triangular	Light	0	0	30	0-100%
			Average	20	45	70	
			Heavy	60	100	100	
	Severity	Triangular	Low	0	0	25	0-100%
			Medium	20	40	60	
			High	50	100	100	
	Rating Score	Triangular	Good	0	0	3	0-10 point scale
			Fair	1	4	7	
			Poor	5	10	10	
Cracking	Density	Triangular	Light	0	0	40	0-100%
			Average	20	50	80	
			Heavy	60	100	100	
	Severity	Triangular	Low	0	0	3	0-10mm

Table 3. Fuzzy Logic and Membership function

Type of distress	Classification	Membership function shape	Fuzzy sets	Function value range			Universe of discourse
				Left intercept	Value equal 1	Right intercept	
			Medium	1	5	9	
			High	6	10	10	
	Rating Score	Triangular	Good	0	0	4	0-10 point scale
			Fair	2	5	8	
			Poor	6	10	10	
Potholes	Density	Triangular	Light	0	0	0.2	0-1%
			Average	0.1	0.5	0.9	
			Heavy	0.8	1	1	
	Severity	Triangular	Low	0	0	25	0-100mm
			Medium	15	37.5	60	
			High	50	100	100	
	Rating Score	Triangular	Good	0	0	4	0-10 point scale
			Fair	2	5	8	
			Poor	6	10	10	
Patching	Density	Triangular	Light	0	0	0.2	0-1%
			Average	0.1	0.5	0.9	
			Heavy	0.8	1	1	
	Severity	Triangular	Low	0	0	6	0-20mm
			Medium	4	9	14	
			High	12	20	20	
	Rating Score	Triangular	Good	0	0	4	0-10 point scale
			Fair	3	5.5	8	
			Poor	7	10	10	
Edge Failure	Density	Triangular	Light	0	0	1	0-5%
			Average	0.5	2.5	4.5	
			Heavy	4	5	5	
	Severity	Triangular	Low	0	0	3	0-10%
			Medium	2	4.5	7	
			High	6	10	10	
	Rating Score	Triangular	Good	0	0	4	0-10 point scale
			Fair	2	4.5	7	
			Poor	5	10	10	

Table 4.Comparison between ratings obtained from Fuzzy Logic and MORTH

Sl.No.	Types of Distress	Rating Score			
		T.W.Fwa(1998)	Observed Value		
			Density	Severity	Rating Score
1	Cracking	1.33-2.35	10	1	1.42
			20	2	1.66
			90	9	8.63
2	Potholes		1	10	5
			0.5	10	1.43
			0.9	90	8.47
3	Raveling	1.58-2.67	10	10	0.672
			50	50	3.5
			70	50	7.79
4	Patching		0.5	10	5.5
			0.1	5	1.75
			0.9	15	8.79
5	Rutting	1.33-2.67	10	5	1.54
			50	15	8.19
			90	25	8.47
6	Edge Failure		1	3	4.5
			4	8	7.82
			3	9	8.28
7	Bleeding		10	10	1.07
			50	50	4
			90	80	8.14

5.1 Fuzzy Rules

The fuzzy rules adopted in the present study can be summarized as follows

R1: If density is light and severity is low, then rating is good

R2: If density is light and severity is medium, then rating is good

R3: If density is light and severity is high, then rating is fair

R4: If density is average and severity is low, then rating is good

R5: If density is average and severity is medium, then rating is fair

R6: If density is average and severity is high, then rating is poor

R7: If density is heavy and severity is low, then rating is fair

R8: If density is heavy and severity is medium, then rating is poor

R9: If density is heavy and severity is high, then rating is poor

6. RESULTS AND DISCUSSIONS

The membership functions for cracking density, severity and rating score are shown in Figure 3-5. Developed model was run and exact truth was proven for the trained data. The rule viewer developed in Figure 7. for cracking is used for computing the rating score for any value of inputs which lies in the degree of discourse. The computed data is given in the Table 4. for each seven types of distresses.

The surface viewer generates and plots an output surface map for two of the inputs and rating score. Surface viewer for cracking is shown in Figure 8.

Several researchers are assigning several weights to the distresses but they are very particular. Rating score observed by the T.W.Fwa (1998) using Fuzzy Logic within the 1-10 point scale is mentioned against the distresses as presented in Table 4. This gives the specific value corresponding to density and severity level. But adopted methodology overcomes this drawback and gives general computation Surface viewer. The advantage of this mapping is that we can able to find rating score for any value of density and severity level under the degree of discourse. Adopted rating score is limited to 1-10 scale has been taken for the comparison point of view. The some values obtained are tabulated separately in density, severity and rating score column of the Table 4. the outputs. On the surface viewer X-axis represents density-axis severity and Z-axis

7. CONCLUSIONS

Results indicates that FIS(Fuzzy inference system) can be used as probabilistic approach in predicting rating score for the type of distress as it may captures many uncertainties. By the use of surface viewer for rating score of distress value can be obtained at any value of density and severity within the defined degree of discourse. This may be said that fuzzy inference system approach can be effectively used for pavement condition rating score and the use of this approach will get simplicity and time savings. Rating score obtained for distresses are revealed one to ten as given in Table 4 and the values are similar as compared with the observation of other researcher.

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CLASSIFICATION MODEL FOR PERFORMANCE DIAGNOSIS OF DRY PORT BY RAIL

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Abstract: Dry port is an inland intermodal terminal directly linked by road or rail to a seaport as a center for the transshipment of sea freight to inland destinations. However roads contribute to pollution more than rail. For sustainable transportation systems, we need to improve the performance of rail dry port systems. The purpose of this research is to propose a diagnostic system for modeling and classification of rail dry port performance, by use of supervised ensemble learning approaches. We propose an empirical comparison of supervised ensemble learning approaches and application for performance diagnosis of dry port by rail. Our results demonstrate that the performance testing of proposed diagnostic system is found to be very satisfactory. The calculation methods demonstrating the results of the data are provided in this study diagnosis of dry port by rail. Finally, the conclusions for classification modeling for dry port by State Railway of Thailand (SRT) are given.

Key Words: Dry port, Ensemble learning, Classifier ensembles, Empirical performance comparison

1.INTRODUCTION

Dry ports or Inland ports is a part of the transport system, particularly in gateway regions having a high confidence on commerce. A dry port is an inland container terminal that has direct road, rail or other access to an adjacent sea port, and has export/import facilities. The dry port should in fact accept the container as if the container has reached the seaport itself. Dry ports offers a one stop service for cargo handling and a logistics solution for international export and import, as well as domestic distribution. It provides integrated port and logistics services with lots of logistics and supply chain businesses, such as exporters, importers, carriers, terminal operators, container freight station, bonded warehouse, transportation, third party logistics (3PL), empty container depot, as well as banks and other supporting facilities. Being the extension gate of international dry port, document formalities for port clearance and customs clearance will be completed in the dry port (United Nations, 2013). It is like taking the sea port to the industrial manufacturing regions that works both as a port of origin and as a port of destination. Dry ports normally have two types, Dry ports by road and rail. This study works on dry port by rail (The State Railway of Thailand) due to road makes pollution more than rail. For sustainable transport, we need to care about the pollution of environment. The rail transport is environmentally friendly with our globe by decrease the impact of pollution by physical of operation. Rail is a sustainable transport. The problem is the question about, How can we encourage the rail transport and competition with road?

The model of performance diagnosis for dry port by rail is the key of the competition performance of rail dry port. The performance diagnosis is a main thing for every problems. The main task of this study is modeling of the diagnosis system then classification the performance for dry port by rail to encourage the sustainable rail transport and competition with road. Supervised ensemble learning approaches are the machine learning method for performance diagnosis using a combination of statistical data and qualitative causal assumptions by expert. From the performance diagnosis by proposed method will yield the performance forecast model for dry port by rail.

Interdisciplinary is relating to more than one branch of knowledge. In this case is comparing and supplement statistical technique with expert knowledge for sustainable transport. Nowaday, It has no method can perform well without qualitative assumptions by expert. As our proposed method, It also has the problem. However the expert can give method about the solution. It’s complement each other like a conductor guides the musician in orchestra. As this study the expert will guide the machine learning method to play the data for given the result to improve the performance of sustainable rail transport. No universal method or multifunctional method. That is why interdisciplinary is necessary to be carefully for proposing the new method.

The paper is organized as follows. Section 2 describes the background of SRT dry port. In Section 3, we describe the methodology of experiments that is used in our research work and Section 4 for our data set of experiments. We propose application to the performance diagnosis in Section 5 with the experimental results of our technique. And Section 6 concludes the paper.

2.BACKGROUND

We will describe the overview background to introduce the important of SRT dry port. In the future, the government plans the development to be the gateway dry port of Southeast Asia. The planning and construction, that would connect all the countries of mainland Southeast Asia as Lat Krabang Inland Container Depot Bangkok is center of the region.

2.1 Lat Krabang Inland Container Depot (LICD)

The concept of an inland container depot near Bangkok has been developed in conjunction with the new deep sea port at Laem Chabang on the eastern seaboard by Japan International Cooperation Agency (JICA) in 1989. The study concluded that the ICD would be needed as a back-up facility to serve a rapid growing of industrial expansion in Thailand; the recommended site was a Greenfield area near Lat Krabang Industrial estate which is approximately 30km east of Bangkok. The chosen location which has been scheduled for development was adjacent to the main eastern railway line and surrounded by new Chonburi highway and new international airport on the north. By early 1993, the government purchased a number of essential lands, and the State Railway of Thailand (SRT) had been authorized to commence filling the site and carrying out the design and facility construction.

A design of the facilities has been implemented in accordance with the layout outlined in the JICA report; however, a number of adjustments have been made by the consultants who closely work with SRT, relevant government bodies, and potential customers.

2.2 Time and Cost of Construction

As a terminal is required by the Government to get ready as soon as possible, a “fast-track” design and construction system has been instituted. The terminal had been built in two overlapping phases; the first phase included the first module (Module A) - common area including road, administration building, utilities supply, and partly railhead area. It was completed in February 9th, 1995. The entire site which included the rest of modules (Modules B-F), perimeter roadways, and the remaining infrastructures and railhead area were finished in October 25th, 1995. The total cost of this project is 2,943.543 Million Baht or 73.59 Million USD (1 USD = 40 Baht).

2.3 Location and Facilities at LICD

Inland Transport Links, Lat Krabang ICD is located approximately 30 km east of Bangkok by rail, northwest of Hue Take railway station and approximately 118 km from Laem Chabang Port. By road: Access to LICD via Chao Khun Tahan road from the north. In the future, the LICD will be directly entered from the south by the new Bangkok-Chonburi express way no. 7 which is now under construction. By rail: LICD is linked to the eastern main line through Hua Takae station. Railway infrastructure has been provided to the rail transfer area inside the LICD alongside the modules. LICD modules, A terminal is provided with a full range of facilities for standardized modern ICD operations. The facilities divided into three sections are listed. Railhead area, 4 track railhead area, laid on ballast, approx.1,200 m long overall, the layout provides 4x500 m berths for train standing, access area are fully paved in reinforced concrete, railhead operators’ office and small workshop. Administration area, main office building, full facilities for customs, SRT, banks, etc. Modules office is available for commercial leasing, extensive car-parking area and large truck rest area, warehouse under customs administration, weigh-bridge. LICD modules, dimensions of a CY area, CFS shed length, and number of reefer points can be varied according to customer requirements. Each module contains the following facilities. Container Yard area is instantly adjacent to railhead operation area. 48 reefer points (380-440 v.3ph). Security fencing to customs standards around the bonded area. Terminal perimeter fencing. Warehouse from 5,800 to 8,440 square metres. Main office building : 1,736 square meters. Container Gate : 780 square meters. Workshop : 720 square meters. Canteen : 336 square meters. Washing area : 500 square meters. Container Yard : 48,000 - 97,600 square meters. Parking and miscellaneous : 14,654 - 25,998 square meters.

2.4 The Concession of LICD

It is the Government’s policy to allocate private sector to participate in the container and cargo handling services to the greatest extent practicable in order to ensure economic efficiency. To this end, the Government has decided to grant concessions to private sector to develop, manage and operate the inland container depot. The concession fees are utilized for developing and managing the common facilities. SRT has been appointed by the Government to be the administrator of the concession with the Module Operators (MO) as concessionaires. SRT invited interested and qualified applicants to submit Tenders for the Concession to manage and operate the Modules at Lat Krabang in March 1995 and June 1996. The Concession Contracts were signed in March 6th, 1996 (Modules A,B,C & F) and December 19th , 1997 (Modules D & E) for the first and second tenders respectively.

Functions of SRT at LICD, Monitoring the activities of the MOs to ensure that the operations have been implemented in accordance with the law and regulations, giving recommendation and providing updated information to the statutory bodies for any necessary changes. Investigating any complaints from the public which have not been resolved by the MOs. Monitoring the MO's performances under the concession contract, especially with regard to operational efficiency, environmental protection, safety procedures and satisfactory maintenance of fixed assets. Requesting and receiving operating statistics from the MOs and preparing reports on the use of the ICD's assets. Controlling land side traffic by ensuring gate control at the main gate, not at the Module gates. Figure 1 presents the operation of LICD.

Figure 1. The operation of LICD

3.METHODOLOGY

The ensemble approaches in machine learning have great potential as a classifier model to significantly increase prediction accuracy over individual classifier models (Schwenker, 2013). Mohamed *et al*. (2013) compared twenty prototypical supervised ensemble learning algorithms. The experiments support the conclusion that the Rotation Forest (Rot) family of algorithms outperforms all other ensemble methods which is much in line with the results earned by Zang (2008). Rot is a method for generating classier ensembles based on feature extraction. To create the training data for a base classier (Rodrı´guez and Kuncheva, 2006). According to the original Rot, let $x = [x_1,...,x_n]^{\top}$ be a data point described by n features and let X be the data set containing the training objects in a form of an $N \times n$ matrix. Let Y be a vector with class labels for the data, $Y = [y_1,...,y_j]^{\top}$, where y_j takes a value from the set of class labels $\{w_1,...,w_c\}$. Denote by $D_{1,1},...,D_{s,L}$ the classifiers that we proposed in to the ensemble and by F, the feature set. As with most Ensemble methods, we need to pick L in advance. In order to be fair in term of ensemble size, we construct an ensemble consisting of 40 Rotation Forests which are learned by AdaBoost during 5 iterations. This ratio has been shown to be approximately the empirically best in (Zhang and Zhang, 2008). The number of trees was fixed to 200 in accordance with a recent empirical study (Lobato *et al.*, 2013) which tends to show that ensembles of size less or equal to 100 are too small for approximating the infinite ensemble prediction. All classifiers can be trained in parallel, Parallel Computing (Almási and Gottlieb, 1989) will be benefit in this case. Rot method builds multiple classifiers on randomized projections of the original dataset. The feature set is randomly split into K subsets (K is a parameter of Rot) and Principal Component Analysis (PCA) (Han, 2001) is applied to each subset in order to create the training data for the base classifier. The idea of the rotation approach is to encourage simultaneously individual accuracy and diversity within the ensemble (Bibimoune *et al*., 2013). The size of each subsets of feature was fixed to 3 by Rodriguez *et al*. (2006). The number of sub classes randomly selected for the PCA was fixed to 1 as we focused on binary classification. The size of the bootstrap sample over the selected class was fixed to 75% of its size (Juan and Ludmila, 2006). Our proposed method investigated the performance $D_{1,1},...,D_{s,L}$ then selected via Mean Squared Normalized Error Performance Function (MSE). MSE is a network performance function. It measures the network's performance according to the mean of squared errors. Let $\hat{Y}$ is a vector of j predictions, and Y is the vector of the true values, then the (estimated) MSE of the predictor is

$$D_{s,L} = \frac{1}{n}\sum_{j=1}^{n}(\hat{Y}_j - Y_j)^2 \qquad (1)$$

Let

$$D = \{\text{Decision Trees, AdaBoost, ET}\} \qquad (2)$$

(Bibimoune *et al.*, 2013) (Breiman *et al.*, 1984) (Coppersmith *et al.*, 1999) (Freund, 2009) (Geurts *et al.*, 2006). Rot voted class prediction from L times to each recording from the best thing of D_s algorithms in Rot. According to the original Rot (Rodrı´guez and Kuncheva, 2006), algorithm 1 depicts view of the Training Phase of Rot then the Choosing Phase chooses only the best D_s by

$$D_s = \frac{1}{n}\sum_{c=1}^{n}(\mu_j(x) - \omega_c)^2,\ j = 1,...,c \qquad (3)$$

then denotes the best D_s by D'.

Classification Phase
Start
- Perform K-Fold Cross-Validation Phase and Training Phase by D' then feed each testing data set and classifier to next step below.
- For a given x, let $d'_{i,j}(\text{testing data set})$ be the probability assigned by the classifier D'_i to the hypothesis that x comes from class ω_j. Calculate the confidence for each class ω_j then assign x to the class with the largest confidence.
End

K-Fold Cross-Validation Phase

Given

$K = 10$;

training data set = Fold f;

testing data set $\neq$ Fold f;

for f = $1...K$ **do**

  Training Phase

  Given

  X : the objects in the training data set (an $N \times n$ matrix);

  Y : the labels of the training set (an $N \times 1$ matrix);

  L : the number of classifiers in the ensemble;

  $\{\omega_1, ..., \omega_c\}$: the number of subsets;

  for $s = 1, ..., n$ **do**

    for $i = 1...L$ **do**

      Prepare the rotation matrix R_i^a

      Split $\mathbf{F}$ (the feature set) into K' subsets: $\mathbf{F}_{i,j}$ (for $j = 1...K'$);

      for $j = 1...K'$ **do**

        Let $X_{i,j}$ be the data set X for the features in $\mathbf{F}_{i,j}$;

        Eliminate from $X_{i,j}$ a random subset of classes;

        Select a bootstrap sample from $X_{i,j}$ of size 75% of the number of objects in $X_{i,j}$. Denote the new set by $X'_{i,j}$;

        Apply PCA on $X'_{i,j}$ to obtain the coefficients in a matrix $C_{i,j}$;

      end

      Arrange the $C_{i,j}$ for $j = 1...K'$ in a rotation matrix R_i;

      Construct R_i^a by rearranging the columns of R_i so as to match the order of features in $\mathbf{F}$;

      Build classifier $D_{s,i}$ **using** (XR_i^a, Y) **as the training set**

    end

  end

end

Algorithm 1. Training Phase

4.DATA DESCRIPTION

The data set used in our experiments was taken from SRT in the period of ten years. It represents a variety of features and four different types of attributes consist of Nominal, Ordinal, Interval and Ratio without selection or preprocessing by expert due to the experiments need to show the method ability. It’s binary classification problem of small size (119 records), many features (152 features) and missing values. The prediction returns two scores to be class whether good or bad performance.

5.APPLICATION

From our database, we extract a training and a test base. First we must choose our training and test data. For this we use K-fold cross-validation method. We repeat the experiment 10 times and average the results, each of them is randomly generated indices for a K-fold cross-validation of N observations. Indices contains equal or approximately equal sections of the integers 1 through K that determine a partition of the N observations into K disjoint subsets. Repeated gives back different randomly generated partitions. K defaults to 10 (McLachlan *et al.*, 2004). In K-fold cross-validation, K-1 folds are used for training and the last fold is used for testing. This mechanism is iterated K times, leaving one different fold for testing each term. The method builds random blocks, which depend on the condition of the default random flow. Therefore, the results from the following experiments will change from those shown. To find the best learner, we compare the Rotation Forest family of algorithms, Rot with Decision Trees (Rot), AdaBoost (Rotb) and Extremely Randomized Tree (RotET) as based learner by Mohamed's literature (Bibimoune *et al.*, 2013) that Rotation Forest family of algorithms outperforms all other ensemble methods. The comparison is performed based on three performance metrics: MSE, area under the ROC curve (AUC) and accuracy (ACC).

Rot builds an ensemble of decision trees according to the classical top-down procedure.

AdaBoost (Freund, 2009) (Hsu *et al.*, 2010) (Friedman, 2001) (Freund and Schapire, 1997) trains learners sequentially. For every learner with index t and computes the weighted classification error as

$$\varepsilon_t = \sum_{i=1}^{n} d_i^{(t)} I(y_i \neq h_t(x_i)) \tag{4}$$

AdaBoost then increases weights for observations misclassified by learner t and reduces weights for observations correctly classified by learner t. The next learner $t + 1$ is then trained on the data with updated weights $d_i^{(t+1)}$. After training finishes, AdaBoost computes prediction for new data using

$$f(x) = \sum_{i=1}^{n} a_i h_i(x) \tag{5}$$

where

$$a_i = \frac{1}{2}\log\frac{1-\varepsilon_i}{\varepsilon_i} \tag{6}$$

are weights of the weak hypotheses in the ensemble. The output from the prediction method of an AdaBoost classification ensemble is an N-by-2 matrix of classification scores for the two classes and N observations.

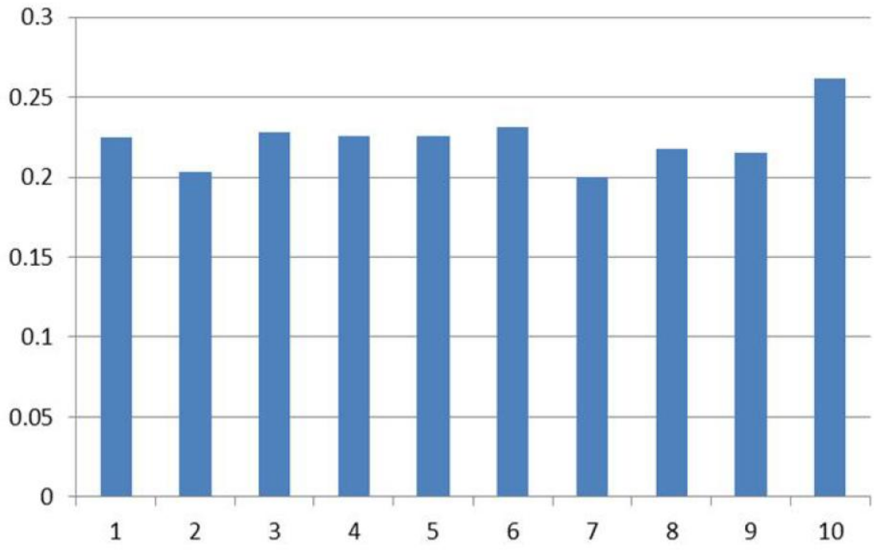
For ET, we use the regression tree package proposed in Geurts *et al*. (2006). The Extra-Trees algorithm builds an ensemble of un-pruned decision or regression trees according to the classical top-down procedure. Its two main differences with other tree based ensemble methods are that it splits nodes by choosing cut-points fully at random and that it uses the whole learning sample (rather than a bootstrap replica) to grow the trees.

Table 1. Mean of MSE, AUC and ACC

	MSE	AUC	ACC
Rot	0.272	0.729	0.729
Rotb	0.229	0.768	0.771
RotET	**0.223**	**0.775**	**0.777**

RotET is the best in three metrics of cost function as shown in table 1. We use the best significant method RotET to extend our experiment.

Figure 2, 3 and 4 show how the mean MSE, AUC and ACC are variation according to the experiment.



Figrue 2. RotET MSE variation according to experiment

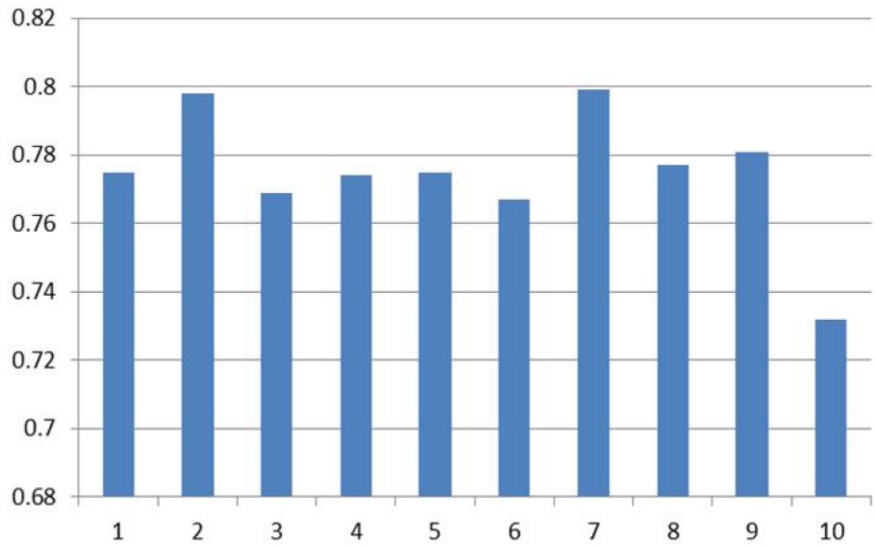


Figure 3. RotET AUC variation according to experiment

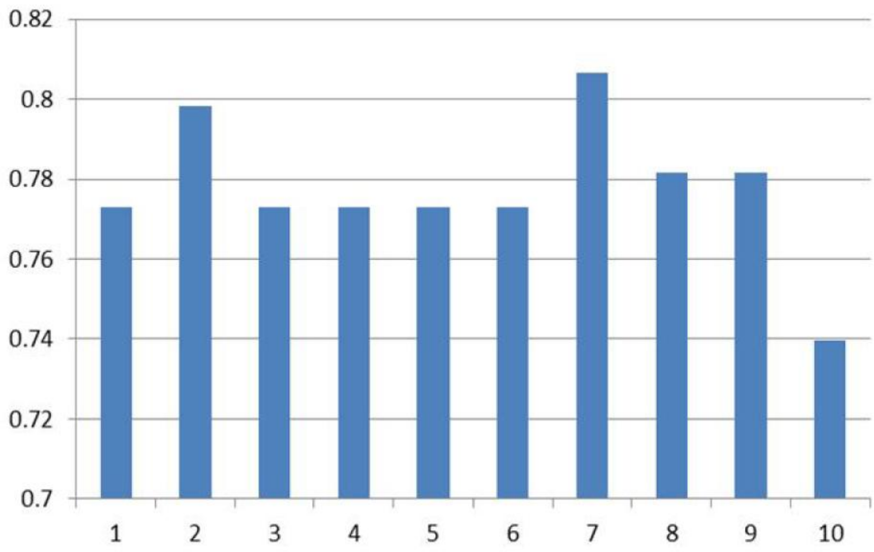


Figure 4. RotET ACC variation according to experiment

6.CONCLUSIONS

We described an empirical comparison between three outstanding prototypical supervised ensemble learning algorithms over SRT dataset with binary labels for SRT problem application. The experiments presented here support the conclusion that the success of RotET approach is closely tied to its ability to simultaneously encourage diversity and individual accuracy via rotating the feature space and keeping all principal components. The model will perform forecasting the performance in real time then the planning of operation and investment will forecast timely planning way by SRT operation unit to encourage the performance for SRT dry port.

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IDENTIFYING BLACK SPOTS USING SAFETY-POTENTIAL-BASED METHOD

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Abstract: The program for treating black spots can have a major impact on improving road safety. Thus, the identification of black spots is the first important step in the program. Identifying black spots based on their safety potential will result in locations with potential saving in accident costs. The identification process selects black spots which are most suitable for treatment. This paper introduces an approach to identify locations with potential saving in accident costs. In such approach, the key parameter for assessing the safety performance of black spots is their safety potential. The approach enables the identification of the black spots where safety improvement measures are expected to have the greatest economic gain, i.e. most cost effective.

Key Words: safety potential, black spot, accident cost, sapo-based, black spots identification

1. INTRODUCTION

Road traffic accident is the key challenge in road transport. The challenge is made more complicated due to the complex flow pattern of vehicular traffic, and the presence of mixed traffic along with pedestrians. Road traffic accidents cause loss of life and property damage.

Road planners and engineers in the highly motorized countries have learnt from the mistakes made in the past and realized the potential of road safety conscious planning and design. However, most of their counterparts in developing countries are often still preoccupied with the problems in road construction and maintenance and the challenge of increasing the network capacity. Thus, all too often, roads and road systems are being built or upgraded with little consideration given to road safety. As a result, black spots and black links are regrettably created and many road users are killed or injured.

Many lives could be saved and many accidents avoided, if the existing road infrastructure was managed according to the best practice in safety engineering. Corrective actions need to be taken on black spots which have been appropriately identified.

Therefore, the purpose of this paper is to introduce a new approach to identify and prioritize locations with potential saving in accident costs.

2. POTENTIAL ACCIDENT REDUCTIONS vs. POTENTIAL SAVING IN ACCIDENT COSTS

Traditional methods of black spot identification are based on numbers of accidents as the main indicator. As a result, the expected improvement is weighted by the reduction in numbers of accidents only, ignoring most other important aspects such as severity and economic effectiveness. To be effective, it is necessary to integrate these factors as indicators in identifying black spots. Such integration is proposed in the authors' new approach to black spot identification based on accident cost which is being considered as a 'master indicator'. This approach enables the identification of the black spots whose treatment can bring the optimal economical effectiveness. In order to have a better understanding of the approach, it is vital to tell the difference between *accident reduction potential* and *potential saving in accident cost*.

2.1 Accident reduction potential

Locations with accident reduction potential are locations where the recorded number of accidents is bigger than the expected number which is determined by using safety performance functions. These locations exhibit a potential accident reduction known as potential for safety improvement (Kononov, 2002).

Potential accident reduction is defined as the difference between the predicted crashes frequency determined by Empirical Bayesian estimation and the crash frequencies predicted by the safety performance function (SPF), as shown in Figure 1 (Tegge *et al.*, 2010).

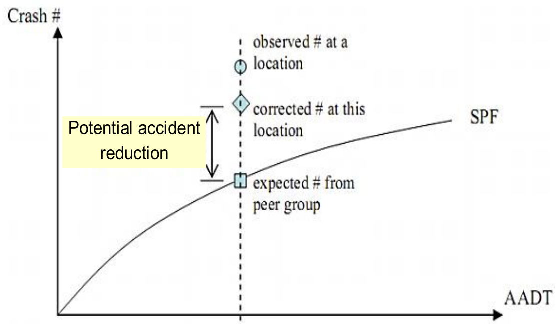

Figure1. Definition sketch of the *potential accident reduction* (Source: Tegge, 2010)

2.2 Potential saving in accident cost

Locations with potential saving in accident costs are where the actual accident costs are higher than the expected accident costs which are estimated based on real accident data. These locations exhibit a potential saving in accident costs known as safety potential (Ganneau and Lemke, 2008).

Safety potential is defined as the difference between actual accident cost and basic accident cost (expected accident cost) as shown in Figure 2. It describes the potential savings in accident costs that could be achieved by remedial measures (Bast and Sétra, 2005).

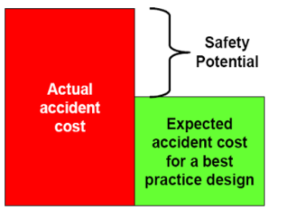

Figure 2. Definition sketch of the *safety potential* (Source: Ganneau and Lemke, 2008)

3. ANALYTICAL FRAMEWORK FOR IDENTIFYING BLACK SPOTS BASED ON SAFETY POTENTIAL

The identification of black spots based on safety potential can be divided into five steps as shown in Figure 3.

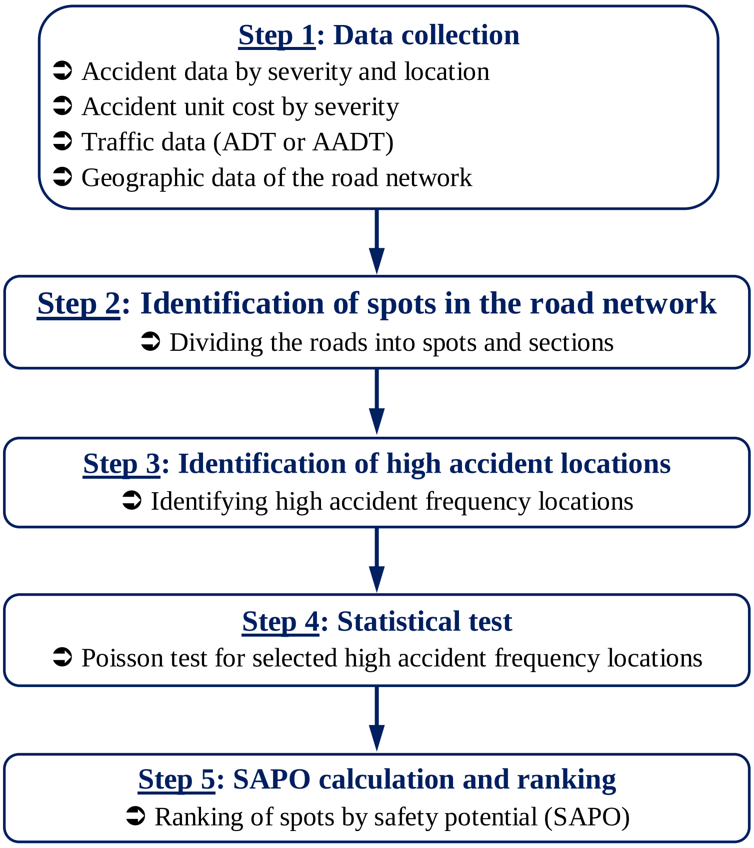

Figure3. Reference framework diagram for identifying black spots based on safety potential

3.1 Step 1 - *Data collection and statistical analysis of accidents*

The data collection is supposed to come up with the quantitative statistics of the following three sets of data:

- Accident data by severity and location;
- Accident unit cost by accident severity;
- *AADT* or *ADT* and Basic accident cost rate *(bACR)* of the road networks.

The crash period of three to five years is the best choice for the sake of data validity and reliability. In fact, a number of experts of road safety support of this point of view. First, Elvik (2008) stated that the length of the period used to identify black spots varies from 1 year to 5 years, a period of 3 years is used frequently. Next, research by Cheng and Washington (2005) showed that the gain in the accuracy of black spot identification obtained by using a longer period of three years was marginal and declined rapidly as the length of the period is increased. So, there is little point in using a longer period than 5 years. Additionally, LTNZ (2004) stressed that a 3-year crash period could be used in heavily trafficked networks or areas where road changes are recent or ongoing.

3.2 Step 2 - *Identification of spots by dividing the roads into sections and spots*

According to Bast and Sétra (2005), there are two possible ways of dividing a road into sections and spots.

(1) First - Dividing the road into sections and spots on basis of the network structure. This method of division is appropriate if a visualization of the accident occurrence on the road network is not available or the accident occurrence is to be analyzed in interaction with other influencing parameters (e.g. road improvement standard, accessibility, traffic) in the road network.

(2) Second - Dividing the road into sections and spots on basis of the accident occurrence. This method is appropriate if a visualization of the accident occurrence (three-year maps of the severe injury accidents) is available (see Figure 4) and no other section demarcations are required on the basis of a joint consideration of various influencing parameters.

3.3 Step 3 - *Identifying high accident frequency locations*

This step is aimed to identify the list of high accident frequency locations within the sample of locations established according to the division of the road into sections and spots as in Step 2. Such identification is based on the threshold value of observed numbers of injury accidents at every site in the sample in three consecutive years. Any site with observed number of accidents higher than the threshold value is listed as a high accident frequency location.

3.4 Step 4 - *Statistical tests*

As crashes are rare and random, the number of reported accidents will change from one time period to another even if the expected average crash frequency remains the same (Elvik *et al.*, 2009). To make sure that the spots identified as hazardous are not merely the result of random variation in accident counts, statistical tests are performed. The test consists of the comparison of the *observed number of accidents* with the *expected number of accidents* of that spot and the determination of the importance of the deviation by calculating the confidence interval of the observed values (Bast and Sétra, 2005).

Furthermore, the Poisson test can be used to determine whether a recent increase in accidents at a site was due to random fluctuation only (Baguley, 1995).

3.5 Step 5 - *Calculation of safety potential and ranking of spots*

This step is aimed to (1) calculate the safety potential *(SAPO)* of the spots identified in Step 3 and verified in Step 4, and (2) rank these spots according to the established safety potential.

The calculation of the *SAPO* is done using the following accident parameters: *accident cost, accident density, accident cost density, basic accident cost density, accident rate, accident cost rate,* and *basic accident cost rate* (Nguyen, 2013). Then, the sites in the road network are ranked on the basis of the magnitude of the safety potential. Such ranking is of great use for further detailed studies to determine possible improvement measures. The higher the *SAPO*, the more societal benefits can be expected from improvements of the sites.

The analytical framework for identifying locations with potential saving in accident costs or safety potential is summarized in Figure 3.

4. PRACTICAL IMPLEMENTATION OF IDENTIFYING BLACK SPOTS BASED ON SAFETY POTENTIAL

Table1. Normative values of various accidents characteristics

ACCIDENTS ON URBAN ROADS IN PHU-NHUAN DISTRICT, HO CHI MINH CITY, VIETNAM				
Categories	**Description**	**Quantity**	**Percent**	
Severity-based accident types	**AS1**: Accidents with fatalities	59	11.11%	
	AS2: Accidents with seriously injured	307	57.82%	
	AS3: Accidents with slightly injured	123	23.16%	
	AS4: Accidents with serious material damage	5	0.94%	
	AS5: Accidents with material damage but with driving while intoxicated	33	6.21%	
	AS6: Accidents with material damage but without driving while intoxicated	4	0.75%	100.00%
Consequences	Persons killed	61	N/A	
	Persons injured	672	N/A	
	Property damage with motorcycles	943	N/A	
	Property damage without motorcycles	186	N/A	
Special circumstances	Accidents involving motorcycles	493	92.84%	493/531
	Accidents involving bicycles	19	3.58%	19/531
	Accidents involving pedestrians	46	8.66%	46/531
	Drink-driving accidents	18	3.39%	18/531
Time-based accident types	**Day-Time Accidents**	167	31.45%	
	Night-Time Accidents	364	68.55%	100.00%
Conflict-based accident types	**AC1: Driving Accidents** (caused by loss of control of the vehicle without influence of other road users)	30	5.65%	
	AC2: Turn-off Accidents (caused by a collision between moving vehicles with other road users during a turn-off maneuver at junctions)	18	3.39%	
	AC3: Turn-into/Crossing Accidents (caused by a collision between moving vehicles with other road users having right of way during a turn-into or crossing maneuver at junctions)	138	25.99%	
	AC4: Accidents With Crossing Pedestrian (caused by a collision between a vehicle and a pedestrian crossing the road)	49	9.23%	
	AC5: Accidents With Parked Vehicle (caused by a collision between moving vehicles with parked or stopped ones)	16	3.01%	
	AC6: Accidents along Longitudinal Direction (caused by a collision between road users which drive in the same or opposite direction)	254	47.83%	
	AC7: Other Accidents (not classified as any of the six types above)	26	4.90%	100.00%
Direction-based accident types	**AD1**: Collision between a moving vehicle with a vehicle that has just started, is stopped, or parked	9	1.69%	
	AD2: Collision with a vehicle which drives in front or has stopped	113	21.28%	
	AD3: Collision with a vehicle which drives parallel in the same direction	42	7.91%	
	AD4: Head-on collision	143	26.93%	
	AD5: Collision with a vehicle which turns into or crosses	136	25.61%	

	AD6: Collision between a vehicle and pedestrian	51	9.60%	
	AD7: Collision with an obstacle on the road	5	0.94%	
	AD8: Run-off accident (right)	11	2.07%	
	AD9: Run-off accident (left)	10	1.88%	
	AD10: Other accidents	11	2.07%	100.00%
Road conditions	Dry road	449	84.56%	
	Wet road	19	3.58%	
	Unknown road condition	63	11.86%	100.00%
	Total Accidents	**531**		

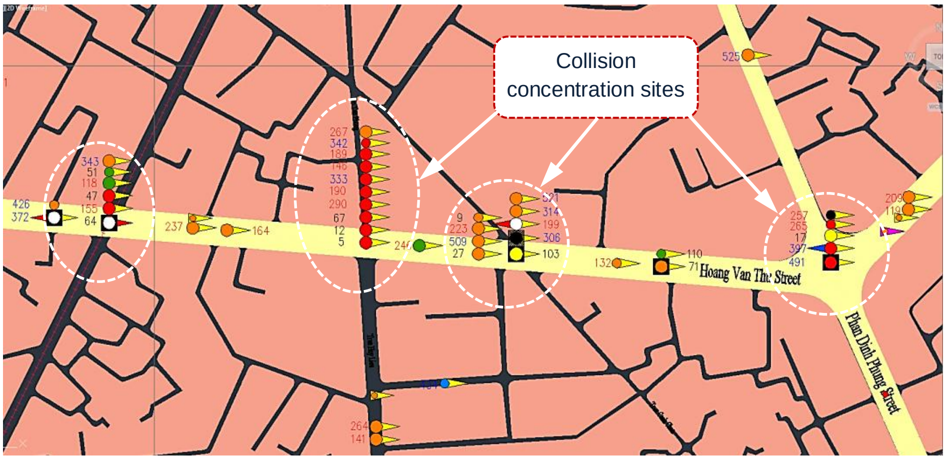

Figure4. Three-year Accident Pin Board of study area

Table2. Statistical test for a number of typical high accident frequency locations

No.	Spot ID	Observed Injury Accidents				Long term Average	95% Confidence Interval		Poisson Cumulative Probability P(X≥x,μ)	
		2009	2010	2011	Total		Min	Max	Formula	Value
1	**S.002**	3	4	3	10	3.33	1.90	4.77	P(X≥6,3.33)	0.1207
2	**S.010**	5	4	3	12	4.00	1.52	6.48	P(X≥8,4.00)	0.0511
3	**S.011**	4	2	3	9	3.00	0.52	5.48	P(X≥7,3.00)	0.0335
4	**S.034**	5	5	4	14	4.67	3.23	6.10	P(X≥8,4.67)	0.1012

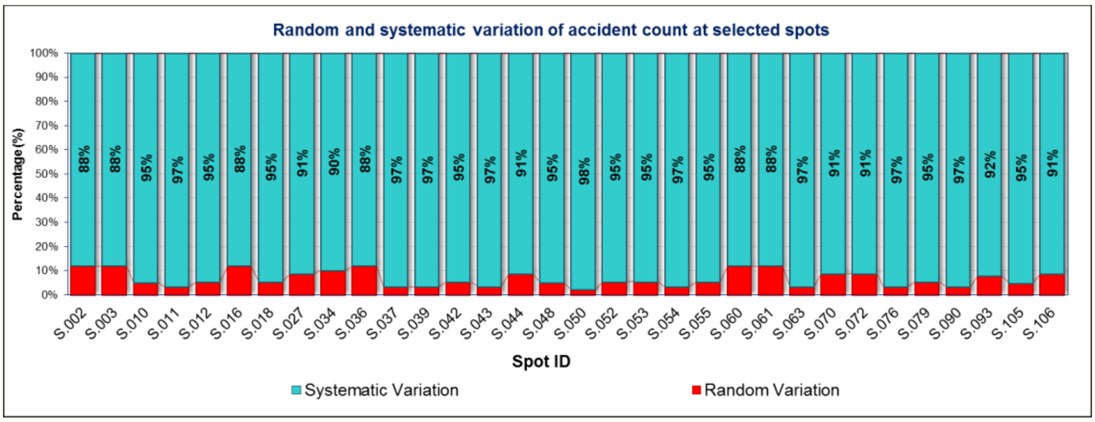

Figure5. Percentage of random and systematic variations of accident counts at 32 selected spots

In order to provide a detailed description of analysis steps in identifying locations with potential saving in accident costs, an urban district named Phu-Nhuan in Ho Chi Minh City (HCMC) was selected as the study area. Before identifying the potential locations, some amount of a priori knowledge about the safety performance of the road network is required. This knowledge was compiled in an extensive data set describing various characteristics of accident distribution profiles as shown in Table 1. This data set was compiled for all types of urban roads over a period of 3 years and contains 36 different parameters related to accident occurrence, such as accident type, severity, and roadway conditions. The set represents a source of a priori knowledge base required for accidents mapping and the estimating of basic accident cost rate.

4.1 Stage 1 - *Accident data collection, statistical analysis, and mapping accidents*

Accident data collection and statistical analysis are the prerequisites for identifying locations with potential saving in accident costs. However, it was only possible to access a limited amount of raw road accident data from the local authorities. Accordingly, by means of the analysis of the raw data, a set of intermediate input data was established – the 3-year Accident Pin Board of the period 2009-2011 (3-year APB). The 3-year APB (Figure 4) serves as an accident map with the detailed information on the following aspects:

- Location of accidents;
- Severity-based accident types;
- Conflict-based accident types;
- Special accident circumstances.

The locations of accidents are marked on the GIS-based map. The severity-based accidents are marked by pin sizes, the conflict-based accidents are marked by pin colors, and special circumstances of accidents are marked by colored triangles as shown in Figure 4.

4.2 Stage 2 - *Dividing the road network into sections and spots based on 3-year APB*

This step aims to identify locations where accidents have clustered with the visual support of the 3-year APB (Figure 4). Collectively, 108 accident spots were identified, coded, and the total number of accidents at each of which was also determined. Such intermediate data not only established the divisions of the road network into sections and spots but also facilitates the identification of high accident frequency locations in the next step.

4.3 Stage 3 - *Identifying high accident frequency locations*

To identify high accident frequency locations, the data of 108 identified accident spots in Step 2 are statistically processed. As a result, the statistical sample of number of injury accidents for the three- year period is established. This sample has an average value of 5.93, median value of 5, and standard deviation of 3.34. Accordingly, the suitable threshold value of 6 is selected. Any spot with more than 6 recorded injury accidents was considered a high accident frequency location. With this threshold as the criterion for identification, a total of 32 high accident frequency locations were determined (see Figure 5) with 302 injury accidents for the three - year period, accounting for 52.86 percent of all injury accidents in the study area.

4.4 Stage 4 - *Statistical test for identified high accident frequency locations*

This step estimates the percentage of random and systematic variation in accident count at each identified location. In order to obtain such estimation, it is necessary to calculate the confidence interval of the particular sample of accident count at each spot. The changes in observed accident numbers within the confidence interval form the systematic variation. The changes in observed number of accidents beyond the confidence interval form the random variation.

The occurrence probability of an observed accident value that is higher than the maximum value of the confidence interval can be calculated by using Poisson probability formula. The percentage of random variation of accident count at a spot is calculated by Poisson cumulative probability as shown in Table 2.

The calculation method applied to the case of Spot S.002 serves as a typical example for all other spots. The annual numbers of recorded injury accidents at this spot for the year 2009, 2010 and 2011 were 3, 4, and 3 respectively. These figures form a sample of 3-year accident count whose long-term average value equals 3.33. The 95% confidence interval of the sample was 1.90 and 4.77. The determined interval indicates that the change in number of observed accidents from 2 accidents to 5 accidents is the real change or systematic variation. This systematic variation makes it possible to estimate the quantity of random variation of observed accidents at this spot by considering whether the annual number of observed accidents were distributed pursuant to Poisson probability distribution. Specifically, for the case of a random variable *X* with the mean number of successes (μ) being 3.33, the cumulative probability $P(X \geq 6, 3.33)$ would be 0.1207 or 12.07%. This value is the very random variation of observed accidents (see Table 2 and Figure 5).

4.5 Stage 5 - *Calculating safety potential and ranking of spots*

The calculation of the safety potential and the ranking of spots according to their safety potential require such accident parameters as *accident cost*, *accident density*, *accident cost density*, *basic accident cost density*, *accident rate*, *accident cost rate*, and *basic accident cost rate*. The results are shown on Figure 6, in which the spots were ranked by their *SAPO* in order to provide a priority list of spots to be treated.

Figure 6 shows that safety potential of a spot is the difference between actual accident cost (AC_a) and its expected accident cost (*bACD*) of the spot. This expected value depends on the basic accident cost rate (*bACR*) for a best-practice design. In this research, the value of *bACR* was estimated from 15 percent of the overall distribution of accident cost rate of every specific type of spots.

The highest value of SAPO in Figure 4 is 116,240 U.S. dollars per year. This means that each year at the spot, an accident cost of 116,240 USD could be saved if the best-practice design was implemented. Therefore, if the cost of a safety countermeasure at the spot is given, the benefit-cost ratio of the safety improvement project can be computed. Furthermore, with the ranking of spots by *SAPO*, it is easy to decide which and how many spots could be treated depending on the financial resources. This fact adds new aspects to the management of black spots and increases the flexibility of the selection of black spots to be treated by means of the prioritization which is based on economic effectiveness of the selected treatment.

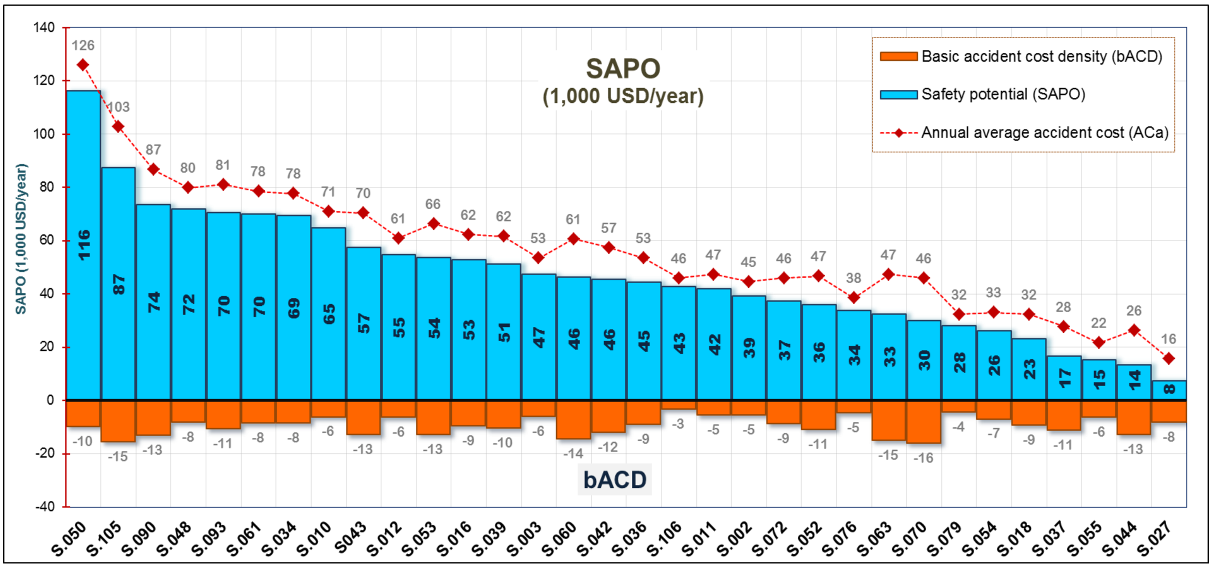

Figure6. Safety potentials of 32 selected spots within the road network (2009 -2011)

5. SUMMARY

This research presents a new black spot identification method which is expected to result in increased economic as well as societal benefits. In order to ensure these benefits, this new method takes safety potential as its key parameter. With this key parameter, the method facilitates not only the identification but also the prioritization of black spots. Such facilitation, in turn, enables the suitable selection of which black spots to be treated first depending on the particular financial conditions of the given region or country.

In conclusion, the method proposed in this research introduces a new aspect in black spot management by integrating prioritization with identification. In this way, the method can help optimize black spot treatment programs with limited financial resources which are facing most developing countries. The benefits obtained are considerable in terms of economic efficiency. Therefore, the method is expected to contribute significantly to accident reduction efforts in developing countries.

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AN EVALUATION OF FLYOVER-IMPROVED INTERSECTIONS: A CASE STUDY OF AIRPORT INTERSECTION

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Abstract: A flyover over an existing at-grade intersection is constructed to reduce traffic congestion. However, under the flyover which has been shown to help relieve traffic congestion at the intersection, the traffic signal control still uses the same control method as the "before" situation; that is the fixed time control plan. After the installation of the flyover, it was found that about 45% of traffic diverted to it, the time delay reduced by 34% over the same period. The economic evaluation results show that the net present value equals 361.64 million baht, benefit cost ratio, 1.34 and internal rate of return, 37.58 percent. The paper describes economic benefits of the flyover and presents the performance of the flyover improved intersection and points out the remaining problems under the flyover. Suggestions for improving performance of the existing traffic signal are made using results from SIDRA software.

Keywords: Flyover, Cost-benefit analysis, Delay, Traffic congestion

1. INTRODUCTION

The site in the case study is an existing at-grade signalized intersection where a flyover was built. The site is located at the intersection of intercity Highway no. 43 and provincial Highway no. 4135 which runs to the Hatyai international airport in Songkhla province, Thailand. This cost of the flyover is 249.5 million baht.

A flyover is a bridge constructed along an intersecting highway over an at-grade intersection. It allows two –direction traffic to flow at free flow speed on the bridge. The flyover is one of the methods for solving traffic problems at at-grade junctions on highways including capacity, congestion, long delay and queue length. Traffic signalization at the improved intersection still uses the same fixed time control plans, even after the installation of a flyover over the intersection.

Most of the flyovers in Thailand are constructed at the junctions on highway bypasses of big cities. There are 29 of these flyovers bridges constructed on one of the two intersecting highways over existing at-grade fixed-time control signalized intersections in Thailand (excluding Bangkok and its vicinity), it can support traffic volume of around 25,000 – 45,000 vehicles/day.

To assess the benefits of a flyover, a study case was chosen. It was an at-grade signalized intersection where two 4-lane highways intersect. The flyover was built along the intercity highway over the highway to the Hatyai airport (Figure 1). Economic evaluation of the flyover was conducted in terms of Net Present Value (NPV), Benefit–Cost Ratio (BCR) and Internal Rate of Return (IRR). To improve the overall performance of this intersection, a better traffic signal timing is needed; optimum cycle times and green times are ontained using the SIDRA software for input into the various fixed time plans.

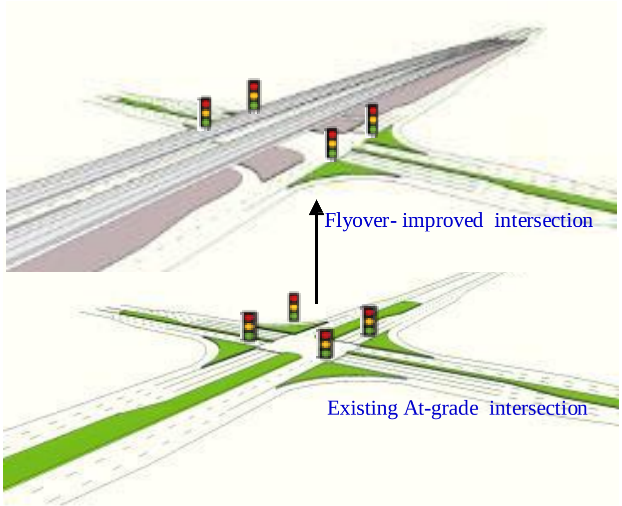


Figure 1. Layout of an at-grade intersection converted to a flyover-improved intersection

2. RESEARCH FRAMEWORK

The research addresses two issues: the efficiency and the road safety aspects of the flyover intersection. This paper focuses on the ecomic efficiency. The research framework consists of six steps (see Figure 2) covering three time periods (before, during and after construction), (see Table 1). The first is the literature review on road safety, cost-benefit analysis and SIDRA software etc,. Second step involves the selection of case study location. The third is data collection; intersection traffic movement count, time of vehicle delay, traffic signal timing, physical layout, accident statistics, and inspection of all hazardous zones. The fourth is the analysis/evaluation step; effect of the flyover on traffic flow, economic analysis, hazardous areas, cause of accidents and accident costs. The fifth is conclusions followed by the recommendations on how to improve the flyover model in terms of traffic flow, vehicles delays and other problems that still exist.

3. DATA COLLECTION

This intersection data were collected over the three time periods (before, during and after construction). Physical and traffic data, accident statistics and construction cost data were collected. Data were collected for the year 2009 to 2012. These data were used to analyze the benefits by comparing the before and after situations, the required data include traffic movements, vehicle delays, signal control plans, and flyover construction cost.

3.1 Traffic movement count

For the existing at-grade intersection; traffic movements were recorded for each of the legs/directions for all vehicles entering the intersection, at locations marked as 1, 2, 3 and 4 in Figure 4 (A), (Figure 3a).

For the flyover- improved situation; traffic movements were counted at the locations marked A, 1, B, C, 2 and D on the main road, and on the secondary road at the locations marked 3 and 4 (Figure 3b). Vehicles were categorized into five groups: 2-wheelers (MC), 3 and 4-wheelers (PC), 6-wheelers (MT), Bus (B) and Heavy truck (L), (Goyal et al., 2009). The traffic volumes were converted to equivalent passenger car unit (PCU) by the unit factor 0.33, 1.0, 1.75, 2.25 and 2.25 (Vesper, A. 2011), respectively.

The 12- hour traffic volumes before the flyover construction equal 60,351 PCU. On highway route 43; from the "East" traffic entering the intersection equals 24,359 PCU, and the "West" entering the intersection 11,842 PCU. On highway route 4135, traffic from the "South" entering the intersection equals 12,196 PCU and traffic from the "North" equals 11,954 PCU (Figure 4 (a)).

After the completion of the flyover, the 12-hour traffic volumes equals 64,219 PCU, a significant increase from the before situation. The traffic on highway route 43, at the ground level, from the "East" entering the intersection equals 9,777 PCU, from the "West" equals 2,546 PCU. On highway route 4135; the corresponding volumes from the "South" and the "North" are 14,298 PCU and 13,294 PCU respectively. On the flyover, the traffic from "East" to "West" and vice versa was 13,426 PCU, and 15,958 PCU respectively (Figure 4 (b)).

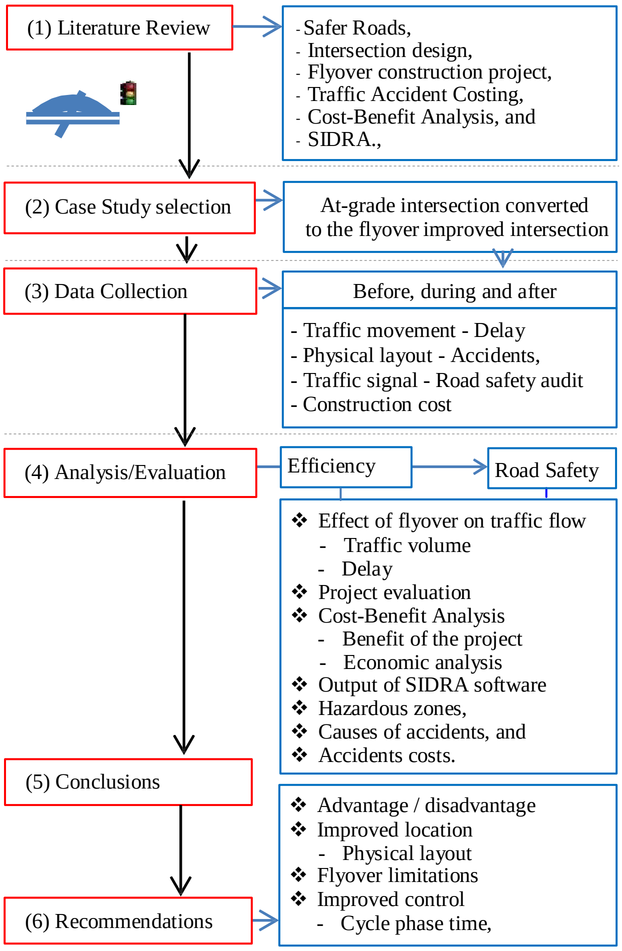


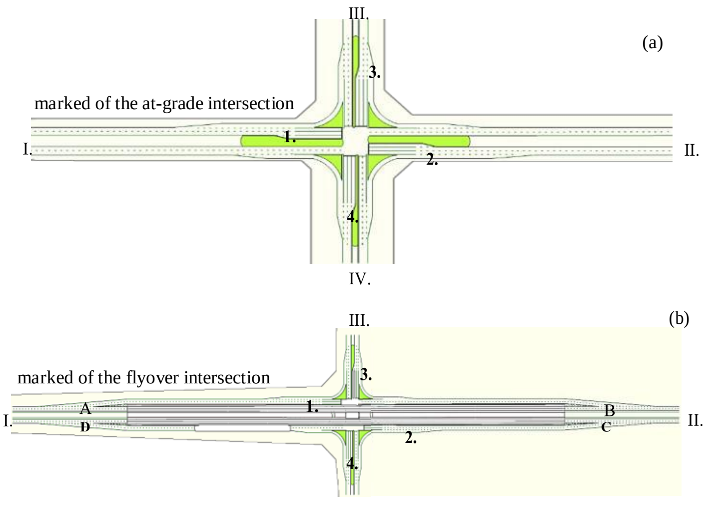
Figure 2. Research framework

3.2 Delay (DL)

This data depend on the cycle phase time of each event, the total delay at the at-grade intersection is 535.27 minutes (32,116 seconds) (Figure 5 (a)) and at the flyover-improved intersection is 347.42 minutes (20,845 seconds) (Figure 5 (b)). Average delay per vehicle for the at-grade situation is 94.88 second and for the flyover- improved situation 90.41 second.

Table 1. Summary collected data

Items \ Time period	At-grade intersection being converted to Flyover intersection		
	Before	During	After
1. Flyover location	Highway route no 43 and highway route no 4135		
2. Traffic movement	Yes	Yes	Yes
3. Delay	Yes	-	Yes
4. Queue length	Yes	-	Yes
5. Traffic Signal	Cycle time 244 s.	Cycle time 254 s.	Cycle time 224 s.
6. Speed	Avg: 28.5 km/hr.	-	Avg: 45.7 km/hr.
7. Dimensions	Yes	-	Yes
8. Conflict points	50 points	-	64 points
9. Road Safety Audit	Yes	Yes	Yes
10. Accident statistics	17 crashes (28 months)	52 crashes (30 months)	9 crashes (15 months)
	7.3 crashes/year	20.8 crashes/year	7.2 crashes/year
11. Construction cost	249,597,672.5 Baht		



Traffic count locations:
A : Vehicles travelling on the main road over the to Intersection to II.
B : Vehicles travelling from A to main road II.
C : Vehicles travelling from II over the Intersection to I.
D : Vehicles from C over the Intersection main road I.
1, 2, 3, 4 : Vehicles approaching the intersection (under bridge) and dispersing to I., II., III. and IV. directions

Figure 3. Turning movement count locations at the existing and flyover improved intersection

3.3 Queue Length (QL)

The q-length of the vehicles that stop to wait for new cycle time on each leg of the intersection depends on the red period of the cycle time. After the installation of the flyover, the queue is reduced. The stopped vehicle ratio of the at-grade situation is 1.55 : 1 and the flyover situation 3.16 : 1.

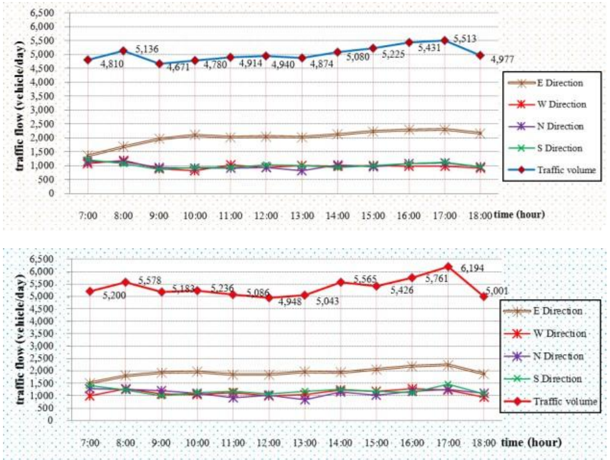


Figure 4. At-grade intersection traffic volume and Flyover intersection traffic volume

3.4 Traffic Signal

Traffic signal for both situations was controlled by fixed time plans. The before situation was controlled by two programs; the cycle time in the first program is 244 seconds (Figure 6 (a)), applied during 0600 to 2100 (4 phases per cycle), and the second program was flashing yellow, applied during 2100 - 0600. The flyover- improved intersection is similarly controlled as in the before situation of the at-grade intersection, although the length of the cycle time has been reduced to 224 seconds (DOH, 2011), but it is still a long cycle time (Figure 6 (b)).

3.5 Other important data

Accident statistics : Accident statistics collected between 2007 – August 2013 by the Department of Highways, Police and Emergency Medical Services System (EMS) are shown in Table 2.

Vehicle Speed : Vehicle speeds in the direction of the flyover were measured by means of a radar-gun are shown in Figure 7, which displays the 50 percentile (mean speed) and the 85 percentile data.

Investment cost : The investment cost of the flyover is about 249 Million Baht, the standard construction cost of a flyover is about 75,000 (2,318.9 USD) Baht/square meter.

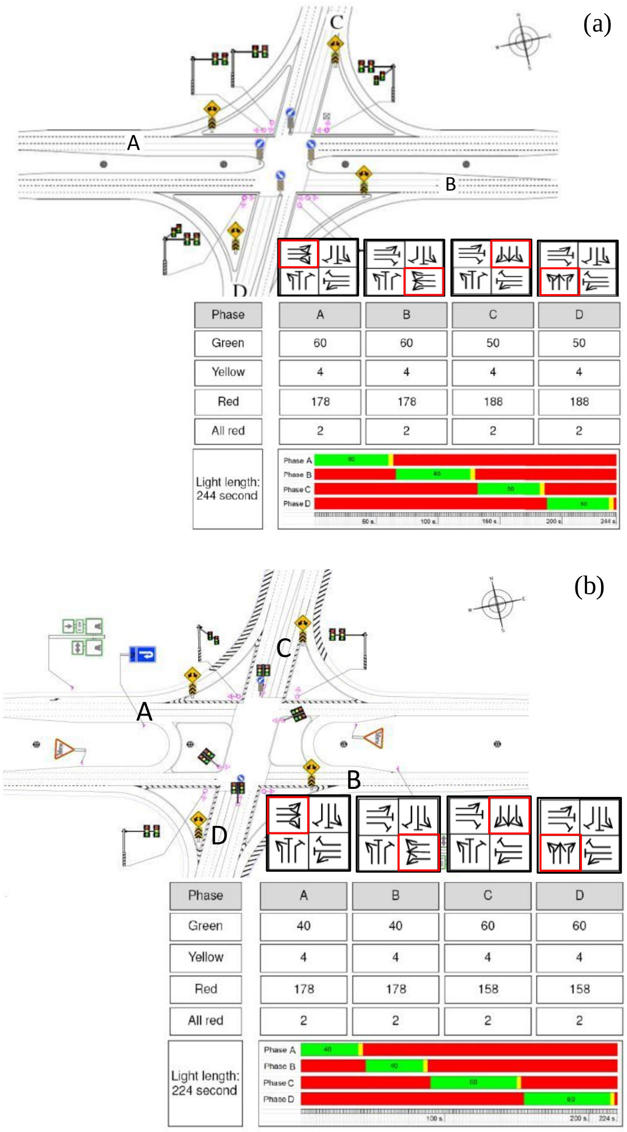


Figure 6. Traffic signal programs for At-grade and Flyover- improved situation

Table 2. Accident statistics (2007–August 2013)

Casualty type	Number of casualties for the 3 periods		
	Existing intersection	**During construction**	**Flyover-improved intersection**
Fatal	-	6	-
Disabled	0.85	1.95	0.45
Seriously injured	8	23	1
Slightly injured	17	39	9
Property damage only	25	67 times + 701,400 Baht	10
Damage to DOH property	-	533,500 Baht	-
Number of Years considered	2.33	2.50	1.25

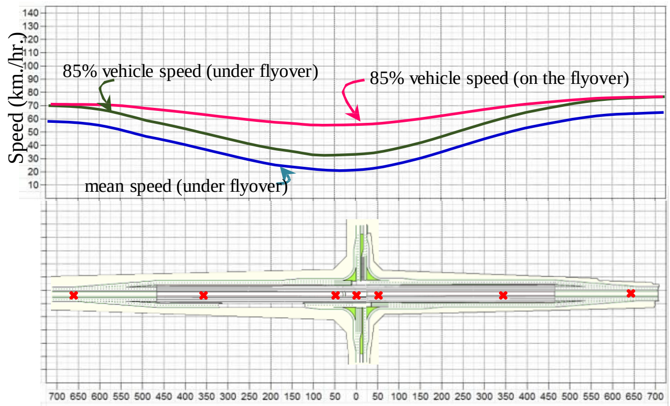


Figure 7. Vehicle speed at marked locations

4. PROJECT EVALUATION

The project evaluation compares the case with and without the flyover project in order to assess the benefits arising from the project. The benefits include savings in the value of time (VOT), vehicle operating cost (VOC) and saving in cost of accidents as shown in Table 3. Details are as follows;

4.1 Vehicle operating costs (VOC)

Vehicle operating costs comprise the cost of fuel, lubricant cost, idling of the engine and operating cost, these correlated to traffic volume, composition, and vehicle speed (V.Watcharin, 1994).

When vehicles are waiting for green signal at the intersection stop line with the engine running; wasteful fuel consumption results which also vary with types of vehicles (Goyal, S. K., Goel, S., & Tamhane, S. M., 2009). The different traffic volume between the case without and with project can be converted to equivalent monetary term.

This study used an average fuel cost of 37.18 Baht/litre (6/08/2013, http://www.pttplc.com/th/Pages/home.aspx), and fuel consumption of an average passenger car unit (PCU) which stops and idles for 1 minute = 20 cc. (http://www.sahavicha.com/?name=knowledge&file=readknowledge&id=1623). This amounts to a monetary loss of 0.75 Baht per minute. On the bridge, Luophongsok used the HDM-4 software to calculate the cost in terms of transportation saving cost at free flow speed, the results are show in Table 4 (Luophongsok et al., 2011).

4.2 Value of time (VOT)

Value of time means the cost (equivalent to money) that is lost due to delay during a trip, but when traffic flow through the intersection is improved after the flyover is operational, the increased intersection eficiency helps reduce travel time and road users can use this time to do other activities.

Value of time in the province of the case study can be calculated from the gross province product (GPP), number of people employed and average hours of work (Table 5). Accordingly, the value of time in Songkhla province was 83.86 Baht/PCU/hour in 2011, adjusted for 2012, the value of time for 2012 was estimated at 84.38 Baht/ PCU/hour.

On the flyover bridge, Luophongsok using the data from Department of Highways estimated the VOT at 117 Baht/PCU/hr (Luophongsok et al., 2011). Adjusted for inflation in at 3.3% (Bank of Thailand, 2012), give the value of time for 2012 at 120.86 Baht/PCU/ hour.

The benefits of the project that consisted of savings in vehicle operating costs (VOC) and the value of time (VOT) are summarized in Table 6.

Table 3. Summary of delay, traffic volume and accident statistics

No.	Items: Issues	(units)	Intersection situation: At-grade	Flyover	Results: Reduction		Increase	
1	Total vehicle delay per day	(second)	32,116	20,845	11,271	34.5% -		
		(minute)	535.3	347.4	187.9			
		(hour)	8.9	5.8	3.1			
2	Traffic volume per day	(PCU/ day)	60,351	64,219 PCU | Truck 47,261 | 16,958 73.6% | 26.4%	-		3,904	6.0%
	Under the flyover		60,351	39,915 (62.16%) PCU | Truck 32,837 | 7,078 82.2% | 17.8%	20,436	33.8%	-	
	On the flyover		-	24,304 (37.8%) PCU | Truck 14,424 | 9,880 59.4% | 39.6%	-		24,304 (37.8%) PCU | Truck 14,424 | 9,880 59.4% | 39.6%	
3	Accident statistics	Before	During	After	After - Before			
	Fatality (Fal)	-	6	-	-	-	-	
	Disability (Dis)	0.85	1.95	0.45	0.01	1%	-	
	Serious Injury (SI)	8	23	1	6 people	75.0%	-	
	Slight Injury (SL)	17	39	9	0 people	1.0%	-	
	Property Damage Only (PDO)	25	67 times + 701,400 Baht	10	22.6%		-	
	DOH damage	-	533,500 Baht	-	set at 28 months		-	
	Months	28	30	15				
	Crash/year	7.3	20.8	7.2	0.1	1.37%	-	

Table 4. Vehicle operating costs in PCU (Luophongsok et al., 2011)

VOC	Speed (kilometer per hour): 10	20	30	40	50	60	70	80	90	100	110	120
(Baht/PCU/ Km.)	10.23	6.15	4.91	4.34	4.09	3.99	4.01	4.13	4.35	4.65	5.04	5.54

Source : Calculated by HDM-4 software

Table 5. Value of time (VOT) in Songkhla province

Year	GPP (Million THB)	Employed	Avg of hours work (year)	Value of time: VOT (THB/hour)
2007	159,008	744,042	2,950	72.44
2008	160,683	766,674	2,985	70.21
2009	151,755	790,553	2,930	65.52
2010	186,457	815,618	2,870	79.65
2011	214,799	837,093	3,060	83.86

Source: Adapted from the National Statistical Office (2012)

4.3 Cost of Accidents

Accident costs were obtained by using Equation . As the accident statistics from the 3 agencies did not record the number of disability people, the calculation was based on the work of Dr.Nima Asgari (WHO, 2013) who stated that " for every road crash, where there is one death, there will be 20 injured people and 1 of 20 injured people will become to a disabled person". Thus for this study, 5% of the number of injured number are taken as the number of disabled.

Table 6. The benefits of the project in terms of VOC and VOT

No.	At-grade to Flyover	Value	Unit	Vehicle operating cost (VOC)	Value of time (VOT)
1	**Under the flyover (intersection)**			Fuel consumption (0.75 Baht/PCU/minute)	Loss of time (84.38 Baht/PCU/hour)
	Time of all vehicle delay (reduced results)	187.9	minute/ day	187.9 x 0.75 = 140.93 Baht/day	187.9 x (84.38/60) = 264.25 Baht/day
				140.93 x 300 = 42,279.00 Baht/year	264.25 x 300 = 79,275.01 Baht/year
				Total = 121,554.01 Baht per year	
2	**On the flyover-bridge**			At 60 Km/hr speed (3.99 Baht/PCU/km)	Value of time on highway (120.86 Baht/PCU/hour)
	Free flow speed of the vehicles in two directions over the bridge	24,304	PCU/ day	24,304 x 3.99 = 96,972.96 Baht/day	2,025 x 120.86 = 244,741.5 Baht/day
		2,025	PCU/ hour	96,972.96 x 300 = 29,091,888 Baht/year	244,741.5 x 300 = 73,422,450 Baht/year
				Total = 102,514,338 Baht per year	

$$ACa = \frac{A(F)*MCA(F) + A(Dis)*MCA(Dis) + A(SI)*MCA(SI) + A(LI)*MCA(LI) + A(PDO)*MCA(PDO)}{t} \quad (1)$$

Where, ACa : annual average accident cost (Baht/year),
A : number of accidents (acci),
MCA : the mean cost per accident (Baht/acci) as shown in Table 7, and
t : the period of time under review (year).

An annual average accident costs for the three situations calculated by Equation (1) are shown in Table 8.

Table 7. Mean cost per accident for various severities

Severity	Thailand (Million Baht)	Bangkok (Million Baht)	Other Provinces (Million Baht)
Fatality (F)	5.062 – 5.956	10.561 - 12.413	4.757 - 5.599
Disability (DI)	5.114 - 6.910	11.611 - 13.934	5.608 - 6.729
Serious Injury (SI)	0.158 - 0.164	0.328 - 0.337	0.148 - 0.155
Slight Injury (SL)	0.0386 - 0.0389	0.1731 - 0.1733	0.0297 - 0.0298
Property Damage Only	0.052	0.164	0.039

Source: Department of Highways, Thailand (2012)

Table 8. Annual average accident cost in each situation

Locations / Mean cost per accident		Number of casualties in 3 situations: At-grade intersection	During construction	Flyover intersection
Fatal	5,178,000	-	6	-
Disabled	6,168,500	0.85	1.95	0.45
Seriously injured	151,500	8	23	1
Slightly injured	29,750	17	39	9
Property damage only	39,000	25	67 times + 701,400 Baht	10
DOH damage		-	533,500 Baht	-
Year consider (year)		2.33	2.50	1.25
Cost		3,405,997	20,635,690	2,868,060
Saving in accident costs resulting from converting at-grade intersection to the flyover intersection per year = 537,937.85 Baht				

5. COST-BENEFIT ANALYSIS (CBA)

CBA is the method for calculating all benefits and costs. The CBA is normally carried out in terms of three key indicators: the Net Present Value (NPV), Benefit–Cost Ratio (BCR) and Internal Rate of Return (IRR) (Garber, N. J., & Hoel, L. A. (2009)).

In this study, the recommended interest rate (i) of 12% was used (DOH, 2009 and World Bank and Office of the National Economic and Social Development). The period of analysis is 10 years (n). The result of analysis is shown in Figure 8.

5.1 Net Present Value (NPV)

This method is defined as the summation of the present values of the individual cash flows of the same entity, Eq (2).

$$NPV = \sum_{t=0}^{n} \frac{(B_t - C_t)}{(1+i)^t} \quad (2)$$

$$NPV = \sum_{t=12}^{10} \frac{(B_{10} - C_{10})}{(1+0.12)^{10}} = \frac{88.7*10^6}{(1.12)^1} + ... + \frac{43.2*10^6}{(1.12)^{10}} - 270.2*10^6 - 3.8*10^6$$

NPV = 361,641,982 Baht

5.2 Benefit–Cost Ratio (BCR)

A ratio ishowing the relationship between the costs and benefits of a proposed project, Eq (3);

$$BCR = \frac{Benefits}{Cost} = \frac{361{,}641{,}982 + 537{,}938 + 121{,}544}{249{,}597{,}672.5 + 20{,}635{,}690} \quad (3)$$

BCR = 1.34

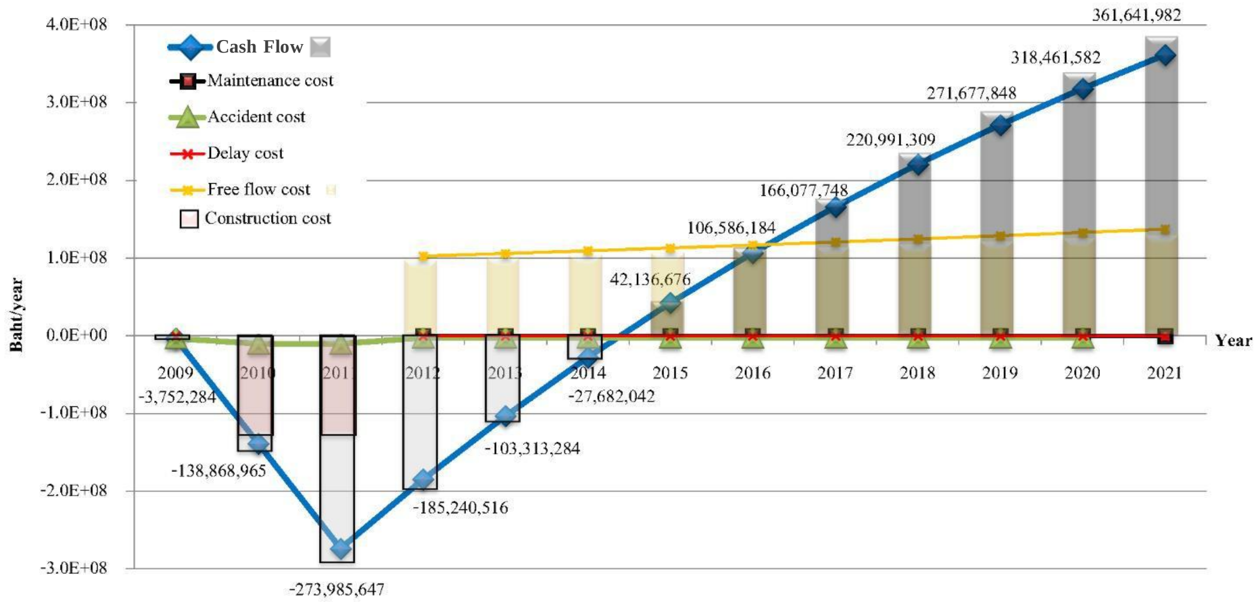
5.3 Internal Rate of Return (IRR)

The interest rate for which NPV equals to zero. For the flyover project, i = 37.58 %

6. ANALYSIS RESULTS FROM SIDRA

To make recommendation to the DOH to improve the performance of the intersection, the authors used SIDRA to analyse the current traffic signal control under the flyover. The software is an advanced micro-analytical tool used for evaluating of alternative intersection designs in terms of capacity, level of service and a wide range of performance measures, including time delay, queue length, as well as fuel consumption, pollutant emissions and operating costs (Akcelik & Associates Pty Ltd., (2011)). The software was used to analyze the performance of the traffic flow, cycle phase time, delay and level of service.

Table 9 shows the optimum cycle times as computed by SIDRA, the values are much smaller than the existing cycle time of 224 seconds.



Intersection		Before	During		After Construction					
Items	Year	2009	2010	2011	2012	2015	2018	2019	2020	2021
Traffic data										
Traffic volume	PCU/day	54912			64219	70789	78031	80606	83266	86013
On the bridge					24304	26791	29532	30506	31513	32553
Under the bridge					39915	43998	48499	50100	51753	53461
Delay	minute	32116			20845	23035	25392	26230	27096	27990
Cost										
Invesment cost	Baht	-249597672.5								
Maintenance cost	Baht/year				-27000	-27000	-27000	-27000	-27000	-27000
Accident cost	Baht/year	-3405998	-20635690		-2868060		-2868060	-2868060	-2868060	-2868060
Saving accident cost	Baht				537938					
Delay cost	Baht/year	-346286			-224732	-248346	-273756	-282790	-292122	-301762
Saving delay cost	Baht				121544					
Free flow cost	Baht/year				102.5E+6	113.0E+6	124.6E+6	128.7E+6	132.9E+6	137.3E+6
Sum	Baht/year	-3.8E+6	-270.2E+6		99.4E+6	109.9E+6	121.4E+6	125.5E+6	129.7E+6	134.1E+6
Cash Flow	**Baht**	-3.8E+6	-138.9E+6	-274.0E+6	-185.2E+6	42.1E+6	221.0E+6	271.7E+6	318.5E+6	361.6E+6

Figure 8. Cost benefit results (2009 – 2021)

Table 9. Optimum cycle-times by SIDRA for 12 time periods (7:00 – 19:00)

Time Periods	New cycle time run by SIDRA (second/cycle)	Time Delay (second)
7:00 – 8:00	140	45.5
8:00 – 9:00	140	45.8
9:00 – 10:00	130	42.2
10:00 – 11:00	130	41.5
11:00 – 12:00	125	40.8
12:00 – 13:00	125	41.4
13:00 – 14:00	115	44.1
14:00 – 15:00	115	48.0
15:00 – 16:00	120	45.2
16:00 – 17:00	130	47.5
17:00 – 18:00	145	61.6
18:00 – 19:00	135	45.8

7. CONCLUSIONS

An at-grade intersection was upgraded with an installation of a flyover-bridge at a cost of 249.5 million THB, with the aim of increasing capacity of the intersection and reduce vehicle delay and long queue at the ground level. The study results can be summarized as follows:

Traffic volume at the intersection increases around 4,000 PCUs or 6.02%, the volume at ground level accounts for 33.8% and free flow on the bridge 45.7%.

Delay at intersection: average time delay was reduced by 34.5%.

Queue length at intersection: The stopped vehicle ratio at this intersection for the at-grade situation and the flyover situation is 1.55 : 1 and 3.16 : 1 respectively.

Traffic signalization: Both before and after situations were controlled by fixed time control plans. At-grade situation operated two daily plans, the first plan used 244 seconds of cycle length, for the period 0600 -2100 (4 phases per one cycle); the second plan used flashing signal for the period 2100-0600. The flyover-improved intersection used similar fixed time control plan, but with the shorter cycle time of 224 seconds.

Speed: saving in travel time from increased vehicle speed, especially on the flyover where the speed increased from 29.8 to 52.5 km/hr.

Project evaluation: the benefits were considered in terms of saving in VOC, VOT and Accident Costs. The saving in costs of 29.13, 73.50 and 0.54 million THB were realized respectively realized with the flyover installation.

The project net present value (NPV) was 361.64 million THB, benefit cost ratio (B/R) 1.34 and internal rate of return (IRR) 37.58%, indicating that it is a worthwhile project.

8. RECOMMENDATIONS

Overall, the project is economically worthwhile and can reduce congestion at the intersection. However, the operation of traffic signal has been and is still controlled by fixed time control plans as the previuos situation of before the construction of the flyover. Long queue and delay of vehicles especially on the minor highway still exist.

To improve performance of the intersection, shorter optimum cycle times as calculated by SIDRA should be adopted for different time of day. The cycle times are shown in Table 9.

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POVERTY REDUCTION AND TRANSPORT: A CASE OF SOUTHERN THAILAND

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ABSTRACT:

This paper presents results of the study of the ultra-poor in the south of Thailand, revisited after 10 years since the original 2000 study. The objectives of the study were to assess the changes in the poverty situation after 10 years, and the impacts of the poverty reduction projects implemented by the government on the poor. The research methodology used both quantitative and qualitative methods. The same villages in the four provinces studied in 2000 were again chosen. The results show that the poverty situation of the ultra-poor groups has not changed much since they lacked the basic key factor to get themselves out of poverty: the ownership of land. Even though the government's projects have not reduced the poverty directly, the projects have significantly contributed to the improvement of the quality of life of the poor and the non-poor in the areas especially through better transport, mainly good roads which have significant impacts on the transport of agricultural produce, access to health and education, personal security, job opportunities and community participation.

KEYWORDS: Poverty and transport, southern Thailand, ultra-poor

1. INTRODUCTION

Since 1997 the poverty situation in Thailand has become one of the national issues during the time of the government headed by the then Prime Minister Thaksin Shinawatra. This coincided with the policy of the World Bank, United Nations and governments in various countries which were determined to eradicate poverty out of the world. In Thailand, there were several projects set up to eradicate poverty such as Thirty-baht Universal Health scheme, Village fund, Poverty Fund, One Tambon, One Product project (generally known as OTOP). After several studies on poverty conducted by NESDB, Thailand Research Fund, The World Bank, Asian Development Bank, the poverty –reduction projects had materialized during the second term of Prime Minister Thaksin Shinawatra. These included the Enlistment of the poor, the Fish Bank, the Poor's Housing. The Poverty Tracking study to investigate corruption and ensure that the government's assistance and resources reached the poor were carried out based on the World Bank model to ensure the poor were really the beneficiaries. After the coup d'état in 2006, the attention on poverty policies and poverty reduction faded to the background as the occurrence of internal politics, political differences, oil crisis, world economic crisis had diverted focus from the continuity of poverty reduction projects.

The ultra-poor study in southern Thailand was carried out in 1999 as a regional project of the nationwide Project on the Ultra-poor in Thailand funded by the Thailand research fund (TRF). The results showed that there was prevalence of poverty among the Thai Muslims in the lower south of Thailand. Factors that caused poverty were lack of employment opportunities and abilities to work, lack of capital and resources, debts, high fertility and problems from children. However, the strong sense of community is deep rooted in the south and significantly contributed to reduce the severity of poverty problem. Furthermore, the study also came across sudden poverty resulted from the falling prices of agricultural produces and rubber, which is the major economic crop of southern Thailand.

From then on, the poverty situation in Thailand has received more attention and the poor have their income and quality of life improved. However, not all assistance has reached down to the poor. Despite all the short comings, the number of the poor people dropped down from 11.5 million in 1999 to 9.6 million in 2009 which were approximately 20%. But the income per capita has almost doubled, for example, for Phatthalung province, one of the poorest provinces in the south; it went from 29,353 baht in 2001 to 47,898 baht in 2005. The overall improvements could be attributed to booming tourism, the higher price of rubber, and the benefits from decentralization efforts of various Thai governments starting three decades ago.

The unrests in the lower south of Thailand since 2005 have made the poverty situation in the south more special and sensitive. The map of poverty and the ultra-poor study show that pockets of poverty were deep rooted in the three border provinces in the lower south and Satun province where the small scale fishermen were one of the poorest groups. The unrest situation has disrupted the normal way of everyday life and obstructed the poverty reduction projects and other development projects from reaching down to the poor, thus deterring government efforts to alleviate the poverty.

The world economic crisis in 2008 and the oil price crisis have had direct impacts on the poor. Since the Ultra-poor study conducted in 1999, it is important that the poverty situation should be revisited after a decade in order to study how the situation has changed, after the poverty reduction projects have been implemented in the areas. The results of the study will be useful in providing future directions in poverty reduction policies.

2. OBJECTIVES

1. To study the poverty situation in southern Thailand over the 10 years period from 1999 to 2009
2. To assess impact of the poverty reduction projects of the government on the poor in southern Thailand especially the target groups.
3. To obtain the data and monitor the situation of poverty in southern Thailand for use in future planning and policy.

3. CONCEPTUAL FRAMEWORK

4. SCOPE OF THE STUDY

Purposive Sampling was used to choose 4 provinces selected for research on the Ultra Poor in the south in the 1999-2000 study which was classified as poor under the criteria of national per capita income. For the upper south, two provinces namely Phatthalung and Nakorn Si Thammarat were chosen to represent the Thai Buddhists and for the lower south, the province of Pattani and Satun were chosen to represent the Thai Muslims. For each province, four villages were chosen and in each village, five to six poorest persons were selected from the village's list of the poor. A total of 347 samples from 65 villages, together with the village leaders were selected for interviewed, 52 leaders were interviewed from 65 villages.

5. RESEARCH METHODOLOGY

The research methodology used both quantitative and qualitative methods. Questionnaires were used to interview the poor, village leaders and government officials. For qualitative method, the in-depth interview and the focus group discussion were used. SPSS program and content analysis were used for quantitative and qualitative data respectively.

6. RESULTS

Due to problems in collecting fieldwork in Pattani province, focus group and in-depth interviews could not be carried out in the province because of the continued unrest situation since 2005. Thus, the results presented in this paper will be mainly from the other three provinces: Phatthalung, Satun and Nakorn Si Thammarat.

Overall results from fieldwork survey, discussions with the poor and the village leaders as well as observation of social and economic conditions of the three provinces show that the poverty situation within the last 10 years has improved. This was due to the impacts of various development projects which the governments have invested in the development of the country at the village and national levels especially the infrastructure development such as roads, water supply, electricity, telephones and reservoirs. In some provinces where rubber was the main agricultural produce, the farmers have higher income from the big increase in rubber price over the last 4-5 years (from 13 baht in 1999 to 129 baht in 2011). The high rubber price helped raise the economic status of the rubber planters who experienced sudden poverty in 1999 when rubber price fell extremely low. Another important finding is the change of occupation of the poor in the studied areas. In Phatthalung, some poor farmers have changed from rice farming to rubber planting or to work more as hired laborers. In 1999, the poorest groups of the Ultra poor were the rice farmers and the small-scale fishermen. The rice farmers also earned more from laboring jobs than rice farming which was their primary occupation.

Over the past ten years, the situation for the small- scale fishermen has not improved much due to the continuous depletion of marine resources and the rising price of petrol which makes it very costly to go fishing and not getting enough in return.

According to the village leaders, numerous poverty reduction projects from the government have changed the poverty situation to the better in many directions. Even though some projects did not directly result in increasing the income of the poor but they helped elevate the quality of life of the poor. The standard of living of the villagers has thus improved. The village leaders were satisfied with the projects that allowed people to have decision making power and participated in the projects. But some expressed opinions that the government had not directly responded to the needs of the poor. The government had not consulted with the poor before launching the projects. And there were no serious follow- ups on the projects.

Better roads are the key infrastructure that helped improve the quality of people’s lives. Some villages revisited after ten years have improved significantly in terms of physical conditions. Roads in some villages have improved from gravel roads to asphalt- paved roads which significantly altered the physical environment among houses in the villages. Paved roads enabled faster, and all-weather transport of agricultural produce to the market, and allowed easier access of the middlemen and goods supplies to the heart of the village, thus reduced the cost of the transport of goods. Roads improved the health of the villagers as they could now go to hospital easier and quicker, and more often. The improved roads made it more convenient for children, especially girls, to go to school in less time than it has taken them previously. Roads do not only save a great deal of time spent on travelling but also provide personal security to the villagers. Roads also provide job opportunities to the villagers who are landless and depend on wages to be able to seek jobs in wider areas. Roads also increase community participation in the activities of the village as people find it easier to travel to the activities in and among villages. These findings support the report published by Asian Development Bank called RETA in 2005 which assessed the impacts of Transport and Energy Infrastructure on Poverty reduction. But the study also found that, in Thailand case, the improvement of road transport and electricity may not benefit the poorest who are handicapped by some factors associated with chronic poverty (Asian Development Bank, 2005). The only problem remains is the quality of the tap water which needs to be redressed urgently.

Quantitative results of the three provinces, 261 households and 994 persons, show that the majority of the poor, 81.6 % remain nuclear family. Only 16.5 % have two families in one household. The sex ratio in the household is 1:1. The poor who live by themselves make up 11.9% and most households have 4 members. The age distribution comprises: 0-14 years old 29%, working age 15-60, 53.1% and 60 years old and more 17.9%. When compared with 1999 (Table 1) the number of the aged has increased (1999= 10.7%, 2009= 17.9%). Another difference is the level of education of the head of households. There is an increase at the secondary levels education from 3.6% to 9.9%. For occupation, 35.2% reported having no occupation but the majority 42.9% are general laborers in agricultural and non-agricultural sectors which is quite different 10 years ago when most (31.5%) had agricultural occupation as secondary occupation. It shows marked decrease in agricultural occupation among the poor. As far as marital status is concerned, the number of singles (8.8%) increase and the married (56.7%) decrease. The divorced (6.5%) and widowed (28%) increase from the last10 years. There is an increase in the use of birth control within the last 10 years and the use of condoms which did not exist in 1999 became a method that 13.75% of the poor use. But the most popular method is the pills, 41.25% use them. The number of disabled members of the poor households increased from 8.9% to 18.8% during the past 10 years. Moreover, the numbers of the chronically ill persons increase for one ill member per one household from 35% to 49.8%. The survey also found two households which have three chronically ill members (Table 2). The poor households have increased numbers of toilets with septic tank from 79.6% to 87% and those with no toilets decrease from 17.6% to 9.6%.

The housing conditions of the poor have improved in terms of physical condition and the materials used for construction. There are less numbers of one-story wooden houses with high floor above the ground, from 57.3% in 1999 down to 39.8% in 2009. There are more one-story brick houses with concrete floors, from 12.6% to 23.4%. What is noted is the roof which changed from thatched or corrugated iron roof to tiles, 73.6%. The estimated value of the houses has also increased for price range 50,000 baht to 100,000 baht from 17.5% in 1999 to 33.3% in 2009. All these figures indicate that there are improvements in terms of income of the poor over the past ten years. However, house ownership shows slight increase but the land ownership has fallen. Landlessness among the poor has increased from 56.3% to 67.4% as well as the size of land owned. In 1999, there were 29% of the poor who owned land 1-5 rais; in 2009, it has gone down to 22.2%.

As far as income is concerned, there is an increase in income of the poor households. In 1999, the income range was 10,000 baht – 75,000 baht per year but in 2009, there are 88.5% of the poor whose income range has gone up from 20,000 baht to 100,000 baht or more. The poor also have less expense in agriculture, lower than in 1999 but most of the expenses (94%) are for living. However, as most are not farmers but laborers so the expenses in agriculture are naturally less. The average income of households in Satun and Phatthalung provinces have gone up considerably; for Satun from 52,767 baht to 85,252 baht per year; and Phatthalung from 46,997 baht to 103,869 baht which is almost double thanks to the high price of rubber in recent years. Still, the net income of the three provinces is not much different (Table 3).

However, the poor households in 1999 and 2009 have more expenses than income exceeding by 46.9% and 38.3% respectively. When considering their debt burden, 50% were in debts in 2009 compared to 65% in 1999 (Table 4). The difference is that in 2009 the debts are more in the formal systems (Bank of Agriculture, Village Co-operatives) than the informal systems (Middlemen, relatives and neighbors) like those in 1999. So their sources of loans come from institutions like banks and Village co-operatives rather than middlemen, relatives and friends. Nonetheless, the poor have been active members of Village Funds as indicated in the 1999 study because in the south of Thailand the Village Fund has been strongly established long before other regions in Thailand. It is obvious that the poor has received the financial assistance from the government agencies, increasing from 8.9% in 1999 to 66.3% in 2009.

For the health insurance, 98.5% in 2009 have Health insurance cards from the government. 50% of the poor households live not far from the good roads, within 10-100 meters. This is because more roads have been constructed in the past ten years. The poor' drinking water come from tap water (27.6%) and rainwater 28%. More than half (54.4%) now have tap water compared with only 10% in 1999 when the majority used water from shallow wells. 95% of sampled households have electricity. The poor watch television more in 2009, 57% compared with 37% in 1999 but read less newspapers than in 1999. For their spare time, 53.3% just rest, doing nothing, 33% watch television or listen to the radio.

Question to the heads of households regarding the chances of getting out of poverty, 33% answered that they could, 60% could not, and 7.7% said they were not poor. This is different from 1999 when 56% said they could get out of poverty. In 2009, the poor list problems in their agricultural occupation as follows: 1. Lack of landownership 2. Unstable weather conditions 3. Lack of capital for investment. In 1999, their problems were: 1. Depletion of natural resources 2. Lack of agricultural equipment. 3. Pests and plants disease. For non-agricultural problems in 2009, they are 1. Health 2. Expenses exceeding incomes 3. Lack of landownership.

The numbers of years the poor have been in poverty range from 1-5 years up to 20 years, for the 1-5 year group, there are 62.9 % in 2009, less than the 78.6% stated in 1999. For those who have been in poverty more than 20 years, there are 16.9% and 15.6% in 2009 and 1999 respectively. Thus, there are those who can be considered as having been in chronic poverty. Looking at Table 5, the causes of poverty in 2009, the first is landlessness 24.1%, second is short of cash, 10%, the third is no regular jobs and irregular income, 8.8%, and fourth, poverty caused by the burden of having children, 6%. Compared to the causes in 1999, the first cause of poverty was no employment, low-paid employment, 25.2%, lack of assets, 18.7%, children, 13.8%, health and lower agricultural price, 8.5% each.

As far as causes of poverty are concerned, lack of assets which is landlessness comes first in 2009 whereas in 1999, no employment and small income came top of the list. In 1999, causes of poverty from having children and poor health are similar to the situation in 2009. However, falling price of agricultural produce is an important cause in 1999 when the rubber price went down drastically from 44 baht to 13 baht per kilogram, creating "sudden poverty" among the rubber planters. But causes of

Table1. Number of the Ultra-poor by Age Distribution

Age range (year)	Nakorn	Satun	Phatthalung	Total 1999	Total 2009	Percentage 1999	Percentage 2009
under 15	93	98	97	370	288	30.9	29.0
15 - 60	179	191	158	701	528	58.5	53.1
above 60	55	53	70	128	178	10.7	17.9
Total	327	342	325	1199	994	100.0	100.0

Table2. Number of Households with Chronically Ill Persons

Number chronically ill	Nakorn	Satun	Phatthalung	Total 1999	Total 2009	Percentage 1999	Percentage 2009
None	23	44	42	142	109	57.7	41.8
1 person	51	44	35	86	130	35	49.8
2 persons	10	4	6	16	20	6.5	7.7
3 persons	1	0	1	-	2	-	0.8
Total	85	92	84	244	261	99.2	100
Average no. chronically ill per household	0.87	0.57	0.56	0.48	0.67	-	-

Table3. Average Net Income per Household per year (baht)

Items	Nakorn 1999	Nakorn 2009	Satun 1999	Satun 2009	Phatthalung 1999	Phatthalung 2009
Average income	69,058.54	68,723.88	52,767.25	85,252.46	46,996.95	103,869.60
Average expenditure	67,402.54	72,948.13	44,668.96	76,506.78	33,449.32	83,521.31
Average net income	1,656.00	-4,243.95	8,098.28	9,227.41	13,547.63	19,909.70

Table4. Number of In-debt Households

Debt	Nakorn	Satun	Phatthalung	Total 1999	Total 2009	Percentage 1999	Percentage 2009
In debt	43	49	39	160	131	65	50.2
Not in debt	42	43	45	86	130	35	49.8
Total	85	92	84	246	261	100	100

Table5. Causes of Poverty

Number	Year 2009	Percentage	Year 1999	Percentage
1	Lack of land ownership	24.1	No jobs/low income	25.2
2	Expenses exceed income	10.0	No assets	18.7
3	Unstable jobs	8.8	Children	13.8
4	Children	6.1	Health	8.5
5	Health problems	5.7	Low farm price	8.5
6	No education/ No skills	5.7	Too many children	7.3
7	Ill member in family	5.0	Expenses exceed income	7.3
8	Disabled member in family	4.6	Widowed/ divorced	6.9

poverty from children and health seem to exist among the poor in both periods. The difference is that in 2009 one of the causes of poverty is having the ill and the disabled members in the family which this was not the cause mentioned in 1999 (Table 5).

7. DISCUSSION AND CONCLUSION

This paper presents the results from the 2009 study of poverty situation in 3 southern provinces of Thailand. The purpose is to revisit the poverty situation after ten years since the 1999 study to assess the changes brought about by the poverty reduction projects of the Thai government. From the results, the causes of the poverty remain unchanged which are the lack of assets, lack of employment because of no capital, knowledge and skills, poor health and burden from having ill members in family and children to look after. The ultra-poor still exist in chronic poverty which they have inherited from the last generation. The economic change has not affected the poor so much as they lack the basic factors to respond to the changes. The projects from the government to develop the areas have not reduced the poverty directly unless they are the projects that generate income. However, these projects have helped improve the quality of life of the poor. For the transport aspect, better roads have significantly improved the quality of life of the poor and the non-poor in the areas. The improved roads have great impacts on the transport of the agricultural produce by reducing transport costs, helped improve access to health and education services, helped increase personal security, helped provide job opportunities for the landless poor and helped increase community participation. The projects that were specifically and directly designed to improve the economic conditions of the ultra-poor would seem to be the answer in getting them out of poverty.

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ROAD SAFETY EVALUATION AT THAI U-TURNS USING CZECH TRAFFIC CONFLICT SEVERITY GRADES

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Abstract. The purpose of this study is to evaluate the road traffic safety at the at-grade U-turns on 4-lane divided highways of Thailand with focusing their layout geometric. In Thailand, the U-turns are considered as one of the major segments of highways that contributing a higher number of crashes. The several layout geometric designs of the U-turns and variation in dimensions of their variables (acceleration lane, deceleration lane and loon/ widening) are influencing factors for the drivers' expectancy; causing undesirable driving behavior and confusion among the road users. These characteristics led to a higher frequency of crashes at the U-turns.

For the study purposes a total eight types of at-grade U-turn layout geometric identified throughout Thailand. Due to the limitation of availability and reliability of road crash data in Thailand a surrogate approach, based on the traffic conflict was adopted for the study. Although the Traffic Conflict Technique (TCT) is widely accepted as an alternative and proactive approach but the subjective nature of its parameters is debatable since its origin. The U-turns' geometric data, traffic conflicts and volume data were recorded in the field.

The *Severity Conflict Rates* (SCR) is assessed by applying the weighing factors (based on severity grades according to the Czech TCT) to the observed conflicts exposed to the conflicting traffic volumes. A higher value of SCR represents a lower level of traffic safety at a U-turn and a significant relationship was obtained between dimension of the variables of U-turn and the level of road traffic safety.

Keywords: Road traffic safety, U-turn, Severity Conflict Rates, CZECH Traffic Conflict Technique.

1 Introduction

1.1 Road traffic crash trend in Thailand

Road traffic crashes in developing and emerging countries tend to be one of the major causes of fatalities and disabilities. In 2010 the United Nations General Assembly unanimously adopted a resolution calling for a “Decade of Action for Road Safety 2011–2020”. The goal of the Decade (2011–2020) is to stabilize and reduce the increasing trend in road traffic fatalities, saving an estimated 5 million lives over the period [1]. Road traffic injuries take an enormous toll on individuals and communities as well as on national economies. The middle-income countries, which are motorizing rapidly, are the hardest hit. The economic growth in Thailand has brought about an expanding network of roads and an increasing number of the driving public. The growing number of vehicles on the roads, in turn, has contributed to significant increases of road crashes annually. In Thailand, the road traffic crash problem is now also regarded as one of the most serious social problems. The total economic losses due to road crashes in Thailand were estimated to be 140,000 million Baht or 2.56 Percent of the Gross Domestic Product (GDP) in 2002 [2]. The total traffic crash costs for Thailand for the year 2004 were estimated as 153,755 million Baht or approximately 2.37 Percent of the GDP [3]. The reported road traffic fatalities (in 2010) 13766 and estimated GDP lost due to road traffic crashes about 3% [1]. Although there is declining trend of traffic crashes in Thailand [4], yet the number of crashes are high among Southeast Asian countries [1]. The Figure 1 shows traffic crash trend in Thailand.

1.2 Function of the U-turns on the Thai highways

The median at-grade U-turns on the divided Thai highways are provided for the U-turning movements to facilitate road users to join the opposite direction traffic stream. The basic functions of the median at-grade U-turns on the Thai highways are shown in the Figure 2.

The U-turns are also constructed to reduce the number of at-grade X-junctions (to avoid direct right turn from a highway to a minor road and direct right turn from a minor road to a highway (for left hand traffic)). Other purposes are to reduce travel time for emergency services, efficient law enforcement and for highway maintenance purposes etc. The distance between the U-turn and minor road is varying (approximately 100 m to 2 km); also there are no specific guidelines available for the separation distance between the U-turns. The experts believe the separation distance between two adjacent U-turns is varying from approximately 1.5 to 3 km on Thai highways, depends upon field geography and local road design practice. The several type layout geometric design practice of the U-turn followed in Thailand, some are standard (as per design guidelines of the Department of Highways) and the remaining are non-standard (based on the local design practice). For the study purpose, the U-turns were classified based on the applications of the geometric variables.

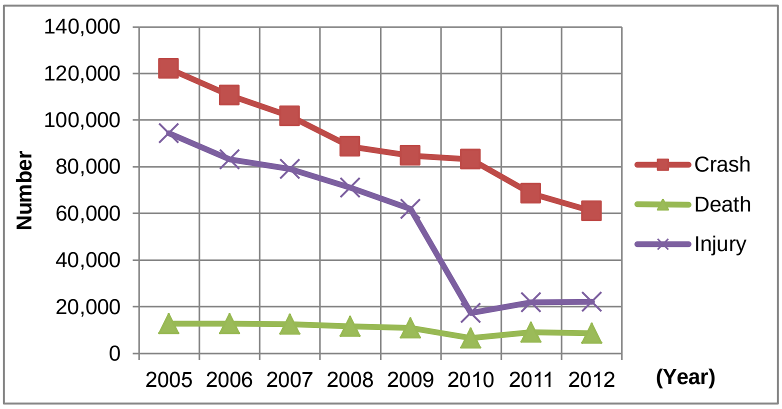

Fig. 1. Road traffic crashes trend in Thailand (*Source: Prapongsena (2012)*)

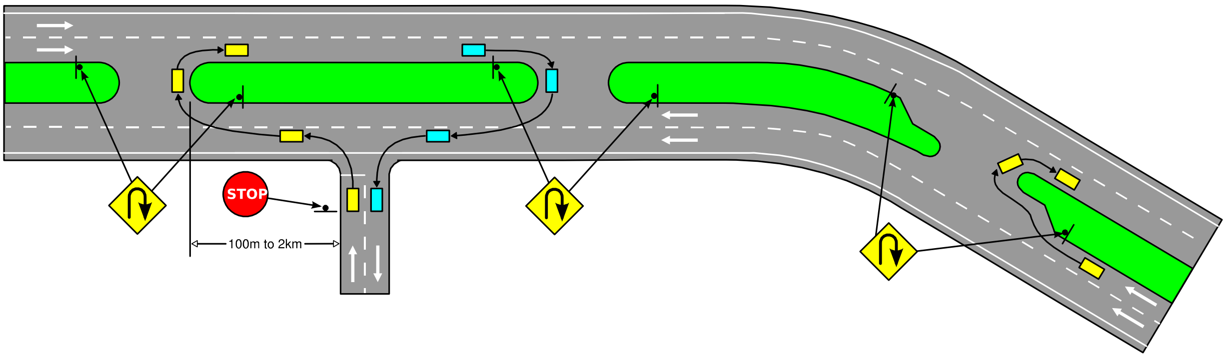

Fig. 2. The basic functions of the median U-turns

1.3 Road traffic safety at the U-turns

The midblock U-turn junctions interrupt the through traffic movement. The U-turning vehicles affect the through traffic movement in the opposite direction when they merge. The U-turning vehicles also affect the through traffic movement in the same direction when they stop and create queue. Sometimes the deceleration lane may get occupied completely. This may lead to a dangerous situation where the vehicles will extend back onto the highway (spill back), obstructing the through movement traffic.

According to the observation at the U-turn junction, when the U-turn traffic has long queue or waited for longer time, the U-turn traffic tends to be more aggressive to make U-turn. At the same time, the conflicting through traffic tends to be willing to stop and allow the U-turn traffic to go. In theory, the through traffic should get priority over the U-turn traffic all the time.

1.4 U-turn density and geometric design consistency

At the U-turns, the merging and diverging movements are performed at the inner lanes which make these susceptible to traffic crashes. Frequent lane-changes on highways at merging, diverging, and weaving areas could disrupt traffic flow and, even worse, lead to crashes. Also lane-changes could have significant bottleneck effects on overall traffic flow. The practitioners believe that crash frequency augments rapidly when the density (number of U-turns per kilometer length) of at-grade U-turns rises.

Furthermore the several type of layout geometric of the U-turns produces inconsistent design characteristics of road infrastructure. This means that drivers cannot drive safely at high speeds all the time and everywhere, since changes in the road environment require constant adaption in speed and influence driver expectancy. The requirement of adapting speed to suit the environment can increase the opportunity for human error and lead to high risk of crash and injury. The posted speed limit at the Thai U-turns is same as mid block speed limit (80 Kilometers per hour). The higher speed increases the severity of the impact in a collision. The conjunction of the high speed and the varying geometric conditions are major factors in crash causation with a high fatal crash rate.

1.5 Effect of geometric variables of the U-turns

The U-turn geometric design varies with application and dimensions of its variables, such as auxiliary lanes (acceleration, deceleration and loons). The acceleration (merging) lane and deceleration (diverging) lane are provided along inner lanes of highways at the U-turns. Practically the inner lanes are used for overtaking and for vehicles moving with a higher speed. So the merging and diverging maneuvers at the inner lanes make the U-turns susceptible towards traffic crash hazards. The lengths of these auxiliary lanes are not uniform at most of the U-turns. The shorter length of these does not have enough space to make comfortable lane change; this may result in a safety problem for the weaving and storage maneuvers. The Thai motorcyclists mostly travel on the outer paved shoulder and rarely use inner auxiliary lanes for the U-turning movements, so these have to cross all through lanes of both the directions. Similarly heavy commercial vehicles having difficulty to use inner acceleration lanes due to requirement of larger turning radius, so these vehicles either merge into through lanes or use loons (outer paved area).

2 Literature review

2.1 NCHRP 524 report [5]

The NCHRP 524 report focused on the safety of the U-turns at unsignalized intersections. It included an intensive safety evaluation of the U-turns for different types of median openings and the places of the median openings on major roads. Some of the findings related to the layout geometric of the U-turns are presented in following sections.

2.1.1 Classification of the U-turns

The U-turns were classified on the basis of layout geometric and used following key variables to classify the design:

- Application of acceleration and/ or deceleration lanes,
- Application of directional island, and
- Application of loons.

2.1.2 Spacing of median openings

The report stated that by increasing the spacing between median openings improves arterial flow and safety by reducing the number of conflicts and conflict points per mile, providing greater distance to anticipate and recover from turning maneuvers. Spacing of openings should be consistent with access management classifications of criteria.

2.1.3 Median acceleration lanes

They provide vehicles a path to accelerate to an appropriate speed before entering into the through travel lanes on a divided highway. Median acceleration lanes provide both safety and operational benefits in that the entering vehicles do not cause vehicles on the through travel lanes to decelerate substantially. They have following advantage and disadvantages as shown in the Table 1.

2.1.4 Loons or outer-widening

The loons are defined as expanded paved aprons opposite a median crossover. Their purpose is to provide additional space to facilitate the larger turning path of commercial vehicles along narrow medians. With the use of loons, it may be possible to gain the safety and operational benefit at a divided roadway. In spite of benefits of loons at the U-turns, following are the safety concerns at loons:

- Fixed-object crashes with delineator posts, sign posts, and guardrail,
- Sideswipe crashes involving vehicles merging into mainline traffic from the loon,
- Commercial vehicles backing up and parking within the crossover.

2.2 Near-crash events as an alternative approach

If there are shortcomings (limitations of the availability and reliability of crash and traffic data) of collision based safety measure, the road traffic safety analysis can benefit greatly from the methods that use an observable and non-collision based interactions. In order to perform a alternative and comprehensive form of safety analysis, and to assess and predict levels of traffic safety at specific types of traffic facilities, there is a distinct need for faster, more informative, and more resource effective methods that yield valid and reliable safety measures in the short-term without the need for (or in addition to) crash data.

2.2.1 Traffic conflict technique (TCT)

The approach is to study traffic conflicts or near miss events which occur more frequently, can be clearly observed and are related to probability of collisions. The main advantage of such measures is related to their resource-effectiveness given that they occur more frequently than crashes and require relatively short periods of observation in order to establish statistically reliable results.

A formalized definition of a traffic conflict was adopted as "an observable situation in which two or more road users approach each other in space and time for such an extent that there is a risk of collision if their movements remain unchanged" [6], and the observation method formalized in the term as Traffic Conflict Technique (TCT).

Table 1. The advantage and disadvantages of acceleration lanes

Advantage	Disadvantages
— reduce delays when traffic volumes are high	— It is difficult to merge from median acceleration lanes because of blind spots
— provide higher merging speeds	— are not used properly by drivers
— reduce the crashes	— create anxiety to through traffic

The conflict safety indicators are particularly useful where there is an emphasis on the assessment and comparison of safety enhancement measures at specific traffic facilities and, in some cases, the interactions of specific road-user categories. The methodologies used to collect conflict data also make the results sensitive to site-specific elements related to roadway design and the dynamic and complex relationships among different traffic variables such as traffic flows, speed and proportions of turning movements [7].

2.2.2 Validity and Reliability of TCT

Despite the many advantages related to the use of TCT, a number of fundamental problems have been identified. The reliability and validity are two issues strongly connected to the usability of TCT. These concern the lack of a consistent definition, their validity as a measure of traffic safety, and the reliability of their associated measurement technique.

A number of studies have tried to address reliability and validity issues ([8], [9], [10], [11]). Some empirical studies found that there were clear relationships between traffic conflicts and crashes [12]. Despite the concerns about those issues, traffic conflict techniques have been used in various studies to evaluate safety.

The relationship between traffic volumes and conflicts has been another subject for researchers to investigate. Salman and Al-Maita (1995, [13]) had a research on three leg intersections. The summation of all volumes entering the intersection and the square root of the product of the volumes that generated the conflicts were used to correlate conflicts and volumes. It was found that the correlation between the conflicts and the square root of the product of volumes was higher than that of the summation of volumes.

For the subjective TCT, the field observers are a source of error when collecting conflict data, due to the subjective nature of deciding if a given driving event is a conflict or not. Each observer is required to judge whether or not a situation is a conflict, resulting in variability in the grading of traffic conflicts by different people. As a result, the human-collected data was not necessarily accurate, especially if multiple observers were used. Nonetheless, traffic conflicts have been shown to have some correlation with crash frequency, and the consensus is that higher rates of conflicts correlate to lower levels of safety [14].

2.2.3 Traffic conflict indicators and conflict severity measurement

The conflict indicators are defined as measures of crash proximity, based on the temporal and/or spatial measures that reflect the ‘closeness’ of road-users (or their vehicles), in relation to projected point of collision. The objective evidence of a traffic conflict by the (NCHRP) definition is the evasive action which is indicated by a brake-light or a lane change affected by the offended driver. First definition of a conflict was mainly based on brake light indications. A variety of observation methods have been developed to measure traffic conflicts including the observation of driver behaviour and recording the number of near misses or avoidance maneuvers. Broadly these can be classified into subjective and objective methods. Subjective methods include considerable judgment by the conflict observer and conflict severity taking into account the level of deceleration (weighted deceleration, which included longitudinal-braking and lateral-swerving-deceleration). To eliminate the subjectivity from traffic conflict analysis, objective measures are used. As objective measures for traffic conflicts having higher validity and include a cardinal or ordinal time-proximity dimension in the severity scale.

There are mainly three indicators are widely recognised and discussed to assess the severity of conflicting situation, Time to Accident / Speed (TA/Speed), Time To Collision (TTC) and Post Encroachment Time (PET).

2.2.3.1 Time to Accident / Speed (TA/Speed)

The conflict measure is determined at a point in time and space when evasive action is first taken by one of the conflicting road-users [15]. The TA/Speed value is based on the necessity of a collision course and evasive action. An event with a low TA and a high Speed value indicates an event with high severity.

The **Conflicting Speed** is the speed of the road user taking evasive action, for whom the TA value is estimated, at the moment just before the start of the evasive action.

The **Time to Accident (TA value)** is the time that remains to an accident from the moment that one of the road users starts an evasive action if they had continued with unchanged speeds and directions.

2.2.3.2 Time to Collision (TTC)

The TTC value is also based on the necessity of a collision course. The proximity is estimated during the approach. TTC is a continuous function of time as long as there is a collision course; the time required for two road users to collide if no evasive action is taken. The TTC_{min} is a specific estimate of the TTC during the entire interactive process of the conflict event, rather than the value recorded at the time evasive action is first taken as in the TA/Speed. So, TTC_{min} is the lowest value of TTC in the approaching process of two road-users on a collision course. A lower value of the TTC or TTC_{min} indicates an event with high severity [16].

2.2.3.3 Post Encroachment Time (PET)

Post-encroachment time (PET) is the time between two vehicles on a near-collision course passing at a common point [17], [18]. To measure PET a collision course or an evasive action of road user(s) is not necessary. As with TTC, a lower PET indicates higher severity, and the minimum value is also the critical value.

2.2.3.4 Grading severity of conflicts

The Table 2 shows the characteristics of severity grades which are assigned to observed conflict situations based on severity of an evasive maneuvers. Situations of specific behaviour or misbehaviour have severity grade 0, since they are situations of one user only and thus do not conform to a conflict definition.

Table 2. Characteristics of severity grades according to the Czech TCT (traffic conflicts are highlighted)

Severity grade (CSG) and description	Indicators	Physical reactions	Events (Related to vehicles)
0 – (mis)behaviour	none	none	breaking the rules without consequences, misbehaviour of road users
1 – slight conflict	low	common	fluent, controlled, predictable maneuvers
2 – medium conflict	obstruction	sudden	pronounced, sudden, unpredictable maneuvers
3 – severe conflict	endangerment	sharp	critical, emergency maneuvers

The *Conflict Severity Grades* 1, 2, 3 (highlighted in the Table 2) are assigned to conflict according to the observed evasive maneuvers severity, together with physical reactions and other characteristics. Obstruction and endangerment, used to distinguish between 2nd and 3rd severity grade, is defined according to the Czech TCT (2014, [19]).

2.2.3.5 Traffic exposure

Yi and Thompson (2011, [20]) used a relationship between the traffic conflicts and the conflicting volumes at intersections as "the total number of traffic conflicts is proportional to the square root of the product of the conflicting volumes". This referred to by Sayed and Zein (1999, [21]) as the "product of entering vehicles" (PEV):

$$PEV = \sqrt{(V_2) \times (V_2)} \qquad (1)$$

where:

V_1 and V_2 represent the traffic volumes (vehicles/hour) of the two conflicting traffic streams.

3 Methodology

3.1 Classification of the U-turns on the Thai highways

The U-turns were classified based on several combinations of its four layout geometric variables, viz. deceleration lane, acceleration lane, directional-island and outer widening or loon. Based on these combinations, for this study purpose the eight types of layout geometry of the U-turns were identified as shown in the Figure 3 and the Table 3

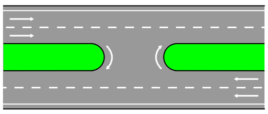
Fig. 3(a). UT-1

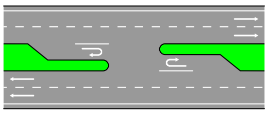
Fig. 3(b). UT-2

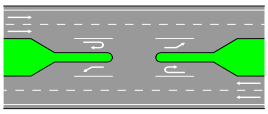
Fig. 3(c). UT-3

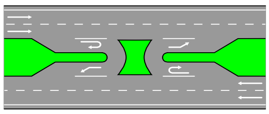
Fig. 3(d). UT-4

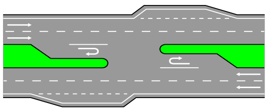
Fig. 3(e). UT-5

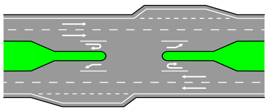
Fig. 3(f). UT-6

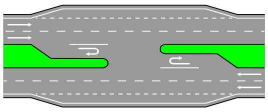
Fig. 3(g). UT-7

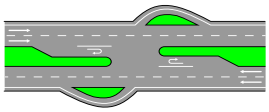
Fig. 3(h). UT-8

Fig. 3. U-turn types on Thai highway

Table 3. Classification of U-turn types on Thai highways

U-turn type	Application of Deceleration lane	Application of acceleration lane	Application of directional island	Application of outer-widening
UT-1	No	No	No	No
UT-2	Yes	No	No	No
UT-3	Yes	Yes	No	No
UT-4	Yes	Yes	Yes	No
UT-5	Yes	No	No	at downstream
UT-6	Yes	Yes	No	at downstream
UT-7	Yes	No	No	at upstream and downstream
UT-8	Yes	No	No	Loons

3.2 Zones at a U-turn

For the study purpose the functional area of a U-turn was considered to be composed of three zones, as shown in the Figure 4. The Upstream Zone consists of through lanes, deceleration lane and sometimes outer widening is also provided. It is used by the U-turning vehicles for substantial speed reduction and storage. The Turning Zone is an open area between the medians and its width is equal to width of the median. For a directional U-turn, an island is installed at this zone to separate both directions turning streams. The Downstream Zone consists of through lanes, acceleration lane and either of outer widening or a loon. This zone is used by the U-turning road users for the acceleration before merging into through traffic streams with an adequate speed.

3.3 Layout geometry of the U-turns

The Figure 5 demonstrates a typical example of U-turn diagram containing layout geometry of its variables.

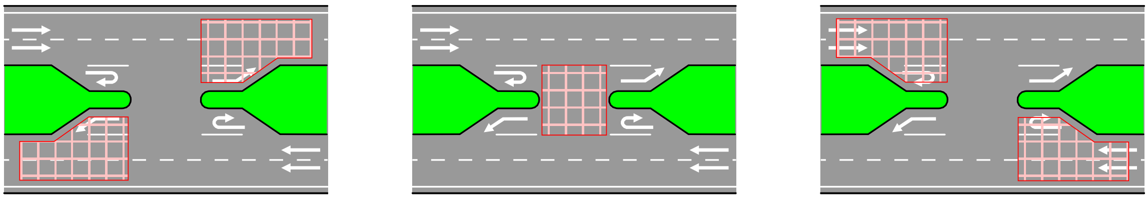

Fig. 4(a). Downstream Zones Fig. 4(b). Turning Zone Fig. 4(c). Upstream Zones

Fig. 4. The three zones at a U-turn

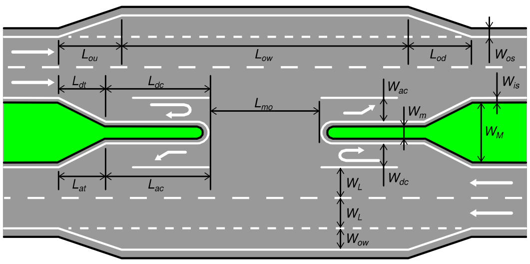

Fig. 5. The dimentions of the layout geometric variable at a U-turn

Where:

W_M —Width of median
W_m —Width of median along aux. lane
W_L —Width of through lane
W_{dc} —Width of deceleration lane
W_{ac} —Width of acceleration lane
W_{ow} —Width of outer widening
W_{os} —Width of outer shoulder
W_{is} —Width of inner shoulder
L_{mo} —Length of median opening
L_{dc} — Length of deceleration lane
L_{dt} — Taper section length of deceleration lane
L_{ac} — Length of acceleration lane
L_{at} — Taper section length of acceleration lane
L_{ow} — Length of outer widening
L_{ou} — Length of taper section of outer widening at Upstream
L_{od} — Length of taper section of outer widening at Downstream

3.4 Functional length of the auxiliary lane

The functional length of a deceleration lane (L_{df}) is defined as the summation of the length of the section of the deceleration lane with full width (L_{dc}) and the half of the length of the tapper section (L_{dt}) of the deceleration lane. The functional length of an acceleration lane (L_{af}) is defined in the similar manner. The typical example of the functional length of auxiliary lanes are shown in the Figure 6

3.5 Selection of *Conflict severity indicators*

The U-turns have a distinct geometry, longer conflict area in longitudinal direction and a higher operating speed. It makes difficult to judge the speed & space between conflicting vehicles and measure the severity of a conflict. Also as this study focus on the U-turns in non built-up areas, were the elevated spots were unavailable to install a camera in a position to get the aerial view. Therefore the use of the indicators *TA/CS* and *TTC* were not practically viable for this study. At the U-turns the majority of conflicting events are produced due to the merging and diverging maneuvers, and the *PET* is suitable to measure the crossing conflict events, therefore the indictor *PET* was not used in this study.

Due to the above mentioned constraints, a subjective approach was considered to measure the severity of traffic conflicts and the complexity of evasive action of the road users was considered as indicator of conflict.

3.6 Product of the conflicting volumes for the U-turns

The *Product of Through and Turning (merging & diverging) Volumes* ($PTTV$) were computed for the U-turns as the traffic exposure to the observed conflicts for calculating the conflict rates. It is defined as "the square root of the product of (average hourly) traffic volumes of conflicting streams (through and turning)".

3.7 Exclusion of the Turning Zone conflicts

During the field investigation it was observed that the conflicts at the Turning Zone were very much infrequent and measurement of the conflict indicators based on a subjective traffic-conflict-technique was practically cumbersome and inappropriate. Therefore Turning Zone conflicts were not considered for the safety investigation.

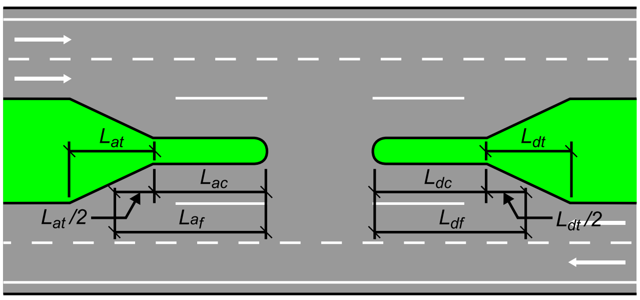

Fig. 6. The functional lengths of the auxiliary lanes

3.8 Conflict Number

3.8.1 Hourly Traffic Conflict Number (HCN)

The *Hourly Traffic Conflict Number* (HCN) is defined as the number of observed conflicts at a zone divided by the number of observation hours for that zone. The three types of *Hourly Traffic Conflict Numbers* were computed based on the classification of the severity of conflicting situation as slight, moderate and severe and location of conflict (Upstream and Downstream Zone).

3.8.2 Average Hourly Traffic Conflict Number (AHN)

The each U-turn has two Downstream Zones and two Upstream Zones, and for the each U-turn type the two locations were investigated. Therefore, for a particular type of zone, of a group of particular U-turn type, the *Average Hourly traffic conflict Number* (AHN) is defined as the summation of *Hourly Traffic Conflict Number*s (HCN) at that particular zones divided by the number of that type of zones in that group. Further the *Average Hourly traffic conflict Number*s were classified based on the severity of the conflicting situations.

3.9 *Severity Conflict Rate* (SCR) for the U-turns

The values of *Conflict Severity Grade* (CSG) from the Table 2 were used as weighting coefficient for giving relative weightiness (importance) to the conflict events and to assess *Severity Conflict Rates* (SCR). The SCR is defined as a ratio of the summation of the product of the Average Hourly Slight, Moderate & Sever Traffic Conflict Numbers (AHN) and their respective value of *Conflict Severity Grade* (CSG) to the *Product of Through and Turning Volumes* ($PTTV$) for U-turns. A higher value of SCR at a traffic facility represent comparative a lower level of traffic-safety. The SCR for the U-turns were computed by the following equation:

$$SCR = \frac{AHN_{sl} \times CSG_{sl} + AHN_{mo} \times CSG_{mo} + AHN_{se} \times CSG_{se}}{PTTV} \qquad (2)$$

where:

SCR – *Severity Conflict Rate* for a U-turn type,
CSG_{sl} – *Weighting coefficient* of CSG for slight conflict = 1,
CSG_{mo} – *Weighting coefficient* of CSG for moderate conflict = 2,
CSG_{se} – *Weighting coefficient* of CSG for severe conflict = 3,
AHN_{sl} – *Average Hourly Slight Traffic Conflict Number*s,
AHN_{mo} – *Average Hourly Moderate Traffic Conflict Numbers,*
AHN_{se} – *Average Hourly Severe Traffic Conflict Numbers,*
$PTTV$ – Product of through and turning (merging & diverging) volumes

4 Data type and data collection

The data which were collected depended on the form of the U-turn being studied and included traffic volumes, U-turning movement counts, using auxiliary lane counts, vehicle compositions, operating speed, geometric data and traffic conflicts. For the classified eight types of U-turn, two locations of each U-turn type were selected. A total 16 sites were selected and investigated throughout Thailand.

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6 Results

6.1 Traffic volumes

At a U-turn there are three types of traffic streams viz. through, diverging and merging. The volume of turning vehicles is a major variable that influencing the numbers of conflict out-turn. The *Percent of Hourly Turning Volume* ($PHTV$) is deified as in the Equation **Error! Reference source not found.**

The observed $PHTV$ are illustrated in the figure 7

6.2 Severity Conflict Rate (SCR)

The assessed *Severity Conflict Rates*, the applications auxiliary lanes and the functional length of the auxiliary lanes at the U-turns are illustrated in the Table 4 and the Figure 8

$$PHTV = \frac{Hourly\ Merging\ Volume\ +\ Hourly\ Diverging\ Volume}{Hourly\ Through\ Volume +\ Hourly\ Merging\ Volume\ +\ Hourly\ Diverging\ Volume} \quad (3)$$

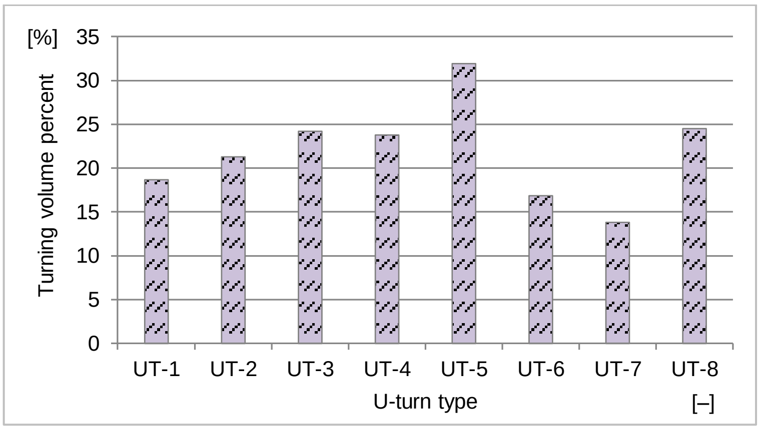

Fig. 7. Percent of the Hourly Turning Volumes

Table 4. The *Severity Conflict Rates* and the length of the auxiliary lanes

U-turn type	SCR ($\times$ **100**) [conflicts/veh]	Functional length of acceleration lane (L_{af})	Functional length of deceleration lane (L_{df})	Application of acceleration lane	Application of deceleration lane	Application of outer-widening or loon
UT-1	16.77	0 m	0 m	No	No	No
UT-2	13.08	0 m	56 m	No	Yes	No
UT-3	7.30	177 m	139 m	Yes	Yes	No
UT-4	7.00	124 m	124 m	Yes	Yes	No
UT-5	7.18	0 m	97 m	No	Yes	Yes
UT-6	9.67	108 m	106 m	Yes	Yes	Yes
UT-7	8.89	0 m	127 m	No	Yes	Yes
UT-8	7.26	0 m	129 m	No	Yes	Yes

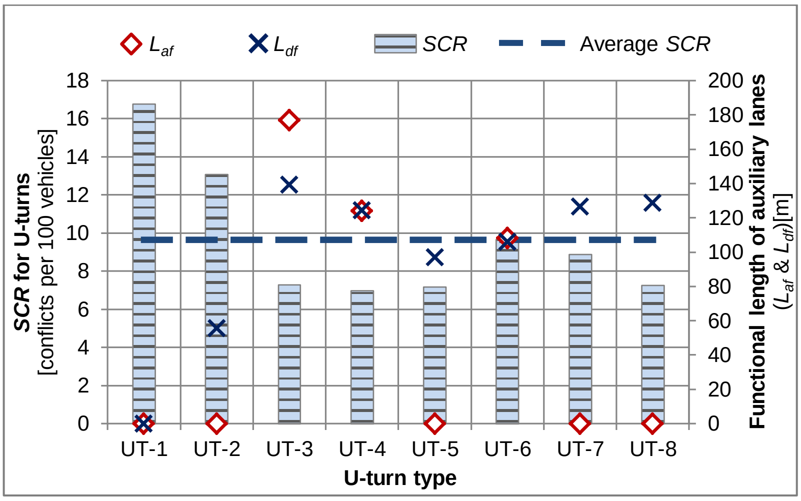

Fig. 8. The relationship between *SCR* and functional length of auxiliary lanes

7 Conclusions

A comparative higher value of the *Severity Conflict Rate* represents a lower level of road traffic safety at a traffic facility.

7.1 *Severity Conflict Rates* (*SCR*) for the U-turns

The U-turn type *UT-1* has a highest value of *SCR* because non of the acceleration lane, deceleration lane and outer-widening/ loons are applied on it, therefore this layout geometric design could be judge with a lowest level of traffic safety followed by the *UT-2*, which has only the deceleration lanes with a shorter length.

The U-turn types *UT-3*, *UT-4*, *UT-5* and *UT-8* have almost equal and lowest values of *SCR* s; therefore these could have a comparative higher level of traffic safety. These U-turn types have only the two layout geometric variables.

The U-turn types *UT-6* and *UT-7* have the medium values of *SCRs* and the moderate level of traffic safety. The one of the possible reason of these findings could be the over-dimensioning of these U-turns which could provide the higher opportunities for undesirable driving behaviors. The U-turn type *UT-6* has three geometric variables the deceleration lanes at the Upstream Zones and, the acceleration lanes and the outer-widening at Downstream Zones. Similarly the *UT-7* also has three geometric variables the deceleration lanes and the outer-widening at the Upstream Zones, and the outer-widening at Downstream Zones. These combinations of the three variables is not only provide a larger area of interaction for the conflicting through and merging streams, and also causing confusion among the drivers of conflicting vehicles to judge each-other maneuvers. The outer-widening at Upstream Zones of the U-turn type *UT-7* is unnecessary and mostly it is only used by the commercial vehicles for illegal parking.

The *Standard Drawing* from the 'Department of Highways' of Thailand illustrate the length of deceleration lane as 160 meters (including 60 meters length of taper section), but only 4 among 8 identified U-turn types were have these dimensions. The rest of U-turn types have a shorter length of the deceleration lanes. A shorter length of deceleration lane does not provide adequate space for comfortable deceleration and lane change for the diverging vehicles; this may result in a lower level of traffic safety for the weaving and storage maneuvers of diverging vehicles.

8 Recommendations

The very first recommendation could be a very serious need of establishment of a well structured and systematic traffic crash data system in the Thailand for improving the road safety strategies to ensure timely & quality results. As this study has undergone to use a surrogate and subjective to human judgment approach, which is frequently debated by the experts and practitioners for its reliability and subjectivity.

The U-turn types *UT-1* and *UT-2* having the lowest level of traffic safety therefore these should be modified as earliest possible and should not applied to the future projects. The U-turn types *UT-6* and *UT-7* also having a comparative lower level of traffic safety therefore these are also needed to modify and should not adopted for the future projects.

Furthermore, there are some areas of this research, which are needed to be improved in future studies. The several conflict severity levels measuring objective methods such as *Time-to-Collision*, *Post-Encroachment-Time* should be considered as an important factor predicting the crash severity and reducing dependency of human judgments.

For the future assessment of the comparative road traffic safety at the U-turns, in contrast to subjective *Traffic Conflict Techniques* the uses of micro-simulation software and programs could be the advanced technological tools to produce the results with a higher level of accuracy, reliability and validity.

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A SIMPLE INVESTIGATION INTO THE STABILITY OF LIGHTWEIGHT MOTORCYCLE

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Abstract: The objective of this study is to investigate the stability of lightweight motorcycle in straight path running test. The stability of three different tyre dimensions was measured using acceleration, angular velocity and vehicle speed signals from smartphone sensors. The signals were analyzed to determine whether standard configuration of tyres used in lightweight motorcycles in various developing countries are safe in terms of vehicle stability. In order to identify effects of tyre width on driving stability, forward speed, angular acceleration and rotational velocity were measured. These measurements are valuable empirical data in the understanding of motorcycle balance mechanism. Results of analysis show that for the range of tyre width 70 to 120 mm used in the test, motorcycle stability is not affected by the tyre width for the straight path run with maximum speed of 60 km/h.

Key Words: motorcycle, stability, smartphone, motorcycle tyre width

1. INTRODUCTION

It is wildly acknowledged that road traffic accident is one of the leading cause of death worldwide. According to (World Health Organization [WHO], 2013) and (Sivak and Schoettle, 2014), Thailand as well as others SEA countries, uses a great number of motorcycles and is confronting with high rate of motorcycle user fatalities and injuries. Motorcycle riders exemplify an important element of road safety aspect. To reduce the number of motorcycle fatalities, extensive efforts on law enforcement, engineering and adaptation of technical regulations have been implemented. However, the numbers of motorcycle fatalities are still unacceptably high.

In recent years there have been large numbers of road deaths in Thailand, especially for motorcycles. (The Road Accident Victims Protection [RVP], 2013) gave details of the claims involving motorcycle users from 2011 to 2013 as shown in Figure 1. The total numbers of injuries are unacceptably high at more than 200,000 per year. Fatality numbers were on average 7,400 cases per year or roughly 20 motorcyclists die on the road due to traffic accidents every day. These poor statistics, however, have to be considered taking into account a strong increase in the motorcycle fleet, with over 1 million units sold annually; the cumulative numbers are almost 20 million vehicles in 2012 (ASEAN Automotive Federation Statistics [AAF], 2014) as shown in Figure 2.

Motorcycles have been a popular mode of transportation. However, because of the vehicle structure, it is not as safe as other vehicles. They are not, in general, provided with protection features e.g. airbags, Anti-Lock Braking System (ABS) and traction control; this makes motorcycles less safe than others. Also, their stability can be a cause of much concern. The motorcycle stability directly depends on its dynamic characteristics (e.g. vehicle speed, lean angle and acceleration) and the static characteristics (e.g. vehicle geometry, mass distribution, frame compliance, suspension characteristics and tyre properties) (Cossalter et al., 2004; Cossalter, 2006; Cossalter et al., 2006).

The vitality of these characteristics have been highlighted in previous studies. In his landmark study, (Kasantikul, 2001) found that about one-eighth of motorcycle accidents in Bangkok were single-vehicle collisions; and the most frequent form of collisions was rear-ending another vehicle. In terms of vehicle factor, half of accidents involved 101 to 125 cc engine capacity and OEM (original equipment manufacturer) tyres. These findings pose the question as to how much influence a tyre characteristics has on the stability of motorcycle (see Figure 3). This is because the tyre is the only component of the motorcycle that transfers forces and moments between the vehicle and the road.

The main aim of this study is to investigate the stability of lightweight motorcycles using three different types of tyre, running on straight section, using forward speed, rotational angle, acceleration and angular velocity signals. The stability investigation involves an analysis of interaction signal generated when the motorcycle was running on straight section experiment, using data from GPS, 3-axis accelerometers and 3-axis gyroscopes sensors which are incorporated in modern smartphones. The measurements recorded by a smartphone are valuable data which are essential for analyzing and understanding the influence of the tyre configuration on motorcycle stability. The initial findings of this study could provide information about driving stability and a number of relevant factors as well as tyre properties.

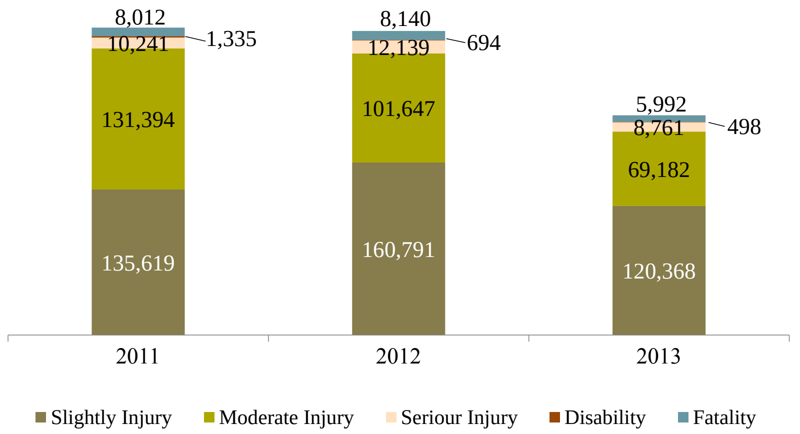

Figure 1 Claims involving motorcycle user (RVP, 2013)

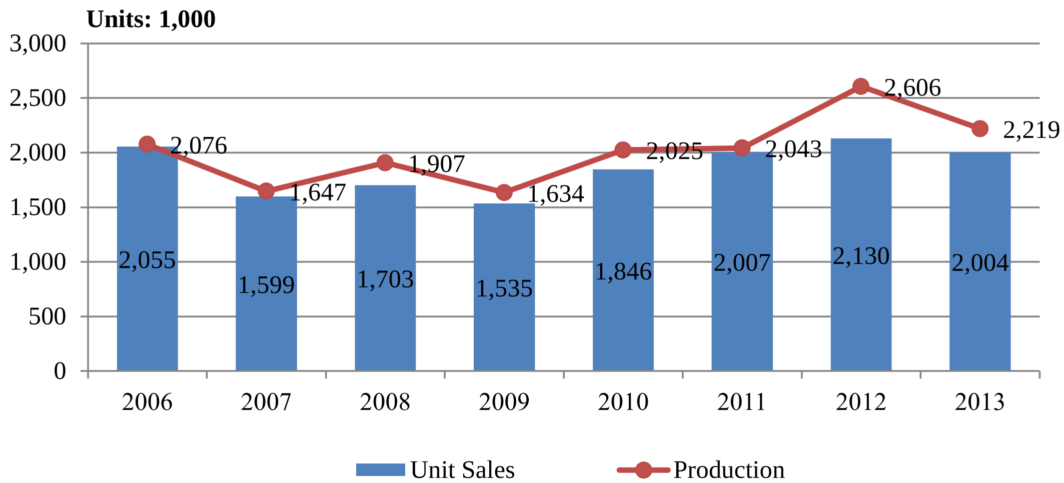

Figure 2 Thailand motorcycle production and domestic sales (AAF, 2014)

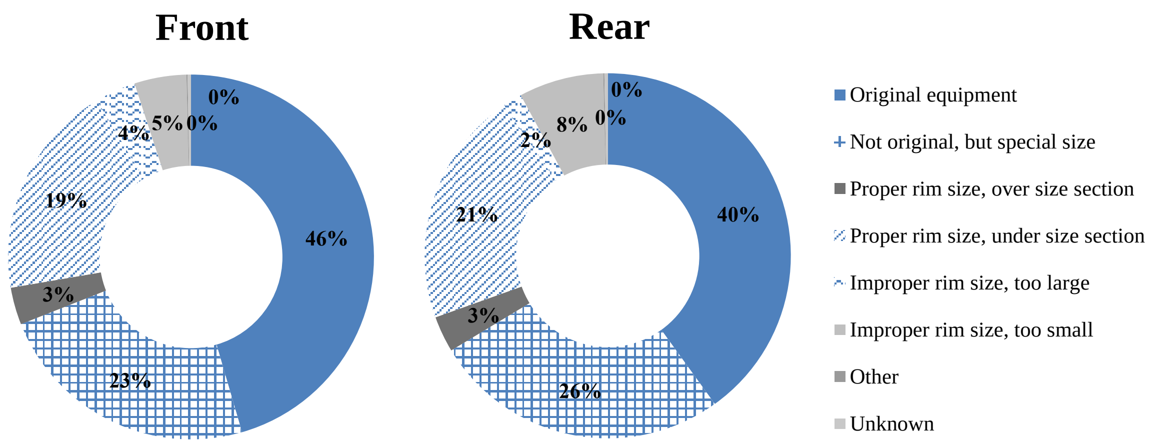

Figure 3 Motorcycle tyre size involved in accidents (Kasantikul, 2001)

2. PREVIOUS WORKS

Generally, stability of motorcycles is a major representation of motorcycle safety and studying this issue is considered a challenge. Dynamical behaviour of motorcycle riding can give rise to high instability due to the complexity of the system. Many related studies were carried out by researchers from developed countries including Italy, Germany and France where appropriate technology and budget are available. Transferring of the four-wheeled vehicles safety systems such as airbag, Electronic Stability Control (ESC), Anti-Lock Braking System (ABS), Traction Control System (TCS) and also airbag jacket systems to motorcycle has been emerging over the last decade. Unfortunately, in developing countries, including Thailand where the motorcycle users make up some 80 percent of road users, the issue of motorcycle stability receives little attention, while it should get the attention it deserves.

A number of important studies have been presented on motorcycle dynamics and control with regard to stability. Many previous studies have focused on stability at cornering condition by using simulation or modelling approach (Ghosh and Mukhopadhyay, 2009; Slimi et al., 2010; Nehaoua et al., 2013). Recently attention was paid to the development of active control systems such as Advanced Rider Assistance Systems (ARAS) (Biral et al., 2014; Boubezeoul et al., 2013; Cheli et al., 2010; Boniolo et al., 2008) Anti-Lock Braking System (ABS) and Traction Control Systems (TCS) using experimental approach (Seiniger et al., 2012). The vehicles used in these studies were normally high performance motorcycles with engine capacity greater than 250 cc. A few studies including (Yuen et al., 2014) have directly investigated lightweight motorcycle with engine capacity lower than 125 cc. It's worthwhile to look closely at this type of motorcycles as they are most common in developing countries.

3. METHODS

3.1 Instrumented Motorcycle

SUZUKI Sky Drive with 125 cc. engine, as shown in figures 4, was selected for the straight running test. It was equipped with a Samsung Galaxy Note 3 smartphone. On board sensors of acceleration, gyroscope and GPS give measurement of accelerations, rate of motion and the positioning information. A DJI FC40 Wi-Fi camera was mounted on the motorcycle rider's jacket to capture the real-time riding information. All video recording is stored in a micro SD card.

Smartphone is a probe device widely used for data recording. It has grown in popularity as an accurate measurement instrument because of its easy to use feature, inexpensive cost and reliable output. A number of recent studies using smartphone including the works of (Douangphachanh and Oneyama, 2013; Douangphachanh and Oneyama, 2014) on road roughness conditions and (Sekine, 2014) which examined the possibility of realizing safe mobility of powered two-wheeler vehicle show that smartphones can give data with high accuracy in the frequency range of 40 to 50 Hz.

The application named AndroSensor and Bubble Level 360 (Google Play, 2013) were pre-installed into the smartphone. The AndroSensor was used to record key data such as 3-axis accelerations, 3-axis angular velocities, and vehicle speeds. The recording interval was done at 20 Hz frequency or 0.05 seconds. All information from the sensors was recorded into a CSV file. The box housing the smartphone was positioned on level plane under the rider seat as shown in Figure 5. The application, Bubble Level 360 was used to accurately position the smartphone.

Figure 4 SUZUKI Sky drive

Figure 5 View of the box fitted under the rider's seat

Three different tyre characteristics were used for the test runs With respect to the standard configurations, the SUZUKI Sky drive has 14 inch spoke wheel rims with 70 mm tyre width/ 80 tyre height for the front wheel and 80 mm tyre width/ 90 tyre height for rear wheel, the configuration was designated as Tyre set A. Motorcycle with the same 90 mm tyre width/ 90 tyre height for both the front and rear wheels was designated as Tyre set B and motorcycle with the front wheel of 110 mm width/ 70 mm height and the rear wheel 120 mm width/70 mm height as Tyre set C; details are as shown in Table 1 and Figure 6 below.

3.2 Straight Running Test Program

The tests were performed on a highway with general grade within Songkhla municipality, Thailand. All straight running tests were conducted in clear weather condition and dry road surface. These allow efficient maneuverability and visibility riding. By using the same rider for each test, it is reasonable to assume that the riding behaviors would have minimal interfere the output. At the starting point, the rider was briefed on the path and the procedure. The test procedure required that the rider controlled the vehicle until the desired speed was attained and then took his hands off the handlebar in order to produce free rotation of the steering system. The rider stopped the vehicle at the end of the path or when oscillation amplitude approached an instability state. The data on travel speed, 3-axis acceleration, 3-axis angular velocity and GPS positions were recorded in the Smart Phone memory card.

The straight running test program was designed to investigate the dynamic behaviors of lightweight motorcycles in terms of the frequency of the principal vibration's mode out-of-plane (roll, pitch and yaw) (Cossalter, 2006). A different set of speeds and tyre widths were changed to verify their impacts on the vehivle stability. Table 2 shows the straight running testing program. For the lower test speeds (30 km/h, 40 km/h) and the higher test speeds (50 km/h and 60 km/h) the instrumented motorcycle was tested with ten replications each. The front and rear tyre inflation pressures for all tyres were fixed in order to control their influence.

Table 1 Experiment arrangement

	Front Wheel	Rear Wheel	Remark
Tyre set A	70/80-14 M/C 34P	80/90-14 M/C 40P	*Standard Configuration
Tyre set B	90/90-14 M/C 46P	90/90-14 M/C 46P	
Tyre set C	110/70-14 M/C 56P	120/70-14 M/C 61P	

Table 2 Straight running test programs

Test run	Tyre set	Speed (km/h)	Number of Replications
1	A	30	10
2		40	10
3		50	10
4		60	10
5	B	30	10
6		40	10
7		50	10
8		60	10
5	C	30	10
6		40	10
7		50	10
8		60	10

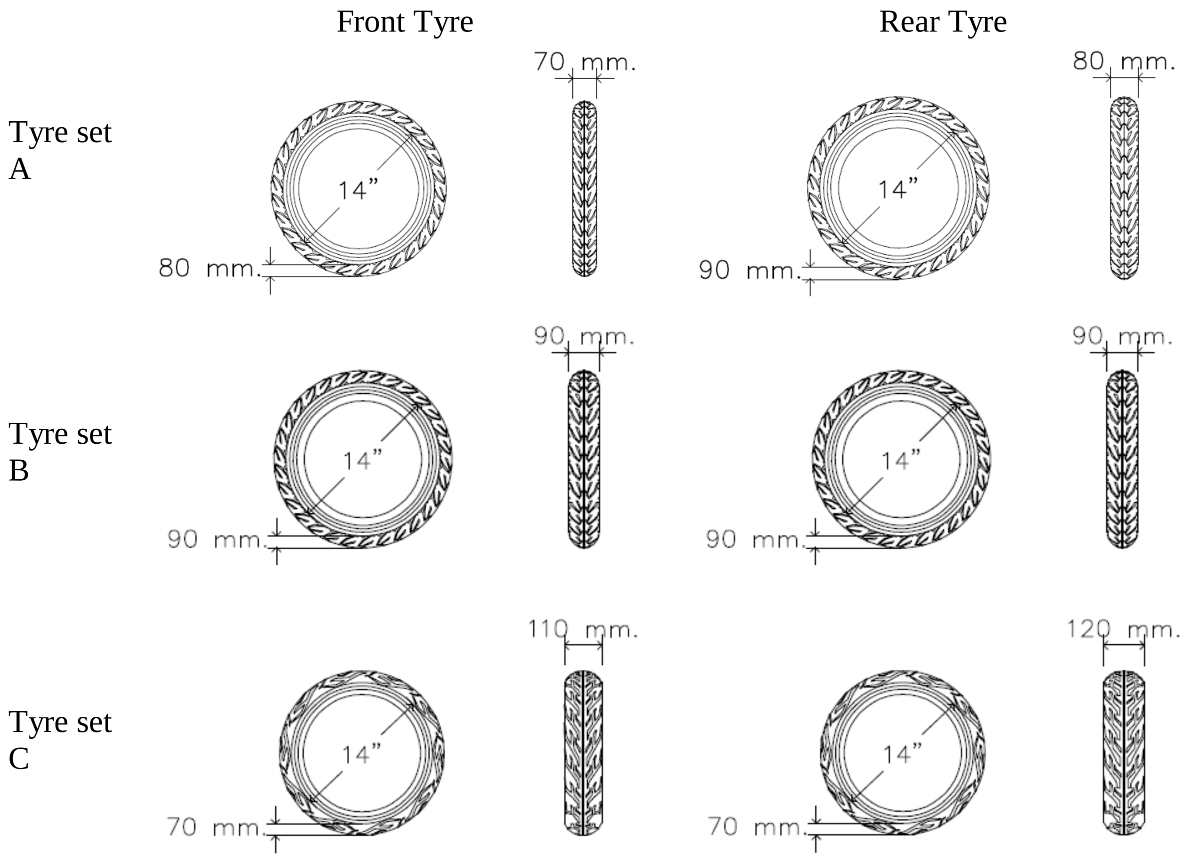

Figure 6 Tyre dimensions

4. DATA ANALYSIS

The measurement of 3-axis accelerations, 3-axis angular velocities and forward speed for each task were recorded from the straight line motion of the motorcycle where the x-axis is rotated along the longitudinal axis of the motorbike, the y-axis is aligned perpendicularity to forward movement direction and the z-axis is the vertical motion. In each measurement data were determined from the logged data and synchronized. The data of motion characteristics were extracted, based on the free motion of steering system for constant forward speed duration. The filtered data were double-checked from the video recorded.

Data were analyzed using a manufacturer software. The roll angle was then calculated and chosen as a stability index in this study because the stability state of motorcycle in longitudinal axis was, rather, heavily influenced than in other directions. This is because the motorcycle tends to easily fall over sideway, while the front and the rear wheel could provide supports for the motorcycle body in y-axis and z-axis (Cocco, 2004).

5. RESULTS

To identify the stability state of a motorcycle, the frequency of out-of-plane mode such as roll rate, pitch rate and yaw rate were principally considered (Nenner et al., 2008; Ghosh and Mukhopadhyay, 2009; Cheli et al., 2010; Jamieson et al., 2013). Figures 7, 8, 9 and 10 show an example of the experimental time histories of the roll, pitch and yaw rate of Tyre set A, Tyre set B and Tyre set C, respectively. From the graph below, a significant oscillation of roll rate (the thick line) shows high amplitude, while pitch rate and yaw rate present smaller amplitude. These figures clearly illustrate that for all experiments the motorcycle can regulate the out-of-plane vibrations of vehicle to return back to the equilibrium position. Among three different tyres, the frequency of roll rate of Tyre set C was quite different in comparison to Tyre set A and Tyre set B with the higher frequency. Moreover the pitch and yaw rate oscillation seem to settle lower frequency and amplitude. Similar performances are observed in the experiment at higher speed of 60 km/h.

In order to compare the stability of these three tyre configurations, Tyre set A, Tyre set B and Tyre set C, statistical techniques were applied to probe dynamical response signal. An average of the roll angle of Tyre set A, Tyre set B and Tyre set C is illustrated in Figure 11. The results show that the fluctuation motion of motorcycle in longitudinal axis for Tyre set A is quite small with respect to zero axis than the Tyre set B and less than the Tyre set C. These imply that, the stability of the motorcycle under three different tyres in straight running tests is not affected by the tyre width. In other words, the tyre width does not create any significant stability issue for light weight motorcycle at speed lower than 60 km/h.

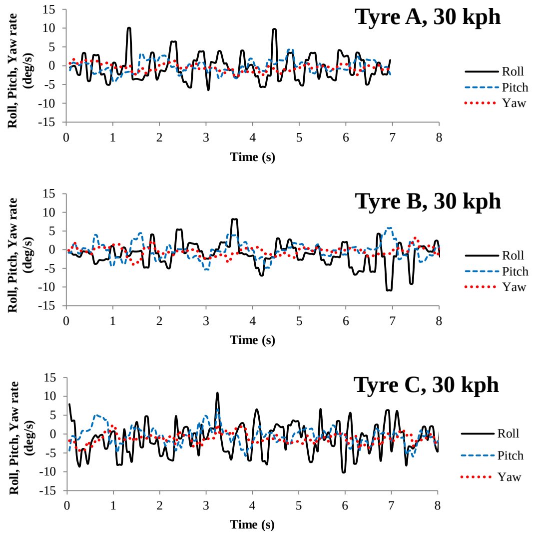

Figure 7 Time history of roll, pitch and yaw rate of three different tyres at speed 30 km/h

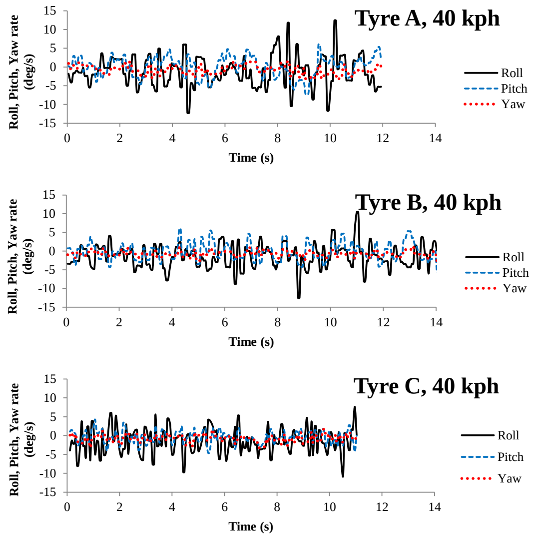

Figure 8 Time history of roll, pitch and yaw rate of three different tyres at speed 40 km/h

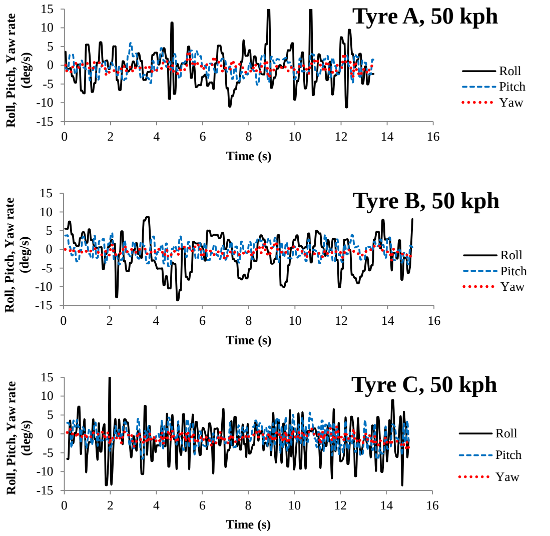

Figure 9 Time history of roll, pitch and yaw rate of three different tyres at speed 50 km/h

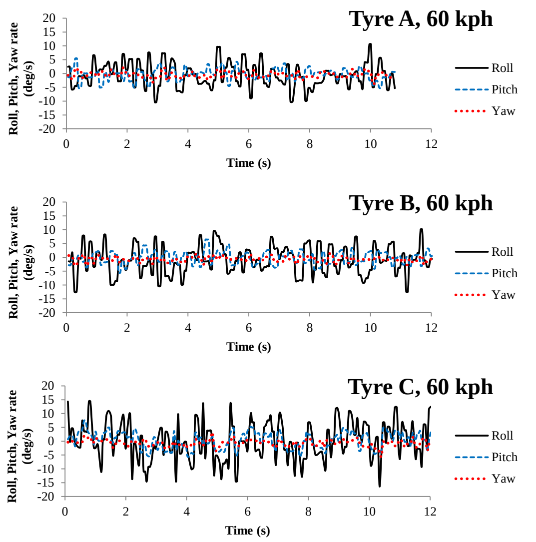

Figure 10 Time history of roll, pitch and yaw rate of three different tyres at speed 60 km/h

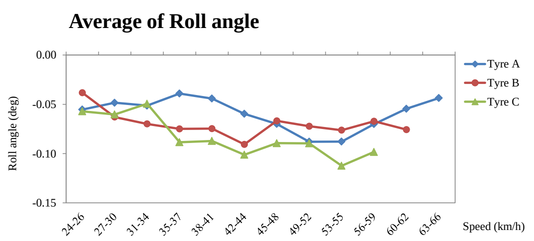

Figure 11 Comparison of average of roll angle

6. CONCLUSION

In this paper, a simple experiment of straight running test has been presented to study the stability of lightweight motorcycle by using a smart phone. The smart phone which has built- in sensors, and with freely available applications proves to be a low cost and effective measuring device. The findings from the straight running test at the maximum speed of 60 km/h show that for up to this speed, the size of tyre used on these small light weight motorcycles has minimal effect on the vehicle's driving stability. The results of the study show that no differences in motorcycle stability on straight motion with longitudinal speed lower than 60 km/h when the tyre width is in the 70 mm to 120 mm range.

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PUBLIC DECISION CHOOSING HYBRID CANAL-RAIL MODE FOR COMMUTE IN BANGKOK: PRELIMINARY STUDY TOWARDS STATE PREFERENCE ANALYSIS

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Abstract: Waterways transportation is being considered as a traditional way of transportation in ancients era, but the importance of this mode has been decreasing since the roadway transportation had introduced. In recent, Bangkok Metropolitan Administration (BMA) are keep trying to revitalize and persuade commuters trying to choose waterway transportation which possibly connected to urban railway transportation such as Mass Transit System (BTS), Bangkok Metro Public Company Limited (MRT), and Airport Rail Link (ARL). Therefore, there are some possibilities to increase the number of passengers to choose the hybrid canal-rail network (HCR) as alternatives mode choice if some criteria are trigger to their demand. The aim of this research is to figure out which factors motivate passengers deciding to use HCR. There are two objectives as follows (1) to define groups of factors that possibly motivate intended passengers decide to use HCR, and (2) to predict the intention of passengers to ride on HCR comparing to others mode of transportation. This research applied Binary Logistic Regression Model for analyzing how passengers choose canal-rail transportation comparing to other modes of transportation. The preliminary result of this research reveals that physical development in terms of Transit-Oriented Development, increase attraction, improve modernization of service vehicle, and decrease travel time, are significantly increasing intention of passenger choosing to use HCR mode rather to their previous mode.

Key words: Canal-rail system, stated preference**,** mode choice, Transit-Oriented Development

1. INTRODUCTION

Waterway transportation is considered as traditional transportation since the ancient era. Waterborne transportation has been used for delivered goods and passengers because the strategic locations of urban settlement are located near canal network or riverside. In modern era, rapid urban development had taken place, which is land-based transportation system (e.g., car, bus, railway and tram) had introduced. Since then, waterway transportation becomes the secondary choice of intra-urban travel demands due to the limitation of access and inconvenient to reach to some area.

The previous studies towards mode choice are being considered as a competitive mode between the potential mode of transportation which had been applied in logistic competition in service, or between urban core and urban fringe area (Derakhshan and Shah) Mode competitive are not only increase the demand and improvement, but the service facilities and the development of transportation system are being considered for improvement (Wadhwa, 1997) According to the Tallahassee Capital Region Transportation Planning Agency research based on mode choice in person trip, between automobile and public transit. It shows that aspects that relates to the waiting time of public transit, speed of service vehicle in peak hour and non-peak hour, walk and drive access to connector (consumption times in intermodal or transition between mode) and level of service are influence passengers deciding to use private transportation or public transportation (Tallahassee Capital Region Transportation Planning Agency, 2008)

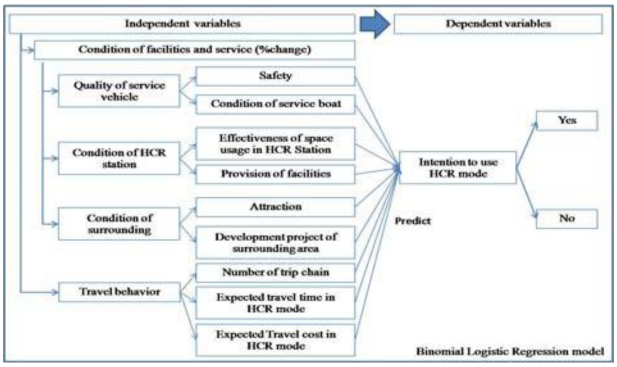
In case of Bangkok, the importance of canal system are slightly decreased since the roadway transportation had introduced. Therefore, some of canal parts in Bangkok were filled up and building had been built and urban areas are continuing expand to suburban area especially in agricultural area. In recent, Bangkok Metropolitan Administration (BMA) had agreed to build the 10 lines of metro network for increasing the connectivity of railways system and to reduce traffic congestion which is considering as a one of major problem in Bangkok. BMA also pushing their canal revitalization projects and implement boat canal services in some part of canal in BMA which connected to railway transportation such as Bangkok Mass Transit System (BTS), Bangkok Metro Public Company (MRT) and Airport Rail Link (ARL) Therefore, development of waterway transportation in intra-urban area are important to motivate passengers deciding to use waterway transportation as the alternative mode to connect to railway system (Hybrid Canal-Rail transportation)

2. OBJECTIVES

1. To define groups of factors that possibly motivate intended passengers decide to use HCR

2. To predict the intention of passengers to ride on HCR mode comparing to other mode of transportation. This research applied Binary logistic Regression Model for analyzing how passengers choose canal-rail transportation comparing to other modes of transportation.

3. CONCEPTUAL FRAMEWORK



4. SCOPE OF THE STUDY

There are 1,200 samples which collected in Bangkok Metropolitan Area (BMA) during November – December 2014. Samples are collected randomly in each 3*3 kilometers grid ranges. The sampling method in this research is random sampling in each grid, therefore, the sampling method are covered all types of passengers and well normalized. According to figure 1, there are four categories in this analysis. First category is the quality of service vehicle (Safety of service vehicle and condition of service boat) second category is the condition of Hybrid Canal-Rail Station (Effectiveness of space usage in Hybrid Canal-Rail Station and Provision of facilities in HCR station) Third category is condition of surrounding (e.g., attraction points nearby HCR station, and development project of surrounding area) And forth category is travel behavior (The number of trip chain, expected travel time in HCR mode and expected travel cost in HCR mode) These four categories are considering as independent variable. Dependent variable is the intention of respondents to ride on HCR (Boat to rail, rail to boat or from other mode to HCR) which considering as "choose" or "not choose" This study applied binomial logistic regression model to predict which factors motivating respondents decide to use HCR mode

5. RESEARCH METHODOLOGY

This research applied factor analysis to grouped variables, there are variables that relevance to preferences to choose HCR mode of transportation.

This research applied factor analysis to group variables and apply binomial logistic regression model to predict the possibility of passengers deciding to use HCR comparing to other modes of transportation. Fundamentally, Binary logistic regression model is developed from regression model in order to predict the relationship between set of independent variables and dependent variable. Logistic Regression model can be described below

$$\log\left(\frac{Py}{1-Py}\right) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \dots \beta_p X_p \qquad (1)$$

$$Odds(P) = \frac{P}{1-P} = e^{a+bx} \qquad (2)$$

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \dots + \beta_n X_n + \varepsilon \qquad (3)$$

And the values of Y are in the range of 0 to 1

where,

Y is the binary and represents the intention to use Hybrid Canal-Rail network

X_1 is the factor 1

X_2 is the factor 2

X_n is the factor n

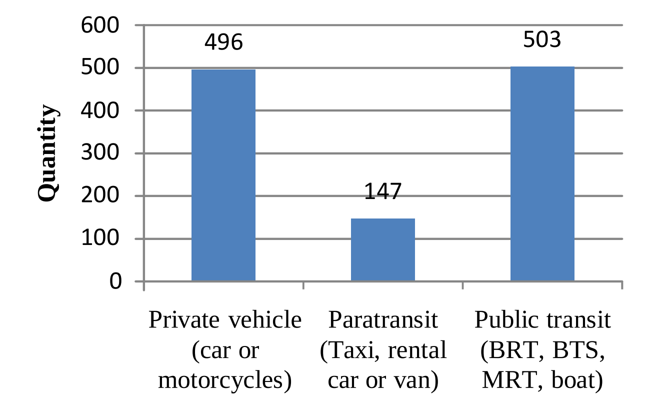
ŧ are the Y-intercept and the slope for variable X

¨, is the random error

6. RESULTS

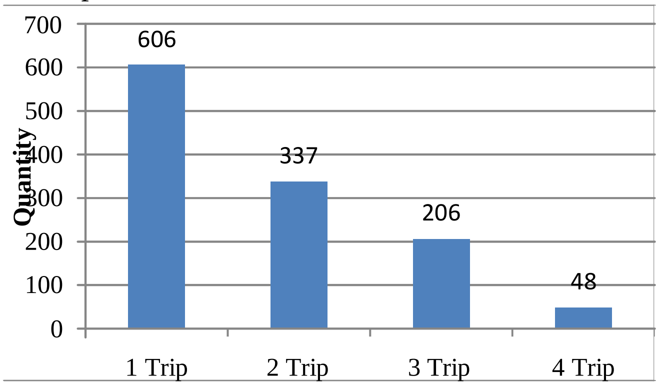
According to the amount of trip chain data from the survey, its shows that most of passengers use only one trip to commute from their origin to their destination, there are 606 samples or equal to 50.50 percent of total respondents who are using the single mode for transport to their destination. Passengers who needs to use modes changes are equal to 49.50% of the total sample size (1,200 cases) According to the current mode of transportation, most of passengers are selected public transit (e.g., MRT, BTS, BRT, Bus and boat) there are 503 respondents who are using the public transit, which is equal to 43.90% Second is private mode (e.g., private car and private motorcycles) there are 496 respondents which is equal to 43.30% are using private transportation. Respondents are least decide to use paratransit (taxi, rental car of van) there are 147 respondents which is equal to 12.80% who are choosing paratransit as mode choice for commute between their origin and destination (Figure 1)

Figure 1 Classification of modes used by respondents



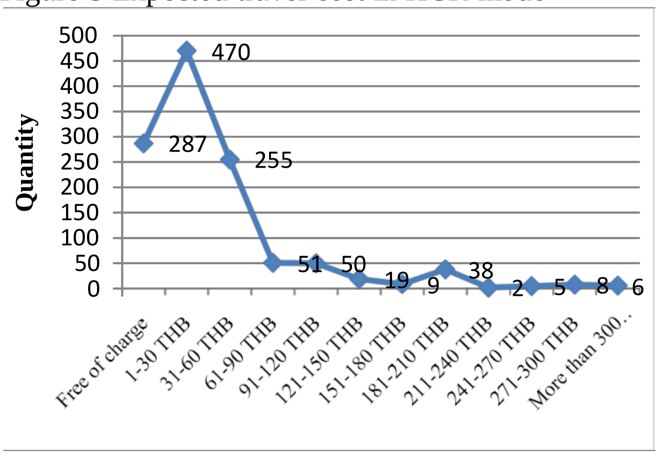
Regards to the amount of trip chain, the result of survey show that most respondents have a direct travel from their origin to their destination, there are 606 respondents who are travel by a single trip chain which is equal to 50.63% of total respondents. Second are the passengers who take two trip chains for transportation, there are 337 passengers which equal to 28.15% of total respondents. Third is passengers who takes three trip chains, there are 206 passengers who takes three trip chains for commuting to their destination, which is equal to 17.21% of total passengers

Figure 2 Number of trip and current mode choice of the respondents



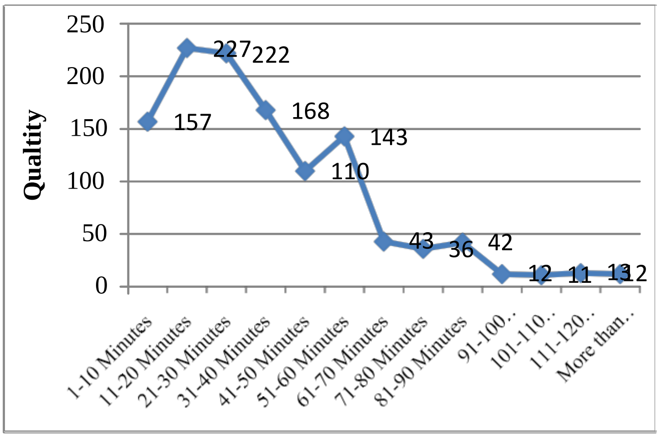
According to travel behavior, the result shows that passenger are expecting the travel cost in HCR mode are approximate 39.09 THB per trip (From the passengers' origin to destination) and standard deviation of the expected travel cost is 58.61 (Figure.3)

Figure 3 Expected travel cost in HCR mode



Regards to expected travel time in Hybrid Canal-Rail (HCR) mode, its shows that passengers are expected to use the HCR mode from their origin to destination within 38.67 minute per one trip, and the standard deviation of the expected travel time is equal to 26.65 (Figure 4)

Figure 4 Expected travel time in HCR mode



Regards to characteristic of sample size, this study conducted questionnaire survey to 1,200 samples whose are living in Bangkok Metropolitan Area (BMA) According to the experience of waterway transportation in BMA, there are 58.40 percent of respondents are experienced to use boat transportation. Regards to the preference, 69.30 percents of all respondents prefers to use canal transportation if able. Most of respondents (58.40%) may use Hybrid Canal-Rail (HCR) transportation if it established. Moreover, passengers who use private car are intent to use this mode of transportation if the station provides area for parking (Table 1)

Table 1 Intention of passengers towards using Hybrid canal-Rail Transportation

		Quantity	Percentage
Have you ever used boat for transport within BMA	Yes	701	58.40
	No	499	41.60
	Total	**1,200**	**100.00**
As your preference, if possible. Will you decide to use boat for your travel trip?	Yes	831	69.30
	No	369	30.80
	Total	**1,200**	**100.00**
If the HCR are established, will you use HCR mode?	Yes	701	58.40
	No	499	41.60
	Total	**1,200**	**100.00**
If you are using private vehicle (e.g., car) if the HCR are established, will you decide to use HCR instead?	Not use	402	33.50
	Parking only	21	1.80
	Park and ride	777	64.80
	Total	**1,200**	**100.00**

However, this research would like to predict between HCR mode and non-HCR mode. Measurable variables in this research are (1) expected travel time on HCR, (2) the number of trip chain, and (3) monthly income of passengers. Immeasurable variables in this research are (1) average of percentage of change in HCR service vehicle, (2) average of percentage of change in HCR station, and (3) average of percentage of change nearby HCR station. This research applied Logit Model to predicting passenger's preferences, and trying to predict how much of passengers who are using the current mode (non-HCR mode) to HCR mode by using Logit model.

This research applied Binomial Logistic Regression Model to predict which factors that influencing factors that motivate passenger decide to use HCR modes of transportation. Based on the analysis (Table 2), shown the comparative result between base model and predicted model. The result shown that the test model will better predict passengers' decision to use HCR system from 58.40 percent to 65.40 percent, and there are 288 passenger who are not choose to use HCR system in normal situation will change to use this system.

Table 2 Possibility to choose HCR mode

Observed			Predicted: If the HCR are established, will you use HCR mode? Not use	Predicted: If the HCR are established, will you use HCR mode? Use	Percentage Correct
Base model	If the HCR are established, will you use HCR mode?	Not use	0	499	0.0
		Use	0	701	100.0
	Overall Percentage				58.4
Predicted model	If the HCR are established, will you use HCR mode?	Not use	211	288	42.3
		Use	127	574	81.9
	Overall Percentage				65.4

According to result of analysis based on binomial logistic regression model showing that some input variable are significantly affect to passengers' intention to use Hybrid Canal Rail (HCR) system. Table 3 shows the result of binomial logistic regression model. The result of analysis shows the factor that highest influence to decision of passenger to ride on HCR is the number of travel trip or trip chain, which can infers that the respondent who are taking more stopover, or frequent trip chain per personal trip will decide to use HCR as mode choice by 1.337 times ($Exp(B)_{Tripchain}$) of passengers who are not decide to change their mode to HCR (The highest range of $EXP(B)_{Tripchain}$ is equal to 1.554 and the lowest range of $EXP(B)_{Tripchain}$ is equal to 1.150) The second influence variable is the condition of the surrounding nearby Hybrid Canal-Rail station (Commercial) this variable are motivate respondent deciding to use HCR approximately 1.121 times ($EXP(B)_{Commercial}$) comparing to passengers who are unintended to use HCR (The highest of $EXP(B)_{Commercial}$ is equal to 1.245 and the lowest range of $EXP(B)_{Commercial}$ is equal to 1.009) The third variable that influence passengers deciding to use HCR is the quality of service vehicle (Modernity of vehicle) are influence 1.013 times ($EXP(B)_{Modern}$) comparing to passengers who are unintended to use HCR as mode of transportation (The highest range of $EXP(B)_{Modern}$ is equal to 1.022 and the lowest range of $EXP(B)_{Modern}$ is equal to 1.004) While factors that relates to the expected of travel time, and income range are negatively affecting to decision of respondent to use HCR mode of transportation. Based on the result model, some variables such as the development nearby HCR station, quality of service vehicles and increasing accessibility are negatively affect to the preference of passengers towards choosing HCR for commute. This could imply that although the improvement aspects such as condition of the hybrid station, quality of accessibility and service vehicle are important and should considers, but it could affect to the travel cost as well. Moreover, regards to safety of service vehicle, there is not much accident occurred in water transportation, and rail transportation. Therefore, passengers may think that it was safe for commute by HCR mode, and there is no improvement is needed. Thus, significantly improve in safety in service vehicle and accessibility may not much affecting to passengers' preference in choosing HCR for future transportation.

Table 3 result of binary logistic regression model

	B	S.E.	Wald	Sig.	Exp(B)	95% C.I. for EXP(B)	
						Lower	Upper
Number of trip	.290	.077	14.247	.000	1.337	1.150	1.554
Expected travel time	-.009	.003	12.223	.000	.991	.986	.996
Income Range	-.648	.175	13.632	.000	.523	.371	.738
Modernization of service vehicle	.013	.004	8.419	.004	1.013	1.004	1.022
Safety of service vehicle	-.015	.005	10.945	.001	.985	.976	.994
Increase efficiency of space usage nearby HCR station	-.018	.004	20.667	.000	.982	.975	.990
Increase commercial attraction	.114	.054	4.516	.034	1.121	1.009	1.245
Increase convenient of accessibility	-.122	.059	4.256	.039	.885	.789	.994
Constant	1.716	.365	22.119	.000	5.561		

Remark: Using Stepwise entering method

In order to predict the percentage of change to use HCR mode comparing to other modes of transportation, this research applied "Maximizing Utility Model" stated in chapter 3 Moreover, due to the constrains of statistical problems, this research selected some policy variables for further analyze the preferences of commuters regarding to use HCR modes. There are three condition analyzed in this research are (1) configuration of the expected travel time, (2) vehicle improvement in modernity of service vehicle, (3) increase attraction nearby HCR station by commercial improvement, and (4) all policy variables are applied. For alternative one to three, this research selected the best result of the preference by using "percentage change" (i.e., 5% change, 10% change, 15% change) and consequently select the best preference in each alternatives. In this preliminary study, there are two stated preferences analyzed in this research are (1) Reduce travel time and (2) Increase attraction nearby HCR station by commercial improvement

1. Reduce travel time

This research did preference analysis by applying "Utilization model" this section selected policy variable name "travel time" This research suppose if the expected travel time of transportation are decrease, passengers may expected to use HCR mode will instead of previous mode of transportation. Therefore, this research had configured value of travel time by reducing 10% 20% and 30% of the expected travel time. Table 4 show the stated preference analysis in case of reducing the expected of travel time. There are two categories of income range (low class income and high class income) The prior result from Binomial Logistic Regression model showing that the high class income are negatively affect to passenger's preference. According to table 4 showing that the "Maximize Utility" in terms of travel time is prefers to low-to-medium income class. The initial preference model (preference use) is equal to 29.70% representing that if the HCR are established and there is no further improvement, passengers approximately 29.70% of total passengers will selected to use HCR mode instead (the average of the expected travel time is equal by 38.70 minutes). The result show that if the expected travel time had configurated 10% faster, the amount of expected passengers in HCR mode will increase from 29.70% to 31.20% If the expected travel time decrease by 30% from the average (approximately 27 minutes) the amount of passengers will increase to 34.01% (Table 4)

2. Increase attraction nearby HCR station by commercial improvement

This research did preference analysis by applying "Utilization model" this section selected policy variable name "Commercial improvement" This research suppose if the expected travel time of transportation are decrease, passengers may expected to use HCR mode will instead of previous mode of transportation. Therefore, this research had configured value of travel time by increasing the passengers' demand (3 is refers to need in moderate level, 4 is refers to need in high level, and 5 refers to need in the highest level). According to result of stated preference analysis by applying "Utilization model" regards to improvement of modernity of service vehicle. As calculated by the initial preference model, it shows that 29.70% of total passengers will selected HCR mode for their trip (the level of commercial demands around HCR station is equal to 3.50 which is refers to "moderate to high" level) Regards to the policy variable "improvement of the modernity of service vehicle", showing that low-class income will change their preference in other mode of transportation to HCR mode by approximately 8% if the needs of commercial place become increased to highest level.

Table 4 Result of stated preference towards HCR mode improvement

				Stated preference 1			Stated preference 2		
	B	Exp (B)	Mean	Reduce travel time			Increase attraction nearby HCR station by commercial improvement		
				10% Faster	20% Faster	30% Faster	3 (Moderate)	4 (High)	5 (Highest)
Number of travel trip	.290	1.337	1.74	1.7	1.7	1.7	1.7	1.7	1.7
Expected travel time	-.009	.991	38.67	34.8	30.9	27.1	38.7	38.7	38.7
Income range	-.648	.523	0.14	0.14	0.14	0.14	0.14	0.14	0.14
Modernization of service vehicle	.013	1.013	62.13	62.1	62.1	62.1	62.1	62.1	62.1
Safety of service vehicle	-.015	.985	65.73	65.7	65.7	65.7	65.7	65.7	65.7
Increase efficiency of space usage nearby HCR station	-.018	.982	62.87	62.9	62.9	62.9	62.9	62.9	62.9
Increase commercial attraction	.114	1.121	3.58	3.6	3.6	3.6	3.6	4.0	5.0
Increase convenient of accessibility	-.122	.885	3.88	3.88	3.88	3.88	3.88	3.88	3.88
Constant	1.716	5.561							
Logit model			0.286	0.303	0.319	0.334	0.286	0.310	0.360
Preference use (Percen			28.61	30.30	31.91	33.45	28.61	30.97	36.01

Table 5 Result of stated preference towards two configurated policies

	B	Exp (B)	Mean	All configured
Number of travel trip	.290	1.337	1.74	1.7
Expected travel time	-.009	.991	38.67	27.10
Income range	-.648	.523	0.14	0.14
Modernization of service vehicle	.013	1.013	62.13	62.13
Safety of service vehicle	-.015	.985	65.73	65.73
Increase efficiency of space usage nearby HCR station	-.018	.982	62.87	62.97
Increase commercial attraction	.114	1.121	3.58	5.00
Increase convenient of accessibility	-.122	.885	3.88	3.88
Constant	1.716	5.561		
Logit model			0.286	0.399
Preference use (Percent)			28.61	39.91

3. Decrease travel time and increase the attractiveness of commercial place nearby HCR station

The prior result from Binomial Logistic Regression model showing that the high class income are negatively affect to passenger's preference. According to table 4 showing that the "Maximize Utility" in terms of travel time is prefers to low-to-medium income class. The initial preference model (preference use) is equal to 29.70% According to the stated preference model (decrease travel time by 30% and increase the attractiveness of commercial use nearby HCR station) The result shows that the passenger's intention to choose HCR mode for intra-urban transportation will raise up to 11.30% from the initial preference.

7. DISCUSSION AND CONCLUSION

Although Bangkok Metropolitan Area have canal network and seems to be well-connected with railway network. Regards to the reason of use boat service, its depending to the trip purpose of respondents but "Expected travel cost of HCR mode" become the important variable for influencing passenger decide to use HCR mode. Passengers who are unintended to use HCR mode may change to use HCR mode if some aspects are being considered for future development (E.g., Expected travel cost of HCR mode, the development of surrounding area and attractive place) to use HCR mode in future. Result of binomial logistic regression model (Reason to use boat) shows that some physical development variable (e.g., intermodal, efficiency of usage space, increase attractiveness in nearby area) are possibly increase overall decision to use HCR mode in all kinds of passengers. This study shows some variable that relates to decision of passenger deciding to use the alternative mode in terms of physical development and some aspects relates to expected travel time and expected travel cost. However, some socio-economic factors such as vehicle ownership, monthly income and of passenger are no analyzed in this study. To become more precise and accurate in decision of choosing, variables that relates to those subjects should be concern. Also, to determine the amount of mode change from other kinds of transportation to HCR, the calculation of mode change are important and interesting to figure how Hybrid Canal-Rail network works comparing to other mode of transportation.

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