A Road Safety and Efficiency Study of Flyover – Improved Junction

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ชื่อวิทยานิพนธ์ การศึกษาประสิทธิภาพและความปลอดภัยทางถนนของทางต่างระดับ (Flyover) - ปรับปรุงที่ทางแยก

ผู้เขียน นายนรบดี สาละธรรม

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ปีการศึกษา 2557

บทคัดย่อ

เพื่อแก้ปัญหาทางหลวงสายหลักผ่านเขตชุมชนเมือง ปัญหาการจราจรติดขัด/ความล่าช้า และอุบัติเหตุจราจรที่ทางแยกระดับเดียว หนึ่งในวิธีที่ถูกนำมาใช้เพื่อช่วยบรรเทาปัญหา คือ การก่อสร้างสะพานพิเศษ (flyover) คร่อมผ่านที่ทางแยกเดิม เพื่ออำนวยความสะดวกให้แก่ผู้สัญจรในทิศทางของสะพานให้เกิดการไหลอย่างต่อเนื่อง อย่างไรก็ตามด้วยงบประมาณการก่อสร้างที่ค่อนข้างสูง (ประมาณ 175 ล้านบาท) และภาพรวมของปัญหายังคงมีอยู่ จึงนำไปสู่การศึกษาวิจัยเพื่อศึกษาถึงประสิทธิภาพ/ความคุ้มค่า และความปลอดภัยทางถนน ในการศึกษาได้แบ่งกรณีศึกษาออกเป็น 2 กรณี คือ 1) กรณีทางแยกระดับเดียวถูกแปลงไปเป็นทางแยกสองระดับ (flyover intersection) และ 2) กรณีทางแยกสองระดับที่มีอยู่ (existing flyover)

ในกรณีที่ 1 จะเปรียบเทียบสภาพก่อนและหลังการปรับปรุง เพื่อศึกษาถึงประสิทธิภาพของมัน เช่น ความล่าช้า, ความยาวแถวคอย, ระดับการให้บริการ, อุบัติเหตุทางถนน รวมถึงตรวจสอบอุปกรณ์/เครื่องมือที่นำมาควบคุมที่ทางแยก และการวิเคราะห์ทางเศรษฐศาสตร์ ซึ่งผลที่ได้หลังจากปรับปรุง พบว่าปริมาณจราจร 37.8% หันไปใช้สะพาน, ความล่าช้าทั้งหมดลดลง 34.5%, จำนวนการเกิดอุบัติเหตุและการควบคุมการจราจรที่ทางแยกมีผลไม่แตกต่างกับสถานการณ์ก่อนมากนัก ส่วนการประเมินโครงการได้ผลที่มีความคุ้มค่า

ในกรณีที่ 2 คัดเลือก 5 กรณีตัวอย่าง (แบ่งไปตามภูมิภาค) จากทั้งหมด 29 จุดในประเทศไทย เพื่อสนับสนุนผลจากการควบคุมด้วยทางแยกประเภทนี้ และค้นหาปัญหาที่ยังคงมีอยู่ เช่น ปัญหาจราจรติดขัดในช่วงชั่วโมงเร่งด่วน, ความเสี่ยงและสถิติอุบัติเหตุ และสภาพทางกายภาพ เป็นต้น โดยผลที่ได้ เช่น มูลค่าอุบัติเหตุต่อพื้นที่อยู่ที่ 9.3 ล้านบาท/ปี และยังพบเห็นจุดเสี่ยงอยู่อย่างน้อย 4 โซน ในพื้นที่ของทางแยกประเภทนี้ เป็นต้น

เพื่อปรับปรุงทางแยกประเภทนี้ให้ดียิ่งขึ้น ในงานวิจัยนี้ได้นำหลักการด้านความปลอดภัยทางถนน และโปรแกรม SIDRA เข้ามาช่วยสนับสนุนข้อเสนอแนะเพื่อให้ทางแยกประเภทดังกล่าวสามารถใช้งานได้อย่างเต็มประสิทธิภาพ ทั้งการรองรับปริมาณจราจรและความเสี่ยงจากอุบัติเหตุ และท้ายที่สุดจะชี้แจงในส่วนของข้อดีและข้อเสีย และการจัดการในรูปแบบอื่นเมื่อปริมาณจราจรเกินขีดจำกัด

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ABSTRACT

To solve of traffic congestion and road accident problems at a large at-grade intersection, one common method is to construct a flyover over the existing intersection, which will increase traffic capacity in two directions on one of the main highways. However, the flyover construction cost is relatively high (about 175 million baht), and it cannot solve all traffic problems. This research investigated the performance of the flyover in terms of its efficiency, benefits and improvement in road safety. The study focused on two situations: 1) an at-grade signalized intersection improved by a flyover and 2) existing flyovers.

The first case study compared the situation before and after to determine the on-site data suchas vehicle delay, queue length, level of service, road accidents and traffic signalization, and analyze the economic of this flyover construction project. After constructed, it was found that about 37.8% of traffic diverted to it, the time delay reduced by 34.5% over the same period, number of accidents and traffic control found that the results like as the situation before. 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%. this project was worthy and efficient for investment.

The second case, 5 study cases of 29 flyover - improved intersections in Thailand (excluding in Bangkok and its vicinity) were chosen to illustrate its effects on road safety and to highlight the issues that still exist at these locations, such as traffic congestion at peak hours, risk and accident statistics and sub-optimol physical layouts. The results of this case found that an average accident cost is 9.3 Million baht/year/location, there are at least 4 zones that still risk to road accidents in the flyover area.

In order to improve the performance of the flyover-improved intersection, this study used the principles of Road Safety Inspection/Audit and a traffic signal analysis software (the SIDRA program) to come up with effective recommendations.

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Narabodee Salatoom

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ABBREVIATION

AADT	: Annual Average Daily Traffic (typically measured in vehicles)
ACR	: Accident Cost Rate
ADT	: Annual Average Traffic Volume
B	: Bus (vehicle)
BCR	: Benefit Cost Ratio
BS	: Black Spot
CBA	: Cost-benefit analysis
CCTV	: Closed-Circuit Television
DL	: Time Delay
DOH	: Department of Highway
EMS	: Emergency Medical Services
FV	: Future value
GPP	: Gross province product
GSJ	: Grade Separation Junction
L	: Heavy-duty (trailer vehicle)
LOS	: Level of Service
IRR	: Internal Rate of Return
ITM	: Intersection Traffic Movement
NPV	: Net Present Value
MC	: Motorcycle (2 wheels)
MT	: Medium truck (6 wheels)
PC	: Passenger Car (4 wheels)
PCU	: Passenger Car Unit (unit factor for changing all vehicle types to the car)
PDO	: a property-damage-only crash, with no personal injuries observed
PV	: Present value
QL	: Queue Length
RSA	: Road Safety Audit
RoSCoE	: EU-Asia Road Safety Centre of Excellence - RoSCoE
SIDRA	: Signalized (and unsignalized) Intersection Design and Research Aid
THB	: Thai Baht

ABBREVIATION (continue)

VOC : Vehicle operating cost

VOT : Value of time

WHO : World Health Organization

CHAPTER 1

INTRODUCTION

1.1 Background

Approximately 1.24 million people died every year on the world's roads, more than 3,000 people are killed by road traffic crashes every day or about 3 people per minute, and another 20 to 50 million sustain non-fatal injuries as a result of road traffic crashes. These injuries and deaths have an immeasurable impact on the families affected and 91% of the world's fatalities on the roads occur in low-income and middle-income countries, even though these countries have approximately half of the world's vehicles. Without action, road traffic crashes are predicted to result in the deaths of around 1.9 million people annually by 2020 (WHO, 2013).

Global status report on road safety in 2013 surveyed about road traffic deaths in the world by type of road users (shown in figure 1.1), the significant differences regarding at the risk depends on country income status; lower-income and middle-income countries will have the pedestrians, cyclists and motorcyclists much higher proportion than high-income countries, so the risk is also higher.

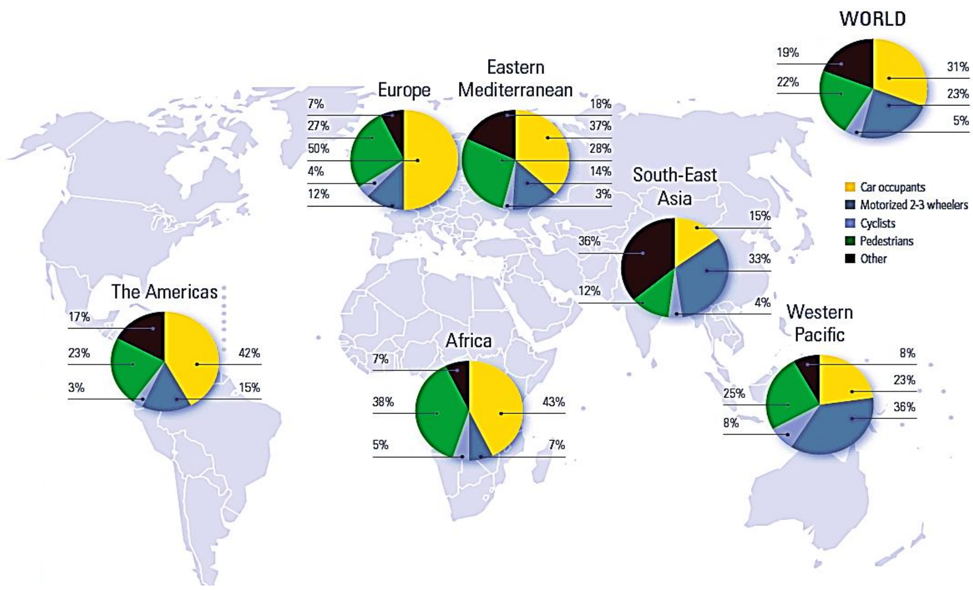


Figure 1.1 Road traffic deaths by type of road users in 2010
Source: World Health Organization (WHO), 2013

In the figure 1.2 shows the statistics of road traffic deaths per 100,000 populations in 39 countries of the high-income and middle-income level in the world, and shows the top 10 countries that are alarming in term of road traffic deaths in 2010 (WHO, 2013). The statistics is also reported that the middle-income countries are more risky to road traffic deaths than high and low-income countries.

Usually middle-income countries are developing countries. There are growth, demand and competition in that country, lead to variation especially change road user behaviours.

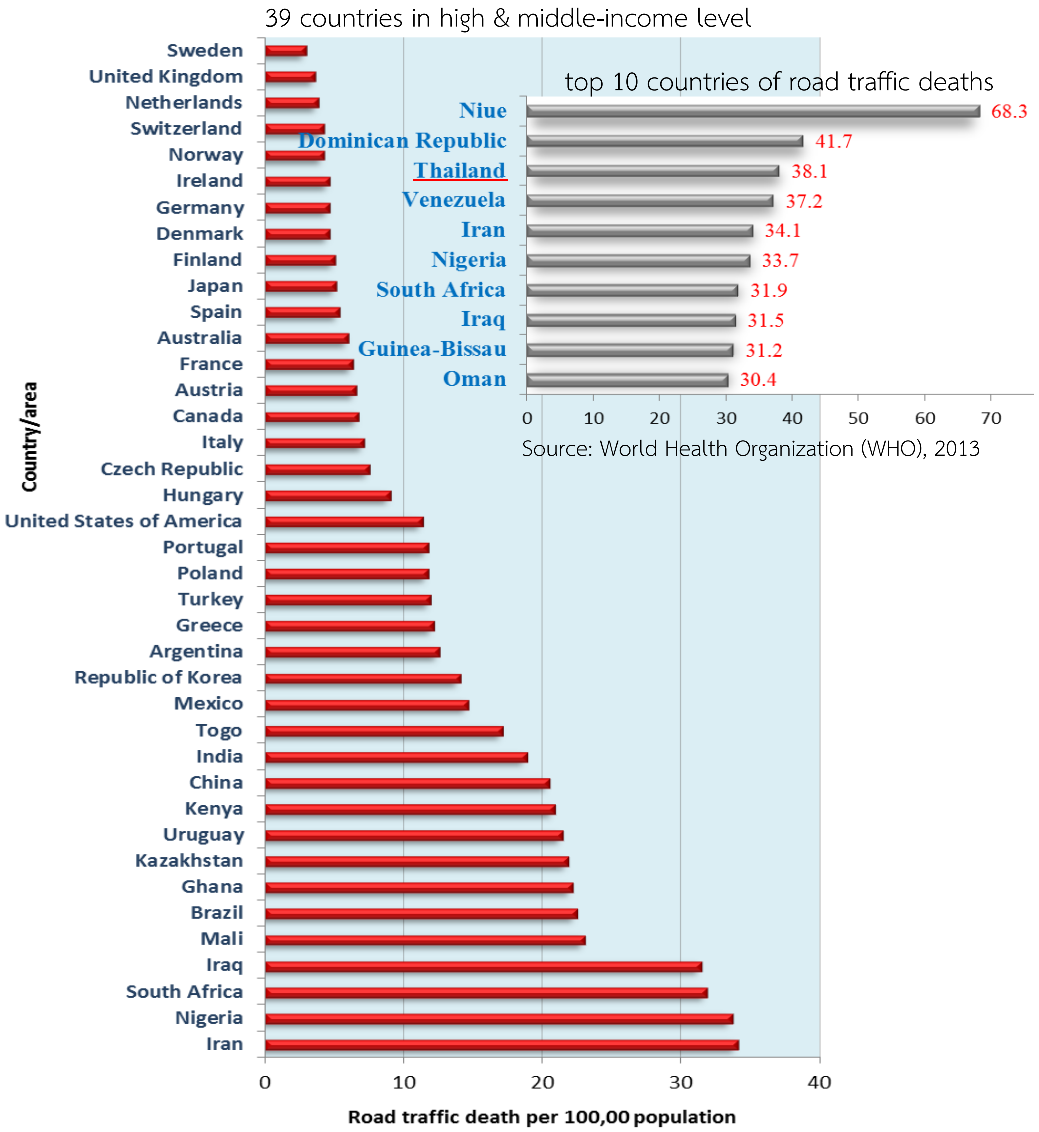


Figure 1.2 Road traffic deaths per 100,000 populations in 2010

Source: World Health Organization (WHO), 2013

1.2 Southeast Asia's Road Accidents

Southeast Asian countries have mostly middle-income level, such as Thailand, Malaysia, Vietnam, Lao and Indonesia, these developing countries may have one vehicle (at least is a motorcycle) per family. Almost 60% of road traffic deaths are between 15–44 year olds or account for 59% of global road traffic deaths and about 77% occurs among men. In the table 1.1 shown the information of Southeast Asian countries of road traffic deaths in 2010, grading on the road traffic deaths per 100,000 populations. Thailand is the top one of eleven countries in this zone.

Table 1.1 Estimated road traffic deaths per 100,000 proportions in Southeast Asia (2010)

No.	Country/ area (Countries in Southeast Asia)	General Information			Road traffic deaths			
					Reported Number of road traffic deaths	Estimated number of road traffic deaths		Estimated road traffic death rate per 100,000 population
		Population numbers for 2010	GNI per capita for 2010 in US dollars	Income level		Point estimate	95% Confidence Interval	
1	Thailand	69,122,232	4,150	Middle	13,365	26,312		38.1
2	Malaysia	28,401,017	7,760	Middle	6,872	7,085		25.0
3	Vietnam.	87,848,460	1,160	Middle	11,859	21,651		24.7
4	PDR of Lao	6,200,894	1,010	Middle	767	1,266	1,098–1,433	20.4
5	PDR of Timor-Leste.	1,124,355	2,730	Middle	99	219	193–244	19.5
6	Indonesia	239,870,944	2,500	Middle	31,234	42,434	37,195–47,673	17.7
7	Cambodia	14,138,255	750	Low	1,816	2,431	2,121–2,741	17.2
8	Myanmar	47,963,010	-	Low	2,464	7,177	6,187–8,166	15.0
9	Philippines.	93,260,800	2,060	Middle	6,739	8,499		9.1
10	Brunei Darussalam.	398,920	31,800	High	46	27		6.8
11	Singapore.	5,086,418	39,410	High	193	259		5.1

Source: World Health Organization (WHO), 2013

1.3 Thailand's Road Accidents

Thailand was ranked the first of estimating road traffic death rates per 100,000 populations (38.1) in Southeast Asia in 2010. Thailand is middle income level country over 20 years. Traffic accidents in Thailand as shown in figure 1.3 is recorded by the

Department of Highways (DOH) during 1987 to 2013. There are two peak points in 1994 and 2004, after 2004 the trend of accidents reduced to this present time but the actuality of people’s deaths is more than 12,000 people per year.

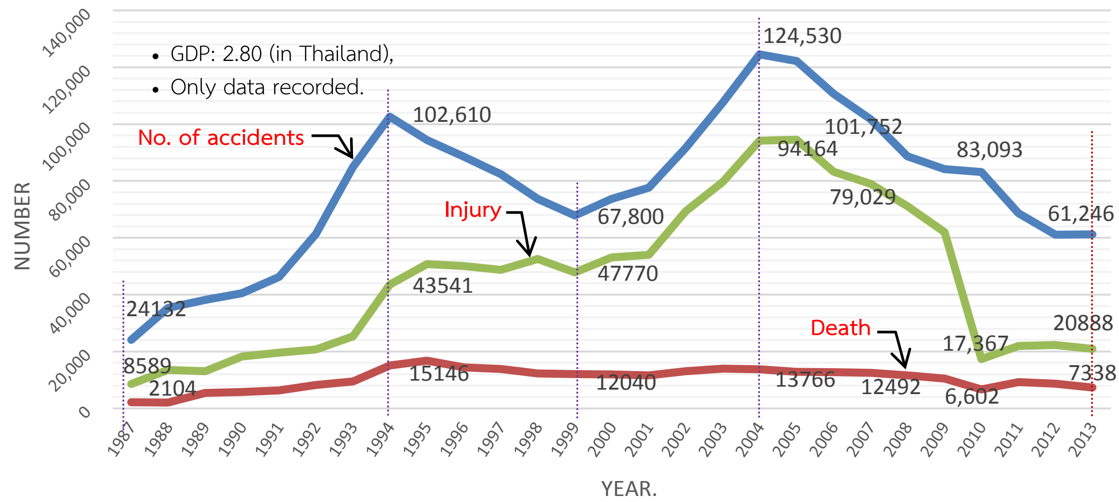
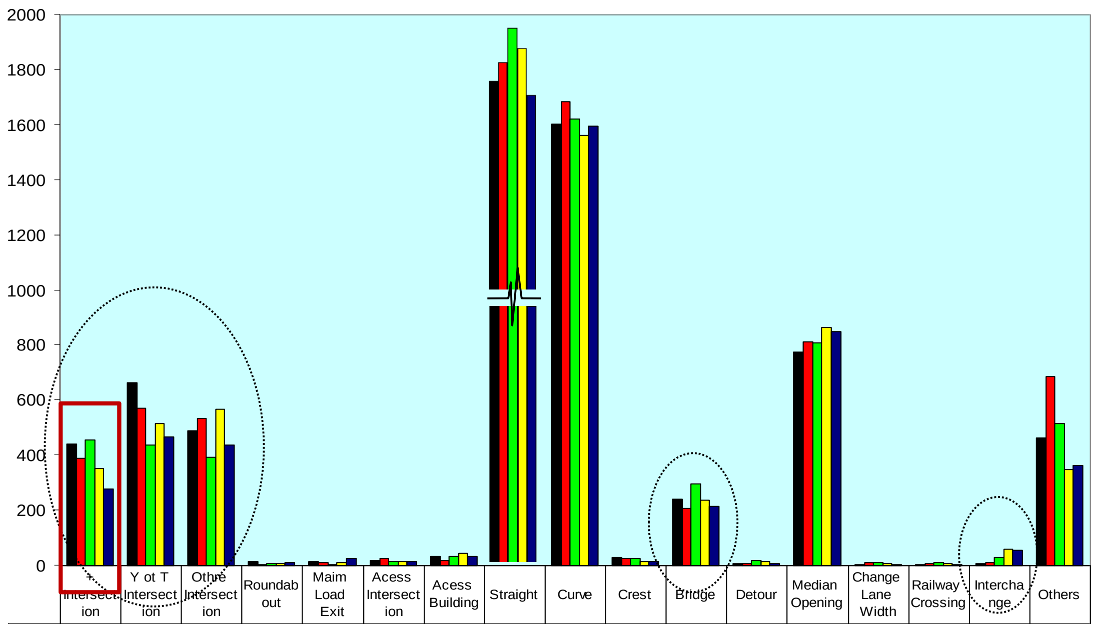


Figure 1.3 Road traffic accidents in Thailand since 1987 to 2013

Source: Bureau of Highways Safety, Department of Highways 2013



	Intersection	Y ot T Intersection	Othre Intersection	Roundabout	Maim Load Exit	Acess Intersection	Acess Building	Straight	Curve	Crest	Bridge	Detour	Median Opening	Change Lane Width	Railway Crossing	Interchange	Others
2006	443	665	490	14	14	20	34	8102	1603	29	243	7	775	4	4	7	464
2007	391	570	535	4	12	25	19	8646	1683	26	209	6	811	11	8	12	685
2008	458	438	395	8	3	13	35	9655	1620	25	296	19	808	11	10	28	514
2009	353	515	569	6	12	14	43	9048	1563	13	237	14	865	7	6	60	349
2010	279	466	437	11	27	14	32	7680	1597	14	215	7	849	3	2	57	364

Figure 1.4 Traffic accidents on highways by location, in Thailand (2006-2010)

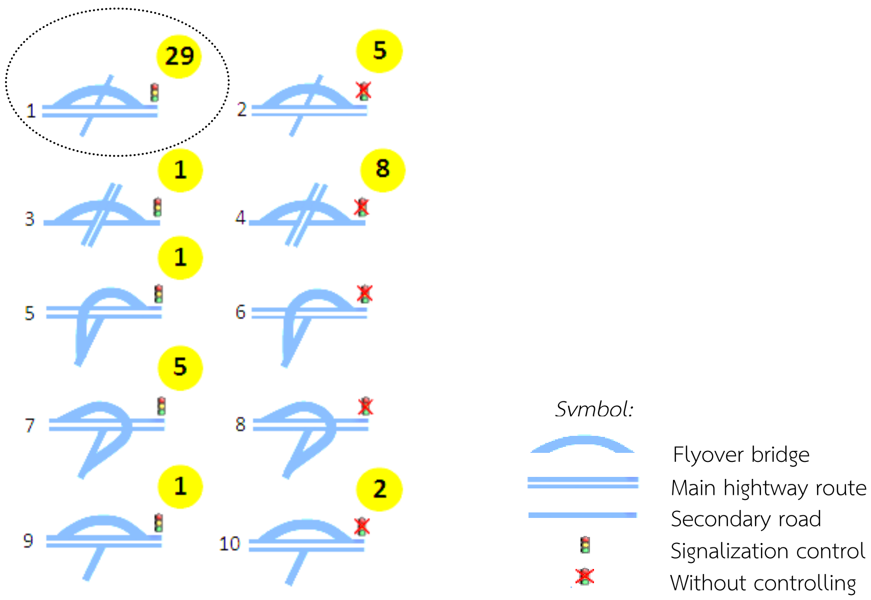
Source: Bureau of Highways Safety, DOH, 2006-2010

Focus on the accident locations, in the figure 1.4 shown that about 65% of the accidents occur on the straight road, 15% of curvy road and 12% on the junction road. Although the accident at the junctions have a chance of accident about 12% of all physical highway locations, a chance of death is 2.75 times which is more dangerous than other areas.

1.4 Problem statement

To solve the traffic problems at the at-grade intersection such as traffic congestion, road accident and support more traffic volume. One of the methods that was used to correct these issues is constructing a special bridge over the old junction.

Most of the flyovers in Thailand are constructed at the junctions on the bypass highway roads near the big city. There are approx 52 flyovers in Thailand (excluding capital region), (figure 1.5). Among various layouts, 29 flyovers are bridge cross-passes the old at-grade intersection on the main road and under the bridge is controlled by traffic signal - focus to study, Table 1.2 is total existing flyover intersection locations in Thailand (recorded in 2012).



Remark: The number of the flyover excluding capital region (https://maps.google.co.th)

Figure 1.5 Number of the flyover at junctions in Thailand (2012)

Table 1.2 Total existing flyover intersection locations in Thailand (recorded in 2012)

No	Flyover location (City, Province)	Highway route number and station control				Location	
		HW	Station	HW	Station	Longitude, Latigtude	
1	Hat Yai, Songkhla	4	1,252+000-1,253+000	43	030+000 - 031+000	6.9745°	100.4794°
2	Mueang, Udon Thani	22	003+000 - 004+000	216	023+000 - 024+000	17.3870°	102.8260°
3	Mueang, Pattalung	4	1,158+000-1,159+000	41	086+500 - 087+500	7.6088°	100.0540°
4	Mueang, Ratchaburi	4	099+000 - 099+750	330	000+000 - 000+700	13.5515°	99.8244°
5	Bang Phae, Ratchaburi	4	079+500 - 080+500	325	000+000 - 000+700	13.7060°	99.8953°
6	Ban Pong, Ratchaburi	4	067+500 - 068+500	3525	068+000 - 069+000	13.8174°	99.8914°
7	Mueang, Suphan Buri	340	100+000 - 101+000	3195	000+000 - 001+000	14.5283°	100.1307°
8	Mueang, Suphan Buri	357	032+000 - 033+000	3195	004+000 - 005+000	14.5375°	100.1642°
9	Mueang, Suphan Buri	329	004+000 - 005+000	357	037+000 - 038+000	14.4619°	100.1706°
10	Mueang, Suphan Buri	322	002+500 - 003+500	357	011+500 - 012+500	14.4991°	100.0478°
11	Mueang, Phitsanulok	12	224+000 - 225+000	126	008+000 - 009+000	16.8627°	100.2144°
12	Mueang, Phitsanulok	11	003+000 - 004+000	126	022+000 - 023+000	16.8471°	100.3449°
13	Mueang, Chiang Mai	108	005+000 - 006+000	1141	001+000 - 002+000	18.7689°	98.9773°
14	Mueang, Rayong	36	055+000 - 056+000	3139	000+750 - 002+750	12.6839°	101.2994°
15	Mueang, Rayong	36	052+000 - 053+000	3138	001+250 - 002+250	12.6972°	101.2730°
16	Mueang, Rayong	36	043+000 - 044+000	3515	003+000 - 004+000	12.7081°	101.2373°
17	Mueang, Rayong	36	054+000 - 055+000	7001	Bypass 36 road	12.6943°	101.2891°
18	Mueang, Rayong	36	048+750 - 049+250	4006	Nikhom Rayong 3	12.7047°	101.2413°
19	Nikhom Phatthana, Rayong	36	038+000 - 039+000	3191	005+000 - 006+000	12.7733°	101.1716°
20	Bang Lamung, Chon Buri	3	144+000 - 145+000	7	000+000 - 001+000	12.9508°	100.9409°
21	Si Racha, Chon Buri	3	128+000 - 129+000	7	Maiklang road	13.0806°	100.9194°
22	Ban Bueng, Chon Buri	331	066+000 - 067+000	344	031+000 - 032+000	13.2298°	101.2290°
23	Ban Bueng, Chon Buri	344	016+000 - 017+000	3138	000+000 - 001+000	13.3036°	101.1225°
24	Mueang, Chon Buri	3	008+000 - 009+000	344	001+000 - 002+000	13.3531°	101.0048°
25	Mueang, Chachoengsao	304	003+000 - 004+000	314	000+000 - 001+000	13.6611°	101.0944°
26	Mueang, Nonthaburi	306	001+000 - 002+000	3344	Nikhom Nonthaburi	13.8346°	100.4996°
27	Mueang, Nonthaburi	301	005+000 - 006+000	306	005+000 - 006+000	13.8430°	100.5109°
28	Mueang, Nonthaburi	302	005+000 - 006+000	306	006+000 - 007+000	13.8590°	100.5216°
29	Chok Chai, Nakhon Ratchasima	24	052+500 - 053+500	224	032+000 - 033+000	14.7407°	102.1648°

The figure 1.6 show an at-grade intersection convested to the flyover intersection by constructing the special bridge over an at-grade intersection in two directions on one of the main road – to increase capacity of traffic flow and reduce the traffic conjunction on these both directions and underneath of the bridge is still used the existing traffic signalization as the situation before to control the traffic volume. However, with an investment budget is relatively high and the original intersection still have the same traffic problems, it only facilitates the traffic volume in the directions of the bridge construction and the infrastructure cannot fully solve the problems such as the traffic congestion, long delay, queue length and road accidents covering of the flyover area, bring about to this research study which will study to two important issues consists of an efficiency and road safety of improved flyover intersection by comparing of both situations.

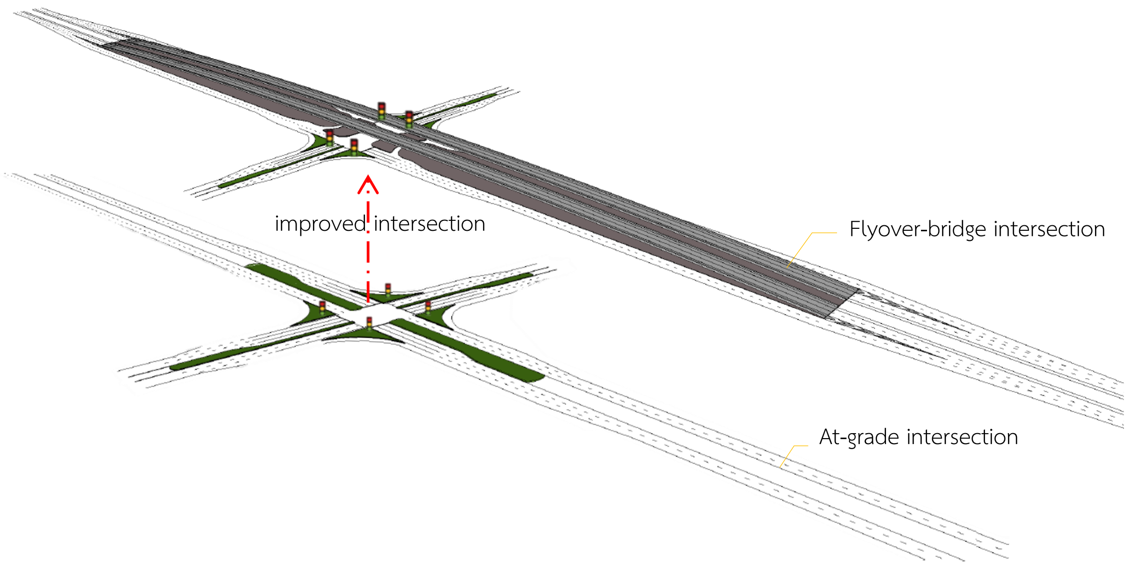


Figure 1.6 The layout of an at-grade intersection converted to a flyover intersection

In terms of efficiency; S. K. Goyal, Sangita Goel and S. M. Tamhane. (2009) "It was found that about 35% of the total traffic is diverted to the flyover, which results in a reduction of about 32% in the total emission generation. Travel on the flyover resulted in as much as 60–70% saving in time, compared to the travel on the main road. The loss of fuel for combustion and the associated cost resulting from waiting for the signal to change are also estimated, and these are found to be significant." Normally of improved flyover has still been controlled by the traffic signalization under the bridge – original at-grade intersection. In this study, the problems will have been assessed in terms of traffic congestion, time saving, fuel saving, vehicle free flow and accident cost.

In terms of road safety; Austroads (2002) road safety audit is "a formal examination of a future road or traffic project or an existing road, in which an independent, qualified team reports on the project’s crash potential and safety performance.” Road safety audits take the principles of the safe systems approach and apply them proactively. The outcome of a road safety audit is a report that identifies any road safety deficiencies. In this study will use the process of Road Safety Audit to generate road safety reports at the case studies.

The case study that will study is selected and divided to two conditions. The first is at-grade intersection converted to flyover intersection – flyover construction project and the second is existing flyover intersections.

Then suggestions to improve to be better in both terms efficiency and road safety such as creating a new cycle phase time of traffic signalization, follow to the actual traffic volume, improving the physical condition to accommodate the increased traffic and reducing the number of road accidents.

1.5 Objectives

1.5.1 To study the Road Safety aspects of a flyover

1.5.1.1 Number and severity of accidents,

1.5.1.2 Causes of accidents,

1.5.1.3 Hazardous zone,

1.5.2 To study the Efficiency of a flyover

1.5.2.1 Effects of a flyover in reducing delay to traffic flow,

1.5.2.2 Costs Benefits Analysis,

1.5.3 To assess possible improvements for existing flyovers

1.5.3.1 Identify the issues of road safety that still exist at the flyover areas,

1.5.3.2 To recommend improvements to existing flyover intersections.

1.6 Scope of Study

The case studies - flyover intersections will be assessed during study as follows:

1.6.1 An at-grade intersection converted to a flyover intersection (flyover construction project) - a case study is selected on highway route no.43

and highway route no. 4135 in Hat Yai District, Songkhla, Thailand (figure 1.7). This intersection will be evaluated and compared in terms of road safety and efficiency in 3 time periods (situation before (at-grade intersection), during construction and after (flyover intersection)).

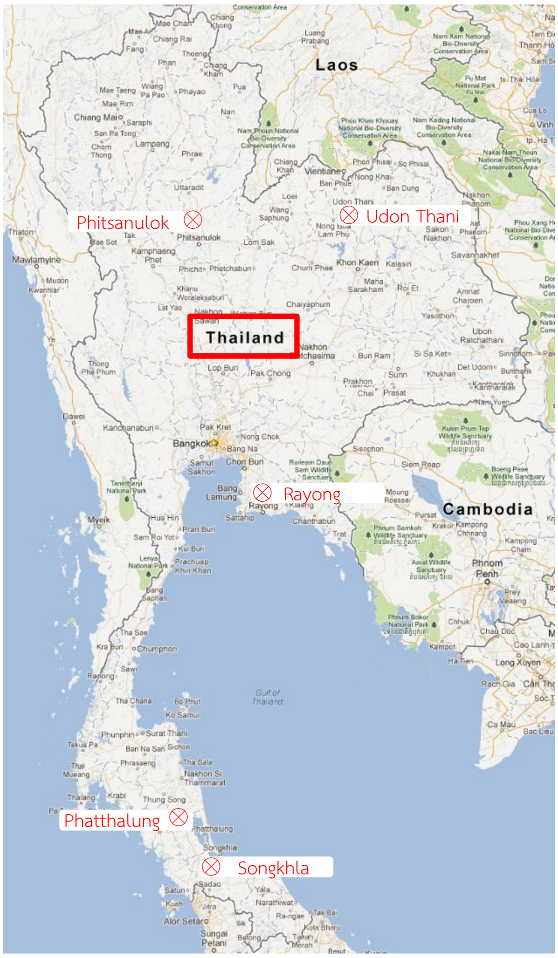
Figure 1.7 A schematic map of Hatyai city with study area marked

1.6.2 The excisting flyover intersections will be also evaluated in terms of Road Safety and Efficiency by selecting about 20% of all flyover in Thailand, because of time to study and budget to data collection is limited (29 flyovers - these are located in regional areas of Thailand), to study. The figure 1.8 shows a map of Thailand with study areas marked.

1.6.3 Used the “SIDRA” processing software as an aid for designing and evaluating, because this software can use for evaluating in of alternative intersection designs in terms of capacity, level of service and a wide range of performance measure, especially it can determine an appropriate time period of phasing in traffic signal programs

1.6.4 Road Safety Audit (RSA) and Road Safety Inspection (RSI) manual are used to audit in term of road safety in the flyover intersection areas, and

1.6.5 Used the accident statistics from 3 agencies which are Department of Highways, Police Station and Emergency Medical Services to analyze.



Case No.	*Flyover Intersection locations (highway route)*
1	Highway route no.4 and route no.43 in Hat Yai District, Songkhla, Thailand.
2	Highway route no.4 and route no.41 in Mueang District, Phatthalung, Thailand
3	Highway route no.36 and route no.3139 in Mueang District, Rayong, Thailand.
4	Highway route no.22 and route no.216 in Mueang District, Udon Thani, Thailand.
5	Highway route no.11 and route no.12 in Mueang District, Phitsanulok, Thailand.

Figure 1.8 A map of Thailand with 5 study areas marked.

1.7 Outcomes of study

1.7.1 Evaluation method will be innovated for a flyover construction project,

1.7.2 Road safety audit results for flyover intersection,

1.7.3 The average accident cost of a flyover is assessed, and

1.7.4 Recommendation to choosing a strategy for management to improve the flyover intersection.

CHAPTER 2

LITERATURE REVIEW

The literature review is considering in two important issues consist of road safety and efficiency of the flyover intersection. The 2 case studies, the first case have to study all of the process of flyover intersection construction and the second case – there are 5 locations considers to the efficiency of the existing flyover intersections.

The related theory in this study is comprehensive data of both theoretical and practical sections such as evaluation of flyover construction project, on-site data collection, road safety audit, intersection types, traffic controller at intersection, processing software and analysis data.

2.1 Intersection types

An intersection is the junction at grade (same level) of two or more roads either meeting or crossing. An intersection may be three-way (a T junction or Y junction), four-way (a crossroads), or have five or more arms. Busy intersections are often controlled by traffic lights, a roundabout and/or two - three levels. Example intersection types shown in figure 2.1.

The selection criteria to control an intersection is depend on many factors such as traffic volume, environment, physical area and road user behavior etc., which are parallel variables. IHT (1997) and TRL (1994) guided that is method to choose a type of junction based on the traffic volume, (shown in the graph-figure 2.2). But, there are exceptions about this method is an intersection and roundabout should not use on the motorways, and signalized intersection should not use on the rural roads except in the special case. In other words, some intersection should be designed to the best benefits.

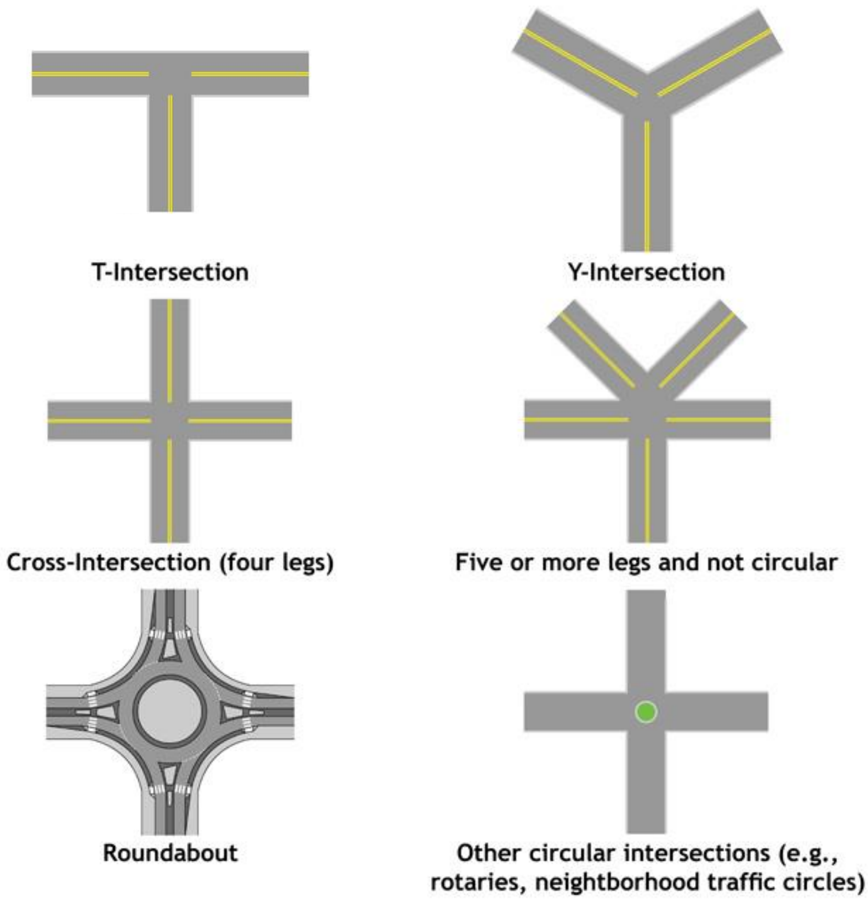


Figure 2.1 Illustration of types of intersection/junction geometry

(Source: http://safety.fhwa.dot.gov/tools/data_tools/mirereport/126.cfm)

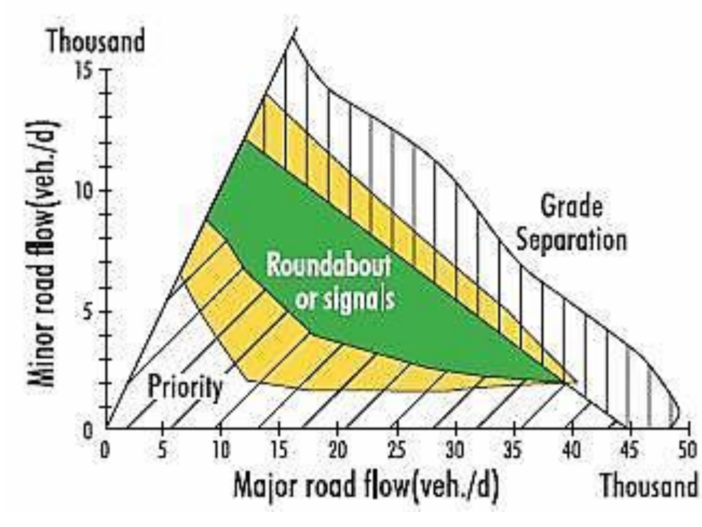


Figure 2.2 Guideline to choose a type of junction, based on the traffic volume

(Source: (IHT. 1997), Transportation Research Laboratory (1994))

2.1.1 At-grade Intersection

At-grade intersection is normally of the crossroad at which two or more road directions cross at the same level (figure 2.3). Normally requires a traffic control device such as a stop sign, traffic signs, traffic signal etc., to manage conflicting traffic.

Figure 2.3 At-grade intersection type (example)

2.1.2 Flyover Intersection

Flyover-bridge intersection is an intersection that has a special bridge constructed over an at-grade intersection to allow for the free flow in two directions on one of the main road – to increase capacity of traffic flow and reduce the traffic conjunction in these both directions, and on the underneath of the bridge is still used the existing traffic signalization to control as the situation before (figure 2.4).

Figure 2.4 Flyover intersection type

2.1.3 Interchange

Interchange or Grade Separation is the method of aligning at the junction to allow for the free flow in each direction of roads – to increase capacity of traffic flow (figure 2.5). Normally don't need the traffic signal, requires a traffic control device such as a give way, traffic signs, route signs etc., to guide to road users.

Figure 2.5 General types of Interchange or Grade Separation junctions (Source: https://en.wikipedia.org/wiki/Interchange_(road))

2.2 Level of Service

Level of service (LOS) is a qualitative measure used to relate the quality of traffic service. LOS is used to analyze highways by categorizing traffic flow and assigning quality levels of traffic based on performance measure like speed, density,etc.

2.2.1 Road level of service

Highway Capacity Manual (HCM) and AASHTO Geometric Design of Highways and Streets ("Green Book"), using letters A through F, with A being the best and F being the worst of Level of Service (LOS) in North American highway.

A: free flow. Traffic flows at or above the posted speed limit and motorists have complete mobility between lanes. The average spacing between vehicles is about 550 ft(167 m) or 27 car lengths. Motorists have a high level of physical and psychological comfort. The effects of incidents or point breakdowns are easily absorbed. LOS A generally occurs late at night in urban areas and frequently in rural areas.

B: reasonably free flow. LOS A speeds are maintained, maneuverability within the traffic stream is slightly restricted. The lowest average vehicle spacing is about 330 ft(100 m) or 16 car lengths. Motorists still have a high level of physical and psychological comfort.

C: stable flow, at or near free flow. Ability to maneuver through lanes is noticeably restricted and lane changes require more driver awareness. Minimum vehicle spacing is about 220 ft(67 m) or 11 car lengths. Most experienced drivers are comfortable, roads remain safely below but efficiently close to capacity, and posted speed is maintained. Minor incidents may still have no effect but localized service will have noticeable effects and traffic delays will form behind the incident. This is the target LOS for some urban and most rural highways.

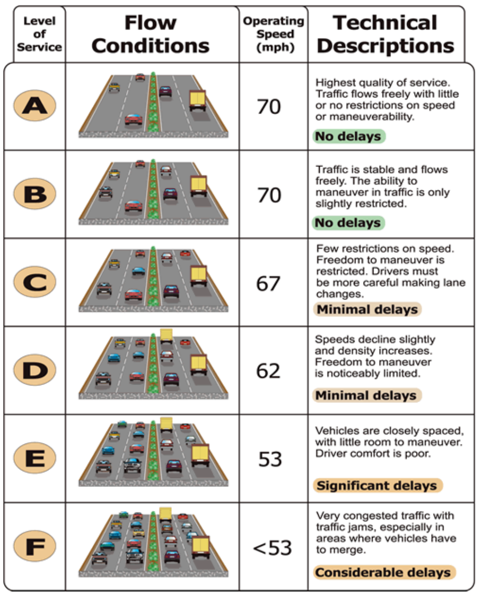
D: approaching unstable flow. Speeds slightly decrease as traffic volume slightly increase. Freedom to maneuver within the traffic stream is much more limited and driver comfort levels decrease. Vehicles are spaced about 160 ft(50m) or 8 car lengths. Minor incidents are expected to create delays. Examples are a busy shopping corridor in the middle of a weekday, or a functional urban highway during commuting hours. It is a common goal for urban streets during peak hours, as attaining LOS C would require prohibitive cost and societal impact in bypass roads and lane additions.

E: unstable flow, operating at capacity. Flow becomes irregular and speed varies rapidly because there are virtually no usable gaps to maneuver in the traffic stream and speeds rarely reach the posted limit. Vehicle spacing is about 6 car lengths, but speeds are still at or above 50 mi/h(80 km/h). Any disruption to traffic flow, such as merging ramp traffic or lane changes, will create a shock wave affecting traffic upstream. Any incident will create serious delays. Drivers' level of comfort become poor.[1] This is a common standard in larger urban areas, where some roadway congestion is inevitable.

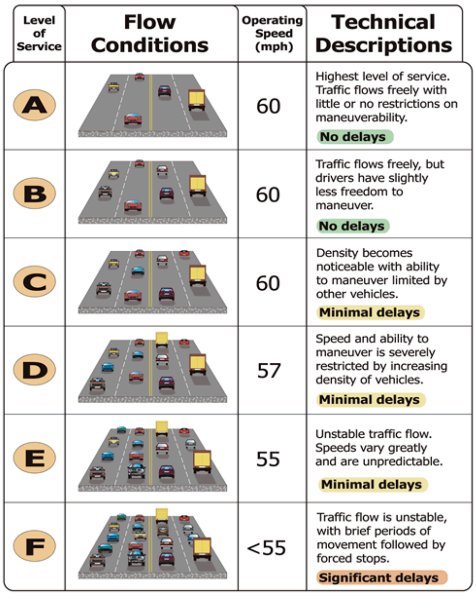
F: forced or breakdown flow. Every vehicle moves in lockstep with the vehicle in front of it, with frequent slowing required. Travel time cannot be predicted, with generally more demand than capacity. A road in a constant traffic jam is at this LOS, because LOS is an average or typical service rather than a constant state. For example, a highway might be at LOS D for the AM peak hour, but have traffic consistent with LOS C some days, LOS E or F others, and come to a halt once every few weeks. (https://en.wikipedia.org/wiki/Level_of_service)

2.2.2 Level of Service of various types

Standard Environmental Reference (SER) used of these style guides of Level of Service (LOS) graphics for various highway facilities and are useful for environmental documents when discussing the purpose and need for a project, as shown in the figure 2.6. (http://www.dot.ca.gov/ser/forms.htm)



Level of Service	Flow Conditions	Operating Speed (mph)	Technical Descriptions
A		70	Highest quality of service. Traffic flows freely with little or no restrictions on speed or maneuverability. **No delays**
B		70	Traffic is stable and flows freely. The ability to maneuver in traffic is only slightly restricted. **No delays**
C		67	Few restrictions on speed. Freedom to maneuver is restricted. Drivers must be more careful making lane changes. **Minimal delays**
D		62	Speeds decline slightly and density increases. Freedom to maneuver is noticeably limited. **Minimal delays**
E		53	Vehicles are closely spaced, with little room to maneuver. Driver comfort is poor. **Significant delays**
F		<53	Very congested traffic with traffic jams, especially in areas where vehicles have to merge. **Considerable delays**



Level of Service	Flow Conditions	Operating Speed (mph)	Technical Descriptions
A		60	Highest level of service. Traffic flows freely with little or no restrictions on maneuverability. **No delays**
B		60	Traffic flows freely, but drivers have slightly less freedom to maneuver. **No delays**
C		60	Density becomes noticeable with ability to maneuver limited by other vehicles. **Minimal delays**
D		57	Speed and ability to maneuver is severely restricted by increasing density of vehicles. **Minimal delays**
E		55	Unstable traffic flow. Speeds vary greatly and are unpredictable. **Minimal delays**
F		<55	Traffic flow is unstable, with brief periods of movement followed by forced stops. **Significant delays**

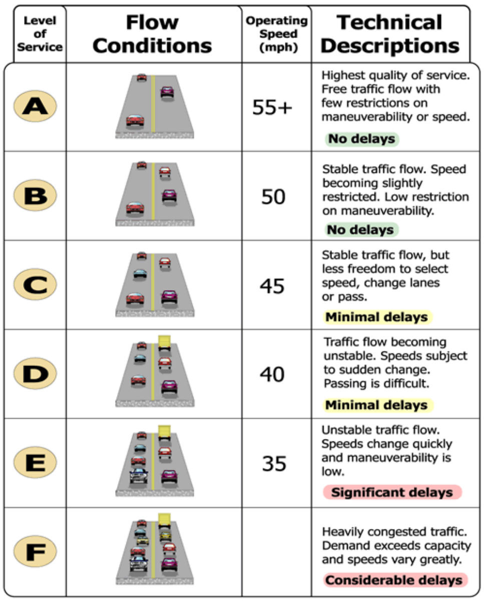
Source: 2000 HCM, Exhibit 21-3, Speed-Flow Curves with LOS Criteria for Multi-Lane Highways

Freeways

Multi-Lane Highway

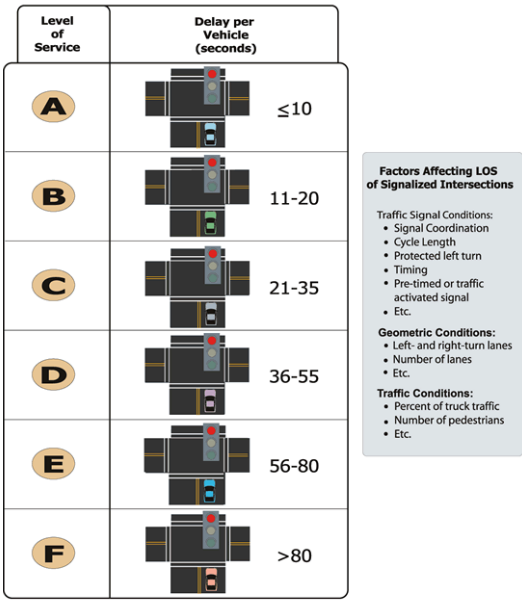
Figure 2.6 Level of Service (LOS) of various types

(Source: http://www.dot.ca.gov/ser/forms.htm)



Level of Service	Flow Conditions	Operating Speed (mph)	Technical Descriptions
A		55+	Highest quality of service. Free traffic flow with few restrictions on maneuverability or speed. No delays
B		50	Stable traffic flow. Speed becoming slightly restricted. Low restriction on maneuverability. No delays
C		45	Stable traffic flow, but less freedom to select speed, change lanes or pass. Minimal delays
D		40	Traffic flow becoming unstable. Speeds subject to sudden change. Passing is difficult. Minimal delays
E		35	Unstable traffic flow. Speeds change quickly and maneuverability is low. Significant delays
F			Heavily congested traffic. Demand exceeds capacity and speeds vary greatly. Considerable delays

Source: 2000 HCM, Exhibit 20-2, LOS Criteria for Two-Lane Highways in Class 1

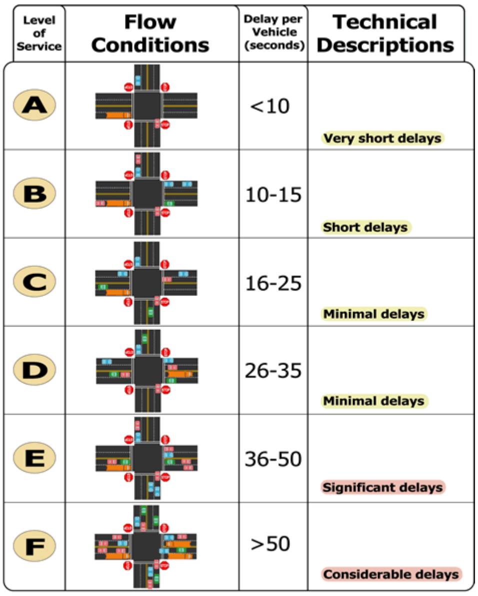


Level of Service		Delay per Vehicle (seconds)
A		≤10
B		11-20
C		21-35
D		36-55
E		56-80
F		>80

Source: 2000 HCM, Exhibit 16-2, Level of Service Criteria for Signalized Intersections

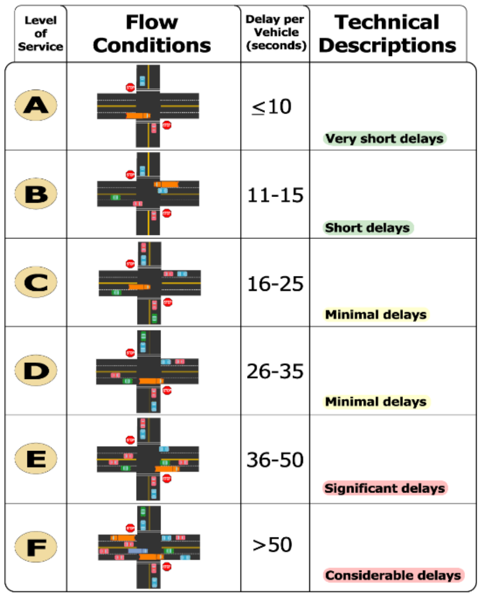
Two-Lane Highways

Signalized Intersections



Level of Service	Flow Conditions	Delay per Vehicle (seconds)	Technical Descriptions
A		<10	Very short delays
B		10-15	Short delays
C		16-25	Minimal delays
D		26-35	Minimal delays
E		36-50	Significant delays
F		>50	Considerable delays

Source: 2000 HCM, Exhibit 17-22, Level of Service Criteria for AWSC Intersections



Level of Service	Flow Conditions	Delay per Vehicle (seconds)	Technical Descriptions
A		≤10	Very short delays
B		11-15	Short delays
C		16-25	Minimal delays
D		26-35	Minimal delays
E		36-50	Significant delays
F		>50	Considerable delays

Source: 2000 HCM, Exhibit 17-2, Level of Service Criteria for TWSC Intersections

Unsignalized Intersections

Two-Way Intersections

Figure 2.6 Level of Service (LOS) of various types (continue)

(Source: http://www.dot.ca.gov/ser/forms.htm)

2.3 Data collection

Traffic fundamentals are important information of an evaluation or analysis in the study. Before making a study or project, these data must show a reality data. There are many sources - data collections for a study such as on-site traffic data, accident statistics and flyover construction cost.

At the intersection, there are 5 methods to checking which are intersection turning movement count, delay count, queue length count, speed survey and traffic signal survey (Vesper. A., (2011) and Roger P. et al., (2004)).

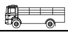
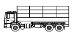
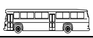
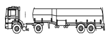
2.3.1 On-site data collection

One of the fundamental measures of traffic on a road system is the volume of traffic using the road in a given interval of time. This is also called the flow and is expressed in vehicle per hour or vehicles per day. When the traffic is composed of a number of types of vehicles, it is a common practice to convert the flow into the equivalent passenger car unit (PCUs), by certain equivalent factors. The flow is then expressed as PCUs per hour or PCUs per day. This means that the vehicle count needs to be called by considering their class & type. Another aspect of the traffic flow is its variety. For example, the variation of traffic flow within an hour is important for traffic signal design.

2.3.1.1 Intersection turning movement count (TMC)

All vehicle types that pass at an intersection in all directions is collected by surveyor. Then the traffic data will be converted into the equivalent passenger car unit (PCUs) by equivalent factors (show in Table 2.1). TMC is usually taken on the working day, during 7:00 a.m. to 7:00 p.m., and the traffic data in three time periods – peak times a day uses to conduct the level of service (LOS). The vehicle is usually recorded as vehicles per hour (vph), and an hour traffic is defined as the four successive fifteen-minute period in traffic records (SIRDC., (2011)).

Table 2.1 Equivalent factor to passenger car unit (PCUs) (outside city factor)

picture	types	factors	picture	types	factors	picture	types	factors
	Bicycle	0.25		Mini bus	1.25		Medium truck	2.00
	Motorcycle	0.50		Medium bus	2.00		Havey truck	3.00
	PC<7people	1.00		Bus	3.00		> 10-wheel trailer truck	3.00
	PC>7people	1.25		Mini truck	1.50			3.00

(Source: adapt from SIRDC., (2011))

2.3.1.2 Delay count (DL)

Delay at an intersection is conducted to evaluate the performance of the system such as traffic control devices (signals). The delay is normally measured in terms of minutes or seconds per vehicle. A minute traffic is defined as the four successive fifteen-seconds period in traffic records, usually of this recorded depending on the cycle length of the traffic signal. The delay data is usually taken with intersection turning movement count on the working day – during 7:00 a.m. to 7:00 p.m. by recording all passenger car units (identify) when stopped in the red cycle phase of signal control in all lanes and directions of intersection, and the delay data in three time periods – peak times a day uses to conduct the level of service (LOS) (SIRDC., (2011)).

2.3.1.3 Queue length count (QL)

Queue length (QL) is conducted to evaluate the performance of the system such as traffic control devices (signals) like the delay survey method. The queue length data is usually taken with intersection turning movement count on the working day – during 7:00 a.m. to 7:00 p.m. by recording all passenger car units (identify) when stopped in the red cycle phase of signal control on the most vehicle stopped lane in each direction of intersection (SIRDC., (2011)).

2.3.1.4 Traffic signal (cycle phase time)

On-site survey of cycle time of traffic signal control is very important data used to evaluation. This data must survey covering one day, because it related with turning traffic movements at intersection.

In Thailand, traffic signalization that controlled by the fixed-time model is normally used to control the traffic volume because of very easy to operate and affordable. Some critical intersection uses a loop detector aiding to control.

All road directions are surveyed a green cycle time, yellow phase time, red phase time and all red, furthermore has to record other significant data such as signal programs, direction controls and time of operation (SIRDC., (2011)).

2.3.1.5 Vehicle speed

Roger P. et al., 2004 (p.204-221) concluded the method to measure the vehicle speeds by using the radar gun to check, this method is called the spot speed measure. Speed of vehicles are checked about 30 to 50 of each vehicle type (i.e., passenger car, heavy truck and motorcycle) of each point, then calculate the "middle speed" and "85 percentages" to analyze (figure 2.7 is shown an example guideline).

SPEED GROUP		TIME GROUP		PASSENGER CARS	TRUCKS	OTHER	TOTALS			
Lower limit (mph)	Upper limit (mph)	Lower limit (secs)	Upper limit (secs)				PC	Trucks	Other	Total
30	32			'						
32	34									
34	36			II	II	I	2	2	1	5
36	38			III	II		3	2	0	5
38	40			卌	I	I	5	1	1	7
40	42			卌 卌	III		10	3	0	13
42	44			卌 卌 卌 III	III		18	3	0	21
44	46			卌 卌 卌 卌 卌 IIII	IIII		29	4	0	33
46	48			卌 卌 卌 卌 卌 卌 卌 卌 II	II	II	42	2	2	46
48	50			卌 卌 卌 卌 卌 卌 卌 卌 卌 卌 卌 卌	II		60	2	0	62
50	52			卌 卌 卌 卌 卌 卌 卌 II			37	0	0	37
52	54			卌 卌 卌 卌 III			23	1	0	24
54	56			卌 卌 III		I	13	0	1	14
56	58			卌 II	I	I	7	1	1	9
58	60			卌			5	0	0	5
60	62			II			2	0	0	2
62	64									
64	66									
66	68									
68	70									

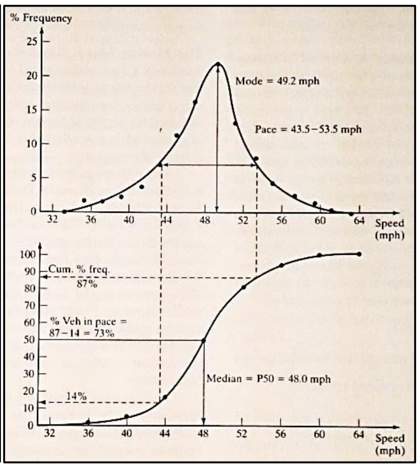


Figure 2.7 Example table and graph to find the speeds

Source: Roger P. Roess et al, (2004) traffic engineer 3th, p208-2011

2.3.2 Accident statistics

Department of Highways (DOH), Police recorded and Emergency Medical Service (EMS) are the three sectors in Thailand that collected these road accidents statistics.

DOH recorded the accident statistics on only highways, the data that collected rather cover in the accident information, especially shown point of accident and collision diagrams at accident location, for example from website : http://haims.doh.go.th (figure 2.8).

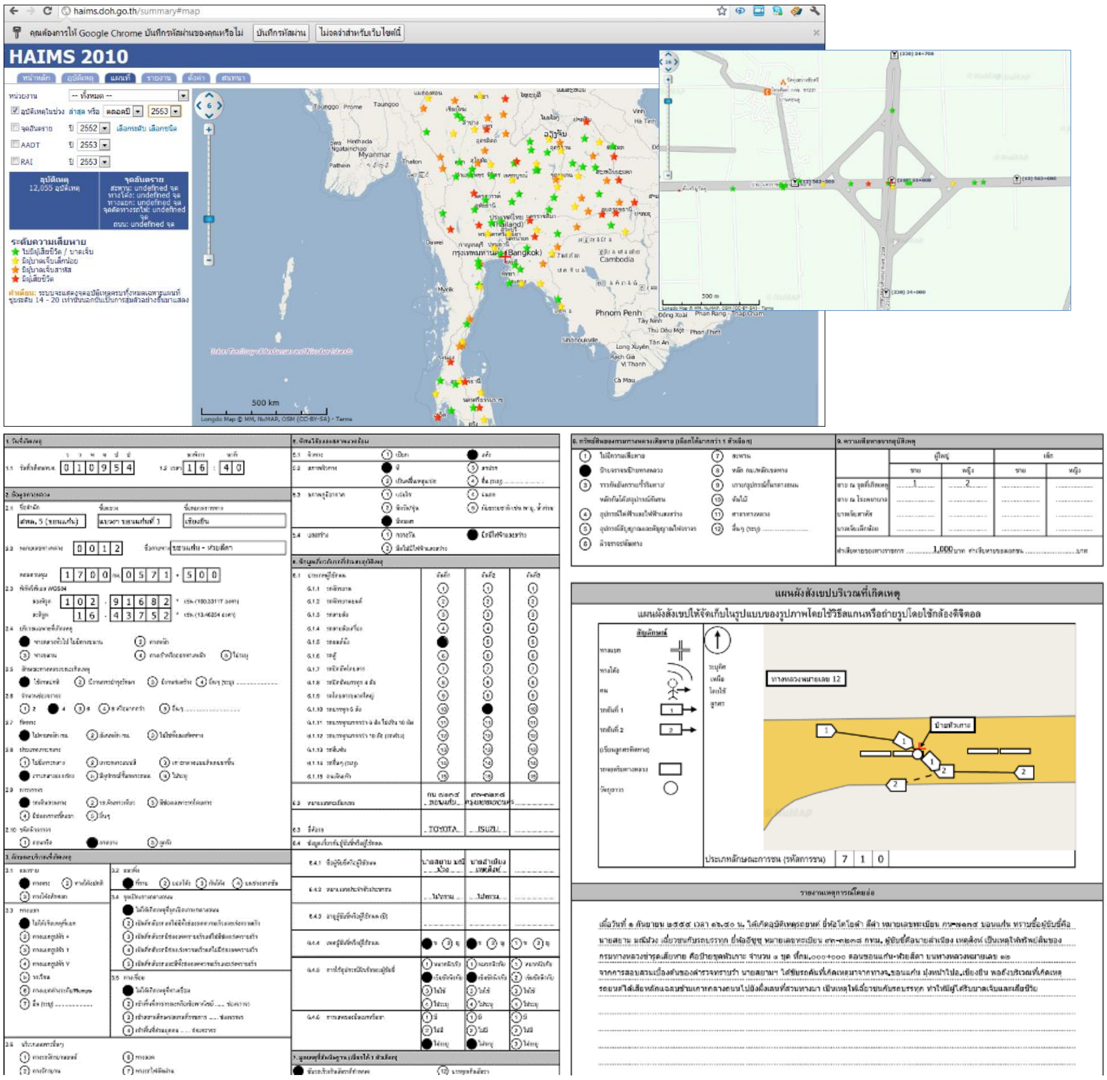


Figure 2.8 Example DOH accident statistics recorded

Source: Department of Highways (DOH), website : http://haims.doh.go.th

Police recorded only the crash that informed to the police daily record by writing as same as the report, show only the document words. If the accident is nobody injury or inform, the data will not be recorded (example recorded as shown in figure 2.9).

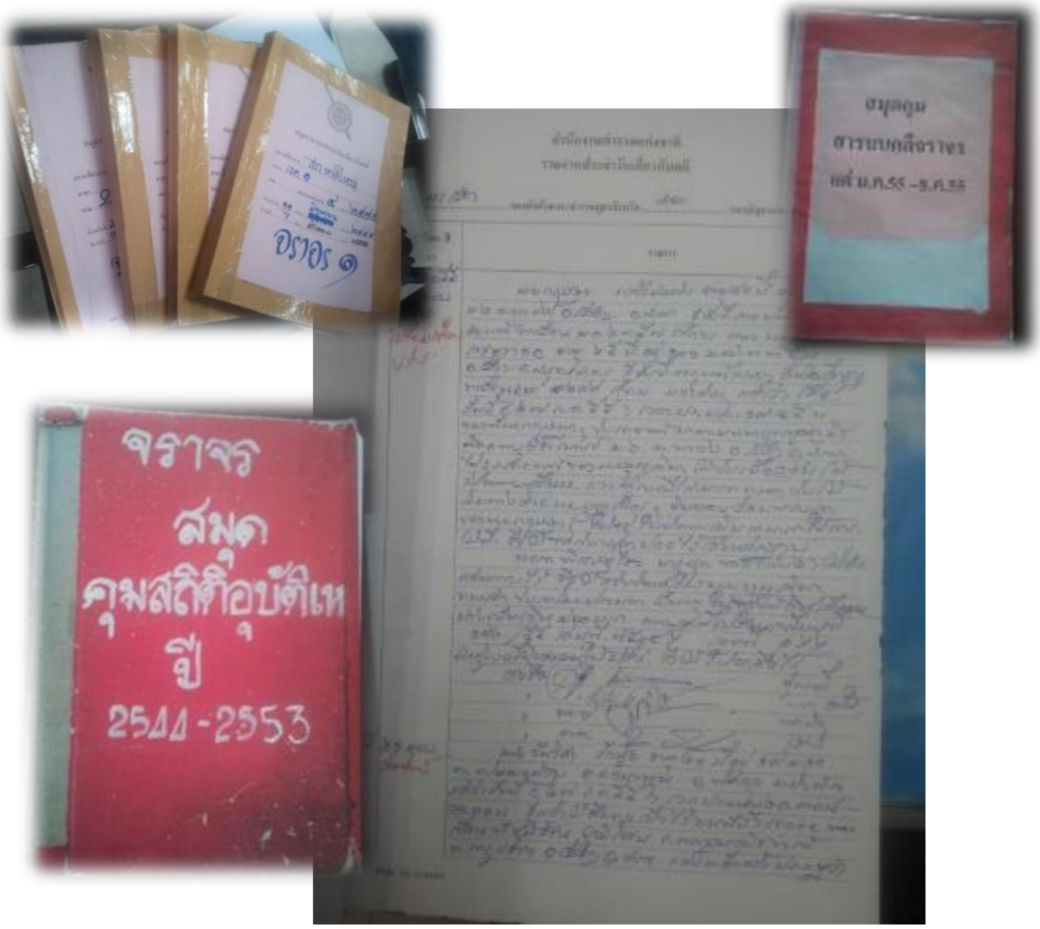


Figure 2.9 Example Police accident statistics recorded

Source: Hatyai Police station, Songkla, Thailand

Emergency Medical Services (EMS) recorded all of the real accidents that people call to 1669 (Emergency Ambulance Hotline for Thailand is 1669). In accident form shown important data which are time of accidents, location – point of accidents and number of casualties. The data covers all of accidents occurred (big and small accident cases), an example recorded as shown in figure 2.10.

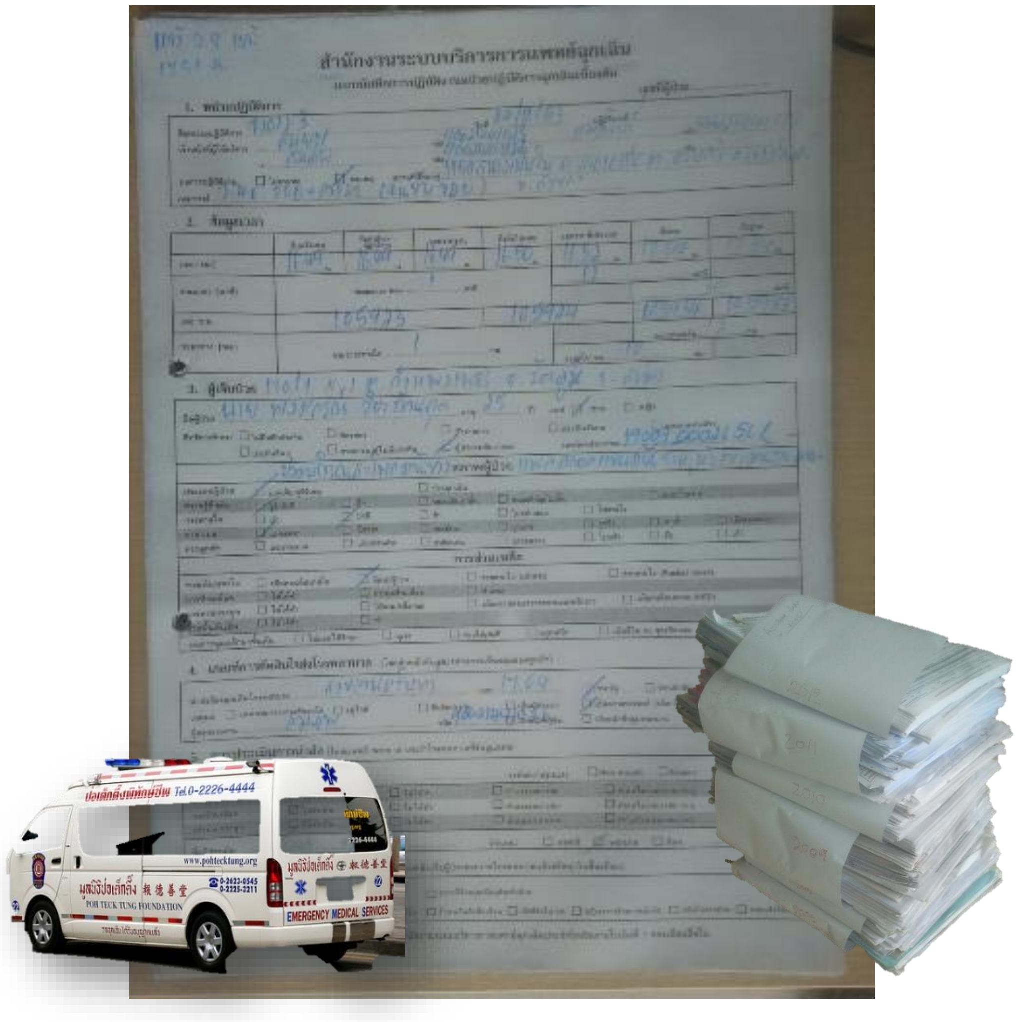


Figure 2.10 Example EMS accident statistics recorded

Source: Hatyai EMS section, Songkla, Thailand

2.3.3 Flyover construction cost

Normally, each of the flyover project is evaluated or studied by and constructed the Department of Highways. The construction cost, it depends on the physical location. DOH set the mean price of the flyover construction project is about 70,000 Baht (2168.4 USD) per square meter (DOH., (2009)).

2.4 Flyover construction project

DOH., (2007) studied flyover construction project at Wiang Sa intersection (highway route no.41 and highway route no.4009), in the final report there are 10 chapters, the important data consist of; 1) problem statement, 2) objectives, 3) physical conditions, 4) Survey and analysis of fundamental data in term of engineering such as survey and prediction of traffic volume, 5) choosing flyover style, 6) Detail design, 7) Hydrology and drainage, 8) Flyover structure design, 9) Road surface design, 10) Construction costs calculation, 11) Management during construction, 12) Environmental operations, 13) Public relations and participation.

DOH., (2012) constructed a flyover intersection construction at the Sanambin Nai intersection (highway route no. 43 and highway route no. 4135) near Hat Yai city, Songkhla, Thailand. The construction cost is 249.59 million baht (7.75 million USD.), in the objectives to reduce traffic congestion at the intersection, develop the economy in the southern region area and increase traffic capacity in this intersection. This project did not make project evaluation befor construction.

2.5 Project evaluation

Pantida et al., (2011) studied the research in the topic “cost-benefit analysis of Sanpatong-Hangdong (phase 1) bypass project, Chiangmai”. The objective of the study were to analyze cost, benefit and economic value analysis of Sanpatong - Hangdong (phase 1) bypass project, Chiangmai. Primary data were collected through traffic and speed survey between Sanpatong - Hangdong (phase 1) bypass project and Highway No.108, Secondary data were collected from related documents. Net Present Value (NPV), Benefit-Cost Ratio (B/C ratio) and internal rate of Return (IRR) were used to analyze cost, benefit and economic value of project. From the analysis, the present value of vehicle operating cost saving was 52.59 million baht, the present value of time saving was 234.0 million baht, the present value of benefit was 286.59 million baht and the present value of cost was 132.65 million baht. The NPV was 153.94 million baht, B/C ratio was 2.16 and IRR was 25.2%. The conclusion is that the project was worthy and efficient for investment.

Nicholas J. Garber, Lester A. Hoel., 2001 (p.571-591) wrote this topic in the textbook: The objective of an evaluation is to furnish the appropriate information about the outcome of each alternative so that a selection can be made. An essential input in the process is to know what information will be important in marking a project selection, evaluation can also be made after a project is completed to determine if the outcome for the project are as had been anticipated.

The criteria selection is a basic element of the evaluation process because the measure used become the basis on which each project is compared. Thus, it is important that the criteria be related as closely as possible to the stated objective. A transportation project is intended to accomplish one or more goals and objective, which are made operational and criteria. The numerical or relative results for each criteria are called measures of effectiveness. Some examples of criteria used in transportation evaluation are listed in table 2.2.

Table 2.2 Criteria for evaluating transportation alternatives

- Capital Costs
    - Construction
    - Left of way
    - Vehicles
- Maintenance Costs
- Facility Operating Costs
    - Total hours and cost of system travel
    - Average door-to-door speed
    - Distribution of door-to-door speed
- Vehicle Operating Costs
- Accident Costs

Source: Nicholas J. Garber, Lester A. Hoel., 2001 (p.574)

2.5.1 Economic analysis

An economic evaluation of a transportation project is completed using one of the following methods: present value (PV), net present value (NPV), the equivalent uniform annual cost (EUAC), benefit-cost ratio (BCR), or internal rate of ratio (IRR). The reason for selecting one over the other is preference for how the results will be presented. Since transportation projects are usually built to serve traffic over the long period of time, it is necessary to consider the time-dependent value of money over the life of a project.

1) **Present value (PV)** is the most straightforward of the methods, since it represents the current value of all the costs that will be incurred over the lifetime of the project is shown at Eq 2.1 below.

$$PV = \sum_{n=0}^{N} \frac{C_n}{(1+i)^n} \qquad (2.1)$$

Where

C_n= facility and user costs incurred in year n

N = service life of the facility (in years)

i = rate of interest

2) **Net Present Value (NPV)** is the present value of a given cash flow that has both receipts and disbursements. The use of an interest rate in an economic evaluation is common practice because it represents the cost of capital. Money spent on a transportation project is no longer available for other investments, a minimal value of interest rate is the rate that would have been earned if the money were invested elsewhere.

For example, if $1,000 were deposited in a bank at 8 percent interest, its value in 5 years would be 1,000(1+0.08)=$1469.33. Discount rates can be higher or lower, depending on risk of investment and economic conditions.

It is helpful to use a cash flow diagram to depict the costs and revenues that will occur over the lifetime of a project. Time is plotted as the horizontal axis and money as the vertical axis, illustrated in figure 2.11. We can calculate the NPV of the project, which is shown at Eq 2.2 below.

$$NPV = \sum_{n=0}^{N} \frac{R_n}{(1+i)^n} + \frac{S}{(1+i)^n} - \sum_{n=0}^{N} \frac{M_n+O_n+U_n}{(1+i)^n} - C_o \qquad (2.2)$$

Where ;

C_o = initial construction cost

n = a specific year

M_n= maintenance cost in year n

O_n = operation cost in year n

U_n = user costs in year n

S = salvage value

R_n= revenues in year n

N = service life, years

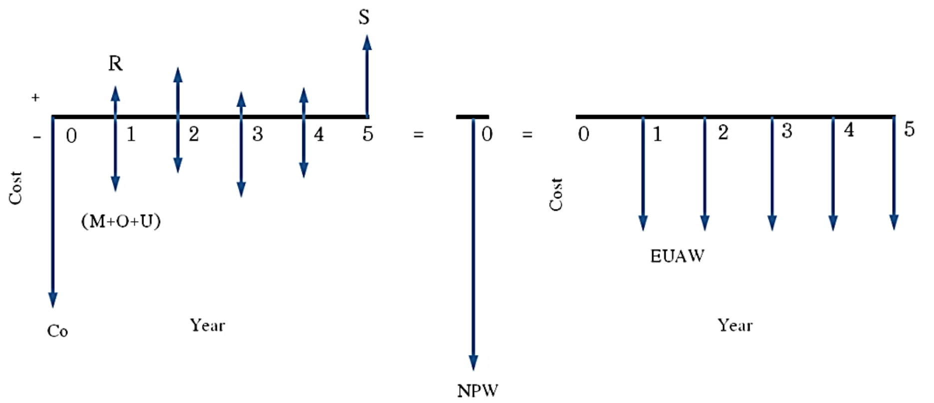


Figure 2.11 Typical cash flow diagram for a transportation alternative and equivalence as net present worth of annual cost

Source: Nicholas J. Garber, Lester A. Hoel., 2001 (p.581)

3) **Equivalent uniform annual value (EUAV)** is a conversion of a given cash flow to a series of equal annual amounts. If the amounts are considered to occur at the end of the interest period, then the formula is shown at Eq 2.3 below.

$$\text{EUAV} = NPV\left[\frac{i(1+i)^N}{(1+i)^N-1}\right] = NPV(A/P - i - N) \quad (2.3)$$

Similarly,

$$\text{NPV} = EUAV\left[\frac{(1+i)^N-1}{i(1+i)^N}\right] = EUAV(P/A - 1 - N) \quad (2.4)$$

Where

$EUAV$ = equivalent uniform annual value

NPV = net present value

i = rate of interest, expressed as a decimal

N = number of years

Formula solutions for values of *i* and *N* that convert a monetary value from a future to a present time period (P/F – *i* – *N*) and from a present time period to equal end-of-period payments (A/P – *i* – *N*) are tabulated in textbooks on engineering economics. Table 2.3 lists values of single-payment present worth factors (P/F) and capital recovery factors (A/P) for a selected range of interest rates and time periods.

Table 2.3 Present value and capital recovery factors

	i = 3		*i = 5*		*i = 10*		*i = 15*	
N	*(P/F)*	*(A/P)*	*(P/F)*	*(A/P)*	*(P/F)*	*(A/P)*	*(P/F)*	*(A/P)*
1	0.9709	1.0300	0.9524	1.0500	0.9091	1.1000	0.8696	1.1500
2	0.9426	0.5226	0.9070	0.5378	0.8264	0.5762	0.7561	0.6151
3	0.9151	0.3535	0.8638	0.3672	0.7513	0.4021	0.6575	0.4380
4	0.8885	0.2690	0.8227	0.2820	0.6830	0.3155	0.5718	0.3503
5	0.8626	0.2184	0.7835	0.2310	0.6209	0.2638	0.4972	0.2983
10	0.7414	0.1172	0.6139	0.1295	0.3855	0.1627	0.2472	0.1993
15	0.6419	0.0838	0.4810	0.0963	0.2394	0.1315	0.1229	0.1710
20	0.5537	0.0672	0.3769	0.0802	0.1486	0.1175	0.0611	0.1598
25	0.4776	0.0574	0.2953	0.0710	0.0923	0.1102	0.0304	0.1547
30	0.4120	0.0510	0.2314	0.0651	0.0573	0.1061	0.0151	0.1523
35	0.3554	0.0465	0.1813	0.0611	0.0356	0.1037	0.0075	0.1511
40	0.3066	0.0433	0.1420	0.0583	0.0221	0.1023	0.0037	0.1506
45	0.2644	0.0408	0.1113	0.0563	0.0137	0.1014	0.0019	0.1503
50	0.2281	0.0389	0.0872	0.0548	0.0085	0.1009	0.0009	0.1501

Source: Nicholas J. Garber, Lester A. Hoel., 2001 (p.583)

4) The benefit-cost ratio (BCR) is a ratio of the present value of net project benefits and net project costs. This method is used in situations where it is desired to show the extent to which an investment in a transportation project will result in a benefit to the investor. To do that, it is necessary to make project comparisons to determine how the added investment compares with the added benefits. The formula for BCR is shown at Eq 2.5 below.

$$BCR_{2/1} = \frac{B_{2/1}}{C_{2/1}} \tag{2.5}$$

Where

$B_{2/1}$= reduction in user and operation costs between higher cost alternative 2 and lower cost alternative 1, expressed as PV or EUAV

$C_{2/1}$= increase in facility costs, expressed as PV or EUAV

If the BCR is 1 or greater, then the higher cost alternative is economically attractive. If the BCR is less than 1, this alternative is discarded.

5) The internal rate-of-ratio (IRR) method determines the interest at which the PV of reduction in user and operation costs $B_{2/1}$ equals the PV of increases in facility costs $C_{2/1}$. If the IRR exceeds the interest rate (referred to as the minimum attractive rate of return), the higher cost project is retained. If the

IRR is less than the interest rate, the higher priced project is eliminated. The procedure for comparison is similar to that used in the BCR method.

2.5.2 Road user cost

The cost of a transportation facility improvement includes two components: first cost and continuing costs. The first cost for a highway or transport project may include engineering design, right of way, and construction, continuing costs include maintenance, operation, and administration. Three commonly used measures of user costs are included in a transportation project evaluation: Costs for vehicle operation, travel time costs, and costs of accidents. These costs are sometimes referred to as benefits, the implication being that the improvements to a transportation facility will reduce the cost for the users-that is, lower the perceived price, and result in a user benefit. The interactions between road user costs and highway geometric and operational factors are illustrated in figure 2.12.

1) **Vehicle Operating Costs (VOC)** : User costs for motor vehicle operation are significant items in a highway project evaluation. For example, a road improvement that eliminates grades, curves, and traffic signals as well as shortening the route can result in major cost reductions to the motorist.

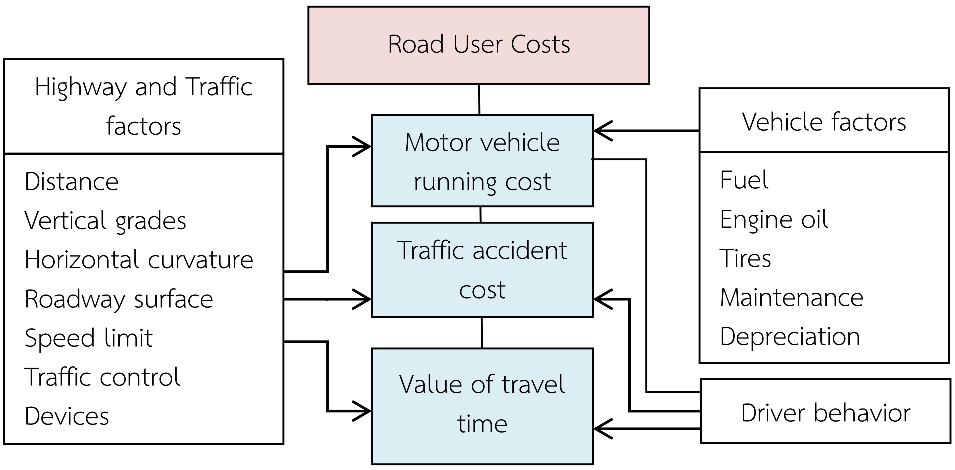


Figure 2.12 Road user cost factors
Source: Highway Engineering Economy, U.S. Department of Transportation, Federal Highway Administration, April 1983, p.28.

2) Vehicle Operating Costs (VOC) : User costs for motor vehicle operation are significant items in a highway project evaluation. For example, a road improvement that eliminates grades, curves, and traffic signals as well as shortening the route can result in major cost reductions to the motorist.

3) Value of Time (VOT) : One of the most important reasons for making transportation improvements is to increase speed or to reduce travel delay. In the world of trade and commerce, time is equivalent to money. The method of handing travel time savings in an economic analysis has stirred considerable debate, how should these be converted to dollar amounts, such as time savings for a tracking firm can be translated directly into savings in labor cost by using an hourly rate for labor and equipment. The value of time saved also depends on the length of trip and family income.

For example, if a highway project that will carry an average daily traffic (ADT) of 50,000 autos saves only 2 minutes per traveler, and the value of time for the average motorist is estimated conservatively at $5.00/hour, the total minimum annual savings is 50,000*(2/60)* 365*5=$3,041,667. At 10 percent interest, these savings could justify spending a total of almost $26 million for a 20-year project life.

4) Accident Costs : Loss if life, injury, and property damage incurred in a transportation accident are a continuing national concern. Reflection the economic cost of accidents requires both an estimate of the number and type of accidents that are likely to occur over the life of the facility and an estimate of the value of each occurrence. Property damage and injury-related accidents can be valued using insurance data. There is no simple numerical answer to the question, "What is the value of human life or the cost of an accident" although everyone would agree that economic value does exist. Published data vary widely, and the most prudent course, if an economic value is desired, is to select a value that appears most appropriate for the given situation.

There is no simple numerical answer to the question; "What is the value of human life or the cost of an accident". Although everyone would agree that economic value does exist, the cost of road accident is different data.

DOH., 2012 created a new mean cost per accident for various severities in Thailand (table 2.4) by dividing into three groups which are covered in Thailand, In Bangkok province and other provinces group. These data (in the table) shown the severities of each case per unit such as one accident in Bangkok area is killed one person, so, that person is value by average about 10.561 - 12.413 million baht.

RIPCORD-ISEREST, (2005) used the equation (2.6) to find the annual average accident cost ($/year). This equation is a relationship with the mean cost per accident for various severities in table 2.4.

$$ACa = \frac{(A(F)xMCA(F))+(A(DL)xMCA(DL))+(A(SI)xMCA(SI))+(A(SL)xMCA(SL))+(A(PDO)xMCA(PDO))}{t} \quad (2.6)$$

Where

A : number of accidents (acci),

MCA : the mean cost per accident ($/acci) as shown in table 2.4, and

t : is the period of time under review (year).

Table 2.4 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 (Dl)	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 (PDO)	0.052	0.164	0.039

Source: Department of Highway, Thailand (2012)

2.6 Road Safety

2.6.1 Road Safety Audit

2.6.1.1 Definitions

A Road Safety Audit (RSA) is defined as “the formal safety performance examination of an existing or future road or intersection by an independent, multidisciplinary team. It is qualitatively estimated and reports on potential road safety issues and identifies opportunities for improvements in safety for all road users" (Taneerananon P. et al., 2009, FHWA., 2009), the definitions of the RSA shown in the table 2.5.

Table 2.5 Definitions of road safety audit/inspection

Sources/ Country	The definition of the Road Safety Audit/Inspection
FHWA Office of Safety	**RSA** is a formal safety performance examination of an existing or future road or intersection by an independent audit team.
IHT, (2002)	**RSA** is the method used to evaluate potential for accidents and safety in the use of construction new road projects, improve and maintain the existing road projects.
Andreas Vesper, (2011)	**"Road Safety Audit"** means an independent detailed systematic and technical safety check relating to the design characteristics of a road infrastructure project. And covering all stages from planning to early operation.
Belcher and Proctor, (1900)	**Road Safety Inspection** means an ordinary periodical verification of the characteristics and defects that require maintenance work for reasons of safety.
Austroads, (2002)	**Road Safety Audit** is examining the formal aspects of road traffic in the future or existing road by a qualified independent auditor. Who will report the potential for accidents and safety deficiency of a project or existing road.

2.6.1.2 Road Safety Principles

Before the traffic accident, this principle is used for protecting the road users "Prevention is better than cure", "Drive, Ride, Walk in Safety". Various stages of the project to make safety audits, The auditors can manage road safety audit in any period of times under a project (table 2.6) as follows; 1) Strategic Stage, 2) Conceptual Design Stage, 3) Detailed Design Stage, 4) During Construction Stage, 5) Pre-Opening to Traffic, and 6) Existing Roads.

Table 2.6 The description of each type of road safety audit

Project phase	Type of road safety audit	Project stage description
Pre-construction	Strategic design	Conducted at the completion of the strategic design stage of the project life cycle. The strategic design stage is where broad options for a proposed project are determined. Also know as the feasibility stage.
	Concept design	Conducted at the completion of the concept design stage of the life cycle. The concept stage is where options are examined for a proposed project and a preferred option is selected. Also known as the preliminary design stage.
	Detailed design	Conducted at the completion of the detailed design stage of the project life cycle. The detail design stage is where a design is completed in sufficient detail to commence construction.
Construction	Roadworks	Conducted at the commencement of each stage of the roadworks where changes affect traffic operations, traffic travel path characteristics, or traffic roadside characteristics during the construction stage of the project life cycle. This may be a one-off. Also known as road work traffic scheme stage.
	Pre-opening	Conducted immediately after the completion of construction of the entire project works or the construction of a roadworks stage and where possible prior to the road/ path being used by traffic.
Post-construction	Finalization	Conducted on an existing road, path or road network some time after the completion of the construction of road infrastructure works. It is typically conducted once road user patterns have settled following the works, or immediately prior to the change over of ownership or responsibility in regard to the assets of network operations following the works. Also knows as post opening stage.
	Existing road	Conducted on an existing road, path or road network where no recent construction works were undertaken.

Source: RTA/Pub No.11.291, website, http://www.rta.nsw.gov.au/roadsafety/downloads/part_1_road_safety_audit.pdf

2.6.1.3 The advantages of road safety audit;

- To ensure of new construction roads is safe,
- The existing road network have safety,
- To reduce the risk and severity of accidents may be occurring,
- To use for reducing the cost of the construction project, and
- To promote for considering of safety of all stages of the projects which are the planning, design, construction and maintenance stages.

2.6.2 Black Spot

2.6.2.1 Definition

Black Spot (BS) is the hazardous road location; Areas where accidents occur frequently. Sometimes called "Black spot", the definitions of Black Spot as shown in table 2.7.

Table 2.7 Definition of the Black Spot

Sources/ Country	The definition of the hazard (Black Spot).
OECD, (1976)	At high risk of an accident. It is a position that can be easily called the Black (Black Spot), or a road called the Black Road (Black Sites) or the area known as the black (Black Areas).
Portugal	The 300 meter long road. There is more than five times the number of accidents.
Norway	The length of 100 meters. Of the injury or death of more than 4 people.
Austroads, (1997)	Areas where accidents often occur repeatedly at the same location. It may be a direct route to the curve or bridge, etc. However, the area has a high chance of an accident. (Without a history of frequent accidents) may be considered a dangerous area.
Belgium	Accidents where there are more than 3 times in 3 years.
Germany	The 300 meter long road. A similar incident occurred five times a year. The accident occurred at the same place three times a year.
USA	The 300 meter long road. A place where the accident happened in the past three years more than 12 times.

Source: European Union Road (2002); OTP, (2004) Department of Highways Ministry of Transport Thailand., (2002) was defined the black spot at the junction and road location as shown in table 2.8.

Table 2.8 Identify of hazardous road location

	Junction type	No. of accidents to be Black Spot (BS)
Junction area	3 legs	> 5 times
	4 legs	> 6 times
	5 legs	> 4 times
	Other Junction	> 5 times
Note : The area covers a distance of 100 meters downstream of the junction.		
Area	**Location/Road**	**Black Spot (BS)**
	Straight	> 4 times
	U-Turn	> 3 times
	Bridge	> 4 times
Note : Around curves, regardless of the distance from the bend and bend each side 50 meters. Each side of the bridge is 15 meters.		

Source: DOH., (2002)

2.6.3 Identify road locations

To ensure that safety objectives are met, a distinction must be made between: (1) locations which are hazardous as identified based on accident experiences, and (2) locations and elements that are potentially hazardous due to their geometrics or physical features. A location can be identified as hazardous by the occurrence of an abnormal number, rate, or severity of accidents over a given period of time.

SIRDC., (2011) : Why need to identify and prioritizing hazardous locations: An important factor is the “budget” that can be applied to remediation projects in any given year. Ranking systems are important, as they can help setting priorities. Priorities are necessary whenever funding is insufficient to addressed all locations identified as needs for investigation and remediation. The method of identifying hazardous locations are 1) Accident Frequency Method, 2) Accident Rate Method, 3) Rate Quality Control Method, 4) Accident Severity Method, and 5) Combination Method.

Three example methods for analyzing the hazardousness of locations include the following :

2.6.3.1 Spot map method

The simplest method for identifying hazardous locations is to examine an accident spot map. The map will show the spots or segments having the greatest numbers of accidents. This is an effective way to get a picture of the accident clusters in small areas.

2.6.3.2 Accident frequency method

The frequency method ranks locations by the number of accidents. The location with the highest number of accidents is ranked first, followed by the location with the second highest number of accidents, and so on. This method does not take into account the differing amounts of traffic at each location. Therefore, the frequency method tends to rank high volume locations as highaccident locations, even if those locations have a relatively low number of accidents for the traffic volume. Many agencies use the frequency method to select a group of high-accident locations, and then use some other method to rank the locations in order of priority.

2.6.3.3 Accident rate method

The accident rate method compares the number of accidents at a location with the number of vehicles or vehicle miles of travel at a location. This comparison results in an accident rate. The rate is stated in terms of "accidents per million vehicles" for intersections (and other spots), and "accidents per million vehicle-miles of travel" for segments. The locations are then ranked in descending order by accident rate.

1) **Spot Accident Rate**

The equation for computing accident rate for a spot location is as shown at Eq 2.7 follows:

$$R_{sp} = (A)\ (1{,}000{,}000)/ADT\ (365)(Yrs) \quad (2.7)$$

Where:

R_{sp} = Accident rate at a spot in accidents per million vehicles,

A = Number of accidents for the study period,

Yrs = Period of study (years or fraction of years),

ADT = Average Annual Daily Traffic (AADT) during the study period. For intersections, the sum of the entering volumes on all approach legs.

A spot location is generally defined as a location about 0.3 miles or less in length. For driveways, the spot length should be equal to the stopping sight distance upstream and downstream of the location. A driveway with a low entering volume and low accident experience can achieve a relatively high accident rate.

2) **Section Accident Rate**

For roadway sections, length becomes a consideration. Equation 2.8 is used to calculation:

$$R_{se} = (A)\ (1{,}000{,}000)\ /\ ADT\ (365)\ (MI)\ (Yrs) \quad (2.8)$$

Where:

R_{se} = Accident rate of the section in accidents per million vehicle miles of travel,

Yrs = Period of study (years or fraction of years),

MI = Length of the section (in miles). Roadway segments of less than 0.3 miles should not be considered as sections.

ADT = Average Annual Daily Traffic (AADT) during the study period.

Since this method takes the location's traffic "exposure" into account, it is less likely to unfairly favor high-volume locations than the accident frequency method. On the other hand, it tends to unjustly favor low-volume locations with relatively few accidents.

An accident rate of between 2 to 3 accidents per million vehicle miles (MVM) is considered by some states to be an average rate on rural two-lane roads (excluding intersections). However, a 1-mile section with a traffic volume of only 300 vehicles per day, and only one accident per year would have an accident rate of 9.1 accidents per million vehicle miles (MVM), which would be more than three times higher than an average rate, even though only one accident has occurred. Thus, the simple accident rate method can give misleading results for low-volume locations.

2.6.4 Conflict points

Conflicts points are commonly used to explain the accident potential of a roadway. Access management strategies are typically designed to reduce the number and density of conflict points.

A conflict point is the point at which a highway user crossing, merging with, or diverging from a road or driveway conflicts with another highway user using the same road or driveway. It is any point where the paths of two through or turning vehicles diverge, merge, or cross (figure 2.13).

Conflict points are associated with increased levels of roadway accidents. A motorist can safely negotiate only so many conflict points within a given area.

Studies have shown that when driveway access to arterial roadways is granted to too many property owners without considering future traffic volumes and roadway classifications, the extra driveways increase the rate of accidents and decrease the efficiency of the roadway. Although this does not appear to be a simple, direct relationship, reducing conflict points has been shown to significantly reduce the accident rate at case study locations (T. J. Simodynes, The Effects of Reducing Conflict Points On Reducing Accident Rates, October (1998)).

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

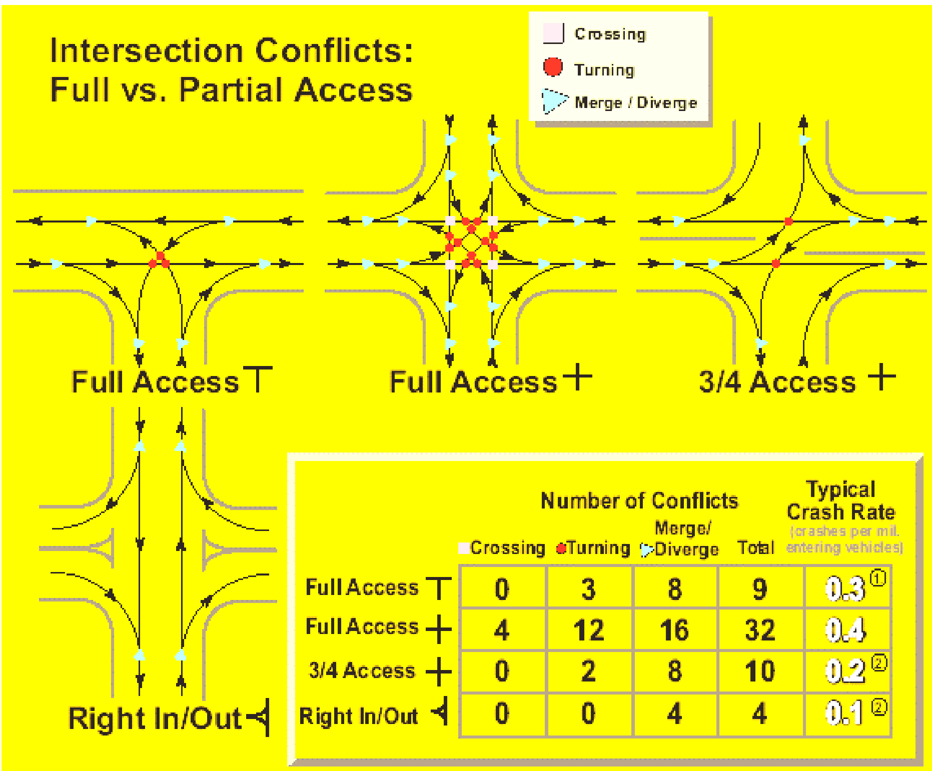


Figure 2.13 Conflict points of each at-grade junction type

Source : SIRDC., (2011), OTP., (2011)

2.6.5 Collision diagrams

Collision diagrams are used to display and identify similar accident patterns. They provide information on the type and number of accidents; including conditions such as time of day, day of week, climatic conditions, pavement conditions, and other information critical to determining the causes of safety problems.

Accident reports should be organized by year of occurrence and accident type for the analysis period. Accidents that occurred after significant changes in highway or local land use should not be included.

Symbols representing the nature of operation, vehicle or object involved and severity of the accident are adopted. Symbols to represent types of collisions diagrams are also standardized. These are shown in the example collision diagram in figure 2.14, which are shown the picture (road user movements, coads and descrition of accidents (DOH., (2013))

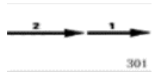
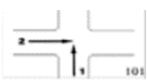
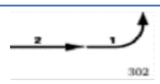
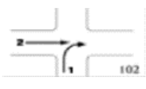
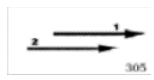
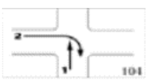
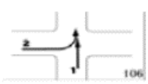
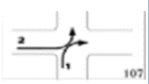
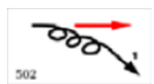
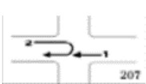
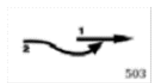
	Hit pedestrian from near side		Rear end in the same lane
	Through hits through traffic from adjacent approach		Rear end during left turn
	Right turn hits through traffic from adjacent approach		Side swipe in parallel lane
	Through hits right turn through traffic from adjacent approach		Other maneuvering accidents
	Through hits left turn through traffic from adjacent approach		Hit with vehicle leaving the parking
	Right turn hits left turn through traffic from adjacent approach		Out of control during overtaking
	Through hits U-turn traffic		Hit by overtaking vehicle during going straight

Figure 2.14 Example of collision diagrams and descriptions

Source : Adapted from DOH., (2013)

2.7 Intersection Traffic control

National Transportation Operations Coalition (NTOC) studied and gave the descriptions about traffic signal.

1) Purpose of traffic signals

Traffic signals manage the right of way at signalized intersections to provide for the safe and efficient movement of vehicles and pedestrians. Traffic engineers and technicians develop and implement signal timing at each intersection to distribute green time amongst the competing traffic flows to provide for efficient operations (figure 2.15).

2) Signal timing

Traffic signals are timed with two goals in mind: 1) to make the traffic system as safe as possible for all users; and 2) to improve traffic flow. Each traffic signal controller is programmed with different timing settings, depending on time of day (morning or afternoon rush hour) or according to what is happening at the intersection at that moment.

There are three basic types of signal timing:

- Fixed time
- Actuated
- Coordinated

Fixed time: Fixed-time signal control uses preset time intervals that are the same every time the signal cycles, regardless of changes in traffic volumes. They give the most green time to the heaviest traffic movement based on historical information. Some fixed-time systems use different preset time intervals for morning rush hour, evening rush hour, and other busy times.

Actuated: An actuated signal controller is able to change the amount of green time for each cycle, based on information from the detectors. Actuated signals are best where traffic volumes fluctuate considerably during the day, when interruptions to major-street traffic flow must be minimized, or when there is very light side-street traffic.

Coordinated: In addition to timing an individual traffic signal, some signals are timed as a coordinated network. The goal of signal coordination is to help traffic flow through a series of signals at a predetermined speed to minimize or avoid stops. In other words, the signal at an intersection turns green just as you arrive. This isn't always possible because of the need to provide smooth flow in two or more directions. This is why traffic engineers use computer programs to determine the best compromise among all the competing directions of traffic.

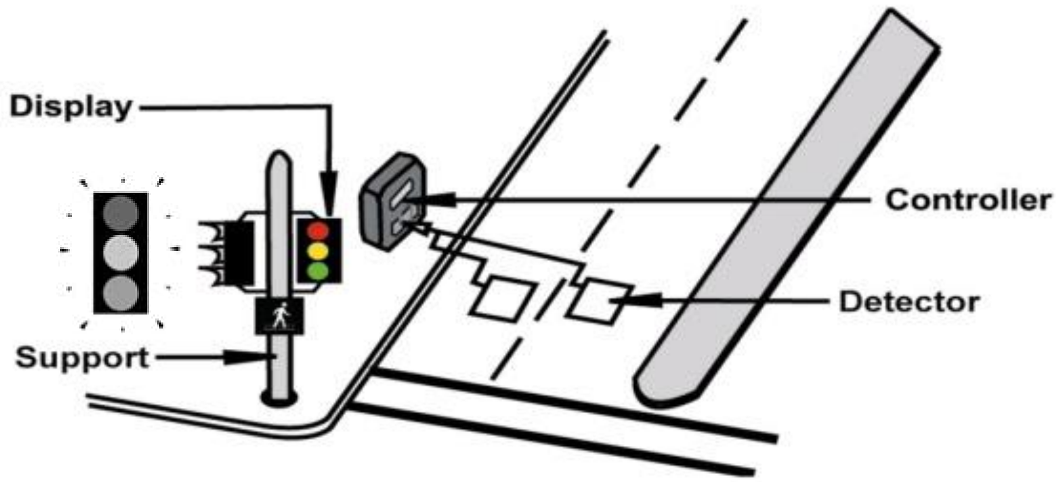


Figure 2.15 Traffic signal control provided for efficient operations
Source : http://library.ite.org/pub/e2654cc1-2354-d714-511b-4cad3fe7c68a

2.8 Processing Software

2.8.1 Signalized (and unsignalized) Intersection Design and Research Aid (SIDRA)

SIDRA was developed by Rahmi Akcelik during 1975-1979 for designing an intersection. Sidra Intersection is a micro-analytical traffic evaluation tool that employs lane-by-lane and vehicle drive cycle models. It can be used to compare alternative treatments of individual intersections and networks of intersections involving signalised intersections (fixed-time/pretimed and actuated), roundabouts (unsignalised), roundabouts with metering signals, fully signalised roundabouts, two-way stop and give-way (yield) sign control, all-way (4-way and 3-way) stop sign control, merging, single-point urban interchanges, traditional diamond and diverging diamond interchanges, basic freeway segments, signalised and unsignalised midblock crossings for pedestrians, and merging analysis.

In 2012, the latest versions of the software were in use by over 1350 organizations with more than 8300 licences in 70 countries such as USA, Australia, South Africa, Canada, New Zealand, Malaysia, Singapore, Arabian Peninsula, as well as over 140 organizations in Europe.

It is a program designed for detailed modelling of delay and travel time components as well as operating cost, fuel consumption and emission estimation. It uses advanced models and methods, including lane-by-lane analysis (rather than analysis by lane groups in the HCM), modelling of shortlanes, detailed modelling of average and percentile queue lengths.

The program was improverd more than 30 years or 15 versions. This research studied during 2011 – 2014, this analysis used SIDRA INTERSECERTION 5.1 to data processing. The operation of the SIDRA INTERSECTION is shown in figure 2.16 and figure 2.17 is an example picture of the software.

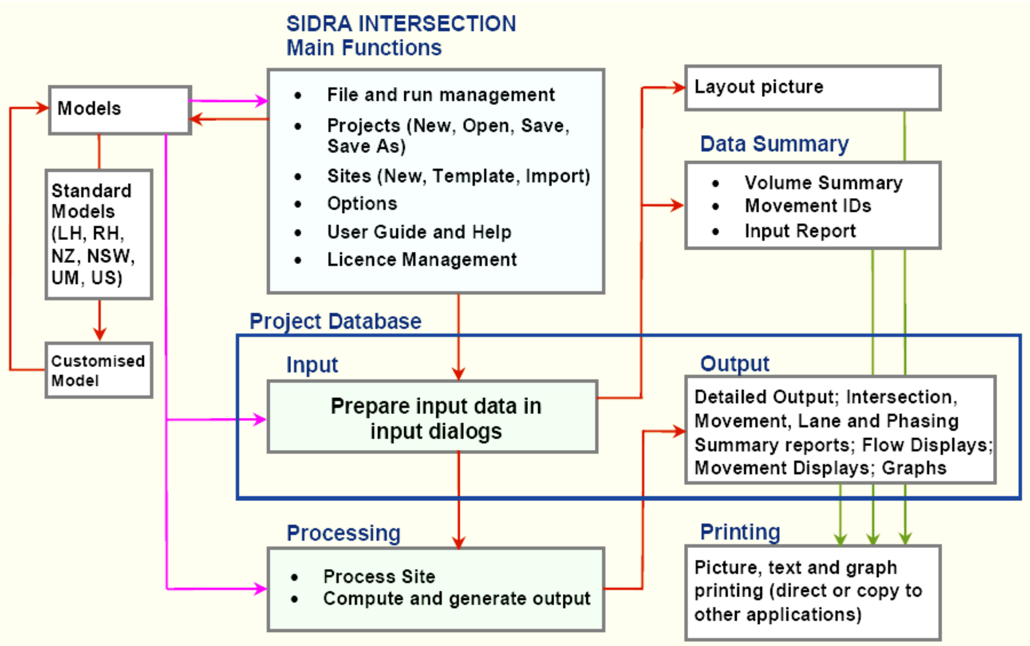


Figure 2.16 Operation of the SIDRA INTERSECTION system

Source : SIDRA INTERSECTION user guide, Akcelik & Associates Pty Ltd (November 2012)

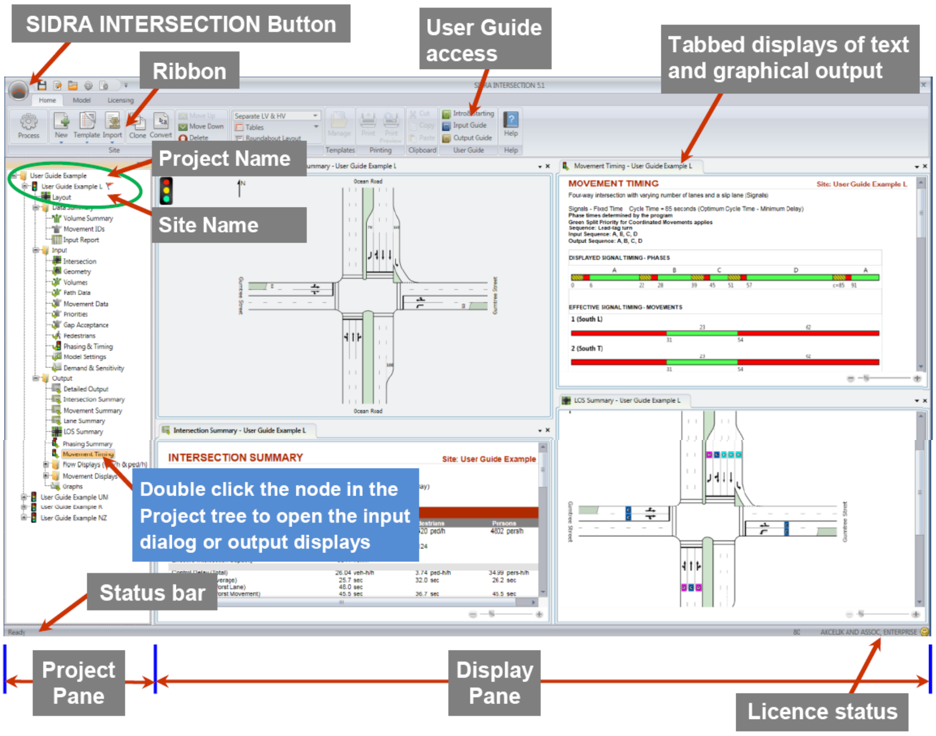


Figure 2.17 An example picture of the SIDRA INTERSECTION user interface

Source : SIDRA INTERSECTION user guide, Akcelik & Associates Pty Ltd (November 2012)

2.8.2 Efficacy of other traffic micro-simulation program

FDOT (2014) studied and made a manual for analyzing traffic conditions by traffic micro-simulation program consist of HCM/ HCS, SIDRA, Synchro/ SimTraffic, CORSIM and VISSIM, as shown in table 2.9.

FDOT (2014) created a chart in the selection of tools to analyze traffic conditions. In order to understand and use easily, and are more appropriate, as shown in figure 2.18.

Table 2.9 Comparing the efficiency of traffic simulation programs

Efficiency	Traffic micro-simulation program				
	HCM/ HCS	SIDRA	Synchro/ SimTraffic	CORSIM	VISSIM
1) Traffic Operations and Control Characteristics					
- Speed	√	√	√	√	√
- Speed Limit	√	√	√	√	√
- Parking	√	√	√	-	√
- Signs	-	√	-	√	√
- Signals	√	-	√	√	√
- Detectors	√	√	√	√	√
- Intersection control	√	√	√	√	√
- Right/left turn treatment	√	√	√	√	√
2) Traffic Characteristics					
- Demand	√	√	√	√	√
- Queue	-	√	√	√	√
- Capacity/Saturation Flow	-	-	√	√	√
- Pedestrian Counts	√	√	√	-	√
- Bicycle counts	√	√	-	-	√
- Bus & Transit	√	-	√	-	√
3) Roadway Characteristics					
- Road Classification	√	√	√	√	√
- Cross Section	√	√	√	√	√
- Geometry	√	√	√	√	√
- Roadside	√	-	-	√	√
- Access Control	√	-	-	√	√
- Access Density	√	-	-	√	√

Source: FDOT (2014)

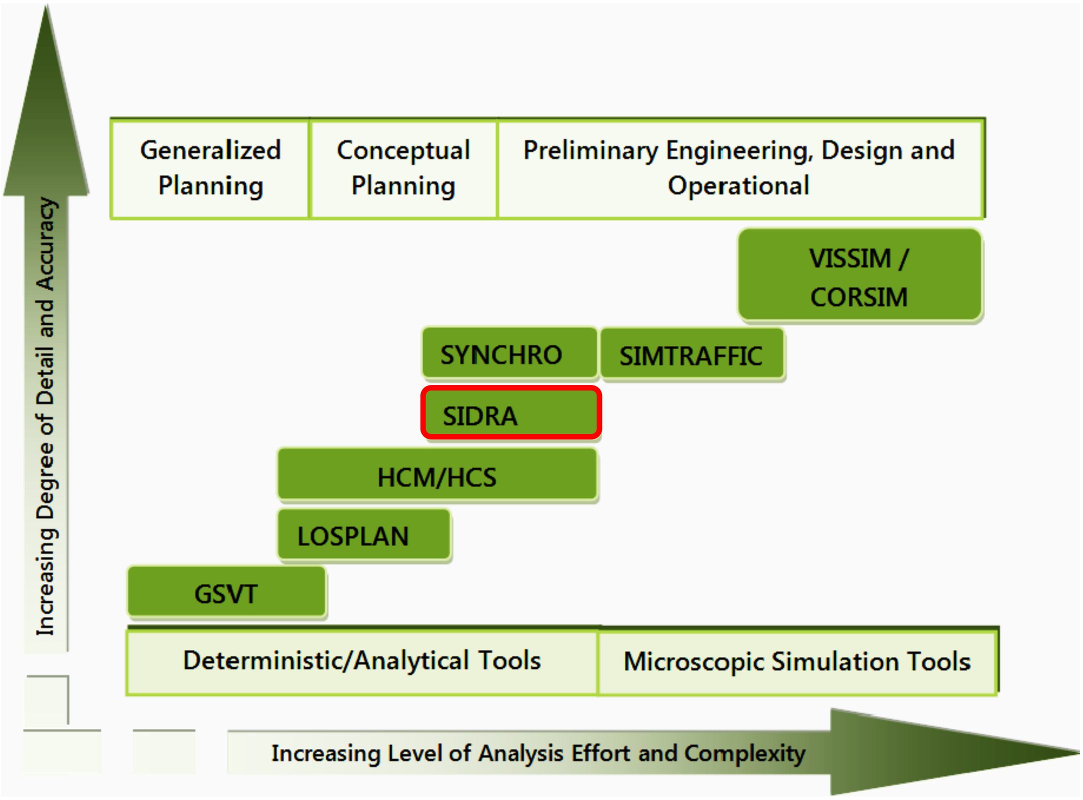


Figure 2.18 Traffic analysis tools

Source: FDOT (2014)

One part of this research focused to study the intersection control in term of optimum performance to traffic flow determining by the program, cycle phase time, delay (DL), queue length (QL) and level of service (LOS), so, the SIDRA processing software is suitable and sufficient tool to evaluate of these requirements.

CHAPTER 3
METHODOLOGY

To achieve the objectives of this study, researcher has concluded the stage of the research divided into 7 main steps as follow;

1) Literature reviews,
2) Case study selection,
3) Data collection,
4) Data assessment,
5) Analysis/Evaluation,
6) Conclusions, and
7) Recommendations.

In the objectives, there are 2 main of studies consist of efficiency and road safety evaluations of the flyover intersection. The case studies were selected to study in two important cases which are **a flyover construction case** (at-grade intersection converted to flyover intersection, the study is assessed in three situations : before, during and after flyover construction) and **an existing flyover intersection case** (about 20% of all existing flyover intersections in Thailand was selected to study).

Figure 3.1 has shown the research framework in all of the steps. The first step is literature reviews: focusing to 3 keywords which are road safety on the flyover intersection area, efficiency of the flyover intersection and processing software (SIDRA). The second is selecting case study: In-depth case and typical case of the flyover intersection. Third is data collection: such as on-site traffic data collection, accident statistic, and road safety etc. Fourth is data assessment: before to solving the issues, these fundamental data must convert to be the basis data in the same unit, for example all vehicle types convert to be PUC-basis. Fifth is analysis and evaluation step: both terms efficiency and road safety of the flyover intersections were assessed. Then is conclusion step: on-site effect of flyover to traffic, project evaluation, road safety, optimizing by SIDRA. And the last step is recommendation: project construction on highways, flyover limitations, advantage/disadvantage, improved intersection, hazard zones, traffic control would be explained.

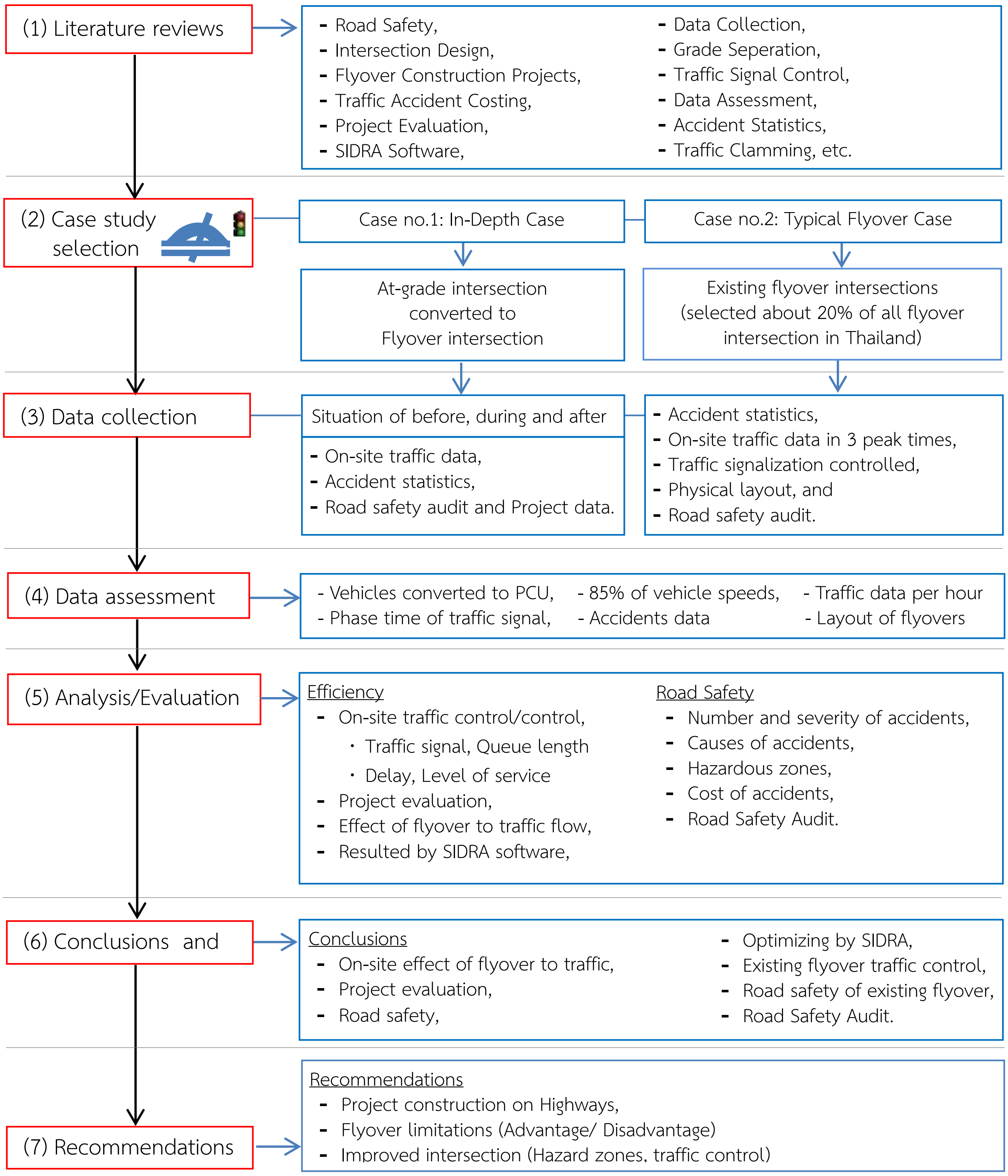


Figure 3.1 Research framework

3.1 Literature reviews

Researcher has reviewed many sources by focusing to 3 keywords as said before: road safety, efficiency and processing software.

The list of literature reviews are Road Safety, Intersection Design, Flyover Construction Projects, Traffic Accident Costing, Project Evaluation, SIDRA Software, Data Collection, Grade Seperation, Traffic Signal Control, Data Assessment, Accident Statistics, Traffic Clamming and implicated papers.

3.2 Case study selection

Researcher selected 2 cases to achieve the objectives of this study consist of;

In-depth case : a flyover intersection construction project that is selected to study is an intersection of highway route number 43 and highway route number 4135 near Hat Yai city, Songkhla, Thailand. This project is constructed during 2009 to 2012 by the Department of Highways, because it is constructed during researcher study, there are enough fundamental data to study and restrictions in terms of the budget to data collection. This case aims to study the in-depth terms covering to the efficiency and road safety data. So, this project is studied in three time periods which are in situations of at-grade intersection (before construction), during construction, and after flyover constructed (after construction).

Typical flyover case : an existing flyover is selected about 20 percent of all this flyover intersection types cover all regions of Thailand. There are 29 flyover intersections in Thailand, selected 5 examples-locations to study which are in the Songkhla, Udon Thani, Rayong, Phatthalung and Phitsanulok provinces. To study the existing problems at the locations, these five case studies are audited as follow as a Road Safety Audit guideline and measured the existing problems such as existing signal timing plan, vehicle delay and road accidents statistics on these locations etc.

3.3 Data Collection

3.3.1 On-site traffic data

The on-site data collection is the important fundamental data using to analyze which are the traffic movement, time delay, queue length, traffic signal control, vehicle speed, flyover layout, conflict points and road safety audit.

3.3.1.1 Intersection traffic movement count (TMC)

For at-grade intersection: the traffic movements are counted in four directions, at the location marked as 1, 2, 3 and 4 (figure 3.2).

For the flyover: the traffic movements are counted in four directions also, at the locations marked as A, 1, B, C, 2 and D on the main road, and on the secondary road at the locations marked as 3 and 4 (figure 3.3).

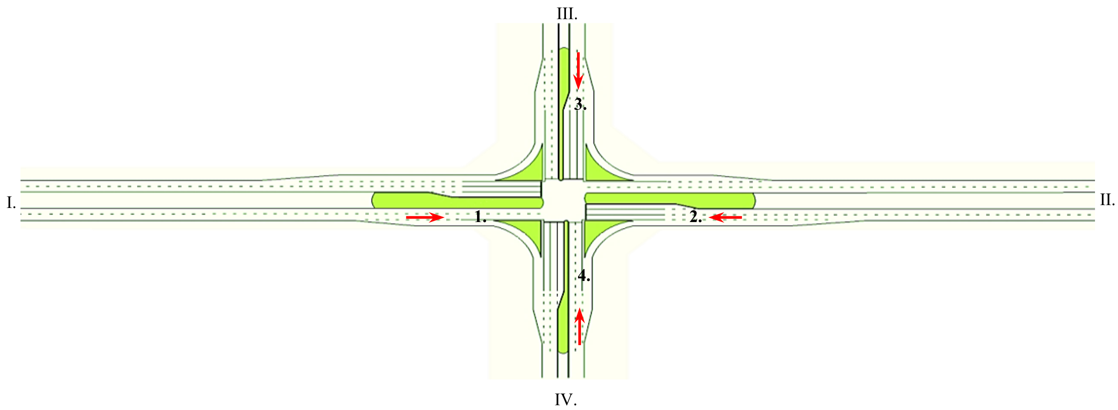


Figure 3.2 Turning movement count location marked of the at-grade intersection

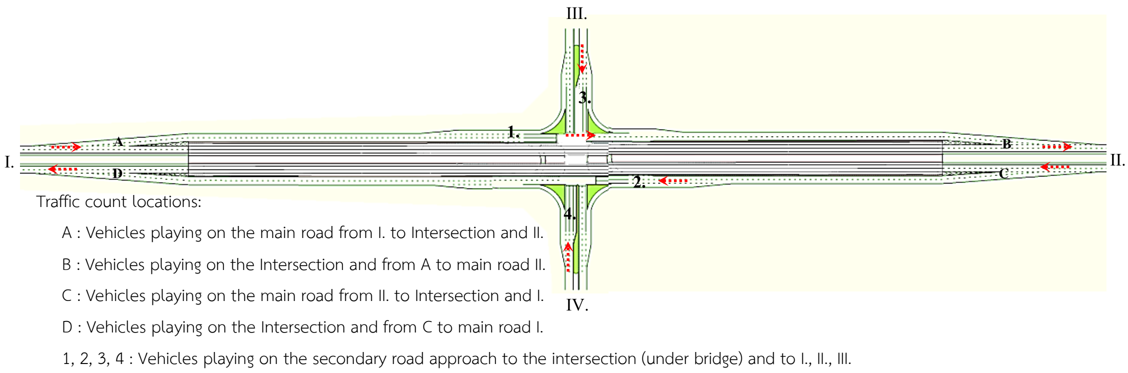


Figure 3.3 Turning movement count location marked of the flyover intersection

The vehicles categorized in 12 groups as follow with the Table 2.1: Bicycle, Motorcycle, PC<7people, PC>7people, Mini bus, Medium bus, Bus, Mini truck, Medium truck, Havey truck, and > 10-wheel trailer truck. (SIRDC., (2011)). In the form, one page for one traffic movement-direction is divided into four parts (15 minutes per part) in one hour, cover all in survey time during 7:00 a.m. to 7:00 p.m. (12 hr.), and the form of intersection turning movement count (TMC) is shown the example form in the ***appendix I-1***.

3.3.1.2 Delay count (DL)

To verify about the time of vehicle delay that stopped for waiting a green cycle phase at the intersection, one method that can be checked is recorded in the field. This checking can assess the optimum the cycle phase time of the traffic signals in each period per cycle by checking with the loss of time.

The form of delay count is divided to sixty lows (60 minutes), in one row (1 minute) divided into 4 parts (15 seconds per part). When the vehicles stopped at the intersection in each time on each block column of the form, a recorder will mark the number of vehicles that stopped as identify as PCU-basis and if the vehicles stopped for waiting a long time (more than 15 seconds) a recorder will record it again in the next block column (next 15 seconds-column), the delay count should count with the day of TMC's survey, the example of the delay form as shown at the ***appendix I-2***.

3.3.1.3 Queue length count (QL)

The objective of this method needs to verify about the queue vehicle length in each direction of an intersection. The queue length count is recorded like the delay count method, but the difference of this method is recording only on a lane that have the most vehicles stopped in each direction of the intersection per one cycle of traffic signal program. The example form of the queue length count form is shown at the ***appendix I-3***.

3.3.1.4 Traffic signal control

The cycle time of the traffic signalization reflects the traffic jam or vehicle delay. Normally, at the flyover intersection is controlled by the fixed-time control plan, not depend on the traffic volume that varies through a day. To check the length of each cycle must be checked every hour on the running time of the programs in a day (24 hours). The traffic signal form as shown in the ***appendix I-4***.

3.3.1.5 Vehicle speeds

Vehicle speed is checked by spot speed method, using the radar-gun tool for checking the vehicle's speed in three categories (PC, Trucks, other). The speed of vehicles is measured when the vehicles freely flow at an intersection, recorded at 7 points as marked in the figure 3.4, then calculate the 50 percentile (mean speed) and compute 85 percentile of the vehicle speeds as follow the example method in the chapter 2 (page no.20) to analyze. The speed check-point form shown at ***appendix I-5***.

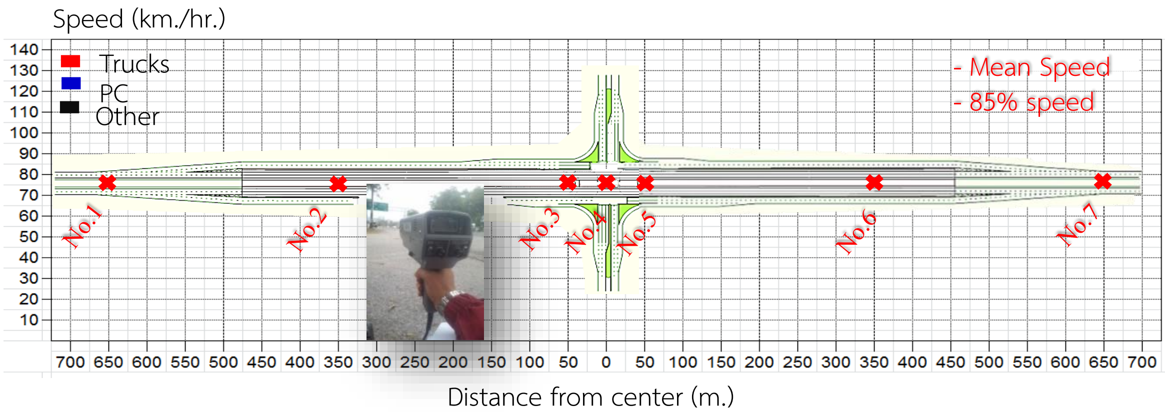


Figure 3.4 The points marked to find the vehicle speed data

3.3.2 Accident Statistics

The accident statistics is collected and recorded in the Thailand by the Department of Highways (DOH), Police Station sector and Emergency Medical Services System (EMS). These agencies recorded this data in different items by depending on their agencies, moreover, may not cover in accident occurred. However, researcher must look into all agencies that recorded it. Due to the different items in the record form (wrote and shown in the chapter 2 (page no.21 - 23), researcher therefore created a new items as shown in example table 3.1 below and ***appendix I-6***, and used it to collect these accident records from 3 agencies.

Normally of accident statistics that be used to evaluate is 2 to 3 years recorded, for in-depth case collected this data in three time periods which are about 2 years before construction, during constrction and about 2 years after construction. The accident statistics is the important data used to measure about the cost and cause of accidents on the flyover intersection area.

Table 3.1 Example record-form that used to collect the accident statistics

No	Zone	D/M/Y of accident	Hw/Sta (km.) Point of accident	Vehicle types of accident	Collision Diagram	Time			Number of Casualties			DOH damage	PDO	Cause
						Day	Night	Rain	Injury	Serious	Death			
1	2	21-Jan-10		Motorcycle	702		3:47		1					Drunkenness
:														
:														
:														
5	1	8-May-10		Truck + Motorcycle	101			19:48			2			Violation of traffic signals

3.3.3 Road Safety Audit (RSA)

Researcher used the Road Safety Audit guideline (Taneerananon, P. et al. 2009) to inspect at on-site of case studies.

In-depth case audits in three time periods (status of at-grade intersection, during construction, and flyover intersection), covering in the processes of opening road (at-grade intersection and flyover intersection situations) and during construction stage (in the in-depth case). Two stages show the items as follows;

❖ Road Safety Audit (Opening Road)

Audit items to be checked as;

- General Grading, Alignment, and Cross-Section,
- General characteristics of the junction,
- Drainage,
- Traffic signs,
- Traffic lights (signal),
- Road Marking,
- Roadside,
- Road surface,
- Road lamp,
- Pedestrians, cyclists, pedestrians crossing,
- Link roads,

- Parking and Bus stop,
- other.

❖ Road Safety Audit (During Construction Stage)

Audit items to be checked as;

1) Traffic Management,
- Traffic control,
- Management and control speed,
- Access to construction zone,

2) Signs and road markings,
- Traffic Signs,
- Terms of installing traffic signs in the daytime and at night,
- Traffic control,
- Road markers and Reflective object,
- Road markings,

3) Traffic Lights,
- Temporary traffic lights,
- The placement of traffic lights,
- Visible of traffic lights,
- Movement of traffic,

4) Pedestrians and cyclists,
- Common Problems,
- Disability people,
- Cyclists,

5) Road surface,
- Damage to the road surface,
- Skid resistance,
- Floods,

6) Other,
- Road alignment,
- Turning radius and flare width (Tapers),
- Safety and visibility of the traffic,
- Security at night,
- Repairs and maintenance,
- Road link,
- Bumper equipment,

3.3.4 Other important information

3.3.4.1 Investment cost

The investment cost is also important data, normally owner (Department of Highways) estimated the construction cost of this model is about 75,000 (2,318.9 USD) Baht/square meter, average of the flyover intersection construction cost is about 175,000,000 Baht per flyover (5,410,912.5 USD).

3.3.4.2 Physical data

The Layout of the flyover intersection that was designed, Department of Highways is an owner. Researchers asked for this data from them and checking this the real layout again in the field. For in-depth case, the layout of two situations 'before and after' is used to compare in terms of hazardous area and conflict points zones. Although the flyover is more designed for supporting the traffic volume on the main road, the flyover is designed by depending on the location. The difference of both layouts are length of the flyover, U-turn under the bridge, and position and direction of the bridge and vehicle conflicts on the road.

3.3.4.3 Supportive data

This supportive data is also significant information such as the picture, VOD, DOH surveyed data, Traffic signal plan and related study etc.

3.4 Data assessment

Before to solving the issues, these fundamental data must convert to be the basis data in the same unit, for example all vehicle types converted to be PUC-basis, created the data (traffic movement by lane-direction, delay, queue length, level of service, and traffic signal plan) in every hour covering in periods of survey (because these data can show the easy understand and have to put in the processing software (SIDRA program)), calculating the 50 percentile (mean speed) and 85 percentile of the vehicle speeds.

3.5 Analysis and Evaluation

3.5.1 In term of Efficiency

In the scope, there are four terms in this study;

3.5.1.1 On-site traffic data/control

Using the comparing method of on-site traffic data/control between situation of 'before and after flyover construction' to illustrate the results which are traffic volume, traffic movement, traffic signal, queue length, delay and level of service.

3.5.1.2 Project evaluation

Considering only the In-depth case, to evaluate the benefits after invested for constructing the flyover intersection with the cost about 249 Million Baht, using the economic analysis method to analyze data.

The traffic movement (average daily traffic), that was counted and recorded in two periods of time (at-grade intersection and flyover intersection periods) is computed by equation (3.1) by DOH., (2006) and (Luophongsok et al., 2011) to predict the growth rate of traffic volume per year in future traffic volume.

$$\mathrm{T} = \left[\left(1+\frac{P}{100}\right)\left(1+\frac{G}{100}\right)^{e}\right]x100-100 \qquad (3.1)$$

Where,

T = escalation rate of traffic volume per year

P = escalation rate of population in the area (7.02)

G = escalation rate of GPP per capita (0.75)

e = elasticities value of escalation rate of traffic volume per income (e : 1.738)

❖ **Road User Costs**

The road user cost consists of value of time, vehicle operating cost, and accident cost.

➢ Value of time (VOT)

Value of time is the cost (equivalent to money) that lost in the travel, but, when the intersection is improved more efficiency, road users can use this time to do another activity to have an economic value increase, by calculating the value of time in the area (province) on the case study, consists of the gross province product (GPP), number of employed and average hours of work (Table 3.2).

Table 3.2 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 (2013)

According to the value of time in Songkhla province is 83.86 Baht/PCU/hour in 2011, to adjust by the growth rate in 2007 to 2011 (0.31), so the value of time in 2012 is 84.38 Baht/ PCU/hour.

- Vehicle operating cost (VOC)

The vehicle operating cost consists of the fuel cost, lubricant cost, idling of engine and operation cost, these correlated with number, type, vehicle speed and traffic volume (V.Watcharin, 1994), when the vehicles are waiting for a green phase at the intersection stop line and turn on the engine (idling of engine), that resulted in the undue combustion of precious fuel and the fuel consumption during idling shall also vary with different types of vehicles (Goyal et al., 2009). This study used an average the fuel cost of passenger car unit (PCU) to analyze (1,000 cc. = 37.18 Baht (Blue Gasohol 91, (6/8/2012), (http://www.pttplc.com/th/pages /home.aspx)), and used the average passenger car unit (PCU) that stopped and idling of engine 1 minute = 20 cc. (http://www. Saha vicha.com/? name =knowledge&file=readknowledge&id=1623), or loss of the money is 0.75 Baht per minute.

➢ Accidents cost

The cost of accident depends on the accidents statistics on the location and mean cost per accident for various severities (in other provinces column in the table 2.4).

To calculate the average unit cost of crash severities of three periods of time (before, during, and after construction), the average unit cost is calculated by 5 equations below (Eqs (3.2), (3.3), (3.4), (3.5) and (3.6)).

$$\text{Avg AcUC}_{(Fal)} = [\text{No.of Fal} * (\text{AcCS}_{(Fal)} + \text{AcCS}_{(DI)} + \text{AcCS}_{(SI)} + \text{AcCS}_{(SL)} + \text{AcCS}_{(PDO)})] \quad (3.2)$$

$$\text{Avg AcUC}_{(DI)} = [\text{No.of DI} * (\text{AcCS}_{(DI)} + \text{AcCS}_{(SI)} + \text{AcCS}_{(SL)} + \text{AcCS}_{(PDO)})] \quad (3.3)$$

$$\text{Avg AcUC}_{(SI)} = [\text{No.of SI} * (\text{AcCS}_{(SI)} + \text{AcCS}_{(SL)} + \text{AcCS}_{(PDO)})] \quad (3.4)$$

$$\text{Avg AcUC}_{(SL)} = [\text{No.of SL} * (\text{AcCS}_{(SL)} + \text{AcCS}_{(PDO)})] \quad (3.5)$$

$$\text{Avg AcUC}_{(PDO)} = [(\text{No.of PDO} * (\text{AcCS}_{(PDO)})) + \text{On-site damage cost}] \quad (3.6)$$

Then, to calculate the accident cost of each situation, the equation (3.7) is used to find this data, it depends on the number of severities and time under review (year).

$$ACa = \frac{(A(F)*M(F))+(A(DI)*M(DI))+(A(SI)*M(SI))+(A(SL)*M(SL))+(A(PDO)*M(PDO))}{t} \quad (3.7)$$

Where,

ACa = average of accident cost ($/year),
A = number of accidents (accident),
M = the mean cost per accident ($/accident) (Table 2.4), and
t = the period of time under review (year).

❖ **Economic Analysis**

Economic analysis is an appropriate analysis to provide a basis for making an investment decision on the project, used the method of cost-benefit analysis which are the net present value (NPV), benefit cost ratio (B/C), and internal rate of return (IRR), (Garber, N. J., & Hoel, L. A.

(2009)),. And from the project cost and benefits of the project data distributed them to the maturity of the scheme (20 years) to find this benefit.

- Net Present Value (NPV)

  The difference between the present value of the benefits and costs of the project in each year. This method is defined as the sum of the present values of the individual cash flows of the same entity (Eq 3.8).

$$NPV = \sum_{t=0}^{n} \frac{(B_t - C_t)}{(1+i)^t} \tag{3.8}$$

Where,

n = number of years considering

B_t = benefit in year t

C_t = cost emerged in year t

i = interest rate per year (% per year)

if NPV > 0 means this project is appropriate for the investment.

- Benefit cost ratio (B/C):

  A ratio attempting to identify the relationship between the cost and benefits of a proposed project (Eq 3.9).

$$B/C = \frac{\sum_{t=0}^{n} \frac{B_t}{(1+r)^t}}{\sum_{t=0}^{n} \frac{C_t}{(1+r)^t}} \tag{3.9}$$

if B/C > 1 means this project is appropriate for the investment.

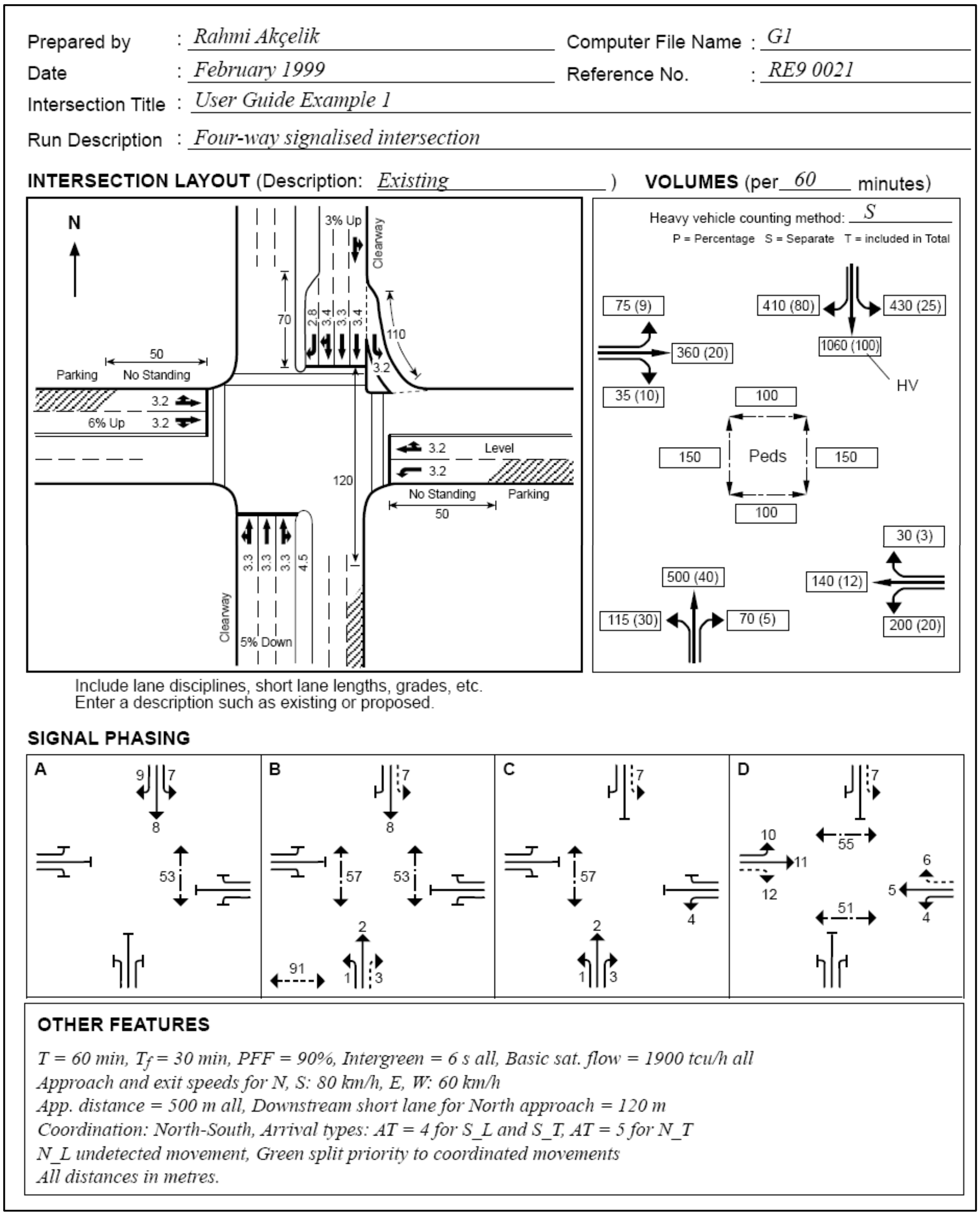
- Internal Rate of Return (IRR):

  Discount rate that makes the present value of benefits equals the present value of the cost. If IRR is greater than the cost of investments, show that the project is appropriate for the investment.

3.5.1.3 Analysis results from SIDRA software

❖ Input data

The first step in preparing input data for SIDRA is to summarise all relevant data in the input data preparation form – the required information is summarised in the figure 3.5 (examples for the left-hand versions of SIDRA). Steps of input data is shown in the figure 3.6.


Prepared by : *Rahmi Akçelik* Computer File Name : *G1*
Date : *February 1999* Reference No. : *RE9 0021*
Intersection Title : *User Guide Example 1*
Run Description : *Four-way signalised intersection*

INTERSECTION LAYOUT (Description: *Existing*) **VOLUMES** (per *60* minutes)

Include lane disciplines, short lane lengths, grades, etc.
Enter a description such as existing or proposed.

SIGNAL PHASING

OTHER FEATURES

T = 60 min, T_f = 30 min, PFF = 90%, Intergreen = 6 s all, Basic sat. flow = 1900 tcu/h all
Approach and exit speeds for N, S: 80 km/h, E, W: 60 km/h
App. distance = 500 m all, Downstream short lane for North approach = 120 m
Coordination: North-South, Arrival types: AT = 4 for S_L and S_T, AT = 5 for N_T
N_L undetected movement, Green split priority to coordinated movements
All distances in metres.

Figure 3.5 Example input data in the preparation form

Source: Akcelik & Associates Pty Ltd. (2011)

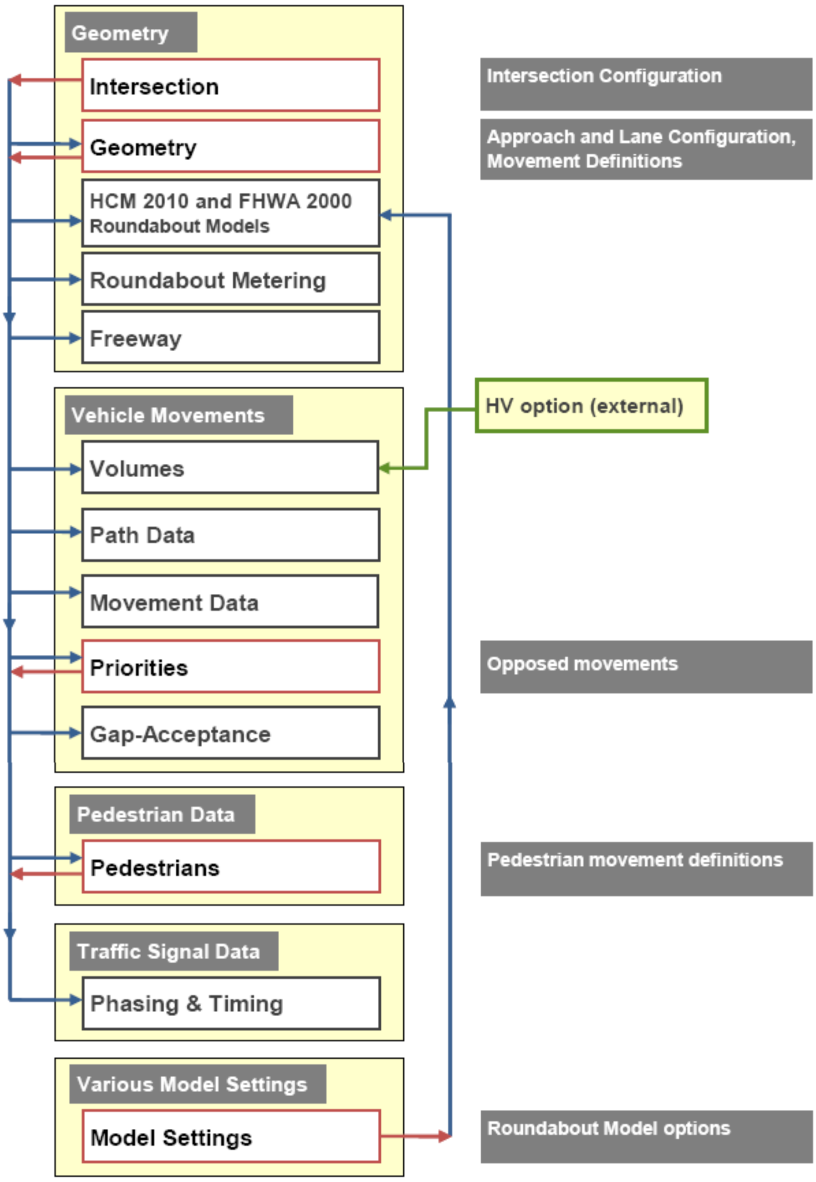


Figure 3.6 Steps to input data

Source: Akcelik & Associates Pty Ltd. (2011)

❖ Output data

The last step in the process of SIDRA is summary all relevant data (figure 3.7) which are;

- Detailed output data,
- Intersection summary,
- Movement summary,
- Lane summary,

- LOS summary,
- Phasing summary,
- Movement timing,
- Flow displays,
- Movement displays,
    - Delay, LOS and Capacity,
    - Queue and Stops,
    - Speed and Travel time,
    - Cost, Fule and Emissions.

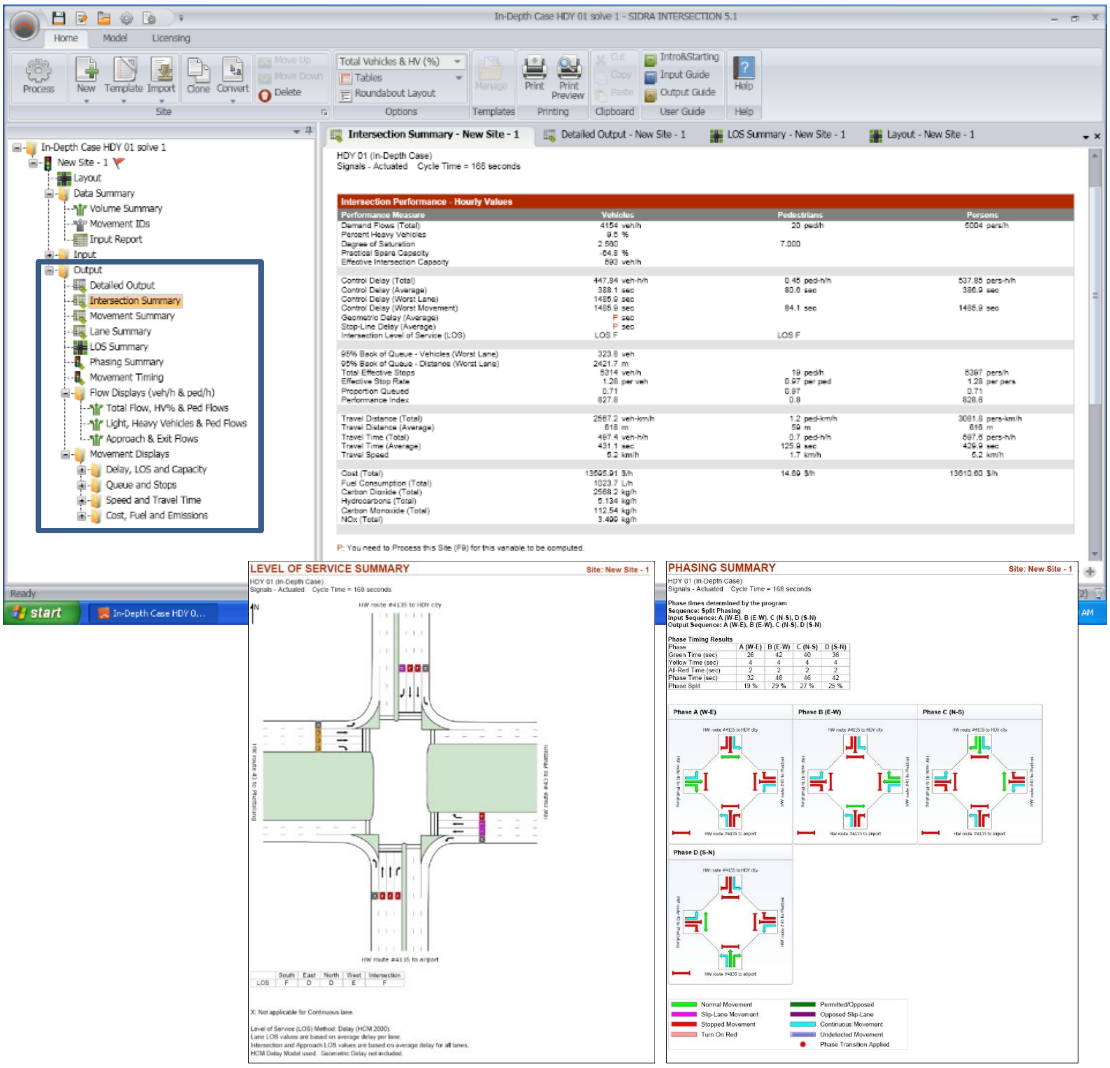


Figure 3.7 Page of the SIDRA intersection 5.1 program and example output data

Source: SIDRA intersection 5.1 (2011)

3.5.1.4 Effect of flyover intersection to traffic flow

This point presents the effect of flyover intersection to traffic flow by comparing of all relevant data. Not only on-site of both at-grade intersection and flyover intersection situations data, but also the data that determined by SIDRA intersection 5.1 program.

3.5.2 Road Safety

3.5.2.1 Summarry accident statistics data by 3 agencies

According to the accident statistics of each case that collected from 3 agencies in Thailand can conclude to in the new table form (as shown the example form in the table 3.1). The statistics of accident data can summarise;

1) Number and severity of accidents,
2) Cause of accidents,
3) Collision diagrams (reference codes as shown at ***appendix I-7***), and
4) Hazardous zones.

3.5.2.4 Cost of accidents

To calculate the accident cost, This point has concluded in the page no.58 in this research by using the equation (3.7) to find out this data. It depends on the number of severities and time under review (year).

3.5.2.5 Road safety audit

Researcher used the Road Safety Audit handbook to be the guideline to auditing at on-site of case studies in three parts which are;

1) Opening road (at-grade intersection),
2) During construction stage, and
3) Processes of opening a road (flyover intersection).

And the second case – existing flyover intersections is used the only opening road stage in the auditing.

Conflict points are also audited, because these points are commonly used to explain the accident potential of a roadway. The conflict points can indicate to the hazardous zone.

3.6 Conclusion

In-depth case: This case presents result of data analysis that studied in three time periods (before construction (at-grade intersection), during flyover construction and after construction (flyover intersection)) in both on-site data and the data from evaluation/analysis in two terms which are road safety and efficiency, the conclude items as follow;

1) On-site effect of flyover to traffic,
2) Project evaluation,
3) Road safety,
4) Optimizing by SIDRA,

3.7 Recommendation

To improve the intersection after concluded these data, the author recommended the advantage/disadvantage, improving location, physical layout, flyover limitation, improving control, and cycle phase time.

1) Project construction on hhighways,
2) Flyover limitations and Advantage/ Disadvantage,
3) Improved intersection (Hazard zones, traffic control)

CHAPTER 4
RESULTS OF STUDY

The result of study is divided to two case studies which are **In-depth case** and **Typical flyover case**. The results of both cases are as follow to these items;

1) **In-depth case**
   - Location of case study
   - Collected data
   - Project evaluation
   - Results from SIDRA
   - Road safety analysis

2) **Typical flyover case**
   - Location of case studies
   - Collected data
   - Data analysis
   - Road Safety Inspection
   - Cost of Accidents
   - Analysis Results from SIDRA

4.1 In-depth case

This case is evaluated in three situations which are "before construction (at-grade intersection)", "during construction" and "after construction (flyover intersection)".

4.1.1. Location of case study

The flyover construction project was constructed during 2009 - 2012 by Department of highways (DOH). The location is on the highway route number 43 and highway route number 4135 in Hat Yai City, Songkhla, Thailand, the schematic map of the Hat Yai City with study area marked as shown in figure 4.1 and figure 4.2. This at-grade intersection was constructed to be a flyover on a highway route number 43 (main road) at station 24+489.400 km., 742 meters of the bridge length. This intersection is situated at 6°59'13.00" N latitude and 100°25'42.93" E longitude, and 20 meters above the sea level.

Highway route number 43: the road is long 104.268 km., linked road from Phatthalung province along the road to Pattani province, there are about 36,200 vehicles per day in 2012, a road is divided 2 directions by the traffic island, 3 lanes per direction, 3.5 meters per lane, outer and inner of the shoulders are 1.0 & 0.5 meter, respectively.

Highway route number 4135: the road is long 9.965 km., linked road from the Sanambin Nok intersection along the road to Hat Yai International Airport, there are 23,000 vehicles per day in 2012, the yellow lines (1.5 meters width) divided the road in two directions, 2 lanes per direction, 3.5 meters per lane, outer and inner of the shoulders are 1.0 & 0.5 meter, respectively.

Figure 4.1 A schematic map of Hat Yai city with study area marked

Figure 4.2 Sanambin Nai Intersection (a case study)

4.1.2 Collected data

4.1.2.1 On-site collected data

1) Intersection traffic movement (TMC)

Traffic volume of at-grade intersection (before construction) at 12 hours (7:00 – 19:00) was collected on 19th September 2009 = 60,351 PCU (adjusted to the situation of flyover). On the highway route 43; from "East" entering to an intersection is 24,359 PCU., from "West" entering to an intersection is 11,842 PCU., and on the highway route 4135; from "South" entering to an intersection is 12,196 PCU., from "North" entering to an intersection is 11,954 PCU (figure 4.3).

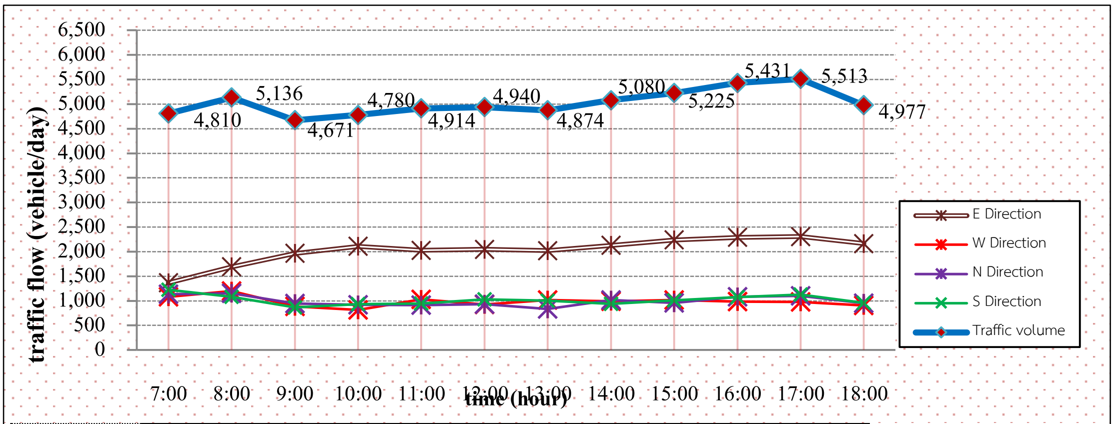
Traffic volume of flyover intersection (after construction) at 12 hours (7:00 – 19:00) was collected on 17th July 2012 = 64,219 PCU. On the ground level: on the highway route 43; from "East" entering to an intersection is 9,777 PCU., from "West" entering to an intersection is 2,546 PCU., and on the highway route 4135; from "South" entering to an intersection is 14,298 PCU., from "North" entering to an intersection is 13,294 PCU., and flow upon the bridge from "East" to "West" is 13,426 PCU., and on the opposite directions is 15,958 PCU (figure 4.4). On-site traffic movement data (12-hour), 17th July 2012 shown at ***appendix II-1***.

2) Delay (DL)

The results of time vehicle delay is depend on the cycle phase time of each event, the delay was collected on the same day with TMC's data = 535.27 minutes (32,116 seconds) and flyover intersection = 347.42 minutes (20,845 seconds). The average time delay is reduced to 184.85 minutes (34.5%) after constructed. An average vehicle delay of at-grade situation is 94.88 second and of flyover situation is 90.41 second per unit. (figure 4.5 - 4.6)

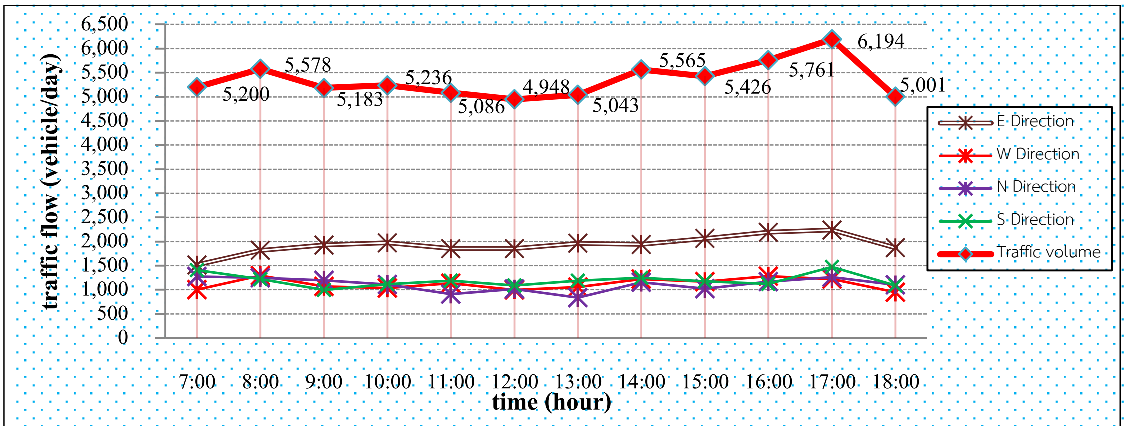
3) Queue Length (QL)

Queue Length at intersection was collected on the same day with TMC's data also. The length of the vehicle queues that stopped for waiting a new cycle in each leg have the relationship with the red-colour cycle phase of a traffic signal. After controlling by flyover method, the queue is reduced, normally on the secondary road. The stopped vehicle ratio at this intersection of at-grade situation is 1.55 : 1 vehicle and flyover situation is 3.16 : 1 vehicle, the average vehicle queue and delay of two intersection types is shown in the figure 4.7 and 4.8.



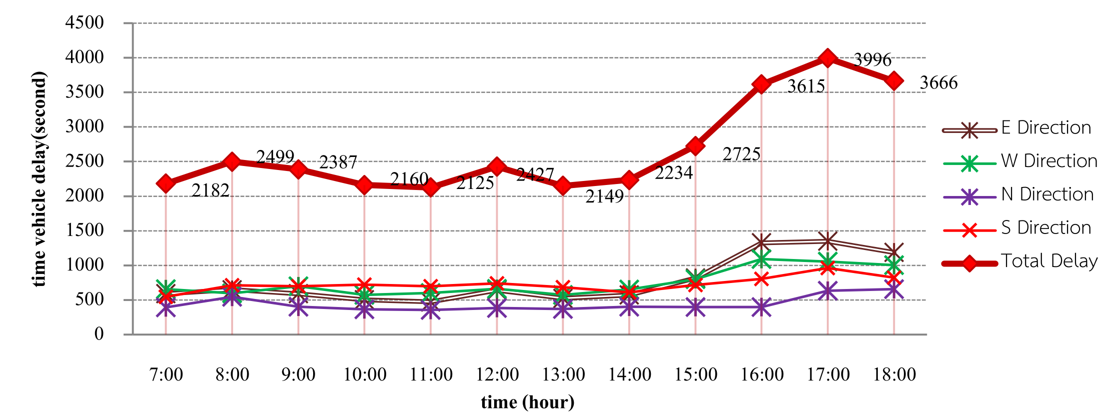
Hour	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00		
E Direction	1366	1693	1967	2109	2026	2048	2021	2129	2238	2292	2307	2163	24,359	60,351 veh/day
W Direction	1083	1202	888	815	1029	927	1017	993	1019	984	977	907	11,842	
N Direction	1137	1157	948	922	911	933	832	1020	957	1081	1104	952	11,954	
S Direction	1225	1084	868	934	948	1031	1004	938	1010	1073	1124	956	12,196	
Traffic volume	4810	5136	4671	4780	4914	4940	4874	5080	5225	5431	5513	4977		

Figure 4.3 At-grade intersection traffic volume (adjusted to the situation of the flyover)



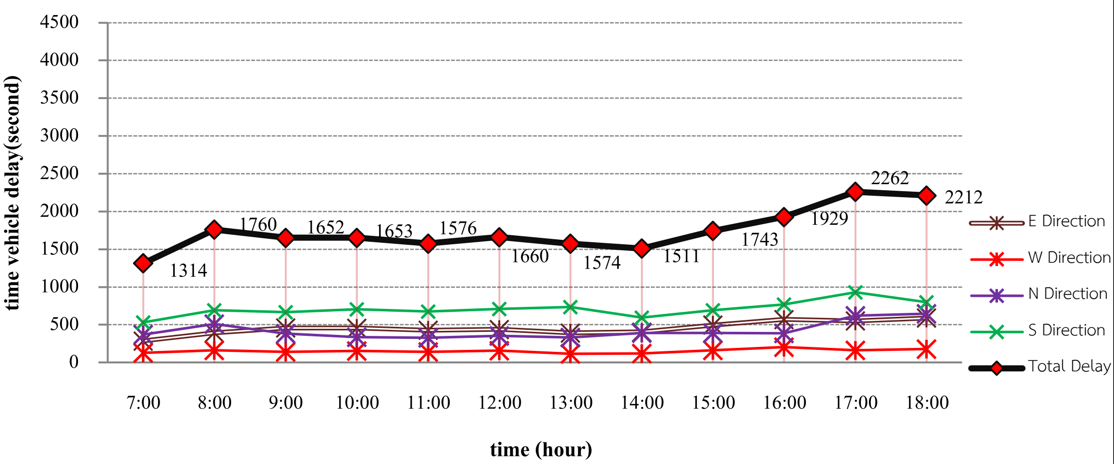
Hour	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00		
E Direction	1,515	1,817	1,926	1,973	1,853	1,854	1,963	1,940	2,064	2,192	2,238	1,870	23,203	64,219 veh/day
W Direction	1,002	1,294	1,068	1,035	1,137	992	1,055	1,223	1,167	1,282	1,223	947	13,424	
N Direction	1,274	1,248	1,197	1,110	912	1,015	838	1,156	1,021	1,168	1,258	1,099	13,294	
S Direction	1,410	1,220	992	1,118	1,185	1,087	1,186	1,247	1,175	1,119	1,475	1,086	14,298	
Traffic volume	4810	5136	4671	4780	4914	4940	4874	5080	5225	5431	5513	4977		

Figure 4.4 Flyover intersection traffic volume



Hour	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00		
E Direction	590	649	590	503	472	642	524	572	816	1325	1348	1187	9,219	
W Direction	654	595	699	571	598	659	571	649	798	1093	1053	1003	8,944	32,116
N Direction	393	544	401	365	356	385	371	401	396	395	634	654	5,295	second
S Direction	544	711	697	721	699	741	683	612	715	802	961	822	8,708	
Total Delay	2182	2499	2387	2160	2125	2427	2149	2234	2725	3615	3996	3666		

Figure 4.5 At-grade intersection time delay (adjusted to the situation of the flyover)



Hour	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00		
E Direction	287	394	458	457	427	438	391	406	495	570	551	589	5,465	
W Direction	129	162	141	153	142	159	117	119	163	203	163	179	1,830	20,845
N Direction	368	509	384	337	330	352	331	389	393	387	619	647	5,046	second
S Direction	531	695	669	706	677	710	735	596	692	769	928	797	8,503	
Traffic volume	1314	1760	1652	1653	1576	1660	1574	1511	1743	1929	2262	2212		

Figure 4.6 Flyover intersection time delay

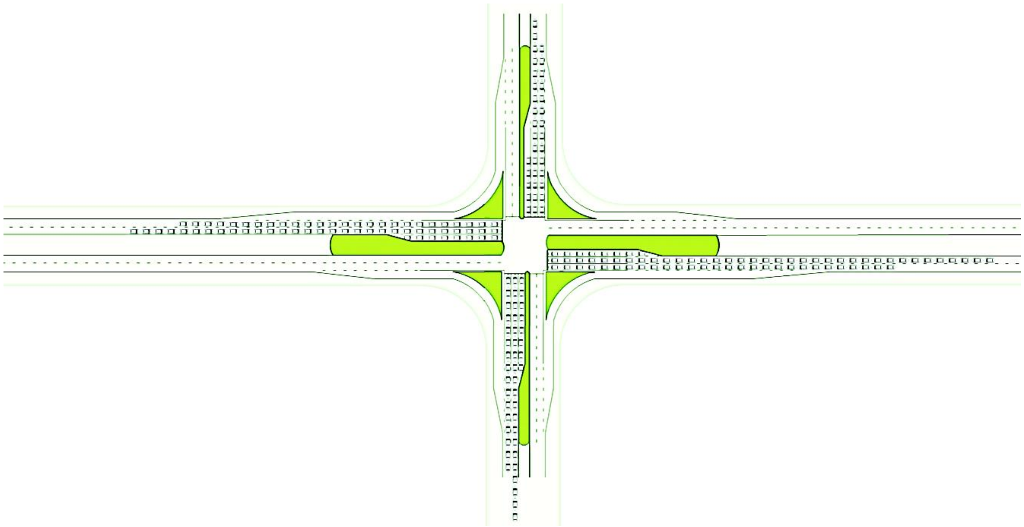


Figure 4.7 Example picture of traffic jam in situation of At-grade intersection (delay and queue length per cycle)

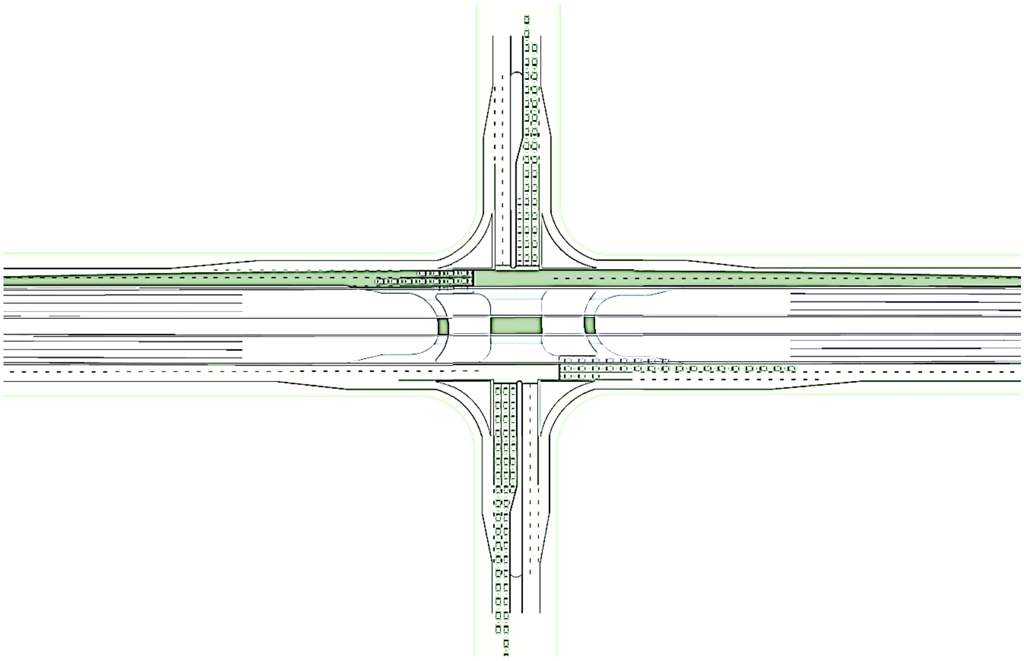
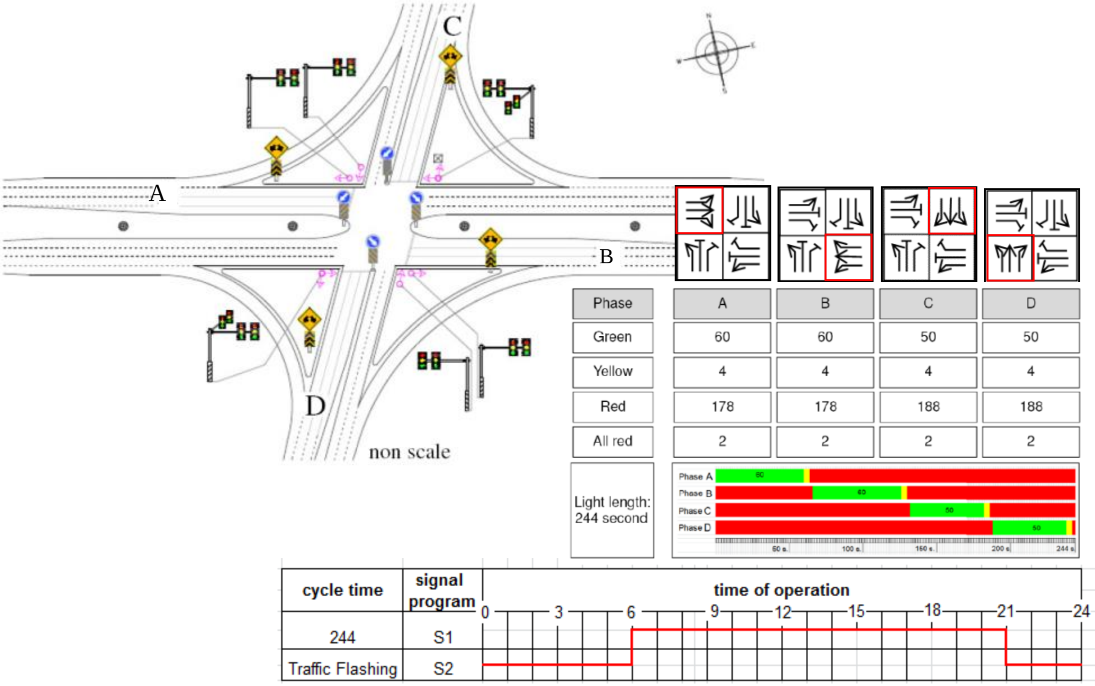


Figure 4.8 Example picture of traffic jam in situation of Flyover intersection (delay and queue length per cycle)

4) Traffic Signal

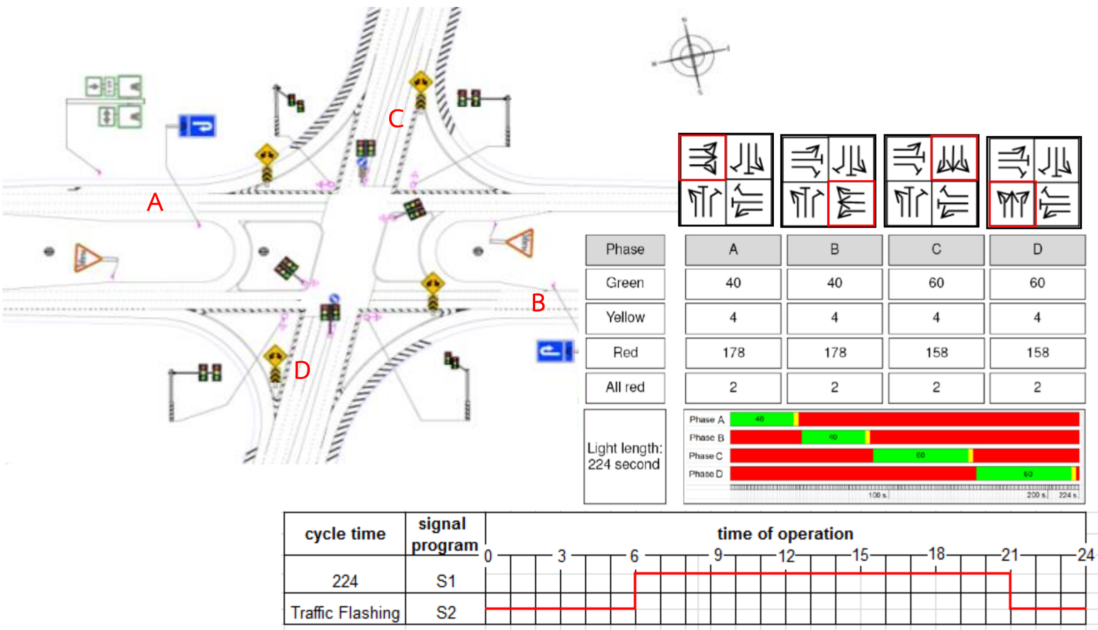
The traffic signal of both situations was controlled by fixed time control plans. The at-grade intersection control have two programs a day, the first plan is 244 seconds per cycle length, controlled during 06:00 a.m. to 9:00 p.m. (4 phases per one cycle), and the second plan controlled during 9:00 p.m. to 06:00 a.m. by traffic flashing. The flyover intersection is also controlled like the same as the situation of at-grade intersection control, but the length of cycle time is changed to 224 seconds per cycle (DOH., (2011), DOH., (2013)), as shown in figure 4.9 - 4.10.



Phase	A	B	C	D
Green	60	60	50	50
Yellow	4	4	4	4
Red	178	178	188	188
All red	2	2	2	2

cycle time	signal program	time of operation (0 – 3 – 6 – 9 – 12 – 15 – 18 – 21 – 24)
244	S1	
Traffic Flashing	S2	

Figure 4.9 At-grade intersection traffic signal control plans



Phase	A	B	C	D
Green	40	40	60	60
Yellow	4	4	4	4
Red	178	178	158	158
All red	2	2	2	2

cycle time	signal program	time of operation (0 – 3 – 6 – 9 – 12 – 15 – 18 – 21 – 24)
224	S1	
Traffic Flashing	S2	

Figure 4.10 Flyover intersection traffic signal control plans

5) Vehicle Speeds

Vehicle speeds in the direction of the bridge were measured by using of a radar-gun, the 50 percentile (mean speed) and the 85 percentile of the vehicle speeds that collected at each point in the area shown in table 4.1 and figure 4.11 to 4.12.

Table 4.1 Frequency distribution table for illustrative spot speed (example speed of PC at the point marked no.1 in figure 3.4)

Speed group		Middle speed (km/hr.)	Totals				% Freq. in group (%)	Cum. % Freq (%)
Lower limit (km/hr.)	Upper limit (km/hr.)		PC	Trucks	Other	Total		
20	24	22	2	4		6	1.74	1.74
24	28	26	6	2	1	9	2.62	4.36
28	32	30	5	3	2	10	2.91	7.27
32	36	34	4	8		12	3.49	10.76
36	40	38	4	7	3	14	4.07	14.83
40	44	42	11	11	7	29	8.43	23.26
44	48	46	17	5	4	26	7.56	30.81
48	52	50	29	3	2	34	9.88	40.70
52	56	54	43	2	1	46	13.37	54.07
56	60	58	61	2	3	66	19.19	73.26
60	64	62	35	1	1	37	10.76	84.01
64	68	66	23			23	6.69	90.70
68	72	70	14	1		15	4.36	95.06
72	76	74	6		2	8	2.33	97.38
76	80	78	6			6	1.74	99.13
80	84	82	3			3	0.87	100.00
Sum			269	49	26	344	100	

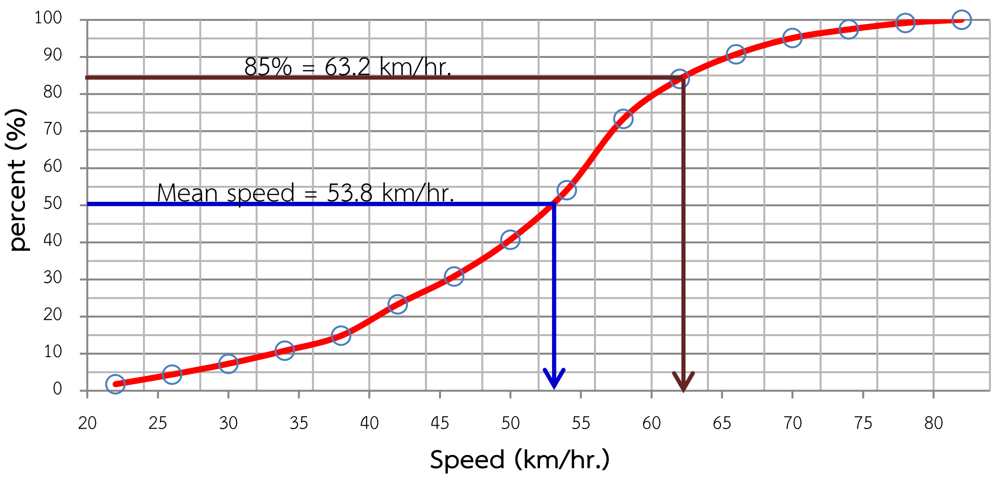


Figure 4.11 Frequency distribution curve for illustrative spot speed (example speed of PC at the point marked no.1 in figure 3.4)

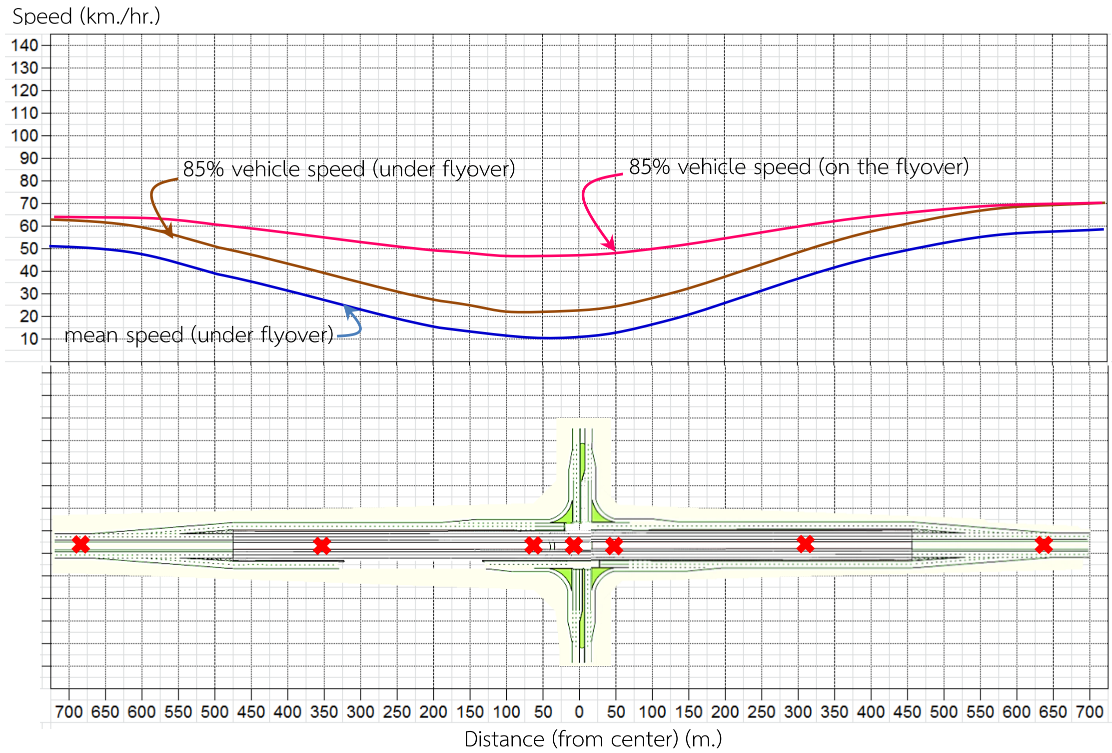


Figure 4.12 The points marked and vehicle speed data

6) Accident Statistics

Researcher used the accident statistics is recorded and collected during 2007 – August 2013 (because of limitation of study time periods) by 3 agencies in the Thailand, which are the Department of Highway (DOH), Police recorded and Emergency Medical Services System (EMS). These agencies recorded different style by depending on their agencies. The accident statistics of In-depth case were collected in three time periods. This important data is used to measure about number and severity of accidents, causes of accidents, hazardous zones, and cost of accidents, as shown this data at ***appendix II-2.*** And ***appendix II-12*** is shown the accident statistics analysis.

7) Physical Layouts

The intersection layout of both at-grade and flyover intersection plan received from owner project -- DOH., (2011), as shown the layout at ***appendix II-3.***

8) Road Safety Audit

Road Safety audited in three time periods by following with the guideline of the Road Safety Audit (Taneerananon, P. et al. (2009)) in the procedure of opening road (at-grade intersection (before construction) and flyover intersection (after construction)) and during the construction stage, the results as shown in the ***appendix II-4***.

9) Other important information

The project was constructed during 22th Sep 2009 - 8th Apr 2012 (about 32 months). The construction cost of this flyover construction project is about 249 Million Baht, and the standard construction cost of a flyover is about 75,000 (2,318.9 USD) Baht/square meter.

The summary collected data of in-depth case as shown in the table 4.2.

Table 4.2 Summary collected data

Items \ Time period	At-grade intersection 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 at Intersection	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. Layout of intersection	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		

4.1.3 Project evaluation

The evaluation is computed in comparing to current at-grade intersection in order to assess the benefits arising from the flyover construction project. The benefits of the flyover project includes **Road User Costs** (savings in the value of time (VOT), vehicle operating cost (VOC) and saving in cost of accidents) and **Economic Analysis** (Net Present Value (NPV), Benefit–Cost Ratio (BCR) and Internal Rate of Return (IRR)).

In the table 4.3 shown the results of both flyover intersection traffic data and at-grade intersection traffic data, and accident statistics of this intersection.

4.1.3.1 Road User Costs

1) Vehicle operating cost (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)).

At the at-grade level, 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, the vehicle operating cost considers in the saving cost of transportation, Luophongsok et al., (2011) used the HDM-4 software to calculate the cost in this term in terms of transportation saving cost by free flow speed in the unit of the PCU, as shown in the table 4.4.

Table 4.3 Summary results of vehicle delay, traffic volume and accident statistics data

No.	Items		Intersection			Results			
	Issues	(units)	At-grade	Flyover		Reducing		Increasing	
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**		-		3,904	6.0%
				PCU	Truck				
				47,261	16,958				
				73.6%	26.4%				
	Under the bridge		**60,351**	**39,915 (62.16%)**		20,436	33.86%	-	
				PCU	Truck				
				32,837	7,078				
				82.2%	17.8%				
	On the flyover		-	**24,304 (37.84%)**		-		24,304 (37.84%)	
				PCU	Truck			PCU	Truck
				14,424	9,880			14,424	9,880
				59.4%	39.6%			59.4%	39.6%
3	Accident statistic		Before	During	After	Before & After			
	Fatality (Fal)		-	6	-	-	-	-	
	Disability (Dis)		0.85	1.95	0.45	-	-	-	
	Serious Injury (SI)		8	23	1	6	75.0%	-	
	Slight Injury (SL)		17	39	9	0	1.0%	-	
	Property Damage Only (PDO)		25	67 times + 701,400 Baht	10	6	25.4%	-	
	DOH damage		-	533,500 Baht	-	-	-	-	
		Mouths	28	30	15	set at 28 mouth		-	
		Crash/year	7.3	20.8	7.2	0.1	1.37%	-	

Table 4.4 Vehicle operating cost in the unit of PCU (Luophongsok et al., (2011))

Speed (kilometer per hour)												
VOC	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

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 increasing efficiency of intersection can reduce travel time and road users can use this time to do other activities.

At the at-grade, value of time depends on locations that the case study is located. It can be calculated from the gross province product (GPP), number of people employed and average hours of work (table 4.5). 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 et al., (2011) used the data from Department of Highways (VOT in 2011 = 117 Baht/PCU/hr). Adjusted for inflation at 3.3% (Bank of Thailand, (2012)), the value of time for 2012 = 120.86 Baht/PCU/ hour.

Table 4.5 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)

The benefits of two terms; vehicle operating costs (VOC) and value of time (VOT) are summarized and shown in table 4.6.

Table 4.6 The benefits of the project in terms of VOC and VOT

<table>
<tr><th>No.</th><th>At-grade to Flyover</th><th>Value</th><th>Unit</th><th>Vehicle operating cost (VOC)</th><th>Value of time (VOT)</th></tr>
<tr><td rowspan="4">1</td><td colspan="3">Under the bridge (intersection)</td><td>Fuel consumption (0.75 Baht/PCU/minute)</td><td>Loss of time (84.38 Baht/PCU/hour)</td></tr>
<tr><td rowspan="3">Time of all vehicle delay (reduced results)</td><td rowspan="3">187.9</td><td rowspan="3">minute/ day</td><td>187.9 x 0.75 = 140.93 Baht/day</td><td>187.9 x (84.38/60) = 264.25 Baht/day</td></tr>
<tr><td>140.93 x 300 = 42,279.00 Baht/year</td><td>264.25 x 300 = 79,275.01 Baht/year</td></tr>
<tr><td colspan="2">Total = 121,554.01 Baht per year</td></tr>
<tr><td rowspan="4">2</td><td colspan="3">On the flyover</td><td>At the 60 Km./hr. speed (3.99 Baht/PCU/km.)</td><td>Value of time in the highway (120.86 Baht/PCU/hour)</td></tr>
<tr><td rowspan="3">Free flow speed of the vehicles in two directions of the bridge length</td><td>24,304</td><td>PCU/ day</td><td>24,304 x 3.99 = 96,972.96 Baht/day</td><td>2,025 x 120.86 = 244,741.5 Baht/day</td></tr>
<tr><td rowspan="2">2,025</td><td rowspan="2">PCU/ hour</td><td>96,972.96 x 300 = 29,091,888 Baht/year</td><td>244,741.5 x 300 = 73,422,450 Baht/year</td></tr>
<tr><td colspan="2">Total = 102,514,338 Baht per year</td></tr>
</table>

3) Cost of Accident

Accident costs were obtained by using equation (4.1). 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.

$$ACa = \frac{A(F)*MCA(F) + A(Dis)*MCA(Dis) + A(SI)*MCA(SI) + A(LI)*MCA(LI) + A(PDO)*MCA(PDO)}{t} \quad (4.1)$$

Where,

ACa : annual average accident cost ($/year),

A : number of accidents (acci),

MCA : the mean cost per accident ($/acci) as shown in table 2.4, and

t : is the period of time under review (year).

The equation (4.1) is used to calculate an annual average accident cost of three situations, the table 4.7 shown these accident costs (below).

Table 4.7 Annual average accident cost in each situation

Locations / **Mean cost per accident**		**Number of casualties in 3 situations**		
		At-grade intersection	**During flyover 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		3,405,997.85	**20,635,690.00**	2,868,060.00
Reduced results of at-grade to the flyover intersection per year = **537,937.85 Baht**				

4.1.3.2 Economic Analysis

Economic Analysis used cost benefit analysis (CBA) 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 4.12.

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, using equation (4.2);

$$NPV = \sum_{t=0}^{n} \frac{(B_t - C_t)}{(1+i)^t} \tag{4.2}$$

So,

$$NPV = \sum_{t=12}^{10} \frac{(B_{10} - C_{10})}{(1+0.12)^{10}} = \frac{88.7*10^6}{(1.12)^1} + \frac{81.9*10^6}{(1.12)^2} + ... + \frac{43.2*10^6}{(1.12)^{10}} - 270.2*10^6 - 3.8*10^6$$

NPV = 361,641,982 Baht <u>*Ans,*</u>

2) Benefit–Cost Ratio (BCR)

A ratio attempting to identify the relationship between the cost and benefits of a proposed project, using equation (4.3);

$$BCR = \frac{Benefits}{Cost} = \frac{361{,}641{,}982 + 537{,}938 + 121{,}544}{249{,}597{,}672.5 + 20{,}635{,}690} \tag{4.3}$$

BCR = 1.34 <u>*Ans,*</u>

3) Internal Rate of Return (IRR)

The discount rate often used in capital budgeting that makes the net present value of all cash, solve for the value of interest rate for which NPV equal to zero.

So, i = 37.585 % <u>*Ans,*</u>

The table 4.8 shown the results in three situations of this case study.

Table 4.8 Analysis the data in three situations of the intersection

Intersection		Before	During		After construction									
Items	Year/Unit	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Traffic data														
Traffic volume	PCU/ day	54912			64219	66338	68527	70789	73125	75538	78031	80606	83266	86013
On the bridge					24304	25106	25935	26791	27675	28588	29532	30506	31513	32553
Under the bridge					39915	41232	42592	43998	45450	46950	48499	50100	51753	53461
Delay	minute	32116			20845	21587	22299	23035	23796	24581	25392	26230	27096	27990
Cost														
Investment cost	Baht	-249597672.5												
Maintenance cost	Baht/year				-27000	-27000	-27000	-27000	-27000	-27000	-27000	-27000	-27000	-27000
Accident cost	Baht/year	-3405998	-20635690		-2868060	-2868060	-2868060	-2868060	-2868060	-2868060	-2868060	-2868060	-2868060	-2868060
Saving accident cost	Baht				537938									
Delay cost	Baht/year	-346286			-224732	-232732	-240413	-248346	-256545	-265011	-273756	-282790	-292122	-301762
Saving delay cost	Baht				121544									
Free flow cost	Baht/year				102.5E+6	105.9E+6	109.4E+6	113.0E+6	116.7E+6	120.6E+6	124.6E+6	128.7E+6	132.9E+6	137.3E+6
Sum	Baht/year	-3.8E+6	-270233362.50		99.4E+6	102.8E+6	06.3E+6	109.9E+6	113.6E+6	117.4E+6	121.4E+6	125.5E+6	129.7E+6	134.1E+6
Cash Flow	Baht	-3.8E+6	-1.3E+8	-2.7E+8	-1.85E+8	-1.03E+8	-27.7E+6	42.1E+6	106.6E+6	166.1E+6	221.0E+6	271.7E+6	318.5E+6	361.6E+6

4.1.4 Results from SIDRA

In this study, the SIDRA software was used to analyze the performance of the traffic flow, delay and level of service under fixed-time plan of traffic signal. Furthermore, It can determine the appropriate fixed-time plans by using the lowest time delay as the indicator.

Table 4.9 shows the results computed by SIDRA software of two situations which are at fixed-time plan (224 seconds per cycle) and at the lowest time delay.

I*nput-data* and output-data as shown at ***appendix II-5*** and ***appendix II-6*** respectively (it is example data during 5:00 – 6:00 p.m. of flyover situation).

Table 4.9 The results that computed by SIDRA for 12 time periods (7:00 – 19:00) of two situations (fixed-time plan (244 sec/cycle) and the lowest time delay)

Periods of time	Cycle time (new cycle time) (second)	Delay (new delay) (second)	(At the lowest time delay—new phase timing results)				
7:00 – 8:00	224 (140)	64.5 (45.5)	Phase	A (W-E)	B (E-W)	C (N-S)	D (S-N)
			Green Time (sec)	25	26	26	39
			Yellow Time (sec)	4	4	4	4
			All-Red Time (sec)	2	2	2	2
			Phase Time (sec)	31	32	32	45
			Phase Split	22 %	23 %	23 %	32 %
8:00 – 9:00	224 (140)	67.2 (45.8)	Phase	A (W-E)	B (E-W)	C (N-S)	D (S-N)
			Green Time (sec)	25	26	26	39
			Yellow Time (sec)	4	4	4	4
			All-Red Time (sec)	2	2	2	2
			Phase Time (sec)	31	32	32	45
			Phase Split	22 %	23 %	23 %	32 %
9:00 – 10:00	224 (130)	64.8 (42.2)	Phase	A (W-E)	B (E-W)	C (N-S)	D (S-N)
			Green Time (sec)	25	25	22	34
			Yellow Time (sec)	4	4	4	4
			All-Red Time (sec)	2	2	2	2
			Phase Time (sec)	31	31	28	40
			Phase Split	24 %	24 %	22 %	31 %
10:00 – 11:00	224 (130)	58.1 (41.5)	Phase	A (W-E)	B (E-W)	C (N-S)	D (S-N)
			Green Time (sec)	25	25	22	34
			Yellow Time (sec)	4	4	4	4
			All-Red Time (sec)	2	2	2	2
			Phase Time (sec)	31	31	28	40
			Phase Split	24 %	24 %	22 %	31 %
11:00 – 12:00	224 (125)	57.0 (40.8)	Phase	A (W-E)	B (E-W)	C (N-S)	D (S-N)
			Green Time (sec)	25	25	20	36
			Yellow Time (sec)	4	4	4	4
			All-Red Time (sec)	2	2	2	2
			Phase Time (sec)	31	31	26	42
			Phase Split	24 %	24 %	20 %	32 %

Table 4.9 The results that computed by SIDRA for 12 time periods (7:00 – 19:00) of two situations (fixed-time plan (244 sec/cycle) and the lowest time delay) (continue)

Periods of time	Cycle time (new cycle time) (second)	Delay (new delay) (second)	(At the lowest time delay—new phase timing results)				
12:00 – 13:00	224 (125)	61.3 (41.4)	Phase	A (W-E)	B (E-W)	C (N-S)	D (S-N)
			Green Time (sec)	25	25	19	32
			Yellow Time (sec)	4	4	4	4
			All-Red Time (sec)	2	2	2	2
			Phase Time (sec)	31	31	25	38
			Phase Split	25 %	25 %	20 %	30 %
13:00 – 14:00	224 (115)	67.4 (44.1)	Phase	A (W-E)	B (E-W)	C (N-S)	D (S-N)
			Green Time (sec)	24	24	17	26
			Yellow Time (sec)	4	4	4	4
			All-Red Time (sec)	2	2	2	2
			Phase Time (sec)	30	30	23	32
			Phase Split	26 %	26 %	20 %	28 %
14:00 – 15:00	224 (115)	75.2 (48.0)	Phase	A (W-E)	B (E-W)	C (N-S)	D (S-N)
			Green Time (sec)	24	24	20	23
			Yellow Time (sec)	4	4	4	4
			All-Red Time (sec)	2	2	2	2
			Phase Time (sec)	30	30	26	29
			Phase Split	26 %	26 %	23 %	25 %
15:00 – 16:00	224 (120)	86.6 (45.2)	Phase	A (W-E)	B (E-W)	C (N-S)	D (S-N)
			Green Time (sec)	24	26	18	28
			Yellow Time (sec)	4	4	4	4
			All-Red Time (sec)	2	2	2	2
			Phase Time (sec)	30	32	24	34
			Phase Split	25 %	27 %	20 %	28 %
16:00 – 17:00	224 (130)	83.1 (47.5)	Phase	A (W-E)	B (E-W)	C (N-S)	D (S-N)
			Green Time (sec)	25	29	22	30
			Yellow Time (sec)	4	4	4	4
			All-Red Time (sec)	2	2	2	2
			Phase Time (sec)	31	35	28	36
			Phase Split	24 %	27 %	22 %	28 %
17:00 – 18:00	224 (145)	103.9 (61.6)	Phase	A (W-E)	B (E-W)	C (N-S)	D (S-N)
			Green Time (sec)	25	34	25	37
			Yellow Time (sec)	4	4	4	4
			All-Red Time (sec)	2	2	2	2
			Phase Time (sec)	31	40	31	43
			Phase Split	21 %	28 %	21 %	30 %
18:00 – 19:00	224 (135)	66.2 (45.8)	Phase	A (W-E)	B (E-W)	C (N-S)	D (S-N)
			Green Time (sec)	25	25	24	37
			Yellow Time (sec)	4	4	4	4
			All-Red Time (sec)	2	2	2	2
			Phase Time (sec)	31	31	30	43
			Phase Split	23 %	23 %	22 %	32 %

4.1.5 Road safety analysis

According to this flyover control was designed for supporting traffic capacity only two directions on one of the highways to the free flow, but at under the bridge, the existing traffic signalization of the intersection still uses the same fixed time control plans while the physical area of intersection has changed to bigger than the old one. So, the problems are still found as similar to the situation of at-grade intersection. Although a new cycle phase time is created to serve the traffic volume on the ground level, a yellow phase time is only about 3 to 4 seconds while a space at the center is wide about 52*28 meters, may lead to traffic accidents by violation of traffic signal. Furthermore the hazardous zone spread to more many zones in the flyover area such as at the approaching and exiting zone, at the drainage ditches on the median of the road, at the U-turn under the bridge, on the shoulder of the road etc, (figure 4.13).

Conflicts points are commonly used to explain the accident potential of a roadway. The conflict points are the line-direction of road users crossing, merging and diverging with other users that used the same road. The conflict points can indicate to the hazardous zone. There are 50 conflict points of the at-grade intersection and 64 conflict points of the flyover intersection (refer with a number of lanes), the conflicts points of both types shown at ***appendix II-7***.

According to the accidents statistics are mostly occurred in the center of the intersection. One issue of road user is not enough time to pass this crossroad, because there are only 4 seconds of the yellow phase time (amber time) and 2 seconds of the all red phase which length is about 52 meters length.

The average radius of the U-turn under the bridge is about 12 meters. It was constructed for serving only the vehicles 2-4 wheels. When the vehicles waiting for next green cycle in the right turning lane along main road more than 5 vehicles (about 20 meters), this U-turn channel will be blocked by these vehicles.

At the exit lane on the main road (at crossroad) is one of hazardous zones, when the vehicles turn right from the secondary road. There is not the gap between vehicle and vehicle of two channels (may occur the crash accidents (sideswipe), when the vehicles compete to pass out this zone).

At the approaching and exiting zone are the new danger zones, the approaching zone may lead to the vehicles weaving and traffic crash, because the vehicles intercept from the right lane to the left lane immediately before into the auxiliary lanes, the exiting zone may lead to the vehicles merging and traffic crash because some vehicles from the auxiliary lane run passing on the nose – chevron markings to the right lane of the main road immediately.

Causes of accidents of each case that collected from 3 agencies can conclude the result of 3 situations as shown in the table 4.10 and 4.11.

Table 4.10 Collision diagram codes of 3 situations

Situation	Collision	Collision diagram code / number of each code													No recored
Before	Code														17 cases
	Number														
During	Code	301	701	708	704	604	200	804	801	703	303	202	107	101	27 cases
	Number	6	4	3	2	2	2	1	1	1	1	1	1	1	
After	Code	701	306	307	702										-
	Number	5	2	1	1										

Note: the collision diagram codes shown at *appendix I-7*

Table 4.11 Cause of accidents of 3 situations

Situation	Cause of accidents	Number (case)
Before	Not recorded	
During	Highest speed limit	15
	Slippery roads	5
	Drowsiness	2
	Violating speed limit	2
	Drunkenness	1
	Not recorded	28
After	Slippery roads	6
	Violating speed limit	2
	Vision is not clear	1

Note: cause of accidents of 3 situations shown at *appendix II-2*

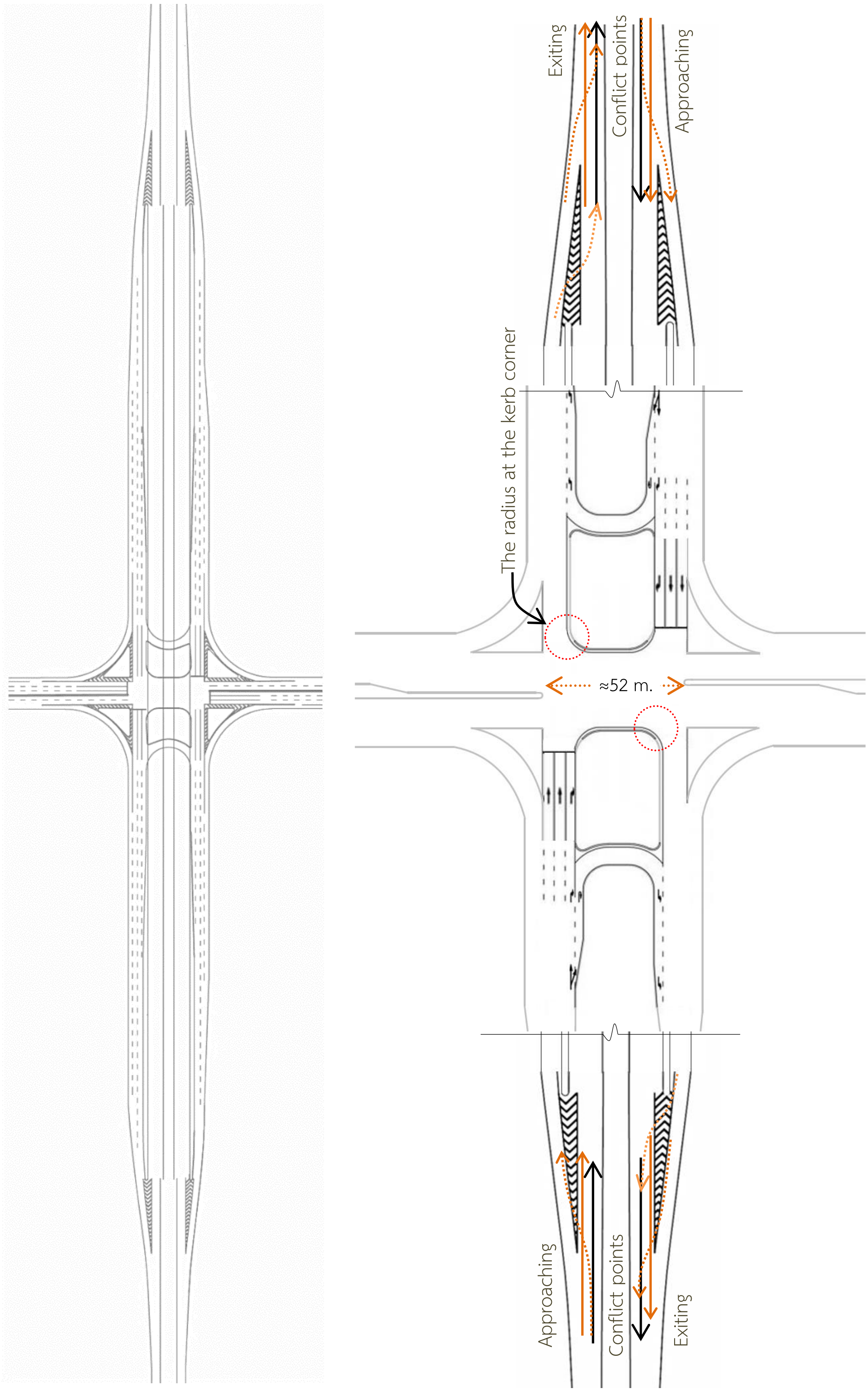


Figure 4.13 Hazardous zones in the flyover physical layout

4.2 Typical flyover case

Existing flyover intersection is selected about 20% of all 29 existing flyover intersections in Thailand to study. The 20% or about 5 flyover intersections – case studies are covering all regions in Thailand. To study the performance of the flyover intersection in terms of both efficiency and road safety.

4.2.1. Location of case studies

These case studies are located in Songkhla, Udon Thani, Phatthalung, Rayong, and Phitsanulok province as shown in the figure 4.14 and table 4.12.

Figure 4.14 Thailand map with studies area (province) marked

Source: Google Earth (updated 4/10/2013)

Table 4.12 Existing flyover intersection locations – case studies

Case No.	Locations			AADT
	Existing flyover intersection	Station (km. control)	Situation	
1	Highway route no. 4 and route no. 43 in Hat Yai District, Songkhla, Thailand.	HW#4 (Km.Sta 1252+00-1253+00) & HW# 43 (Km.Sta 31+00-32+00)	6^0 58’ 28.51’’ N 100^0 28’ 45.64’’ E 17 m above sea level	45,999
2	Highway route no. 22 and route no. 216 in Mueang District, Udon Thani, Thailand.	HW#22 (Km.Sta 3+250-4+250) & HW# 216 (Km.Sta 23+100-24+100)	17^0 23’ 12.51’’ N 102^0 49’ 33.14’’ E 186 m above sea level	61,342
3	Highway route no. 4 and route no. 41 in Mueang District, Phatthalung, Thailand	HW#4 (Km.Sta 86+750-87+750) & HW# 41 (Km.Sta 86+500-87+500)	7^0 36’ 31.64’’ N 100^0 3’ 13.90’’ E 15 m above sea level	75,026
4	Highway route no. 36 and route no. 3139 in Mueang District, Rayong, Thailand.	HW#36 (Km.Sta 55+600-56+600) & HW# 3139 (Km.Sta 1+000-2+000)	12^0 41’ 2.72’’ N 101^0 17’ 57.73’’ E 7 m above sea level	43,952
5	Highway route no. 11 and route no. 126 in Mueang District, Phitsanulok, Thailand.	HW#11 (Km.Sta 3+000-4+000) & HW# 126 (Km.Sta 22+000-23+000)	16^0 50’ 49.56’’ N 100^0 20’ 41.39’’ E 46 m above sea level	21,618

4.2.2 Collected data

4.2.2.1 On-site collected data

Intersection Traffic Movement (TMC), Delay (DL), Queue Length (QL), Traffic Signal, and Vehicle speeds use the same method as in-depth case data collection and assessment of data, recorded data at three peaks-time ((07:00 - 08:00 a.m.), (12:00 a.m. – 01:00 p.m.), and (04:00 – 05:00 pm.)) in a working day.

In the figure 4.15 is an example on-site colleted data which are traffic movement, delay and queue length information (all case studies shown in the ***appendix II-8***), and figure 4.16 shows the traffic signal information (all case studies shown in the ***appendix II-9***).

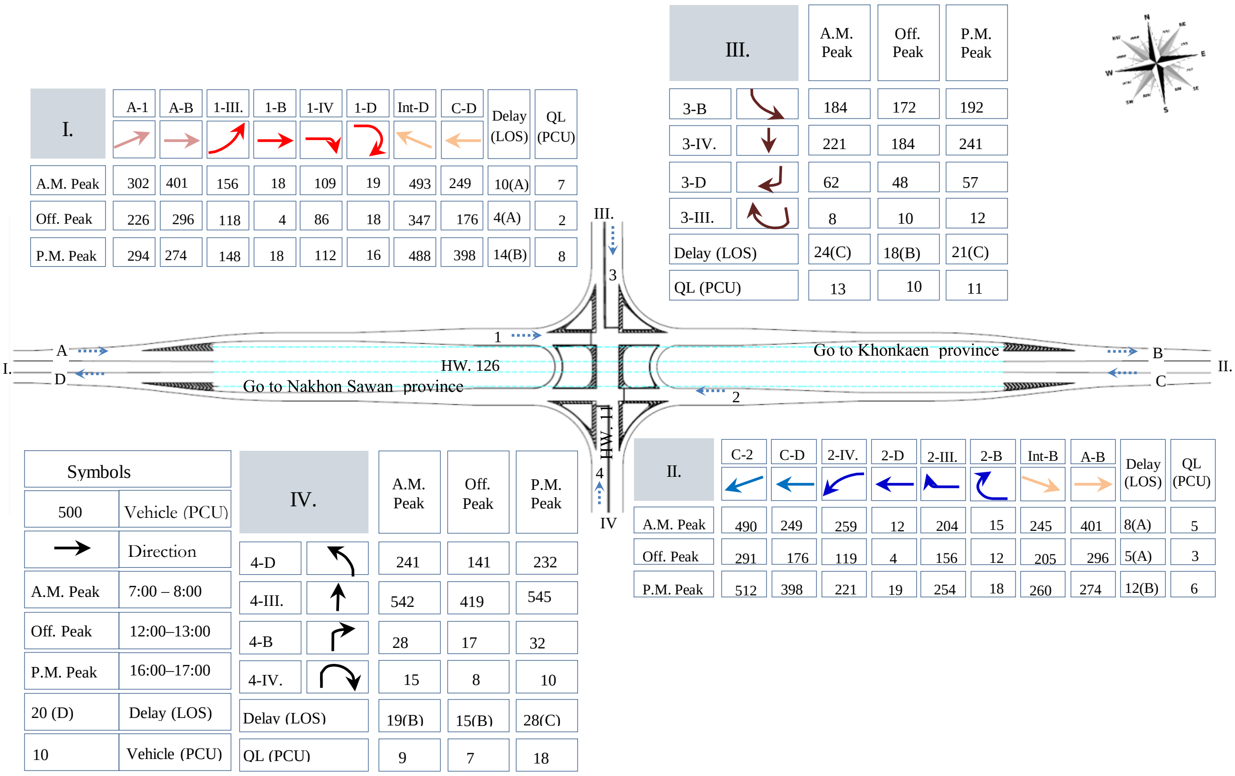


Figure 4.15 Traffic movements, Delay and Queue length information at three peak times a day (Phitsanulok example case)

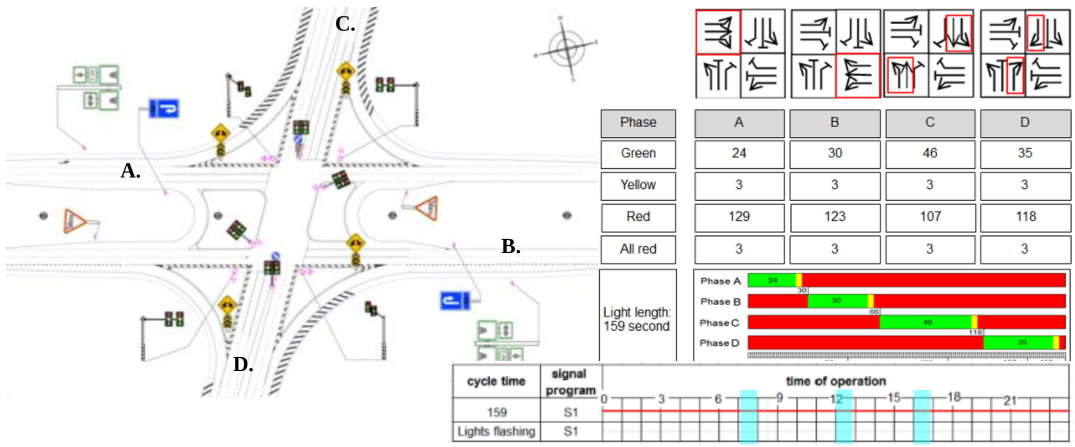


Figure 4.16 Traffic signal information (Phitsanulok example case)

Table 4.13 shows the passenger car units (PCU) data of both levels and cycle length of all case studies.

Table 4.13 Passenger Car Units (PCU) data per peak times and cycle times.

Location / Items		5 existing flyovers (province in Thailand)														
		Songkhla			Udon Thani			Rayong			Phatthalung			Phitsanulok		
Time period considers		A.M. (7:00-8:00)	Mid (11:00-12:00)	P.M. (16:00-17:00)	A.M. (7:00-8:00)	Mid (11:00-12:00)	P.M. (16:00-17:00)	A.M. (7:00-8:00)	Mid (11:00-12:00)	P.M. (16:00-17:00)	A.M. (7:00-8:00)	Mid (11:00-12:00)	P.M. (16:00-17:00)	A.M. (7:00-8:00)	Mid (11:00-12:00)	P.M. (16:00-17:00)
Cycle time (second)		176	176	176	190	190	190	160	160	160	184	144	184	159	159	159
PCU	on bridge	1802	1038	1538	2470	2102	2969	3242	3146	3535	1965	1710	2182	650	472	672
	at-grade level	5643	5566	6521	5213	4701	5225	2383	1970	3070	4492	3516	4120	2036	1464	2071

4.2.2.2 Accident statistics (Existing flyover)

Accident statistics of each location were collected for 3 years (2010-2012) from 3 agencies in Thailand consisting of Department of Highways (DOH), Police records and Emergency Medical Services (EMS). The statistics were used for computing costs of accident that occurred at these existing locations. Table 4.14 shows the number of casualties in 3 years of accidents. Eq. (4.4) was used to find an annual average accident cost, to describe the combined effects of the number and severity of the accidents in these case studies. And ***appendix II-13*** is shown the accident statistics analysis.

Table 4.14 Number of casualties and time of accidents, 3 years (2010 – 2012)

Case studies	Time of accident			Number of Casualties			DOH Damage	PDO (times)
	Day	Night	Rain	Slight Injuries	Serious Injuries	Deaths		
Songkhla	12	15	0	24	1	2	-	27
Udon Thani	27	13	0	21	14	2	-	40
Rayong	15	15	0	20	10	3	-	30
Phatthalung	6	7	4	12	4	5	-	17
Phitsanulok	12	25	0	42	6	5	-	37
Sum	70	75	4	119	35	17	None	151

Source: Accident statistics at the flyover areas: DOH., EMS., and Police records (2010 - 2012).

$$ACa = \frac{A(F)*MCA(F) + A(Dis)*MCA(Dis) + A(SI)*MCA(SI) + A(LI)*MCA(LI) + A(PDO)*MCA(PDO)}{t} \quad (4.4)$$

Source: RIPCORD-ISEREST (2005), R. Elvik. (2008)

Where,

ACa : annual average accident cost ($/year),
A : number of accidents (acci),
MCA : the mean cost per accident ($/acci) as shown in table 4.15, and
t : the period of time under review (year).

Table 4.15 Mean cost per accident for various severities (2012)

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 (Dis)	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 (LI)	0.0386 - 0.0389	0.1731 - 0.1733	0.0297 - 0.0298
Property Damage Only (PDO)	0.052	0.164	0.039

Source: Source: Mean cost of severities per road accident in Thailand: DOH. (2012)

The mean cost per accident in Thailand is used to estimate the accident cost, the number of casualties per unit is transformed to be the cost value (money), in this case used the mean value of the other provinces (in table 4.15) to estimate.

The accident statistics that collected in 3 years (2010-2012) of each location by 3 agencies which are the Department of Highway (DOH), Police recorded and Emergency Medical Services (EMS) are analyzed and shown in the ***appendix II-10***.

Not only on-fields collected data, but also the important information such as the construction costs, number of casualties and flyover designs, in table 4.16 shows these items of 5 example cases. Each location is different in the design and management because it is designed by depending on its physical locations (***appendix II-11***), some locations must have an auditor for recording and inspection of these information more than six people such as at Udon Thani case study location – the dimension of the intersection is very big (it's located on the bypass highway), consequently, we need help with video record for checking traffic movement of each direction on the ground level, furthermore, author can also check and calibrate to the SIDRA software such as road user behavior and cycle phase time.

Table 4.16 Collected data of 5 existing flyover intersections – case studies

Items \ Location	5 existing flyovers (province in Thailand)				
	Songkhla	Udon Thani	Rayong	Phatthalung	Phitsanulok
1. Flyover locations	HW# (4 + 43)	HW# (22+216)	HW# (36+3139)	HW# (4 + 41)	HW# (11+126)
2. Traffic survey - vehicle movement - delay and queue length	Collected data at three peaks-time (07:00 - 08:00 am., 12:00 am. – 01:00 pm., and 04:00 – 05:00 pm.) in a working day.				
3. Cycle times (fixed-time), (second/cycle)	176, 176, 176	178, 178, 178	160, 160, 160	184, 144, 184	159, 159, 159
4. Average speed (km/hr)	65	62	68	58	64
5. Dimension (Bridge length (meter))	390	750	340	410	670
6. Road Safety Inspection - Conflict points - No. of accidents (3 years)	64 27	64 40	40 30	64 17	66 37
7. Construction cost (Million Baht) and Opening date	117.00 Aug, 1996	242.20 2008	203.80 Aug, 2001	198.97 Sep, 2008	116.20 2002

4.2.3 Data analysis

Although the control of intersection is improved by the installation of a flyover bridge, it still has many limits and can’t fully solve the traffic problems that exist in similar situation of the at-grade intersection model such as vehicle delay, traffic congestion and road accidents. The bridge is just increasing the convenience for the road users in two directions on one of the two main roads while under the bridge, the same traffic control plans as the “before the flyover” were still in use. Even though it was found that about 30-35% of the total traffic volume diverted to the bridge and the vehicle delays reduced by 30% over the same period, the traffic flow situation on the secondary road is almost the same as that of the previous at-grade intersection.

The fixed-time cycle plan of the traffic signalization was used to control traffic volumes at ground level (4 in 5 case studies used only one plan of control throughout the day), it leads to an unnecessary loss of vehicle time. Table 4.17 further describes the issues relating to the flyover model that were found in this study, in terms of its advantages and disadvantages

Table 4.17 Advantages and disadvantages of the flyover intersection.

Items	Disadvantages	Advantages
The bridge over an at-grade level	- The visual landscape is obscured, especially the commercial building that located near this area.	- Convenient for road users using the bridge, free flow on the bridge
Traffic capacity	- Small increase in traffic capacity for the secondary road	- Empowered to handle large traffic volume, especially on the main road
Delay & Queue length	- The delay and queue on secondary road are quite the same as the situation of the at-grade intersection	- Reducing a number of delays and vehicle queues in the direction of the bridge constructed (main road) - Saving travel time, increasing vehicle speed, especially, on the main road from 29.8 km/hr. to 52.5 km/hr. (at 85% vehicle speed)
Traffic control	- Traffic signalization still uses the fixed-time control plans as the previous situation of at-grade intersection, which does not fully utilize the benefits of having a flyover	- Reducing time for waiting at the intersection (by adjusting a new cycle time for flyover situation)
Road Safety	- In the flyover area, the hazard zone is spread to more zones, especially at the approaching and exiting zones of the bridge	- Reduce traffic conflict points at the junction - Reducing rear-end collisions
Cost and benefit	- During construction, road accidents and vehicle time delay incurred extra costs - Higher maintenance costs	- The flyover is an essential part of the highest type of highway, the expressway or freeway. It has cheaper construction cost than other types of grade separations. - No land needs to be expropriated.

4.2.4 Road Safety Inspection

According to the physical data, the area of intersection has increased compared to the old one and under the bridge, the existing traffic signalization still uses the same previous fixed time control plans; hence, similar problems as those of the previous at-grade intersection still exist. Furthermore the hazardous zone has spread out to other zones in the flyover area (as shown in figure 4.13) as follows:

At the approaching and exiting zone of the bridge (bottleneck); road users behavior at an approaching zone may lead road crashes from weaving conflicts because the vehicles cutting in sharply from the right lane to the left lane before entering the auxiliary lanes or heading for the bridge. At the exiting zone, conflicts of vehicles merging can lead to road crash because some vehicles from the left auxiliary lane cutting across the chevron markings to the right lane of the main road abruptly (figure 4.17).

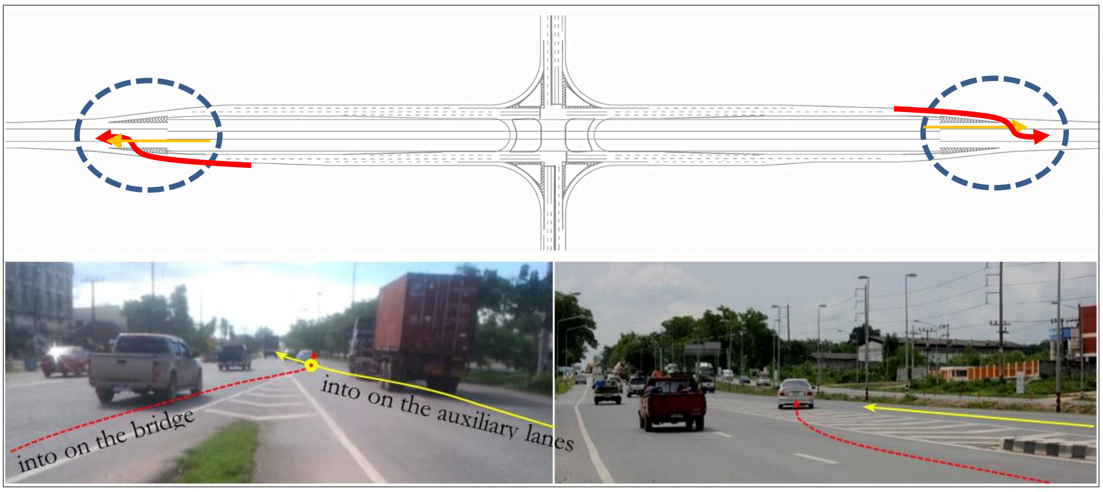


Figure 4.17 Traffic conflicts at the approaching and exiting zones

The drainage ditches on the median of the road, at the beginning of the bridge there are illegal paths that were used by motorists for crossing to opposite direction, when a high speed vehicle on the main road passes this area, a crash may occur as a result of the vehicles on the main road hitting the motorcycle emerging from the drainage median (figure 4.18).

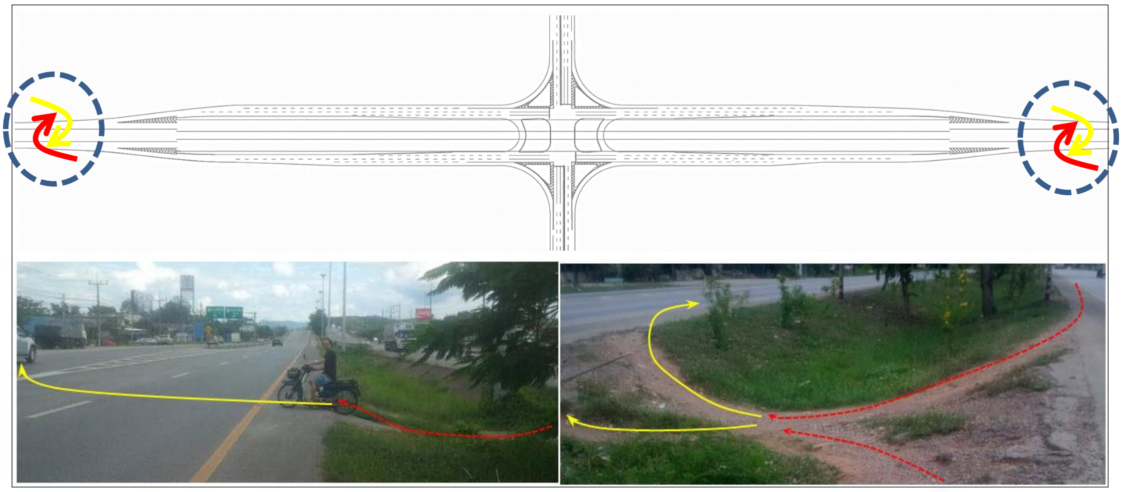


Figure 4.18 An illegal movement at the drainage ditches on the median of the road

The U-turn under the bridge, it is located near the stop line markings on the bridge direction about 17 meters or 3-vehicle length. For Udon Thani case study, this type of U-turn which allows movements in two directions and becomes an illegal channel for motorcycles, could cause the right or left angle collisions and head-on collisions (figure 4.19).

Figure 4.19 Illegal movements at U-turn under the bridge

On the shoulder of the road, there are many heavy trucks that stop and wait for repair and recess. Some incidents may occur when motorcycles using the shoulder at night time and cannot see a truck in time, a rear-end collision could result (figure 4.20)

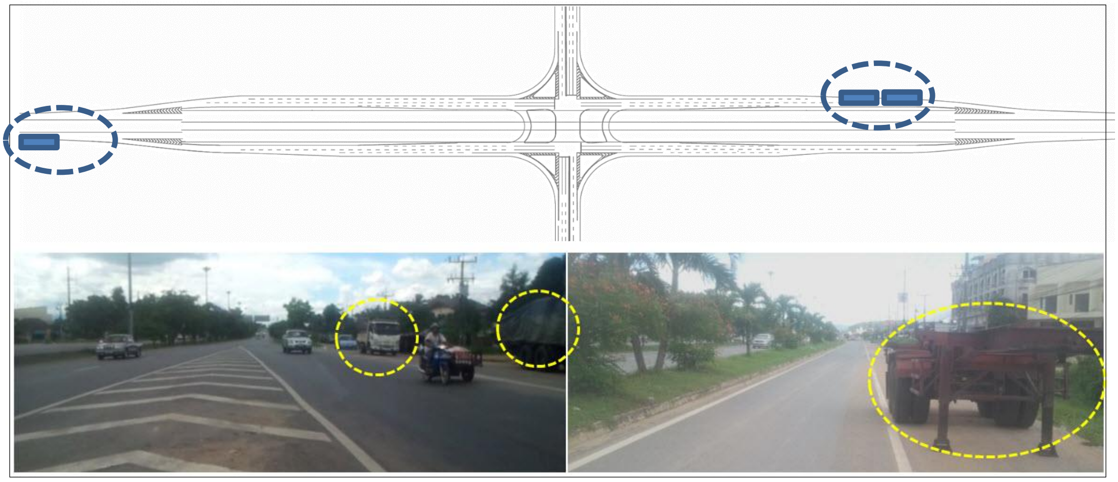


Figure 4.20 A fixed object - heavy trucks stopped for repair and recess at the shoulder of the road near flyover intersection area

Other problems near the flyover area, because the flyover model doesn't have a standard design, the Phitsanulok case study has a different traffic control for example the U-turn is opened on secondary road (figure 4.21 (A)), for the Udon Thani case study, a supermarket is located near the flyover location (figure 4.21 (B)) and for the Phatthalung case study, the U-turn has no auxiliary lane (figure 4.21 (C)).

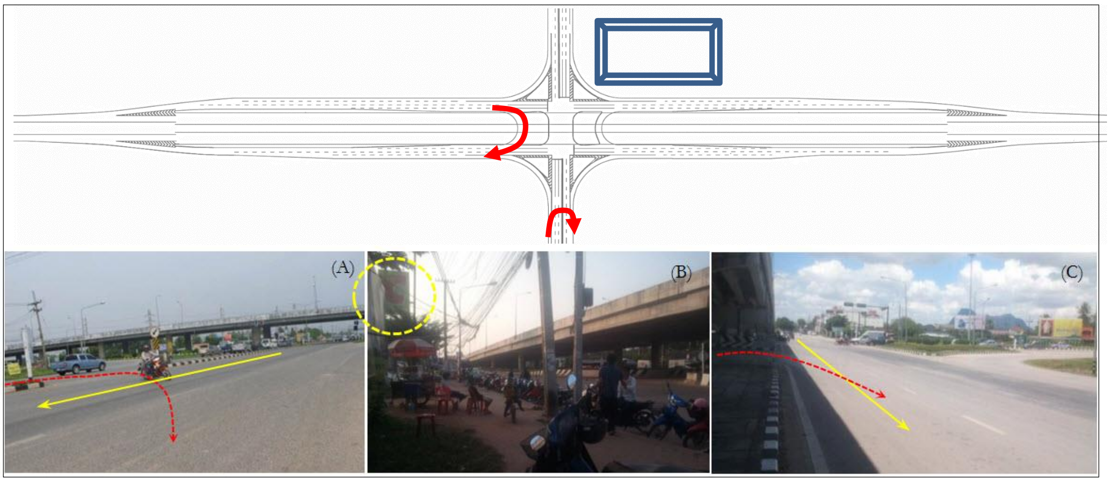


Figure 4.21 Other problems near the flyover areas

4.2.5 Cost of Accidents

To assess the accident cost at the existing flyover intersections (5 case studies), Eq. (4.4) is used to estimate the annual average accident cost.

Because the accident statistics from the 3 agencies did not record the number of people who were disabled by the accidents; the authors used estimate as given by Dr. Nima Asgari (WHO., (2013)) who stated that "every crash of road accidents in one year will be one person's death, injured 20 people and 1 of 20 people become to a disabled person", so, if there are 100 injured people, 5 people may become disabled. For this reason this paper uses 5% of the slightly injured number as the number of disabled people.

Equation (4.4) is used to calculate an annual average accident cost (ACa) as shown in Table 4.18.

Table 4.18 Annual average accident cost of 5 case studies.

Mean cost per accident \ Locations		Number of casualties (3 years recorded)				
		Songkhla	Udon Thani	Rayong	Phatthalung	Phitsanulok
Fatal	5,178,000 Baht	2	2	3	5	5
Disabled	6,168,500 Baht	1.2	1.05	1.0	0.6	2.1
Seriously injured	151,500 Baht	1	14	10	4	6
Slightly injured	29,750 Baht	24	21	20	12	42
Property damage only	39,000 Baht	27	40	30	20	37
ACa [Baht/year]		6,558,900	7,046,225	8,327,500	10,444,700	14,148,450
		Avg ACa = **9,305,155** Baht/year				

4.2.6 Analysis Results from SIDRA

This software is an advanced micro-analytical tool used for evaluating of alternative intersection designs in many terms such as capacity, level of service, time delay, queue length, as well as fuel consumption, pollutant emissions and operating costs (Akcelik & Associates Pty Ltd. (2011)). In this study, the software was used to analyse the performance of each flyover improved intersection and point out the average delay, average queue length and level of service (table 4.19).

And to further improve the performance of the intersections, the same data were used to calculate the optimum cycle-phase times by using the lowest time delay as the indicator. Table 4.20 shows the optimum cycle time and its results for 3 time periods of the 5 case studies.

Table 4.19 Analysis of field data by SIDRA for 3 time periods

Locations	Songkhla			Udon Thani			Rayong			Phatthalung			Phitsanulok		
Items \ Time	A.M.	Mid	P.M.	A.M.	Mid	P.M.	A.M.	Mid	P.M.	A.M.	Mid	P.M.	A.M.	Mid	P.M.
Cycle time (sec)	176	176	176	190	190	190	160	160	160	184	144	184	159	159	159
Average delay (sec/veh)	159	151	195	204	162	191	46	45	46	207	165	232	37	36	38
Average queue length (vehicle) and (meter)	83 & 543	80& 516	96& 563	72& 474	56& 375	63& 413	13& 77	11& 66	15& 87	66& 395	35& 216	65& 407	11& 66	9& 53	12& 67
Level of service	F	F	F	F	F	F	D	D	D	F	F	F	D	D	D

Table 4.20 Optimum cycle-phase time by SIDRA for 3 time periods

Locations	Songkhla			Udon Thani			Rayong			Phatthalung			Phitsanulok		
Items \ Time	A.M.	Mid	P.M.	A.M.	Mid	P.M.	A.M.	Mid	P.M.	A.M.	Mid	P.M.	A.M.	Mid	P.M.
Cycle phase time (sec)	130	140	150	185	160	170	115	106	115	178	178	178	80	80	80
Average delay (sec/veh)	153	143	175	140	98	109	38	37	39	139	76	142	28	27	28
Average queue length (vehicle) and (meter)	65& 432	67& 446	86& 501	64& 422	44& 292	53& 336	10& 61	10& 57	13& 76	58& 347	32& 193	57& 357	10& 60	7& 43	9& 54
Level of service	F	F	F	F	F	F	D	D	D	F	E	F	C	C	C

CHAPTER 5
CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions of study

The conclusions are divided to two parts which are **In-depth case** and **Typical flyover case** parts. The conclusions of the study of both cases are as follow to these items;

1) **In-depth case**
- On-site effect of flyover to traffic,
- Project evaluation,
- Analysis and Optimization by SIDRA,

2) **Typical flyover case**
- Existing flyover traffic control,
- Road safety of existing flyover,
- Result from SIDRA.

5.1.1 In-depth case

Sananbin Nai Intersection on highway route number 43 and highway route number 4135 near Hat Yai city, Songkhla, Thailand is selected to study because it is constructed during 2009 to 2012 by the Department of Highways and during researcher studied, there are enough fundamental data to study and restrictions in terms of the budget to data collection. This case study is consists of three situations which are the "*before construction* (at-grade intersection)", "*during flyover construction*" and "*after construction* (flyover intersection)". The results of the study is as follows;

5.1.1.1 On-site effect of flyover to traffic

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:

1) 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%.

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

3) 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.

4) 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 06:00 -21:00 (4 phases per one cycle); the second plan used flashing signal for the period 21:00-06:00. The flyover-improved intersection used similar fixed time control plan, but with the shorter cycle time of 224 seconds.

5) 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.

6) Accident statistics : Accident statistics of the flyover that controlled at this intersection was not different from an at-grade intersection accident statistics (at-grade intersection = 7.3 crashes/year, flyover intersection = 7.2 crashes/year). Interestingly, there were 20.8 crashes/year during flyover construction time. Mostly of accident cause of flyover control is rear end in the same lane. And the accident cost of three situations are 3,405,997.85 Baht of at-grade intersection situation, 20,635,690.00 Baht during construction time and 2,868,060.00 Baht of flyover intersection situation.

7) Traffic conflicts : Because of the flyover intersection bigger than at-grade intersection and there are 2 merging and 2 diverging-zones connected to the bridge. The conflict points of at-grade intersection are 50 points and the flyover intersection are 64 points (conflict points counted as follow as a number of lanes).

8) Hazardous zones : The hazardous zones are only under the bridge. Although the physical layout of intersection has changed to bigger than the old one, the problems are still found as similar to the situation of at-grade intersection. The hazardous zone spread to more many zones in the flyover area such as at the approaching and exiting zone, at the U-turn under the bridge and at the crossroad under the bridge. The inspections are as follows;

❖ *At the crossroad under the bridge*: according to mostly of accidents statistics occurred at the center of the intersection. One issue of road user is not enough time to pass this intersection on the yellow time (mostly of road user is non stop in yellow time), because of only 4 seconds of the yellow phase-time (amber time) with limit vehicle speed around 30 km./hr., may lead to traffic accidents by violation of traffic signal.

❖ *At the exit lane on the main road (under the bridge)* is one of hazardous zones. When the vehicles turn right from the secondary road, there have not the gap enough between vehicle lane no. 1 and vehicle lane no. 2 of the channels, may occur the crash accidents by sideswipe when the vehicles compete to pass out this zone.

❖ *U-turn under the bridge* is radius about 12 meters. It was constructed for serving only the vehicles of 2-4 wheels. In this case, the trailer or truck can not turn on this lane. And when the vehicles waiting for a green cycle in the right turning lane along the main road or the direction of the bridge more than 5 vehicles (about 20 meters), this U-turn channel will be blocked by these vehicles.

❖ *At the approaching and exiting zone* become to the new dangerous zones. The approaching zone may lead to the vehicles weaving and traffic crash because the vehicles intercept from the right lane to the left lane immediately before into the auxiliary lanes, the exiting zone may lead to the vehicles merging and traffic crash because some vehicles from the auxiliary lane run passing on the nose – chevron markings to the right lane of the main road immediately.

On-site data of both conditions of this intersection was concluded and compared and shown the conclusion in table 5.1 again.

Table 5.1 On-site effect of flyover to traffic

Items	Results of both conditions		Increase (+) Decrease (-)	Remarks
	Before	After		
1) Cycle time of traffic signal	244 sec/cycle (Fixed time)	224 sec/cycle (Fixed time)	- 20 seconds	No comments
2) Traffic volume - on ground - on the bridge	 60,351 PCU. -	 20,400 PCU. 29,384 PCU.	 - 33.8% + 45.7%	 Reduce traffic jam Good free-flows,
3) Average Delay (12-hour)	94.88 sec/PCU	90.41 sec/PCU	- 4.7%	The vehicle delay depend on cycle phase time of traffic signalization,
4) Average Queue length (12-hour)	106 veh/cycle time	52 veh/cycle time	- 50.9%	> 80% Reduced on the bridge direction,
5) Average LOS (12-hour)	**F** Level of service	**E** Level of service	One Level	The LOS depend on cycle phase time of traffic signalization also,
6) Average vehicle speeds	29.8 km/hr.	52.5 km/hr.	+ 43% (at 85% vehicle speed)	Saving travel time, increasing vehicle speed, especially, on the main road
7) Road safety - No. of accidents - Cost of accident - Conflict points	 7.3 crashes/year 3,405,997 Baht 50 points	 7.2 crashes/year 2,868,060 Baht 64 points	 Not different - 15.8% + 14 points	 It depends on road users behaviour, Increase more conflict zones

5.1.1.2 Project evaluation

The flyover construction project invested cost about 249.5 Million THB. To evaluate the project, this study conducted a CBA evaluation on a flyover improved intersection. The savings in vehicle operating cost, travel time and accident cost are considered as the benefit of the improved intersection. Construction and maintenance costs are considered as the cost of the improved intersection.

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.

The evaluation of this flyover intersection construction project was concluded and shown the conclusion results in table 5.2 again.

And discounted cash flow is also computed to represent the capital time cost, the figure 5.1 shown that the summary cash flow per year (2009 – 2021).

Table 5.2 Results of the project evaluated

Project evaluation : the benefit of the project is computed in comparing to current at-grade intersection.	
Road user costs : the benefit of the improved intersection	
1) Vehicle operating cost (VOC)	= saving 29.13 million baht
2) Value of time (VOT)	= saving 73.50 million baht
3) Accident cost	= saving 0.54 million baht
Cost benefit analysis : the cost of the improved intersection	
1) Net Present Value (NPV)	= 361.64 million baht
2) Benefit Cost Ratio (BCR)	= 1.34
3) Internal Rate of Return (IRR)	= 37.58%
Note: year consider (t) = 10 year, interest rate per year (i) = 12%)	

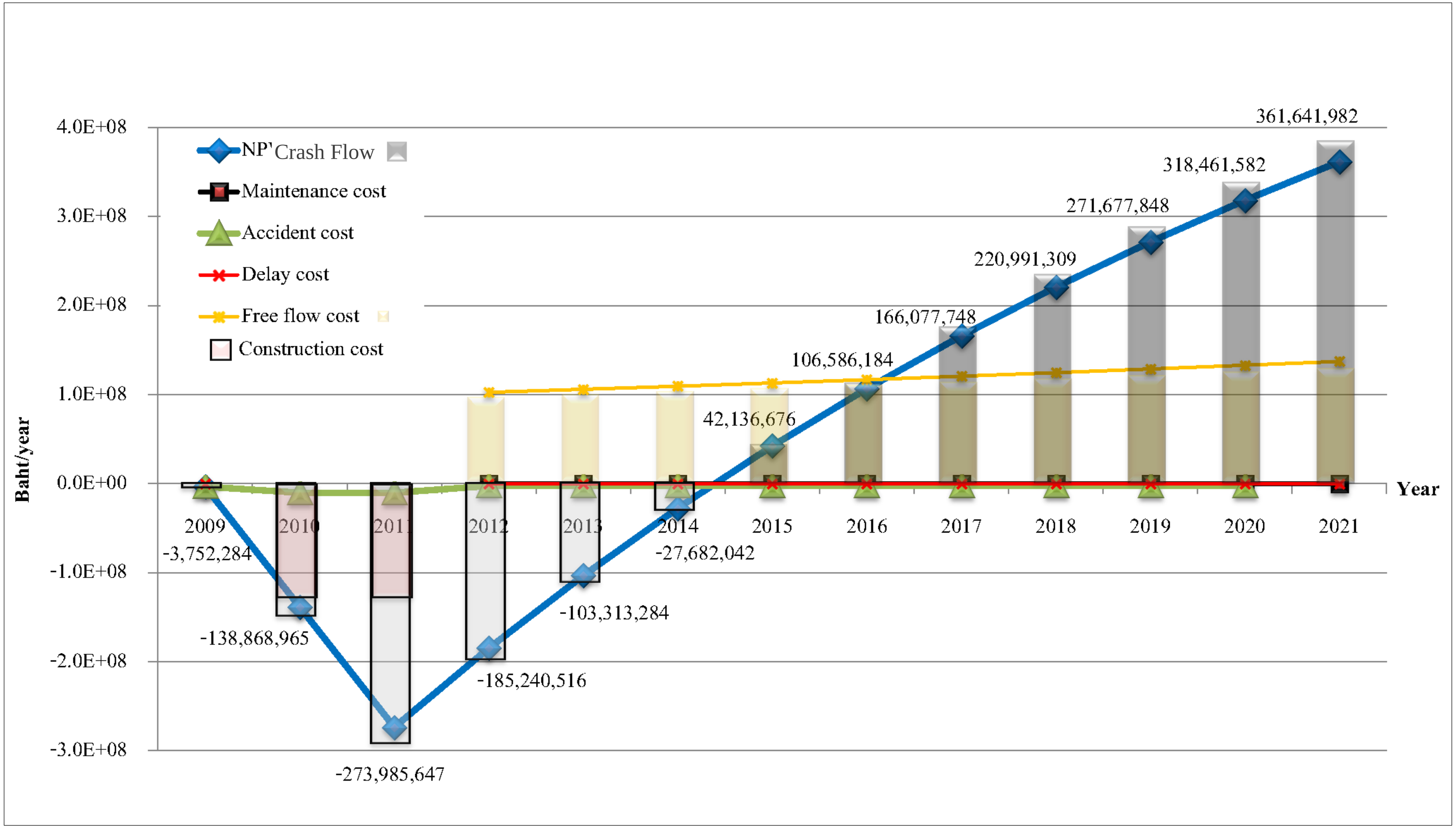


Figure 5.1 Cash Flow per year (2009 – 2021)

5.1.1.3 Analysis and Optimization by SIDRA

This software is an advanced micro-analytical tool used for evaluating of alternative intersection designs in many terms such as capacity, level of service, time delay, queue length, as well as fuel consumption, pollutant emissions and operating costs (Akcelik & Associates Pty Ltd. (2011)). In this study, the software was used to analyse the performance of flyover improved intersection and point out the average delay, average queue length and level of service (table 5.3).

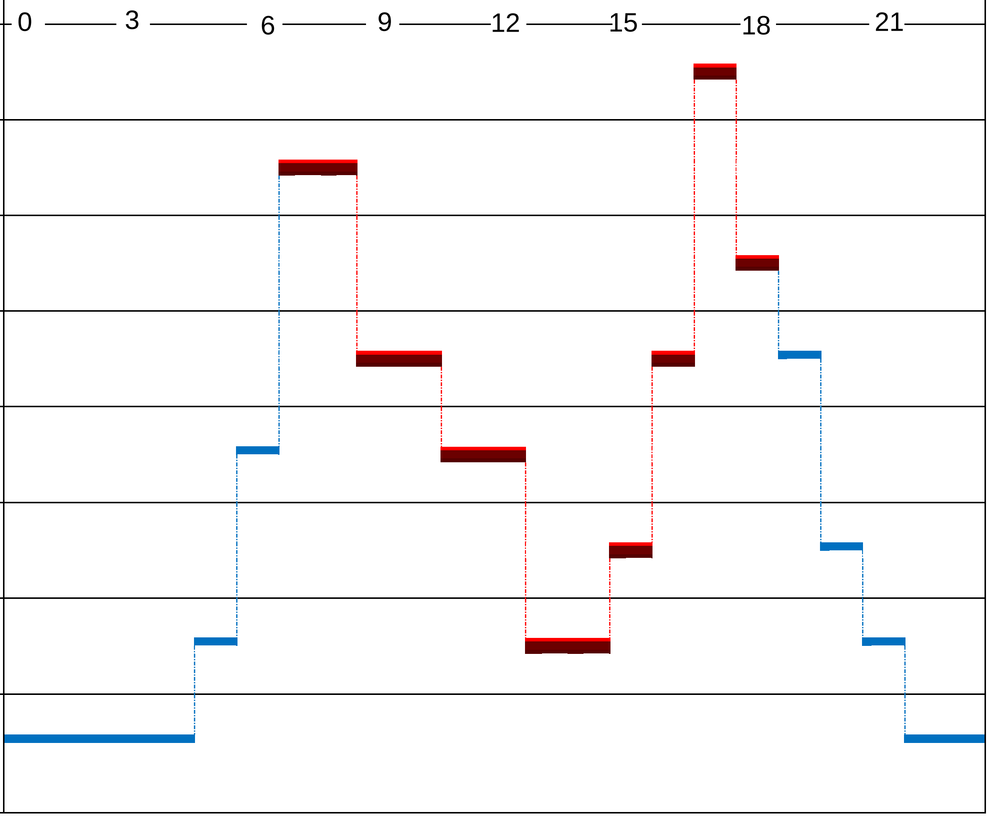
Table 5.3 Computed data and Optimizing by SIDRA

Situation of / Items	at-grade intersection	flyover intersection	
	By fixed-time control plan (244 sec/cycle)	By fixed-time control plan (224 sec/cycle)	Optimizing at the lowest time delay
Average Delay 12-hour (second/cycle)	105 sec/PCU	71 sec/PCU	45 sec/PCU
Average Queue 12-hour (second/cycle)	112 veh/cycle	56 veh/cycle	44 veh/cycle
Average Level of Service (LOS) 12-hour	F	E	D

Furthermore, at the lowest time delay, the software is determined new fixed cycle phase time per hour during 7:00 to 19:00 (12-hour) by depending also with traffic volume per hour. And researcher adjusted traffic volume to 24-hour, the table 5.4 is 24-hour of traffic signal plan, there are 8 programs per day and still control by fixed time plan.

Table 5.4 Optimum cycle times per hour by SIDRA (Red colour: 7:00 – 19:00 (12–hour), adjusted to 24-hour: Green colour)

Cycle time	Signal program	Time of operation
145	S1	
140	S2	
135	S3	
130	S4	
125	S5	
120	S6	
115	S7	
flashing yellow lights	S8	



5.1.2 Typical flyover case

This part presented the performance of the 5 case studies flyovers and suggested improvements to 29 flyover intersections in Thailand. These case studies are located in Songkhla, Udon Thani, Phatthalung, Rayong, and Phitsanulok province. On-site data are recorded at three peaks-time ((07:00 - 08:00 a.m.), (12:00 a.m. – 01:00 p.m.), and (04:00 – 05:00 pm.)) in a working day.

An at-grade intersection was upgraded with an installation of a flyover at a cost of about 175 million THB, to increase capacity of the intersection and reduce vehicle delay and long queue at the at-grade level, the flyover is one of the methods that supported traffic volume about 25,000 – 45,000 vehicle/day (IHT. (1997)).

5.1.2.1 Existing flyover traffic control,

The results of study, however, show that traffic signalization for both the existing at-grade situation and flyover upgraded situation has been and is still controlled by fixed time control plans, there is still long queue and delay especially on the secondary highways (summarized on-site data in table 4.16).

5.1.2.2 Road safety of existing flyover,

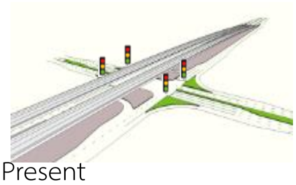
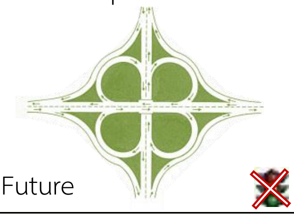
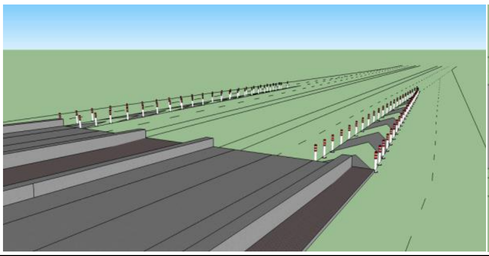
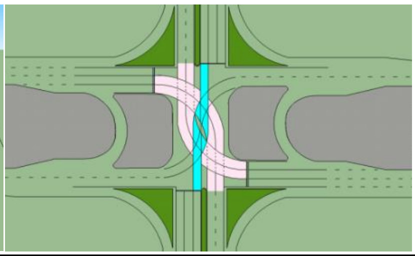
Hazardous zones in the flyover area spread out to other zones which are at the approaching and exiting areas, at the drainage ditches on a median of roads, at the U-turn under the bridge and at the crossroad under flyover, furthermore, the conflict points increased from 50 points to 64 points (table 5.5).

Accident cost is about 9.3 Million THB/year/flyover intersection, average accident number is about 30 crashes, 30 injured people and 1 person death per year (table 5.5).

5.1.2.3 Result from SIDRA

To improve the performance of the flyover intersections, the SIDRA software (version: SIDRA intersection 5.1) was used to calculate the optimum cycle-phase times which based on the lowest time delay as the indicator, table 4.20 shows the optimum cycle time and its results for 3 time periods of the 5 case studies (table 5.5).

Table 5.5 Conclusion data of existing flyover intersections – case studies

Items	Intersection		
Figure	At-grade  Past	Flyover-bridge  Present	Grade seperation  Future
Construction cost (approximate)	40,000 Baht/square^2	75,000 Baht/square^2 (Avg = 175.63 million baht)	80,000 Baht/square^2
Traffic capacity of each type	≈1,500 – 25,000 vehicles/day	≈25,000 – 45,000 vehicles/day	> 45,000 vehicles/day
- Situations	Analysis of field data by SIDRA	Optimum cycle times by SIDRA	
Delay	Avg Delay = 127 second/cycle	= 92 second/cycle (reducing to 27.5%)	
Phase time	Avg cycle phase time = 174 second/cycle	= 136 second/cycle (reducing to 38 second)	
Queue length	Avg Queue = 45 vehicles or 287 meters	= 29 vehicles or 245 meters (reducing to 14.0%)	
LOS	between F to E	between F to D	
Accidents	Average number of accidents = 30 crash /location/year		
No.of injured	Average number of injured = 30 people /location/year		
Death	Average a number of deaths = 1 person /location/year		
Accident cost	Average accident cost is about 9,305,155 Baht/year/location (285,724.09 USD)		
Hazardous zones	Install flexible traffic posts 	Paint the guidelines for road users 	

5.2 Recommendations

5.2.1 Project study

The process of feasibility study of the flyover construction was used to evaluate the benefits of the project, Department of Highways has already made with the good process. This study conducted a CBA evaluation on a flyover improved intersection. The savings in vehicle operating cost, travel time and accident cost are considered as the benefit of the improved intersection. Construction and maintenance costs are considered as the cost of the improved intersection.

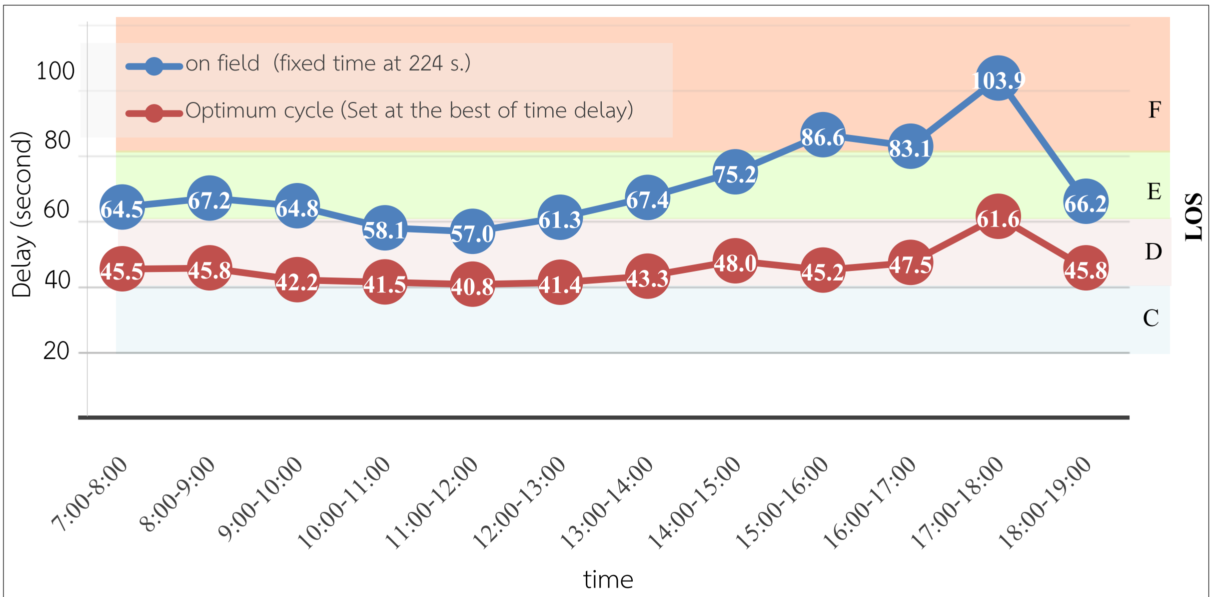
However, researcher has worried about road safety in during construction stage, due to the accident statistics has presented the number of accidents which have 53 times in 34 months – construction periods. So, At the field works should have traffic engineering staff for controlling or checking the possibility of accidents.

5.2.2 Traffic signalization

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. For this example, The SIDRA is used to find the optimum cycle times to improve and solve the traffic congestion of each leg at intersection by setting the targer at the least vehicle time delay per hour (comparing with fixed time at 224 second/cycle), the cycle times are shown in figure 5.2.

Better solution to solve the traffic congestion at intersection, Traffic-Actuated Signals should be used. It has been created to alleviate this problem by efficiently managing traffic flow. It can improve traffic congestion by responding to road conditions as problem occer.



Time	7:00-8:00	8:00-9:00	9:00-10:00	10:00-11:00	11:00-12:00	12:00-13:00	13:00-14:00	14:00-15:00	15:00-16:00	16:00-17:00	17:00-18:00	18:00-19:00
	64.5	67.2	64.8	58.1	57.0	61.3	67.4	75.2	86.6	83.1	103.9	66.2
	45.5	45.8	42.2	41.5	40.8	41.4	43.3	48.0	45.2	47.5	61.6	45.8
Difference	19.0	21.5	22.2	16.6	16.2	19.9	24.1	31.9	41.4	35.6	42.3	20.4

Figure 5.2 Comparing of vehicle time delay result on field data and in optimum cycle times per hour during 7:00 am – 7:00 pm that run by SIDRA software (example of in-depth case)

5.2.3 Road Safety

For existing flyover intersection;

1) At the beginning/ exiting of the bridge flexible traffic posts should be installed along the line of the nose-ghost island, the direction arrows should be painted on the weaving zones, installation of traffic signs: speed limit sign, give way sign and intersection warning sign.

2) At the drainage ditches on the median of the main road concrete barriers should be installed to close off the illegal paths.

3) At the U-turn under the bridge, one way traffic control should be used.

4) At the junction underneath the bridge, guideline should be painted for road users in all directions.

5) For a typical existing flyover intersection, around 60-80% time delay is on the secondary road, traffic engineer should design a new cycle-phase times of traffic signalization especially the yellow phase-time which should be appropriately designed in accordance with the size of the intersection.

For during construction stage (in-depth case);

1) The “temporary traffic signs” should use standard signs, installed at appropriate and sufficient locations “Road surface” should not have pothole and soil aggregates on the road surface.

2) “Street-lights” should be installed consecutively and turned on every night.

3) “Concrete Blocks” should be installed at appropriate locations, they should clearly show which are road user, roadside and construction zones. They should be installed covering the project construction area without gaps.

4) Traffic signal control during construction and open road should follow traffic volumes of each leg and period of the day, and

5) Field works should have traffic engineering staff for controlling or checking the possibility of accidents.

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Appendix I

Data collection Form and Reference

Appendix I – 1: Intersection Turning Movement Count (TMC) ((Example Form during 7:00 -11:00))

Traffic movement count form

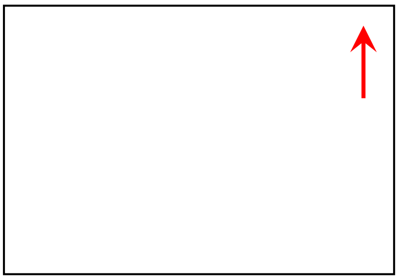
Date / Month / Year: ....

Investigator:... **Name the controller**: ....

TMC No: .... **Direction**:...

Time	Bicycle 2 - 3 wheel	Motorcycle	PC<7people	PC>7people	Mini bus	Medium bus	Bus	Mini truck	Medium truck	Havey truck	> 10-wheel	trailer truck
07:00 - 07:15												
07:15 - 07:30												
07:30 - 07:45												
07:45 - 08:00												
08:00 - 08:15												
08:15 - 08:30												
08:30 - 08:45												
08:45 - 09:00												
09:00 - 09:15												
09:15 - 09:30												
09:30 - 09:45												
09:45 - 10:00												
10:00 - 10:15												
10:15 - 10:30												
10:30 - 10:45												
10:45 - 11:00												

Appendix I – 2: Delay count (DL) Form (Example Form during 7:00 -8:00)



Delay count (DL)

DL No....................... Road............................. and...............................

Investigator: .... Date / Month / Year: .... Weather: ....

Time	Number of vehicles stopped in time phase (allow to count the same vehicle)			
	0-15 second	15-30 second	30-45 second	45-60 second
7:01				
7:02				
7:03				
:				
:				
:				
7:58				
7:59				
8:00				

Appendix I – 3: Queue length count (QL) (Example Form during 7:00 -8:00)

Queue length count (QL)

QL No........................ Road..............................and................................

Investigator: .... Date / Month / Year: .... Weather: ....

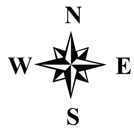
Time	Number of vehicles stopped in time phase (allow to count the same vehicle)			
	0-15 second	15-30 second	30-45 second	45-60 second
7:01				
7:02				
7:03				
:				
:				
:				
7:58				
7:59				
8:00				

Appendix I – 4: Traffic signal Form

Traffic signal form.

No.............. Main Road............................... and...

Date / Month / Year:.........................Time: .... Investigator:...............................



Traffic light System ☐ Fixed Time Signal ☐ Actuated Signal

Condition ○ Very Good ○ Good ○ Medium ○ Fail ○ Impracticable

Type ☐ ☐ ☐

Time to turn on....................... Time to turn off.......................

Control by the police ☐ Without ☐ Have (If yes, please specify the time interval in each well)

Morning........................... Midday............................. Evening.......................................

The length of cycle phase......................... second.

Phase	A	B	C	D
Green				
Yellow				
Rad				
All rad				

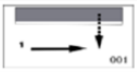
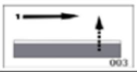
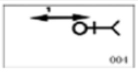
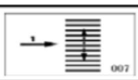
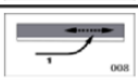
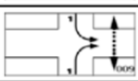
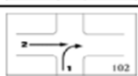
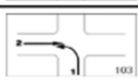
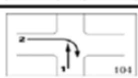
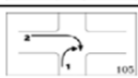
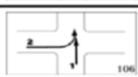
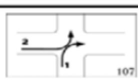
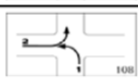
Appendix I - 5: Spot speed table Form

Speed group		Middle speed (km/hr.)	Totals				% Freq. in group (%)	Cum. % Freq (%)
Lower limit (km/hr.)	Upper limit (km/hr.)		PC	Trucks	Other	Total		
Sum								

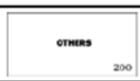
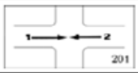
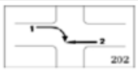
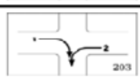
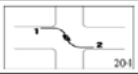
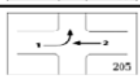
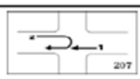
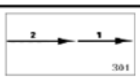
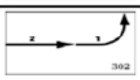
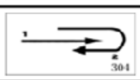
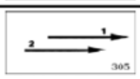
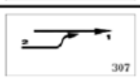
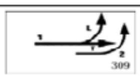
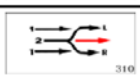
Appendix I – 6: Example accident statistics record Form

No	Zone	D/M/Y of accident	Hw/Sta (km.) Point of accident	Vehicle types of accident	Collision Diagram	Time			Number of Casualties			DOH damage	PDO	Cause
						Day	Night	Rain	Injury	Serious	Death			

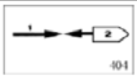
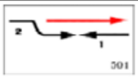
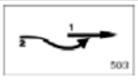
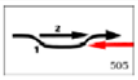
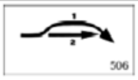
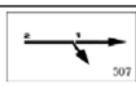
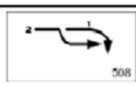
Appendix I - 7: Collision Diagram

Collision Type	Accident Code	Figure	Description
	000		Other pedestrian accidents
	001		Hit pedestrian from near side
	002		Hit pedestrian emerging in front of or back of parked vehicle
	003		Hit pedestrian from far side
	004		Hit pedestrian playing, working, lying, standing on carriageway
(Pedestrian)	005		Hit pedestrian walking with the traffic
	006		Hit pedestrian walking against the traffic
	007		Hit pedestrian at zebra crossing
	008		Hit pedestrian on footway
	009		Hit pedestrian during turning to the access or minor road
	100		Other intersection accidents
	101		Through hits through traffic from adjacent approach
	102		Right turn hits through traffic from adjacent approach
	103		Left turn hits through traffic from adjacent approach
(Intersection vehicle from adjacent approaches)	104		Through hits right turn traffic from adjacent approach
	105		Right turn hits right turn traffic from adjacent approach
	106		Through hits left turn traffic from adjacent approach
	107		Right turn hits left turn traffic from adjacent approach
	108		Left turn hits left turn traffic from adjacent approach

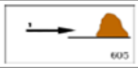
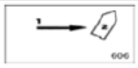
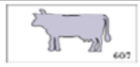
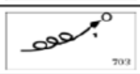
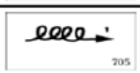
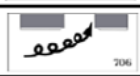
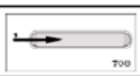
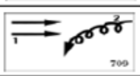
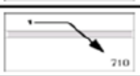
Appendix I - 7: Collision Diagram (continue)

Collision Type	Accident Code	Figure	Description
(Vehicle from Opposite Direction)	200		Other opposite direction accidents
	201		Head on
	202		Right turn hits through traffic
	203		Right turn hits left turn traffic
	204		Right turn hits right turn traffic
	205		Left turn hits through traffic
	206		Left turn hits left turn traffic
	207		Through hits U-turn traffic
(Vehicle from One Direction)	300		Other one direction accidents
	301		Rear end in the same lane
	302		Rear end during left turn
	303		Rear end during right turn
	304		Rear end during U-turn
	305		Side swipe in parallel lane
	306		Hit by vehicle changing lane to the right
	307		Hit by vehicle changing lane to the left
	308		Vehicle making through or right turn hit by another vehicle making right turn
	309		Vehicle making through or left turn hit by another vehicle making left turn
	310		Hit vehicle pulling out

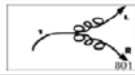
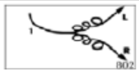
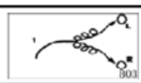
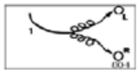
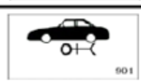
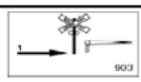
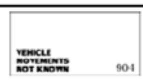
Appendix I - 7: Collision Diagram (continue)

Collision Type	Accident Code	Figure	Description
อุบัติเหตุจาก)	400		Other manoeuvering accidents
	401		Hit with vehicle leaving the parking
	402		Hit with vehicle entering the parking
	403		Hit during parking
	404		Hit with reversing vehicle
	405		Hit fixed object during reversing
	406		Hit vehicle leaving driveway
	407		Hit vehicle from footway
อุบัติเหตุจาก การแซง (Overtaking)	500		Other overtaking accidents
	501		Head on with overtaking vehicle
	502		Out of control during overtaking
	503		Hit by overtaking vehicle during going straight
	504		Rear end by overtaking vehicle during pulling out
	505		Rear end during cutting in
	506		Rear end during overtaking to the left
	507		Rear end by pulling out vehicle
	508		Hit by overtaking vehicle during right turn

Appendix I - 7: Collision Diagram (continue)

Collision Type	Accident Code	Figure	Description
(On Path)	600		Other on path accidents
	601		Hit parked vehicle
	602		Hit double parked vehicles
	603		Hit car door
	604		Hit permanent obstruction
	605		Hit temporary roadwork or other objects
	606		Hit broken down or accident vehicle
	607		Hit the animal
	608		Hit the falling object from loading vehicle ahead
	609		Hit opposing vehicle driving illegally
(Off Path on Straight)	700		Other off carriageway accidents on the straight
	701		Off carriageway to the left
	702		Off carriageway to the right
	703		Off carriageway to the left and hit the fixed object
	704		Off carriageway to the right and hit the fixed object
	705		Out of control on carriageway
	706		Off carriageway at the access on left side during left turn
	707		Off carriageway at the access on left side during right turn
	708		Mounts the traffic island
	709		Off carriageway due to opposing traffic
	710		Off carriageway and across median

Appendix I - 7: Collision Diagram/ Road User Movement (continue)

Collision Type	Accident Code	Figure	Description
(Off Path on Curve)	800		Other off carriageway accidents on the bend
	801		Off carriageway during on the right bend
	802		Off carriageway during on the left bend
	803		Off carriageway and hit the fixed object during on the right bend
	804		Off carriageway and hit the fixed object during on the left bend
	805		Off carriageway at the access on the left bend during left turn
	806		Off carriageway at the access on the right bend during right turn
(Miscellaneous)	900		Other passenger and miscellaneous accidents
	901		Fall in/from vehicle
	902		Hit train
	903		Hit railway crossing furniture
	904		Vehicle movement not known

Appendix II

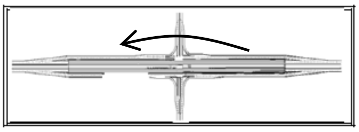
Results of Study

Appendix II – 1: On-site traffic movement data (12-hour), 17th July 2012

Date / Month / Year: ....17 July 2012..................

Investigator:.. Name the controller: ....

TMC No: ......Sanambin Nai Intersection.. Direction:..................EW on the bridge.....................................



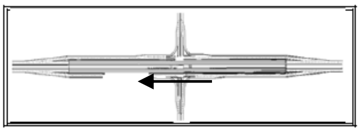
time	Bicycle 2 - 3 wheel	Motorcycle	PC<7people	PC>7people	Mini bus	Medium bus	Bus	Mini truck	Medium truck	Havey truck	> 10-wheel	trailer truck
07:00 - 07:15		41	60	19			1	15	2	2	4	2
07:15 - 07:30		35	69	24			1	19	1		4	3
07:30 - 07:45		50	118	10	2			24	3	4	4	5
07:45 - 08:00		39	143	12			2	32	2	6	4	2
08:00 - 08:15		41	119	12				28	8	2	2	2
08:15 - 08:30		41	122	17			4	27	7	4	1	2
08:30 - 08:45		37	107	14			2	24	4	2	6	5
08:45 - 09:00		27	124	15			1	30	9	7	6	2
09:00 - 09:15		33	127	15	1		2	28	14	9	7	6
09:15 - 09:30		29	104	19			3	24	9	4	5	7
09:30 - 09:45		29	103	11				26	14		3	9
09:45 - 10:00		38	121	22				28	12		4	8
10:00 - 10:15		33	127	17				29	6	7	2	14
10:15 - 10:30		27	108	18			1	30	12	11	4	8
10:30 - 10:45		31	114	12			3	29	12	9	12	7
10:45 - 11:00		25	125	14				24	9	6	4	12
11:00 - 11:15		34	117	15				32	6	8	4	13
11:15 - 11:30		30	102	10	1		1	27	4	3	5	9
11:30 - 11:45		37	142	19			4	44	4	10	3	5
11:45 - 12:00		30	109	12			2	27	7	4	4	14
12:00 - 12:15		24	116	16			1	24	4	6	5	11
12:15 - 12:30		35	116	14			2	25	9	8	7	10
12:30 - 12:45		28	110	14				23	7	6	11	6
12:45 - 13:00		32	99	20			2	23	4	7	5	13
13:00 - 13:15		24	126	15			1	29	9	12	6	10
13:15 - 13:30		29	114	17			3	27	9	7	1	10
13:30 - 13:45		26	131	15			2	29	6	6	5	13
13:45 - 14:00		29	132	16			1	26	11	11	2	13
14:00 - 14:15		27	128	19	3			20	6	5	4	10
14:15 - 14:30		35	142	14			1	34	13	5	1	4
14:30 - 14:45		32	120	17			2	30	8	10	1	9
14:45 - 15:00		31	141	21			3	31	10	5	4	3
15:00 - 15:15		31	144	21			1	32	9	4	3	14
15:15 - 15:30		39	159	20	3		3	36	4	6	4	10
15:30 - 15:45		42	160	15				19	7	6	3	13
15:45 - 16:00		49	129	12			2	32	11	10	4	8
16:00 - 16:15		40	152	13			1	33	13	10	3	6
16:15 - 16:30		38	149	15	1		5	18	3	11	2	8
16:30 - 16:45		40	168	15				28	4	10	1	13
16:45 - 17:00		52	152	17			3	18	7	10	6	7
17:00 - 17:15		42	154	18			4	23	6	5	1	10
17:15 - 17:30		55	188	15	1		4	17	3	7	3	12
17:30 - 17:45		37	168	12			1	18	3	9	2	9
17:45 - 18:00		46	188	14			3	17	3	8	3	6
18:00 - 18:15		52	169	19			5	18	12	6	2	4
18:15 - 18:30		31	149	16	1		3	15	6	10		7
18:30 - 18:45		41	125	10			4	16	3	3	5	9
18:45 - 19:00		36	119	10			2	16	7	4	1	7

Appendix II – 1: On-site traffic movement data (12-hour), 17th July 2012 (continue)

Date / Month / Year: ....17 July 2012..................

Investigator:.. Name the controller: ....

TMC No: ......Sanambin Nai Intersection.. Direction:.................EW under the bridge..................................



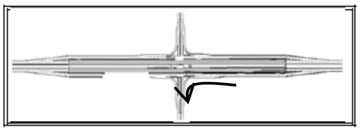
time	Bicycle 2 - 3 wheel	Motorcycle	PC<7people	PC>7people	Mini bus	Medium bus	Bus	Mini truck	Medium truck	Havey truck	> 10-wheel	trailer truck
07:00 - 07:15		1	1									
07:15 - 07:30		2	2									
07:30 - 07:45		3	4									
07:45 - 08:00	1	5	10									
08:00 - 08:15		7	1									
08:15 - 08:30		2	2									
08:30 - 08:45		2										
08:45 - 09:00		4										
09:00 - 09:15	1	2	1					1				
09:15 - 09:30												
09:30 - 09:45												
09:45 - 10:00		1	1						1			
10:00 - 10:15			1									
10:15 - 10:30	1		1									
10:30 - 10:45												
10:45 - 11:00			1	1								
11:00 - 11:15		1	1									
11:15 - 11:30		1	4							1		
11:30 - 11:45		2	2									
11:45 - 12:00			5									
12:00 - 12:15			2									
12:15 - 12:30		1	2				1					
12:30 - 12:45												
12:45 - 13:00		1	2			2						
13:00 - 13:15		2	2								1	
13:15 - 13:30			2									
13:30 - 13:45		1										
13:45 - 14:00		1	1									
14:00 - 14:15			2									
14:15 - 14:30			2									
14:30 - 14:45		1	1									
14:45 - 15:00			1									
15:00 - 15:15		2	3									
15:15 - 15:30			3						1			
15:30 - 15:45		1	5									
15:45 - 16:00			1									
16:00 - 16:15		4	5						1			
16:15 - 16:30		2	4									
16:30 - 16:45			2									
16:45 - 17:00		3	2									
17:00 - 17:15	1	5	2									
17:15 - 17:30		4										
17:30 - 17:45			2									
17:45 - 18:00			3									
18:00 - 18:15		2	2									
18:15 - 18:30												
18:30 - 18:45		3	5									
18:45 - 19:00			2									

Appendix II – 1: On-site traffic movement data (12-hour), 17th July 2012 (continue)

Date / Month / Year: ....17 July 2012...................

Investigator:.. Name the controller: ....

TMC No: ......Sanambin Nai Intersection.. Direction:..................E-S.....................................



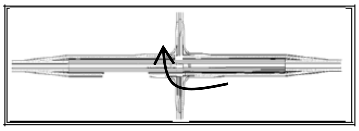
time	Bicycle 2 - 3 wheel	Motorcycle	PC<7people	PC>7people	Mini bus	Medium bus	Bus	Mini truck	Medium truck	Havey truck	> 10-wheel	trailer truck
07:00 - 07:15		8	49	2	1							
07:15 - 07:30		7	55	12	3	2						
07:30 - 07:45		15	54	10		5	1					
07:45 - 08:00		22	61	10		3		2	2	1		
08:00 - 08:15	1	16	54	14	4	1			1			
08:15 - 08:30	2	16	54	6	5			3	2			
08:30 - 08:45	2	18	48	16	4	1		4				
08:45 - 09:00		12	58	11	2				1			
09:00 - 09:15	2	13	49	6	1	2		1	3			
09:15 - 09:30	1	3	57	9		8		6	8			
09:30 - 09:45		7	52	8	1	5		4				
09:45 - 10:00		14	86	12		4		4	1			
10:00 - 10:15		14	68	15		6		5	2			
10:15 - 10:30	1	11	50	11	1	6	1	4	3			
10:30 - 10:45	1	7	67	10	6	1		4	2			
10:45 - 11:00	2	6	56	11	3	2		8	1			
11:00 - 11:15		11	49	2		10		2	2	1		
11:15 - 11:30		3	48	11		4	1	4	2			
11:30 - 11:45		14	50	4	2	8		2	1			
11:45 - 12:00		7	60	4		8		4		1		
12:00 - 12:15		9	51	10		5			1	2		
12:15 - 12:30		11	44	12		2		2	1			
12:30 - 12:45		9	47	8	1	1	1	3				
12:45 - 13:00		10	44	8	2	3		3		1		
13:00 - 13:15		16	41	15	1	2		2				1
13:15 - 13:30		6	49	10		1		1				
13:30 - 13:45		9	40	15		2						1
13:45 - 14:00		8	50	9	1	4		4				1
14:00 - 14:15		7	46	3				1	1			
14:15 - 14:30		12	35	8	1			1				
14:30 - 14:45		13	77	2	1	4		2		1		
14:45 - 15:00		6	54	6		3		4	2	1		
15:00 - 15:15		6	37	5		3		1				
15:15 - 15:30		7	44	14	1			1				
15:30 - 15:45		7	49	5	5	3	1	1		1		
15:45 - 16:00		4	52	2	2	1						
16:00 - 16:15		9	40		3	2		3	1			
16:15 - 16:30		18	72	2	1	3		3		2		
16:30 - 16:45		10	54	6		2	1	3				
16:45 - 17:00		15	69	9		5		3				
17:00 - 17:15	1	18	34	6	1	3		2				
17:15 - 17:30		19	54	8		1		3				
17:30 - 17:45		15	61	4	1	3		1				
17:45 - 18:00	2	13	58	13	2	3		4			1	
18:00 - 18:15		15	59	6	1	1		3	1			
18:15 - 18:30		19	44	7		2		1				
18:30 - 18:45		10	64	5	2	3		1				
18:45 - 19:00		10	55	8		1		1				

Appendix II – 1: On-site traffic movement data (12-hour), 17th July 2012 (continue)

Date / Month / Year: ....17 July 2012..................

Investigator:.. **Name the controller:** ....

TMC No: ......Sanambin Nai Intersection.. **Direction:**..................E–N...................................



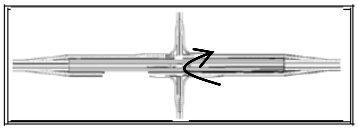
time	Bicycle 2 - 3 wheel	Motorcycle	PC<7people	PC>7people	Mini bus	Medium bus	Bus	Mini truck	Medium truck	Havey truck	> 10-wheel	trailer truck
07:00 - 07:15		13	38								1	4
07:15 - 07:30		15	41	5	1	2				2		1
07:30 - 07:45		12	42	6	2			2		1		2
07:45 - 08:00		12	54	8		1		1		1		3
08:00 - 08:15		17	46	3	2	3		1	3			3
08:15 - 08:30		9	55	2		2		5	8		1	4
08:30 - 08:45		8	54	3	1	3		8	5		1	1
08:45 - 09:00		6	58	9		7		4	9			3
09:00 - 09:15		8	47	1		1		9	4	2		2
09:15 - 09:30		4	36	5		5		7	5	8		2
09:30 - 09:45		7	40	2		2		9	6	1		5
09:45 - 10:00		5	54	2		2		9	4	3		2
10:00 - 10:15		10	35	4	1	4		6	4	1	1	2
10:15 - 10:30		8	39	7				3	4	3	2	2
10:30 - 10:45		2	49	1		1		4	3	2	6	1
10:45 - 11:00		2	37	8	2	1		5			1	7
11:00 - 11:15		11	36	3		3	1	6	1	2		3
11:15 - 11:30		8	39	1		1		6		4		1
11:30 - 11:45		6	38	1		1		5	1	4		2
11:45 - 12:00		5	27	2	2			7	3	1		3
12:00 - 12:15		1	47	10		3		1	1			2
12:15 - 12:30		5	42	6		3		3	3	2		1
12:30 - 12:45		5	49	9		2		3	5	6		6
12:45 - 13:00		3	43	2	1	2	1	8	4	3		3
13:00 - 13:15		10	51	3		4		5	2	4		5
13:15 - 13:30		5	49	5		5		3	4	1	2	2
13:30 - 13:45		3	40	5		5		10	5	3		6
13:45 - 14:00		3	39	4		2						3
14:00 - 14:15		7	42	1		1		4	1	2	1	4
14:15 - 14:30		11	45	3	2	5	1	11	2	4		5
14:30 - 14:45		4	50	8	2	3		5	5	4	1	4
14:45 - 15:00		4	44	5		2		5	4	4		7
15:00 - 15:15		8	42	7		3		8	2	4	1	4
15:15 - 15:30		3	65	3		4		7	8	2	2	5
15:30 - 15:45		8	42	2		5	1	3	4	1		5
15:45 - 16:00		7	66	1		3		5	3	4		7
16:00 - 16:15		18	56	1		3	1	3	5	1	2	2
16:15 - 16:30		9	53	4	1	1		5	3			6
16:30 - 16:45		10	62	6	1	5		7	4	2		3
16:45 - 17:00		8	73	6		3		7	10			8
17:00 - 17:15		17	83	3	1	3		7	1	3		5
17:15 - 17:30		16	82	9		3		5	2	2		3
17:30 - 17:45		10	84	5	1	2		4	2	1	1	6
17:45 - 18:00		12	56	7	1	4	1	10		2		3
18:00 - 18:15		19	58	4	2	2	1	1	6	2		2
18:15 - 18:30		9	60	2		5		5	2	3		2
18:30 - 18:45		10	51	4	1	2		4	2	3		3
18:45 - 19:00		8	44	4		3		5		2	1	4

Appendix II – 1: On-site traffic movement data (12-hour), 17th July 2012 (continue)

Date / Month / Year: ………17 July 2012………………

Investigator:………………………………………………………… Name the controller: ……………………………………………

TMC No: ……Sanambin Nai Intersection…………………………… Direction:………………E–E……………………………



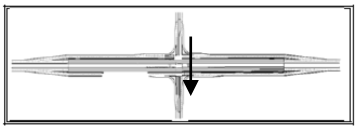
time	Bicycle 2 - 3 wheel	Motorcycle	PC<7people	PC>7people	Mini bus	Medium bus	Bus	Mini truck	Medium truck	Havey truck	> 10-wheel	trailer truck
07:00 - 07:15			3									
07:15 - 07:30			7									1
07:30 - 07:45		2	17									
07:45 - 08:00		4	4								1	1
08:00 - 08:15		4	15						1			
08:15 - 08:30		4	12						1			
08:30 - 08:45		6	15	1					1			
08:45 - 09:00		4	6						1		3	
09:00 - 09:15		2	20					1	2		1	
09:15 - 09:30		3	11	1								
09:30 - 09:45			5								4	
09:45 - 10:00	1	2	8						2	1		
10:00 - 10:15		1	7						2			
10:15 - 10:30		1	9						2			
10:30 - 10:45			7						2	1		
10:45 - 11:00		4	11						1			1
11:00 - 11:15		1	14						1			
11:15 - 11:30		2	19	1		1		1	2			1
11:30 - 11:45		3	10						1			
11:45 - 12:00	1		15	1		1		2		2		
12:00 - 12:15		3	9					3		2	1	1
12:15 - 12:30		4	12			1		1		2		
12:30 - 12:45		1	11			1			1		1	
12:45 - 13:00		2	18			1				2	1	
13:00 - 13:15		5	9			1		1	1			
13:15 - 13:30		2	23			1		1		2	1	
13:30 - 13:45		3	15			4						
13:45 - 14:00		3	20						1			
14:00 - 14:15		6	9					3	2	1		
14:15 - 14:30		1	7			2		1		1	1	
14:30 - 14:45		3	21									
14:45 - 15:00		2	19	1	1				1			
15:00 - 15:15		3	9									
15:15 - 15:30		1	10		1				3	1		
15:30 - 15:45		3	5		1			1	1			
15:45 - 16:00		1	12					1	1		1	
16:00 - 16:15		8	14							1	1	
16:15 - 16:30		8	12					3		2		
16:30 - 16:45		6	19	1	2			2				
16:45 - 17:00		5	12		1			1				
17:00 - 17:15		5	14			1			1	2		1
17:15 - 17:30		8	23			1		1	1			
17:30 - 17:45		2	18			1		2	1			
17:45 - 18:00	1	6	21					2	1			
18:00 - 18:15	1	9	17								1	
18:15 - 18:30		2	13					2	1			
18:30 - 18:45		4	12									
18:45 - 19:00		5	12					1				

Appendix II – 1: On-site traffic movement data (12-hour), 17th July 2012 (continue)

Date / Month / Year: ....17 July 2012..................

Investigator:.. **Name the controller:** ....

TMC No: ......Sanambin Nai Intersection.. **Direction:**..................N–S...................................



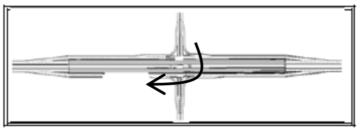
time	Bicycle 2 - 3 wheel	Motorcycle	PC<7people	PC>7people	Mini bus	Medium bus	Bus	Mini truck	Medium truck	Havey truck	> 10-wheel	trailer truck
07:00 - 07:15		33	117	3	4			1				
07:15 - 07:30		37	113	5	5			2			2	
07:30 - 07:45		38	115	3	10			1				
07:45 - 08:00		60	131	2	6							
08:00 - 08:15		34	110	1	6			2	1			
08:15 - 08:30		51	124	1	6			8	1			
08:30 - 08:45		34	125	1	10			7	4			
08:45 - 09:00		29	88	3	7			13	1		1	
09:00 - 09:15		30	104	4	4			7	5			1
09:15 - 09:30		35	108	3	3			11	3		1	1
09:30 - 09:45		17	69	4	2			5	4			
09:45 - 10:00		19	100	6	4			12	2			
10:00 - 10:15		31	115	6	2			2	1			
10:15 - 10:30		21	80	8	3			6	3	1	1	
10:30 - 10:45		30	115	6	7			7	4			
10:45 - 11:00		30	82	11	5			8	2	1		
11:00 - 11:15		28	90	3	8			6	3	1		
11:15 - 11:30		29	93	8	5		1	3	2	1	1	
11:30 - 11:45		15	81	5	3			5	1			1
11:45 - 12:00		21	90	5	6			3	2	1		
12:00 - 12:15		22	123	2	6			8	3	2		
12:15 - 12:30		18	84	3	1			3				
12:30 - 12:45		21	100	7	6				3			
12:45 - 13:00		14	94	5	5			4	1			
13:00 - 13:15		22	95	6	10			2	1			
13:15 - 13:30		27	108	1	8			4	1			
13:30 - 13:45		16	86	5	4			3	2			
13:45 - 14:00		20	104	8	4			1	3	2		
14:00 - 14:15		22	81	5	7			6	2			
14:15 - 14:30		28	159	5	4			7	10	4		
14:30 - 14:45		14	107	6	6			1	1			
14:45 - 15:00		35	113		8			5	2			
15:00 - 15:15		22	103	5	3			5	3			
15:15 - 15:30		17	90		3			2	2			
15:30 - 15:45		25	71	5	6			2	1	1		
15:45 - 16:00		28	134	7	6			5	1			
16:00 - 16:15		30	119	5	6			2	1	3		
16:15 - 16:30		23	93	2	2			2	1	1		
16:30 - 16:45		39	142	6	7			5	1			
16:45 - 17:00		27	119	3	5			1				
17:00 - 17:15		31	124		6				2			
17:15 - 17:30		40	122	2	8			3	1			
17:30 - 17:45		50	112	5	5			4	2			
17:45 - 18:00		33	111	3	2			2	2			
18:00 - 18:15		47	159	9	6			7	2	1		
18:15 - 18:30		32	107	4	5			2				
18:30 - 18:45		35	84	7	2			7				
18:45 - 19:00		36	115	2			1	1				

Appendix II – 1: On-site traffic movement data (12-hour), 17th July 2012 (continue)

Date / Month / Year: ....**17 July 2012**...................

Investigator:.. **Name the controller:** ....

TMC No: ......**Sanambin Nai Intersection**.. **Direction:**..................**N–W**....................................



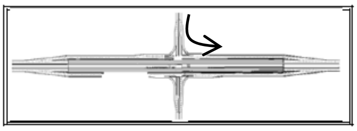
time	Bicycle 2 - 3 wheel	Motorcycle	PC<7people	PC>7people	Mini bus	Medium bus	Bus	Mini truck	Medium truck	Havey truck	> 10-wheel	trailer truck
07:00 - 07:15		2	2									
07:15 - 07:30		2										
07:30 - 07:45		2	3									
07:45 - 08:00		8	2									
08:00 - 08:15		1	2									
08:15 - 08:30			2									
08:30 - 08:45		1	1									
08:45 - 09:00			2					1				
09:00 - 09:15		1						1				
09:15 - 09:30			2					1				
09:30 - 09:45		1	2									
09:45 - 10:00		1	2									
10:00 - 10:15		1	6					2				
10:15 - 10:30			3			1				1		
10:30 - 10:45		2	3									
10:45 - 11:00		1	2									
11:00 - 11:15		2	1									
11:15 - 11:30		1	5									
11:30 - 11:45		1	3									
11:45 - 12:00	1	1	2									
12:00 - 12:15		1	3									
12:15 - 12:30			2									
12:30 - 12:45		1	4									
12:45 - 13:00		1	6									
13:00 - 13:15		1										
13:15 - 13:30			4									
13:30 - 13:45		5	3									
13:45 - 14:00		3	2									
14:00 - 14:15		5	4									
14:15 - 14:30			1									
14:30 - 14:45			2									
14:45 - 15:00		1	6									
15:00 - 15:15		2	5									
15:15 - 15:30		1	2									
15:30 - 15:45		1	4									
15:45 - 16:00		1	1									
16:00 - 16:15		1	2									
16:15 - 16:30		2	4									
16:30 - 16:45		1	2									
16:45 - 17:00			2					1				
17:00 - 17:15		2	3									
17:15 - 17:30		4	2									
17:30 - 17:45		2	3					1				
17:45 - 18:00		2	5					1				
18:00 - 18:15		2	3									
18:15 - 18:30		8	2									
18:30 - 18:45		2	4									
18:45 - 19:00		2	1									

Appendix II – 1: On-site traffic movement data (12-hour), 17th July 2012 (continue)

Date / Month / Year: ....17 July 2012...................

Investigator:.. Name the controller: ....

TMC No: ......Sanambin Nai Intersection.. Direction:..................N–E....................................



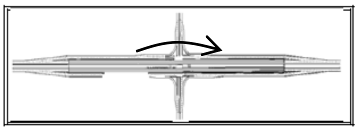
time	Bicycle 2 - 3 wheel	Motorcycle	PC<7people	PC>7people	Mini bus	Medium bus	Bus	Mini truck	Medium truck	Havey truck	> 10-wheel	trailer truck
07:00 - 07:15		20	78	9	3			7	1	3		4
07:15 - 07:30	1	25	74	11	2			4	4	2		3
07:30 - 07:45	1	31	88	20	6			2		3		10
07:45 - 08:00		34	95	9	6			8		5	1	11
08:00 - 08:15		39	86	10	6		1	10	3	4	2	19
08:15 - 08:30		14	60	3	4	1		7	2	4		10
08:30 - 08:45		14	89	4	3			8	4	3		14
08:45 - 09:00	1	10	45	3	2			3	2	1		3
09:00 - 09:15		12	95	10				25	5	3	1	7
09:15 - 09:30		13	69	5				12	8	4	2	6
09:30 - 09:45		10	71	2			1	10	11	3		2
09:45 - 10:00		16	80	2				14	2	2		9
10:00 - 10:15	1	12	54	1				14	5	5		5
10:15 - 10:30		12	59					7	3	4	3	5
10:30 - 10:45		7	76	3				4	10	4		4
10:45 - 11:00		20	62				1	14	3	7		6
11:00 - 11:15		9	51	1	1			7	2			7
11:15 - 11:30		5	38	3				7	3	4	1	3
11:30 - 11:45		16	52	4				14	9	4		2
11:45 - 12:00		6	43	1	1			7	2	2		5
12:00 - 12:15		9	70	3	2			10	4	2		5
12:15 - 12:30		6	65	5	1			11	3	1		2
12:30 - 12:45		6	50	2	1			9	3	2		7
12:45 - 13:00		12	75	3			1	11	5	4	1	3
13:00 - 13:15		11	35	1	2			4	1			3
13:15 - 13:30		5	32					5	1	1		8
13:30 - 13:45		14	45	2	1			9	2	2		2
13:45 - 14:00		8	49	1	2			5	3			3
14:00 - 14:15		10	57	3	1			4	2	2		2
14:15 - 14:30		9	78	1	1			11	8	4		7
14:30 - 14:45		10	65	2				6	6	4		9
14:45 - 15:00		14	93	1				18	1			2
15:00 - 15:15		12	47	4	2	1		8	4	2		5
15:15 - 15:30	1	18	62	2	1			19	5	5		3
15:30 - 15:45		12	55					9	2	2		3
15:45 - 16:00		18	91				2	4	5	4		4
16:00 - 16:15		11	60	2	1		1	7	2	1		4
16:15 - 16:30		21	72	2				18	4	2	1	4
16:30 - 16:45		10	60	1	2			15	5	4		9
16:45 - 17:00		15	85	1	3			21	4	3		5
17:00 - 17:15	1	27	95	1	1		1	11	5	3	1	4
17:15 - 17:30		21	110	1	1			9	2	1		4
17:30 - 17:45	3	31	95	3	2			8	4	2		7
17:45 - 18:00		18	90	2	1			7	3	2		5
18:00 - 18:15	1	13	115	3			1	10	2	2	1	9
18:15 - 18:30		10	78	1				3				3
18:30 - 18:45		8	57		3			9	2	3		5
18:45 - 19:00		3	50	1	1		1	2		3		2

Appendix II – 1: On-site traffic movement data (12-hour), 17th July 2012 (continue)

Date / Month / Year: ....17 July 2012...................

Investigator:... Name the controller: ....

TMC No: ......Sanambin Nai Intersection... Direction:.................W-E up on the bridge..........................



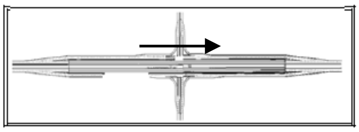
time	Bicycle 2 - 3 wheel	Motorcycle	PC<7people	PC>7people	Mini bus	Medium bus	Bus	Mini truck	Medium truck	Havey truck	> 10-wheel	trailer truck
07:00 - 07:15		25	73	3		1		12	2	1	3	3
07:15 - 07:30		30	78	3		2		11	6	2		7
07:30 - 07:45		69	121	5	1	2	2	16	10			7
07:45 - 08:00		71	120	6		3	2	18	2	6	4	11
08:00 - 08:15		49	128	11		1	1	20	3	5	4	15
08:15 - 08:30		35	108	14		3		18	5	10	2	20
08:30 - 08:45		36	92	8		2	2	13	6	5	7	18
08:45 - 09:00		38	98	6		2	3	13	5	8	1	10
09:00 - 09:15		27	101	8		1	5	16	8	6	4	19
09:15 - 09:30		27	80	11		1	1	16	5	2	3	15
09:30 - 09:45		23	85	7		1	1	16	7	2	1	10
09:45 - 10:00		20	85	4		1	2	14	9	6	2	12
10:00 - 10:15		25	96	5		2	1	17	6	6	8	15
10:15 - 10:30		22	87	5		2	2	15	5	5	4	9
10:30 - 10:45		22	91	3		3		17	6	4	3	10
10:45 - 11:00		21	96	11		2		14	8	6	6	4
11:00 - 11:15		22	88	3		1		16	7	5	1	17
11:15 - 11:30		18	89	7		1	1	16	8	4	5	14
11:30 - 11:45		23	72	30			1	16	5	9	11	9
11:45 - 12:00		25	105	5		1	1	18	6	4	3	14
12:00 - 12:15		21	97	5		1	2	16	2	4	5	15
12:15 - 12:30		22	106	5		1	1	18	2	4	5	7
12:30 - 12:45		22	100	7		3		16	3	4		16
12:45 - 13:00		17	68	2		2		10	4	3	5	13
13:00 - 13:15		29	90	4		2	1	16	4	5	5	9
13:15 - 13:30		20	79	1		1	1	14	9	8	4	10
13:30 - 13:45		21	102	11		2		24	3	5	3	13
13:45 - 14:00		16	80	4		3		22	8	2	2	17
14:00 - 14:15		19	89	9		2	2	25	8	6	4	11
14:15 - 14:30		19	84	6		1	11	37	9	2	1	19
14:30 - 14:45		19	90	3		2		28	7	4	3	19
14:45 - 15:00		29	98	8		4	2	36	5	5	3	13
15:00 - 15:15		26	85	4		3	4	23	4	6	3	14
15:15 - 15:30		22	89	9		2	2	30	8	7	2	12
15:30 - 15:45		23	97	9	1	1		20	2	8	4	16
15:45 - 16:00		24	100	14	2	3	1	17	6	2	1	14
16:00 - 16:15		18	101	10		2		26	4	3	6	14
16:15 - 16:30		27	114	6	1	2	7	23	4	5	6	25
16:30 - 16:45		28	95	11		1	4	18	4	3	2	16
16:45 - 17:00		28	111	9		2	1	20	3	5	2	13
17:00 - 17:15		38	112	4		2	3	15	3	6	1	18
17:15 - 17:30		43	143	6		3	2	20	4	5	4	7
17:30 - 17:45		37	124	9	1	1		21	4	6	1	13
17:45 - 18:00		37	118	3		3		23		2	1	4
18:00 - 18:15		40	107	10	1	3	1	16	5	1	2	18
18:15 - 18:30		30	90	10		2	2	12	2	4	3	3
18:30 - 18:45		33	92	5		2		13	1	3	2	9
18:45 - 19:00		26	85	5		1		12	4	1	3	6

Appendix II – 1: On-site traffic movement data (12-hour), 17th July 2012 (continue)

Date / Month / Year: ....17 July 2012...................

Investigator:.. **Name the controller:** ....

TMC No: ......Sanambin Nai Intersection... **Direction:**..................W–E ouder the bridge...........................



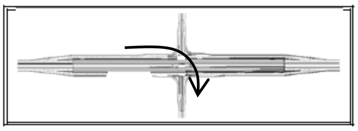
time	Bicycle 2 - 3 wheel	Motorcycle	PC<7people	PC>7people	Mini bus	Medium bus	Bus	Mini truck	Medium truck	Havey truck	> 10-wheel	trailer truck
07:00 - 07:15			2									
07:15 - 07:30		1	2									
07:30 - 07:45								2			1	
07:45 - 08:00	1	2	1									
08:00 - 08:15			1									
08:15 - 08:30		3										
08:30 - 08:45			1	1				1				
08:45 - 09:00		2		1					1			
09:00 - 09:15		1	3									
09:15 - 09:30		1										
09:30 - 09:45			1									
09:45 - 10:00												
10:00 - 10:15		1	1					1				
10:15 - 10:30							1					
10:30 - 10:45			1									
10:45 - 11:00			1						1			
11:00 - 11:15								1				
11:15 - 11:30							1					
11:30 - 11:45			1									
11:45 - 12:00		1										
12:00 - 12:15		1										
12:15 - 12:30												2
12:30 - 12:45			1									
12:45 - 13:00		1						1	1			
13:00 - 13:15										1		
13:15 - 13:30												
13:30 - 13:45			2									1
13:45 - 14:00		1	2									
14:00 - 14:15		2	2									
14:15 - 14:30			3									
14:30 - 14:45			1					1				
14:45 - 15:00			1						1			
15:00 - 15:15		1	2							1		
15:15 - 15:30		1	2									
15:30 - 15:45		1	2						1			2
15:45 - 16:00		1	1									
16:00 - 16:15		2										
16:15 - 16:30		1	2									
16:30 - 16:45		1	3									1
16:45 - 17:00		1	2					1				
17:00 - 17:15		2	2									
17:15 - 17:30			3									
17:30 - 17:45			1									
17:45 - 18:00		2										
18:00 - 18:15			1								1	
18:15 - 18:30		2	2									2
18:30 - 18:45			2									
18:45 - 19:00			1									

Appendix II – 1: On-site traffic movement data (12-hour), 17th July 2012 (continue)

Date / Month / Year: ....17 July 2012....................

Investigator:.. **Name the controller:** ....

TMC No: ......Sanambin Nai Intersection.. **Direction:**..................W–S...........................



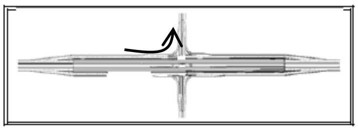
time	Bicycle 2 - 3 wheel	Motorcycle	PC<7people	PC>7people	Mini bus	Medium bus	Bus	Mini truck	Medium truck	Havey truck	> 10-wheel	trailer truck
07:00 - 07:15		1	14					1				1
07:15 - 07:30		5	24	2				2			4	
07:30 - 07:45		5	14	2				1	1	1	1	
07:45 - 08:00		6	22					1	3	1		1
08:00 - 08:15		1	25	1					3		6	
08:15 - 08:30		8	23						1	1	2	
08:30 - 08:45		7	10							4	4	
08:45 - 09:00		2	25	1					1	1		
09:00 - 09:15			22						3	1	2	
09:15 - 09:30		3	28	2				1	1		2	
09:30 - 09:45		2	15	1						1		
09:45 - 10:00		3	18						1	2		
10:00 - 10:15		4	15					1	1	1		
10:15 - 10:30		5	17						2			
10:30 - 10:45			13					1	1	1		
10:45 - 11:00		5	21					3	2	1		
11:00 - 11:15		10	27	1	1			5	2	1	1	1
11:15 - 11:30			13					2	2	2	1	
11:30 - 11:45		5	17					3	2	1		
11:45 - 12:00		2	21	1	1			1	3	1	1	1
12:00 - 12:15		2	20							2		
12:15 - 12:30		1	19						1			
12:30 - 12:45		5	24	1	1			1	1	1		
12:45 - 13:00		1	15				1	3	1		2	
13:00 - 13:15		2	20					2	1	3	1	
13:15 - 13:30		7	26	2				1	1	1		
13:30 - 13:45		2	31	1				1	1			
13:45 - 14:00		2	13				1	4	2	1	1	
14:00 - 14:15		2	27	1				3	2		1	
14:15 - 14:30		6	22	1	1			2		1	1	
14:30 - 14:45		4	13	3				2		3	1	
14:45 - 15:00		1	23	1				3				
15:00 - 15:15		2	23		1				3	1	1	
15:15 - 15:30		5	21	1				2	3		1	
15:30 - 15:45		1	29					2		1	1	1
15:45 - 16:00		5	32	2				2				
16:00 - 16:15		4	25	4	1			3				2
16:15 - 16:30		4	24					10	2	1	1	
16:30 - 16:45		10	23					4	2			
16:45 - 17:00		3	35						3	1	1	
17:00 - 17:15		11	25				2	3	4	1		
17:15 - 17:30		12	34	2				5	3	1		
17:30 - 17:45		3	33	1				5	1			
17:45 - 18:00		4	17					4		1		
18:00 - 18:15		8	45			1		1		1		
18:15 - 18:30		5	25	1								
18:30 - 18:45		3	13	1								
18:45 - 19:00		3	18	1				2				

Appendix II – 1: On-site traffic movement data (12-hour), 17th July 2012 (continue)

Date / Month / Year: ………17 July 2012………………….

Investigator:……………………………………………………………… Name the controller: ……………………………………………………

TMC No: ……Sanambin Nai Intersection……………………………………… Direction:………………W–N………………………



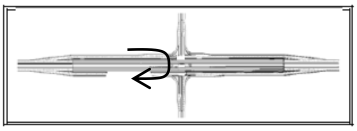
time	Bicycle 2 - 3 wheel	Motorcycle	PC<7people	PC>7people	Mini bus	Medium bus	Bus	Mini truck	Medium truck	Havey truck	> 10-wheel	trailer truck
07:00 - 07:15	1	8	1					3				
07:15 - 07:30		10	1			1		3				
07:30 - 07:45		11	2					3				
07:45 - 08:00		9	12					2				
08:00 - 08:15		11	14					3				
08:15 - 08:30		4	6					1				
08:30 - 08:45		3	2			1						
08:45 - 09:00		4	9			1		4				
09:00 - 09:15		2	2					1	1			
09:15 - 09:30		5	7			1		3	1			
09:30 - 09:45		1	8							1		
09:45 - 10:00		5	4									
10:00 - 10:15		4	4			1		1	1	1		
10:15 - 10:30		2	5									
10:30 - 10:45		1	9			1						
10:45 - 11:00		3	5					1				
11:00 - 11:15		9	8					1				
11:15 - 11:30		1	5	1				2				
11:30 - 11:45		1	9					3				
11:45 - 12:00		3	5					2				
12:00 - 12:15		8	6		1			2				
12:15 - 12:30		9	2									
12:30 - 12:45		6	5									
12:45 - 13:00		3	5	1				1				
13:00 - 13:15		4	8			1			1			1
13:15 - 13:30		3	4									
13:30 - 13:45		5	2									
13:45 - 14:00			2							2		
14:00 - 14:15		4	7									
14:15 - 14:30		3	6									
14:30 - 14:45		1	5		1							
14:45 - 15:00		3	7					1			1	
15:00 - 15:15		2	3									
15:15 - 15:30		4	5									
15:30 - 15:45		4	4	1	1			2			1	
15:45 - 16:00		1	4		1							
16:00 - 16:15		14	2					3				
16:15 - 16:30		3	6		1							
16:30 - 16:45		1	5		1			1				
16:45 - 17:00		2	4					1				
17:00 - 17:15		8	5									
17:15 - 17:30		5	5		1							
17:30 - 17:45		6	7							1		
17:45 - 18:00		3	6									
18:00 - 18:15		5	9									
18:15 - 18:30		6	5									
18:30 - 18:45		2	3									
18:45 - 19:00		3	1			1				1		

Appendix II – 1: On-site traffic movement data (12-hour), 17th July 2012 (continue)

Date / Month / Year: ....17 July 2012...................

Investigator:.. **Name the controller:** ....

TMC No: ......Sanambin Nai Intersection.. **Direction:**..................W–W...........................



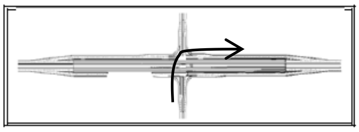
time	Bicycle 2 - 3 wheel	Motorcycle	PC<7people	PC>7people	Mini bus	Medium bus	Bus	Mini truck	Medium truck	Havey truck	> 10-wheel	trailer truck
07:00 - 07:15		1										
07:15 - 07:30		2	1									
07:30 - 07:45		3	1									
07:45 - 08:00		3	1									
08:00 - 08:15	1	4	3					1				
08:15 - 08:30		3	4					1		2		
08:30 - 08:45		1	1							1		
08:45 - 09:00			2					1	1			
09:00 - 09:15		1	3							2	1	
09:15 - 09:30		2							1		1	
09:30 - 09:45		2	2									
09:45 - 10:00			1							1		
10:00 - 10:15			3									
10:15 - 10:30			2							2		
10:30 - 10:45			2					1			1	
10:45 - 11:00		1					1			2		
11:00 - 11:15										1		
11:15 - 11:30								1		1	1	1
11:30 - 11:45										1		
11:45 - 12:00			1						1			
12:00 - 12:15			1							1		
12:15 - 12:30		2	3									
12:30 - 12:45		1	1							1		
12:45 - 13:00		1	1									
13:00 - 13:15			2						1			
13:15 - 13:30									1			
13:30 - 13:45		1	1									
13:45 - 14:00			1							1		
14:00 - 14:15			1									
14:15 - 14:30			5						1	1		
14:30 - 14:45								1				1
14:45 - 15:00										1		
15:00 - 15:15			2									
15:15 - 15:30			1									
15:30 - 15:45		1								1		
15:45 - 16:00		1	1					1	1			
16:00 - 16:15		2	5						1	1		
16:15 - 16:30		1	2					1	1			
16:30 - 16:45									2			
16:45 - 17:00		1										
17:00 - 17:15			1							2		
17:15 - 17:30			1									
17:30 - 17:45										1		
17:45 - 18:00			1									
18:00 - 18:15												
18:15 - 18:30									1			
18:30 - 18:45		2										
18:45 - 19:00			2									

Appendix II – 1: On-site traffic movement data (12-hour), 17th July 2012 (continue)

Date / Month / Year: ....17 July 2012..................

Investigator:.. Name the controller: ....

TMC No: ......Sanambin Nai Intersection.. Direction:..................S–E...........................



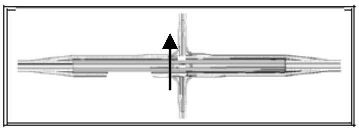
time	Bicycle 2 - 3 wheel	Motorcycle	PC<7people	PC>7people	Mini bus	Medium bus	Bus	Mini truck	Medium truck	Havey truck	> 10-wheel	trailer truck
07:00 - 07:15		32	90	3								
07:15 - 07:30		40	110	4	2	5		6	2	1		
07:30 - 07:45		66	162	10		5		2	2	1	1	
07:45 - 08:00		30	52	2			1		3	1	1	
08:00 - 08:15		27	79	1				1	2	2	1	
08:15 - 08:30		22	47	2		1		3	1	1		
08:30 - 08:45		22	122	2	2	1		6		2		1
08:45 - 09:00		16	42	1				2	1	1		
09:00 - 09:15		10	51					2				
09:15 - 09:30		11	39					2				
09:30 - 09:45		14	74		1	6		2		1		
09:45 - 10:00		15	48	1		3		2		2		
10:00 - 10:15		15	56	2				4		2		
10:15 - 10:30		12	52	3					4			
10:30 - 10:45		12	74	2					3	1		
10:45 - 11:00		10	88	2	1			2	1	2		
11:00 - 11:15		8	72	4	1	4		1	2	1		1
11:15 - 11:30		14	58	2	1	3	1	4	1	1		
11:30 - 11:45		6	54	3	1			3	1	1		
11:45 - 12:00		7	51	4	1			3	2			
12:00 - 12:15		13	76	1		3		5	3			
12:15 - 12:30		4	55	2		5					1	
12:30 - 12:45		9	70	2				4	1			
12:45 - 13:00		6	55			1		2	1	2		
13:00 - 13:15		8	77	2	1	4		1				
13:15 - 13:30		12	50	5	2	5		2	1	1		
13:30 - 13:45		6	62	4	3			3				
13:45 - 14:00		13	97		2	8		5				
14:00 - 14:15		4	89	4			2	1	1			
14:15 - 14:30		16	47	2	4			2				
14:30 - 14:45		9	62	3	2			1				
14:45 - 15:00		17	101			5		1	1			
15:00 - 15:15		9	60	6				3	1			
15:15 - 15:30		13	91	2	1				2	2	2	
15:30 - 15:45		12	77		2			3				
15:45 - 16:00		9	86	4	5							
16:00 - 16:15		13	56	3	2			1				
16:15 - 16:30		6	48	2				2				
16:30 - 16:45		20	92	3				7	1			
16:45 - 17:00		10	44	2				5	1		1	1
17:00 - 17:15		24	124	4	1			4	2		1	
17:15 - 17:30		14	79	6	1			1				
17:30 - 17:45		23	101	3	2			7				
17:45 - 18:00	1	10	44	2								
18:00 - 18:15		16	81	1				2				
18:15 - 18:30		15	56	3	2				2			
18:30 - 18:45		20	99	5			1	5				
18:45 - 19:00		12	55	8				2	1			

Appendix II – 1: On-site traffic movement data (12-hour), 17th July 2012 (continue)

Date / Month / Year: ....17 July 2012...................

Investigator:... Name the controller: ....

TMC No: ......Sanambin Nai Intersection... Direction:.................S–N..........................



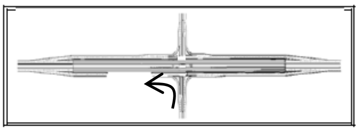
time	Bicycle 2 - 3 wheel	Motorcycle	PC<7people	PC>7people	Mini bus	Medium bus	Bus	Mini truck	Medium truck	Havey truck	> 10-wheel	trailer truck
07:00 - 07:15		32	64		5	1		1	1	1		
07:15 - 07:30		45	92	1				2	1	1		
07:30 - 07:45		52	126	4	4				1			
07:45 - 08:00	1	55	123	10	7				1	1		
08:00 - 08:15		44	99	1	6				1	3		
08:15 - 08:30		36	110	4	3			1				
08:30 - 08:45		36	109	4	4							
08:45 - 09:00		26	92	5	2				1			
09:00 - 09:15		24	79	4	1			4				1
09:15 - 09:30		22	86	2	3			4	1	1	1	
09:30 - 09:45		19	94		2			1	3			
09:45 - 10:00		23	62	4	6			1	1	1		
10:00 - 10:15		23	106	4	5			1	3			2
10:15 - 10:30		24	79	2	1					1		
10:30 - 10:45		28	89	2	3				5	2		1
10:45 - 11:00		18	81	3	5			1	1	1		
11:00 - 11:15		26	94	6	3			3	6			
11:15 - 11:30		24	92	4	3				1	1		
11:30 - 11:45		25	113	7	4			4	3			
11:45 - 12:00		20	110	2	6	1		4				
12:00 - 12:15		29	90	1	6			7		1		
12:15 - 12:30		20	95	6	2			3	2		1	
12:30 - 12:45		16	66		3			2	4	2		
12:45 - 13:00		12	82	3	2			6	2	1	1	
13:00 - 13:15		23	102	2	4			2	4	1		1
13:15 - 13:30		22	92		3			5				
13:30 - 13:45		14	66	4	4			4	1	1		
13:45 - 14:00		22	110	9	5			2	1			
14:00 - 14:15	1	17	104	1	5			2				
14:15 - 14:30		22	94	3	1		1	4	2			
14:30 - 14:45		22	75	1	6			4	1			
14:45 - 15:00		25	124	6	3			3			2	
15:00 - 15:15		18	92	2	3			1	3			
15:15 - 15:30		26	95	7	5			3	3			
15:30 - 15:45		23	110	6	5			1	4			
15:45 - 16:00		32	25	2	2			5	3	2	1	
16:00 - 16:15		25	77		4		1	1	2	1		
16:15 - 16:30		19	98	4	7			3	3			
16:30 - 16:45		30	94	3	6			1	1	2		
16:45 - 17:00		22	104	6	4			5	1			
17:00 - 17:15		64	166	5	4			1	1			
17:15 - 17:30		52	169	3	2			5				
17:30 - 17:45		33	133	2	5			2		1		1
17:45 - 18:00	2	49	81	2	2					1		
18:00 - 18:15		34	97	2	2			5	3			1
18:15 - 18:30	2	29	64		2			2		1		
18:30 - 18:45		25	107	4	5			3	1			
18:45 - 19:00		14	79		1			2				

Appendix II – 1: On-site traffic movement data (12-hour), 17th July 2012 (continue)

Date / Month / Year: ....17 July 2012..................

Investigator:.. Name the controller: ....

TMC No: ......Sanambin Nai Intersection.. Direction:..................S–W...........................



time	Bicycle 2 - 3 wheel	Motorcycle	PC<7people	PC>7people	Mini bus	Medium bus	Bus	Mini truck	Medium truck	Havey truck	> 10-wheel	trailer truck
07:00 - 07:15		16	32	4				1	1	1		
07:15 - 07:30	1	16	40	3	2							
07:30 - 07:45		22	45	9				3		1		
07:45 - 08:00		30	52	3				3			2	
08:00 - 08:15		19	57	2			1					
08:15 - 08:30		19	52	3				2				1
08:30 - 08:45		21	55	5				2	2	2	1	
08:45 - 09:00		14	51					1				
09:00 - 09:15		15	48	2	1			3	1	1		
09:15 - 09:30		17	46	3				1	2		1	
09:30 - 09:45		17	44	4					3	1	2	1
09:45 - 10:00		20	51	2				1	1	1	1	
10:00 - 10:15		17	48	2				2	3	4		2
10:15 - 10:30		18	45	3				2	1	3		
10:30 - 10:45		17	36	2				1				
10:45 - 11:00		19	59	3				5	5			
11:00 - 11:15		19	65	6				1	1	4		
11:15 - 11:30		15	41	2				4	1			
11:30 - 11:45		21	51	2				6	3	2		1
11:45 - 12:00		17	47	2				2			1	1
12:00 - 12:15		16	41	2				4	2	1	1	
12:15 - 12:30		15	44	4				2		1	1	4
12:30 - 12:45		18	54	2	1			5	2		1	
12:45 - 13:00		15	45	3					1	1	1	1
13:00 - 13:15		15	52					2	1		2	
13:15 - 13:30		22	60	2				5	2	2	1	
13:30 - 13:45		20	42	3				5		1	1	
13:45 - 14:00		18	53	4				5		1		
14:00 - 14:15		18	59	2	1			9			1	1
14:15 - 14:30		16	57			1		8	1			1
14:30 - 14:45		15	63	2				8	1	2		3
14:45 - 15:00		15	58					7	3		1	3
15:00 - 15:15		18	53		2			5	2		1	2
15:15 - 15:30		19	46	2				5		1		
15:30 - 15:45		17	47	5				8	6	2	4	1
15:45 - 16:00		16	48	3					3			
16:00 - 16:15		13	48	3	1			3	2	1	1	1
16:15 - 16:30		16	49	3						1		
16:30 - 16:45		24	58	4					1	2		2
16:45 - 17:00		21	43	2				5		2		1
17:00 - 17:15		35	74	3				3	2		2	3
17:15 - 17:30		26	68									
17:30 - 17:45		23	56	2	2			1		1		1
17:45 - 18:00		18	45					2				1
18:00 - 18:15	9	22	57	3	2			2				
18:15 - 18:30		19	46	2				1	1		1	
18:30 - 18:45		15	44	3	2			2		1		1
18:45 - 19:00		16	41	2				1				1

Appendix II – 2: Accident statistics of in-depth case during 2007 – August 2013

No	Zone	D/M/Y	Hw/Sta (km.)	Vehicle type		Collision	Time			Number of Casualty			DOH	PDO	Cause
				Veh 1	Veh 2	Code	Day	Night	Rain	Injury	Serious	Died	damage		
1		26-Feb-2007	Intersection	Motorcycle			11:45			1					
2		21-Aug-2007	Intersection	Motorcycle			14:42			1					
3		23-Aug-2007	Intersection	Motorcycle	Motorcycle			20:50		2					
4		15-Sep-2007	Intersection	Motorcycle	Pickup		10:45			3					
5		13-Oct-2007	Intersection	Pickup	Pickup		14:05			1	1				
6		1-Nov-2007	Intersection	Motorcycle				19:10		1					
7		19-Nov-2007	Intersection	Motorcycle	Pickup		6:10				1				
8		28-Nov-2007	Intersection	Pickup	Van			22:44			3				
9		30-Nov-2007	Intersection	Pickup	Motorcycle		11:45			1					
10		30-Apr-2008	Intersection	Motorcycle	Pickup			19:20		1					
11		2-Aug-2008	Intersection	Motorcycle	10 wheels		18:00			2	1				
12		25-Oct-2008	Intersection	Tricycle	Car		9:57			1					
13		22-Dec-2008	Intersection	Motorcycle			11:39				1				
14		9-Jan-2009	Intersection	Motorcycle	Car			22:43			1				
15		16-Apr-2009	Intersection	Motorcycle			14:16			1					
16		25-Jun-2009	Intersection	Car	Motorcycle		7:50			1					
17		17-Jul-2009	Intersection	Bus	Motorcycle		8:26			1					
18		13-Sep-2009	Intersection	Motorcycle	Pickup		14:58				1				
19		1-Oct-2009	Intersection	Pickup	Pickup		12:48			1	1				
20		19-Nov-2009	Intersection	Pickup	10 wheels			1:47		1					
21	1	13-Dec-2009	43/200 (24+471)	10 wheels		708	8:35			1			404,000	35,000	Slippery roads
22		15-Dec-2009	Intersection	Car	Motorcycle			18:28			1				
23	2	29-Dec-2009	43/200 (24+441)	Car		708		23:30		1			1,000	2,500	Drunkenness
24	3	2-Jan-2010	43/200 (23+856)	Pickup		804		0:05		1			8,000	10,000	High speed driving
25	3	19-Jan-2010	43/200 (23+821)	Trailer		701		1:00					1,000	10,000	Drowsiness
26	2	1-Feb-2010	43/200 (24+183)	Motorcycle	Trailer	301		23:30				2	1,000	45,000	High speed ride
27		15-Feb-2010	Intersection	Motorcycle	10 wheels		9:47			1					
28		19-Feb-2010	Intersection	Motorcycle	Pickup		17:59			1	1				
29		26-Feb-2010	Intersection	Motorcycle	Pickup		11:25				1				
30		26-Feb-2010	Intersection	Motorcycle	10 wheels			20:01			1				
31		2-Mar-2010	43/200 (24+489)	Pickup	Trailer	107		4:45		1	1		5,000	75,000	Mounts the traffic island
32	3	14-Mar-2010	43/200 (24+010)	Trailer		604		20:15		1			67,000	25,000	High speed driving than hit the bridgehead
33		2-Apr-2010	Intersection	Pickup			13:00			1	1				
34	3	13-Apr-2010	43/200 (24+010)	Car	Car	301	14:30			1			1,000	20,000	High speed driving, then rear-end in the same lane

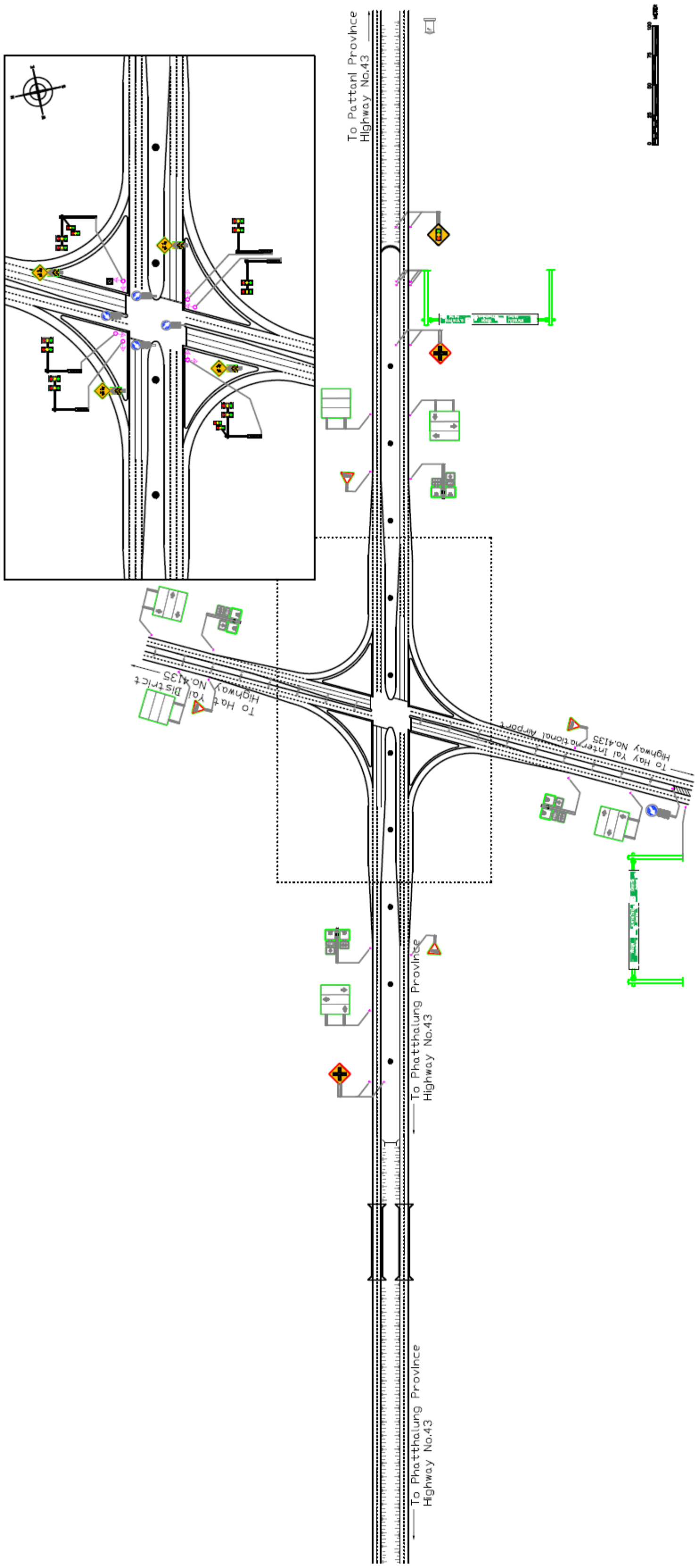
Appendix II – 2: Accident statistics of in-depth case during 2007 – August 2013 (continue)

No	Zone	D/M/Y	Hw/Sta	Vehicle type		Collision	Time			Number of Casualty			DOH	PDO	Cause
			(km.)	Veh 1	Veh 2	Code	Day	Night	Rain	Injury	Serious	Died	damage		
35	2	17-Apr-2010	43/200 (24+750)	Pickup		701			14:20				1,000	2,000	High speed driving
36	2	17-Apr-2010	43/200 (24+625)	Pickup		701			14:40	1			1,000	7,000	High speed driving
37		5-May-2010	Intersection	Car	Trailer		13:00				1				
38	2	14-May-2010	43/200 (24+752)	Pickup		604			14:15	2			8,000	20,000	High speed driving and hits a concrete barrier on the right hand side
39		31-May-2010	Intersection	Motorcycle			15:35			1					
40		31-May-2010	Intersection	Pickup	Motorcycle			20:50			2				
41		1-Jun-2010	Intersection	Motorcycle	6 wheels		11:10			2					
42	2	1-Jun-2010	43/200 (24+170)	Car		704		3:00		1			6,000	20,000	High speed driving, then hit the fixed object at roadside
43		12-Jun-2010	Intersection	Pickup	Motorcycle		7:30				1				
44		26-Jun-2010	Intersection	Motor, Motor, Mot	Pickup		8:15			2					
45		5-Aug-2010	Intersection	10 wheels	Motorcycle		16:56				1				
46		11-Oct-2010	Intersection	Motorcycle	Non			0:23		1					
47	1	21-Nov-2010	43/200 (24+490)	Pickup	Medium truck	101	14:00			1	1		135,000	40,000	Violating speed limit
48		24-Nov-2010	Intersection	Motorcycle	Pickup		16:49			1					
49	2	5-Dec-2010	43/200 (24+120)	Car		708		1:40		1			27,000	50,000	Drowsiness (near temporary U-turn)
50	3	11-Dec-2010	43/200 (23+774)	Car		801		20:30			1	1	1,000	20,000	High speed driving
51	3	13-Dec-2010	43/200 (23+970)	Motorcycle	Trailer	301	12:15				1	1	1,000	45,000	High speed ride and rear-end Trailer in the same lane
52		23-Dec-2010	Intersection	Motorcycle				20:49		1					
53	3	30-Dec-2010	43/200 (23+996)	Car, Car	Car	301			15:50				1,000	30,000	Slippery roads, then rear-end in the same lane
54	2	30-Dec-2010	43/200 (24+101)	Pickup	Pickup	301			16:00				1,000	20,000	High speed driving, then rear-end in the same lane and that time was raining/ slippery roads
55	2	31-Dec-2010	43/200 (24+452)	Car, Car	Car	301			16:20	1			1,000	30,000	High speed driving and Rear-end in the same lane
56		26-Feb-2011	Intersection	Pickup	Trailer		14:20				1				
57	2	13-Jun-2011	43/200 (24+170)	Pickup		701	17:00			1			-	20,000	High speed driving
58	1	5-May-2011	4135/100 (3+360)	Pickup, Car,	Car	200		18:30		3			1,000	30,000	High speed driving and hit the island at the intersection
59		28-Jun-2011	4135/100 (3+325)	Pickup	Motorcycle	202	16:45			1	2		-	40,000	Violation of traffic signals

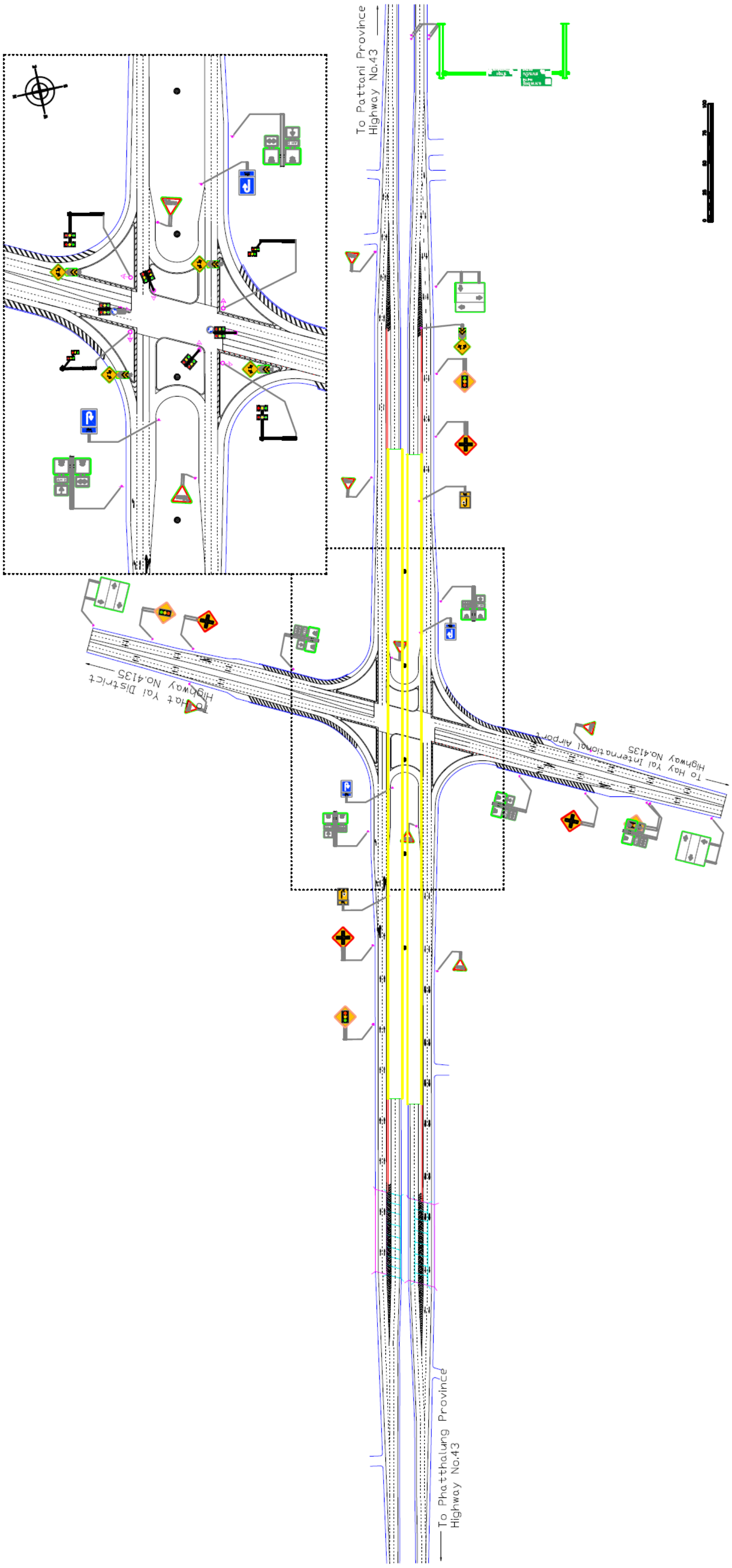
Appendix II – 2: Accident statistics of in-depth case during 2007 – August 2013 (continue)

No	Zone	D/M/Y	Hw/Sta (km.)	Vehicle type		Collision	Time			Number of Casualty			DOH	PDO	Cause
				Veh 1	Veh 2	Code	Day	Night	Rain	Injury	Serious	Died	damage		
60		1-Jul-2011	Intersection	Trailer	Car			4:13		2					
61		19-Jul-2011	Intersection	Motorcycle			16:28				1				
62	2	1-Aug-2011	43/200 (24+738)	Car		704	18:00			1			4,400	45,000	Slippery roads and hit a concrete block on the right hand side of the flyover
63		24-Aug-2011	Intersection	Motorcycle	Motorcycle		8:16			2					
64		5-Sep-2011	Intersection	Motorcycle			13:27			1					
65	1	8-Sep-2011	43/200 (24+495)	Trailer	Trailer	703		23:00		1			25,000	10,000	Slippery roads
66		2-Oct-2011	Intersection	Motorcycle	Car		16:03				1				
67		2-Nov-2011	Intersection	Motorcycle	Car		16:30				1				
68		12-Nov-2011	Intersection	Motorcycle	Van		14:17			1					
69	1	6-Jan-2012	43/200 (24+450)	Motorcycle	Trailer	305	9:00					2	-	1,000	Slippery roads
70		27-Jan-2012	Intersection	Pickup, Pickup	Car, Motor		6:39				1				
71	3	27-Apr-2013		Motorcycle		701	11:30			1					Slippery roads
72	3	6-July-2012		Pickup	Motorcycle	306	8:56			1					Violating speed limit
73	On Fly	3-Aug-2012	On the bridge	Motorcycle		701		19:50		1					Slippery roads
74	On Fly	17-Oct-2012	On the bridge	Motorcycle		701		18:30		1					Slippery roads
75	3	7-Mar-2013		Car	Motorcycle	306		21:52		1					Violating speed limit
76		21-Mar-2013		Motorcycle		701	8:52			2					Slippery roads
77		31-Mar-2013		Motorcycle		701		2:49		1					Slippery roads
78	On Fly	8-Apr-2013	On the bridge	10 wheels	Motorcycle	307		18:58			1				The driver cannot see
79		24-June-2013		Motorcycle		702		19:00		1					Slippery roads

Appendix II – 3: Layout of at-grade intersection (1/2)



Appendix II – 3: Layout of flyover intersection (2/2)



Appendix II – 4: RSA of In-depth case (At-grade intersection)

Ref No.	Road alignment and cross section “ExI Case 01-1”
Location	At the stop lines on HW route 43 (two directions)
Problem Group	Sight distance and pavement markings
Audit Findings	the bush and other obstructions may visually obscured in sight distances. The pavement marking faded and lose the road friction.  
Potential Accident Type	Right angle, rear end or sideswipe collision
Risk Category	Undesirable
Recommendation	Cut the bushes to improve the sight distance, paving a new road surface and paint new marking.

Appendix II – 4: RSA of In-depth case (At-grade intersection) (continue)

Ref No.	Drainage "Exl Case 01-2"
Location	At the intersection
Problem Group	Drainage
Audit Findings	Flooding on road surface due to inadequate drainage or incorrect road levels.  
Potential Accident Type	Vehicles slides out of the road especially motorcycles,
Risk Category	Undesirable
Recommendation	All road users should reduce speed when drive the vehicle pass this location.

Appendix II – 4: RSA of In-depth case (At-grade intersection) (continue)

<table>
<tr><td>Ref No.</td><td>Traffic Sign “ExI Case 01-3”</td></tr>
<tr><td>Location</td><td>Access to the intersection</td></tr>
<tr><td>Problem Group</td><td>Sign</td></tr>
<tr><td>Audit Findings</td><td>There are too many words in the traffic guide signs, road users may be confusion.


</td></tr>
<tr><td>Potential Accident Type</td><td>Rear end in the same lane because of road users reduce speed to read the word</td></tr>
<tr><td>Risk Category</td><td>Tolerable</td></tr>
<tr><td>Recommendation</td><td>Relocate signs or move to another zone</td></tr>
</table>

Appendix II – 4: RSA of In-depth case (At-grade intersection) (continue)

Ref No.	Signal control “ExI Case 01-4”
Location	At an at-grade intersection
Problem Group	Fixed time control plans
Audit Findings	The traffic signalization for intersection was controlled by fixed time control plans. There are two programs a day. The length of one cycle is 244 seconds, is controlled during 06:00 a.m. to 12:00 p.m. (4 phases per one cycle), and controlled by traffic flashers during 00:01 a.m. to 05:59 a.m..  
Potential Accident Type	Side-swipe/crossing collision/ rear-end collision
Risk Category	Tolerable
Recommendation	In the preliminary plan we should design the new of the signal timing phase by depending on the traffic volume in each direction.

Appendix II – 4: RSA of In-depth case (At-grade intersection) (continue)

Ref No.	Pavement markings "ExI Case 01-5"
Location	At the intersection
Problem Group	Pavement markings
Audit Findings	It is not sure about the gap of vehicles when the vehicles entering to intersection. And arrow markings, and pavement markings is faded.  
Potential Accident Type	Sideswipe collision
Risk Category	Tolerable
Recommendation	Paving a new surface and painted new road markings of each leg.

Appendix II – 4: RSA of In-depth case (At-grade intersection) (continue)

Ref No.	Roadside “ExI Case 01-6”
Location	Access to intersection
Problem Group	Clear zones
Audit Findings	Roadside before entering to intersection is not enough clear zones due to the trees and other obstructions fixed near the surface of road about 1 meter.  
Potential Accident Type	run out of the road to crash the trees
Risk Category	Intolerable
Recommendation	Cut the trees off to give the clear zones or install the guardrails for protecting road user that run out of road.

Appendix II – 4: RSA of In-depth case (At-grade intersection) (continue)

Ref No.	Road Surface “ExI Case 01-7”
Location	access to intersection (HW#43)
Problem Group	Damaged road surfaces
Audit Findings	The damage on the surface seems severe alligator cracking and the road may be slippery.  
Potential Accident Type	Rear end in the same lane or sideswipe collision
Risk Category	Intolerable
Recommendation	Paving a new surface and painted new road markings of each leg.

Appendix II – 4: RSA of In-depth case (At-grade intersection) (continue)

Ref No.	Lighting "ExI Case 01-8"
Location	At the intersection
Problem Group	Lighting
Audit Findings	This intersection has 5 spotlights along the highway route 43.  
Potential Accident Type	Rear end collision
Risk Category	Undesirable
Recommendation	It should be installed also on the secondary road.

Appendix II – 4: RSA of In-depth case (At-grade intersection) (continue)

Ref No.	Crosswalk “ExI Case 01-9”
Location	At the intersection
Problem Group	Crosswalk for pedestrians
Audit Findings	Lack of crosswalk for pedestrians of all directions, it only have the stop lines.  
Potential Accident Type	Vehicle hit pedestrians
Risk Category	Undesirable
Recommendation	Install pedestrian crosswalk (zebra crossing)

Appendix II – 4: RSA of In-depth case (At-grade intersection) (continue)

Ref No.	Other problems "ExI Case 01-10"
Location	At the intersection
Problem Group	Illegal movement
Audit Findings	Illegal movement by motorcyclists for crossing, the problem is when a height vehicle speed on the main road pass this area may hit the motorcycle from the near side. 
Potential Accident Type	Hit motorcycle from near side
Risk Category	Intolerable
Recommendation	Install the guardrail or concrete barrier at the median of road in both directions covering to the area for protecting the vehicle from the near side (motorcycle).

Appendix II – 4: RSA of In-depth case (During construction)

Ref No.	Other issues “During Con… Case 02-1.1”
Location	Access to intersection on HW route 43 (two directions)
Problem Group	Road equipment
Audit Findings	Concrete blocks did not cover to the construction zone, it did not protect the road users and construction zones. On the contrary, their different sizes and installed at inappropriate locations.  
Potential Accident Type	Sideswipe collision to fixed rigid objects
Risk Category	Intolerable
Recommendation	“Concrete Blocks” should be installed at appropriate locations, they should clearly show to road users. They should be installed covering the project construction area without the gaps.

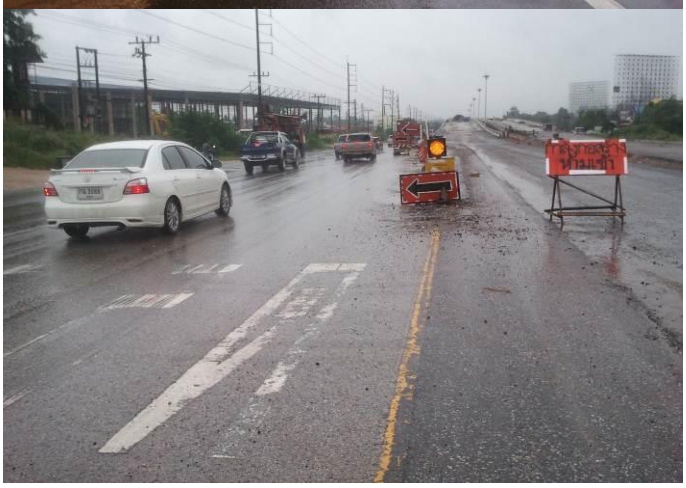
Appendix II – 4: RSA of In-depth case (During construction) (continue)

Ref No.	Other issues "During Con… Case 02-1.2"
Location	Access to intersection (HW#43)
Problem Group	Link road and temporary U-turn
Audit Findings	Near the construction area has a building that constructed at that time. And at the end of flyover construction of both sides, the temporary U-turn was constructed for serving the vehicles as shown in the figure.  
Potential Accident Type	Right angle, rear end or sideswipe collision
Risk Category	Intolerable
Recommendation	Relocate the temporary U-turn to another zone of construction area for protecting road user behaviour that may occur this zone.

Appendix II – 4: RSA of In-depth case (During construction) (continue)

Ref No.	Other issues “During Con… Case 02-1.3”
Location	Access to intersection (HW#43)
Problem Group	Night time's safety
Audit Findings	At the entering and exiting out construction area, the traffic light did not turn on of all lamps and temporary traffic sign is also not standard, not reflective at night time. “Road surface” have potholes and soil aggregates on the road surface. 
Potential Accident Type	Side-swipe/ rear-end collision/ run off road crashes
Risk Category	Intolerable
Recommendation	The “temporary traffic signs” should use standard signs, installed at appropriate and sufficient locations, “Road surface” should not have potholes and soil aggregates on the road surface. And “Street-lights” should be installed consecutively and turned on every night.

Appendix II – 4: RSA of In-depth case (During construction) (continue)

Ref No.	Other issues “During Con… Case 02-1.4”
Location	Access to intersection (HW#43)
Problem Group	Sight distance and Pavement marking
Audit Findings	The sight distances before entering to the intersection, the vision is not clear, background (brown) and text (black). The temporary traffic signs is not clear. The pavement marking is faded and not have the road friction.  
Potential Accident Type	Sideswipe and run out of the road
Risk Category	Tolerable
Recommendation	The “temporary traffic signs” should use the standard signs, install at appropriate point and sufficient.

Appendix II – 4: RSA of In-depth case (During construction) (continue)

Ref No.	Traffic management "During Con… Case 02-2.1"
Location	Access to intersection
Problem Group	Enter and exit of the flyover area
Audit Findings	The temporary traffic sign on background (brown) and text (black) in traffic signs is not clear and standard size.  
Potential Accident Type	Sideswipe and run off road crashes
Risk Category	Tolerable
Recommendation	The "temporary traffic signs" should use the standard signs, installed at appropriate and sufficient locations.

Appendix II – 4: RSA of In-depth case (During construction) (continue)

Ref No.	Traffic management "During Con... Case 02-2.2"
Location	Access to intersection
Problem Group	Speed limit control
Audit Findings	Auditor found only one of the speed limit signs (50 km/h); it was installed on the HW route 43 before access to intersection at 300 meters. 
Potential Accident Type	Sideswipe and run off road crashes
Risk Category	Tolerable
Recommendation	The "temporary speed limit signs" should use standard signs, installed at appropriate and sufficient locations.

Appendix II – 4: RSA of In-depth case (During construction) (continue)

Ref No.	Traffic management "During Con... Case 02-2.3"
Location	At the intersection
Problem Group	Traffic flow
Audit Findings	There are 929 days to construction this project, there are three temporary opened road near the crossroad for traffic flow of all directions, in the area found the concrete block that installed to block the channel of lanes is not continuous, difference dimension and difference gaps. And road surface was not smooth - it is bumpy when raining time, the vehicle may crash of accident.  
Potential Accident Type	Sideswipe / run off road crashes/ rear-end collision
Risk Category	Intolerable
Recommendation	"Concrete Blocks" should installed at appropriate locations, it should clear to show to road users and covering to the project construction without the gaps. "Road surface" should not have pothole and soil aggregates on the road surface.

Appendix II – 4: RSA of In-depth case (During construction) (continue)

Ref No.	Sign and Marking "During Con… Case 02-3.1"
Location	In the construction area
Problem Group	Sign
Audit Findings	The installation of temporary traffic signs was not stable, not enough and insufficient. Traffic signs were not reflective at night and some traffic signs were damaged. Background (brown) and text (black) in traffic signs are not clear and there were traffic signs with different characteristics. 
Potential Accident Type	Rear-end collision, hitting with a fixed object
Risk Category	Intolerable
Recommendation	The "temporary traffic signs" should use the standard signs, installed at appropriate, sufficient locations and reflective at night time.

Appendix II – 4: RSA of In-depth case (During construction) (continue)

Ref No.	Sign and Marking “During Con... Case 02-3.3”
Location	In the construction area
Problem Group	Diversion
Audit Findings	The concrete block that installed to block the channel of lanes is not continuous, it is difference dimension and difference gaps, not standard, not reflection at night and some of electric light did not turn on at night.  
Potential Accident Type	Sideswipe and run off road crashes
Risk Category	Intolerable
Recommendation	The “temporary traffic signs” should use standard signs, installed at appropriate, sufficient locations and reflective at night. “Concrete Blocks” should installed at appropriate locations, they should clearly show to road users, and should installed covering the construction project area without the gaps.

Appendix II – 4: RSA of In-depth case (During construction) (continue)

Ref No.	Signal control “During Con... Case 02-4.1”
Location	At the flyover area
Problem Group	Fixed time control plans
Audit Findings	The traffic signal control that was controlled have 4 phases per cycle, it consisted of 2 programs a day; the first program 254 seconds (operating from 06:00 am to 12:00 pm. The second program was controlled by flashing amber, it was controlled from 00:00 am to 06:00 am.  
Potential Accident Type	Rear-end collision, crossing collision
Risk Category	Tolerable
Recommendation	In the field work should have a traffic engineering staff to control in the peak time of the day, and set the new cycle time by depending on traffic volume in each leg

Appendix II – 4: RSA of In-depth case (During construction) (continue)

Ref No.	Pedestrian and ride cycle "During Con… Case 02-5.1"
Location	At the intersection
Problem Group	Pedestrian crossing
Audit Findings	In the area not found the line for pedestrian, there were scraps on the shoulder of the road, furthermore did not the barrier blocked. 
Potential Accident Type	Vehicles hit pedestrians
Risk Category	Tolerable
Recommendation	Install pedestrian lines at the construction area and at unsafe locations.

Appendix II – 4: RSA of In-depth case (During construction) (continue)

<table>
<tr><td>Ref No.</td><td>Pavement “During Con… Case 02-6.1”</td></tr>
<tr><td>Location</td><td>At the flyover area</td></tr>
<tr><td>Problem Group</td><td>Pavement</td></tr>
<tr><td>Audit Findings</td><td>Road surface was not smooth and it’s bumpy. There was water on the surface, mud mound, soil, and raw aggregates after raining.

</td></tr>
<tr><td>Potential Accident Type</td><td>Rear-end collision</td></tr>
<tr><td>Risk Category</td><td>Tolerable</td></tr>
<tr><td>Recommendation</td><td>“Road surfaces” were not smooth and it is bumpy. These problem areas should use the motor grader prove these surface.</td></tr>
</table>

Appendix II – 4: RSA of In-depth case (During construction) (continue)

Ref No.	Pavement “During Con... Case 02-6.2”
Location	Flyover area
Problem Group	Flooding on the surface
Audit Findings	“Road surfaces” were not smooth, the mud mound on the shoulder of the road made always a problem when raining.  
Potential Accident Type	Sideswipe and run off road crashes
Risk Category	Tolerable
Recommendation	“Road surface” should not have potholes and soil aggregates on the road surface or installing drains.

Appendix II – 4: RSA of In-depth case (After construction)

Ref No.	Road alignment and cross section “ExI Case 03-1”
Location	Access to intersection on HW route 43 (two directions)
Problem Group	Sight distance and pavement markings
Audit Findings	The sight distances before entering an intersection, the vision is not clear, traffic signs could not be seen clearly. It was obscured visibility by trees. The marking on surface found only one point.  
Potential Accident Type	Sideswipe collision
Risk Category	Undesirable
Recommendation	Trim the trees to clear for road users, provide the guidelines for entering to the intersection more than one point for road users.

Appendix II – 4: RSA of In-depth case (After construction) (continue)

Ref No.	Drainage "ExI Case 03-2"
Location	At the intersection and on the bridge
Problem Group	Drainage
Audit Findings	Insufficient drainage or incorrect road slopes-levels, there was mud mound, soil, and raw aggregates on the surface of road after raining, many time this scrap to block the charnel water.  
Potential Accident Type	Vehicle slides on the surface road
Risk Category	Undesirable
Recommendation	Remove raw aggregates and other scrap on the surface of road, ensure adequate drainage at this location by changing road levels or installing drains.

Appendix II – 4: RSA of In-depth case (After construction) (continue)

Ref No.	Traffic Sign "ExI Case 03-3"
Location	Entrance of intersection
Problem Group	Sign
Audit Findings	There are to many the same of traffic signs, too many words to read.  
Potential Accident Type	Road users confused
Risk Category	Tolerable
Recommendation	Relocate signs to another zone or remove.

Appendix II – 4: RSA of In-depth case (After construction) (continue)

Ref No.	Signal control "ExI Case 03-4"
Location	At the intersection
Problem Group	Fixed time control plans
Audit Findings	The traffic signal control was controlled by 4 phases per cycle. It consists of 2 programs a day; the first program is 224 seconds, it was operated from 06:00 am to 12:00 pm. The second program was controlled by flashing light; it was operated from 00:00 am to 06:00 am.  
Potential Accident Type	Rear-end collision, crossing collision
Risk Category	Tolerable
Recommendation	Design a new phase of traffic signal by depending on the traffic volume in each direction.

Appendix II – 4: RSA of In-depth case (After construction) (continue)

Ref No.	Pavement markings “Exl Case 03-5”
Location	At the intersection
Problem Group	Markings on road surface
Audit Findings	Markings are faded, there was rock scrap on the surface of road.  
Potential Accident Type	Rear-end collision, Vehicle slides on the surface road
Risk Category	Tolerable
Recommendation	Remove raw aggregates and other scrap on the surface of road.

Appendix II – 4: RSA of In-depth case (After construction) (continue)

Ref No.	Sideways "ExI Case 03-6"
Location	Access to intersection
Problem Group	Clear zones
Audit Findings	Near the shoulder of road about 1 foot there are the electricity posts and traffic sign column (as shown on figure below mark), and about 1 meter length from trees and surface road before approaching to an intersection.  
Potential Accident Type	Vehicle hit columns or fixed objects near road area
Risk Category	Undesirable
Recommendation	Relocate the columns to appropriate point or install the grade rail for protecting vehicles that may run off the road.

Appendix II – 4: RSA of In-depth case (After construction) (continue)

Ref No.	Sideways “Exl Case 03-6.1”
Location	Entrance of intersection
Problem Group	Clear zones
Audit Findings	At the roadside did not have the grade rail or barrier to protect vehicles that may run off the road, and at the end of a bridge (as show in the figure below) of canal did not have protection for road users.  
Potential Accident Type	Vehicle hit the end of bridge or run off road crashes
Risk Category	Tolerable
Recommendation	Install the grade rail to protect vehicles and road users that may run off the road or through hit the end of the canal bridge.

Appendix II – 4: RSA of In-depth case (After construction) (continue)

Ref No.	Link road “ExI Case 03-7”
Location	Access to intersection (HW#43)
Problem Group	Link road on the flyover area
Audit Findings	There was link road to the shop near the intersection and not have the auxiliary road for turn left to the shop. 
Potential Accident Type	Rear end collision
Risk Category	Tolerable
Recommendation	Change to another side or make the life auxiliary lane to the shop.

Appendix II – 4: RSA of In-depth case (After construction) (continue)

Ref No.	Lighting “ExI Case 03-8”
Location	At the intersection
Problem Group	Lighting
Audit Findings	This intersection have 5 spotlights along the highway route 43.  
Potential Accident Type	Rear end collision
Risk Category	Undesirable
Recommendation	Should also install on the secondary road.

Appendix II – 4: RSA of In-depth case (After construction) (continue)

Ref No.	Crosswalk “ExI Case 03-9”
Location	At the intersection
Problem Group	Crosswalk for pedestrians
Audit Findings	Lack of crosswalk for pedestrians of all directions, it only has stopped lines at the waiting areas.  
Potential Accident Type	Vehicle hit pedestrians
Risk Category	Undesirable
Recommendation	Install pedestrian crosswalk (zebra crossing)

Appendix II – 4: RSA of In-depth case (After construction) (continue)

Ref No.	Other problems "ExI Case 03-10"
Location	Under the bridge
Problem Group	U-turn and kerb corner under the bridge
Audit Findings	The average radius of the U-turn is about 12 meters, it was constructed for serving only the vehicles 2-4 wheels and at the exiting zone of this U-turn (no control) is one hazardous area. At the kerb-corner (as marked in the picture below) is one of hazardous points, when the vehicles right turn from the secondary road has not the gap between the vehicles of two channels (may occur the crash accidents and competition of the vehicles to pass this area) and not enough space for the angle of the trailers.  
Potential Accident Type	Sideswipe collision and vehicles hit kerb corner
Risk Category	Tolerable
Recommendation	The radius at the kerb-corner and U-turn under the bridge should be designed by depending on turning radius of the trailer, and painted or highlighted the line of road lane to guide the road user.

Appendix II – 4: RSA of In-depth case (After construction) (continue)

Ref No.	Other problems "ExI Case 03-10.1"
Location	Flyover area
Problem Group	Auxiliary lane
Audit Findings	At the exiting zone of this U-turn is one of the hazardous zone because it has no control. When vehicles exit out from the U-turn and from the intersection and at the merging zone between road from the bridge and road from the intersection will compete to pass this zone, may crash of accident by sideswipe.  
Potential Accident Type	Sideswipe and rear end collision
Risk Category	Tolerable
Recommendation	At the U-turn under the bridge should install a traffic sign to allow only 2-4 wheels vehicle and "GIVE WAY". At the merge zone should install the PVC orange reflective flexible traffic warning post to divide of the lane and install the sign "GIVE WAY" at this area too.

Appendix II – 4: RSA of In-depth case (After construction) (continue)

Ref No.	Other problems “ExI Case 03-10.2”
Location	At the intersection
Problem Group	U-turn and right turning of traffic movement
Audit Findings	At the stopped line, when vehicle wait a phase time of the traffic signal on the more than five vehicles or 20 meters, this channel will be blocked. And at the crossroad did not have the guide of road line.  
Potential Accident Type	Sideswipe and rear end collision
Risk Category	Tolerable
Recommendation	Painted or highlighted the line of road lane to guide the road user on the intersection area.

Appendix II – 5: Input data for example case 1-hour of flyover situations

INPUT REPORT

Site: New Site - 1

HDY 01 (In-Depth Case)

Intersection Parameters	
Title	HDY 01 (In-Depth Case)
Intersection ID	HDY 01
Unit Time (for volumes)	60 minutes
Peak Flow Period (for performance)	30 minutes
Signal Analysis Method	Fixed Time

Geometry - Approach Data

Location	Name	Type	No. of App. Lanes	No. of Exit Lanes	Median Width m	Extra Bunching %
South	HW route #4135 to airport	Two-way	4	3	2.00	0.0
East	HW route #43 to Phattani	Two-way	4	3	31.00	0.0
North	HW route #4135 to HDY city	Two-way	4	3	2.00	0.0
West	HW route 43 to Phattalung	Two-way	4	3	31.00	0.0

Geometry - Approach Lane Data - Signalised

Lane Number	Lane Type	Lane Discip.	Basic Satn Flow tcu/h	Utilisation Ratio %	Saturation Speed km/h	Capacity Adjustment %	Buses Stopping veh/h	Parking Man. veh/h	SL Green Constraint	Free Queue L veh	T veh	R veh
South	HW route #4135 to airport											
App. Lane 1	Continuous	L	1950	–	–	0.0	–	–	No	0	0	0
App. Lane 2	Normal	T	1950	–	–	0.0	2	–	No	0	0	0
App. Lane 3	Normal	T	1950	–	–	0.0	2	–	No	0	0	0
App. Lane 4	Normal	R	1950	–	–	0.0	2	–	No	0	0	0
East	HW route #43 to Phattani											
App. Lane 1	Continuous	L	1950	–	–	0.0	–	–	No	0	0	0
App. Lane 2	Normal	T	1950	–	–	0.0	–	–	No	0	0	0
App. Lane 3	Normal	T	1950	–	–	0.0	–	–	No	0	0	0
App. Lane 4	Normal	R	1950	–	–	0.0	3	–	No	0	0	0
North	HW route #4135 to HDY city											
App. Lane 1	Continuous	L	1950	–	–	0.0	–	–	No	0	0	0
App. Lane 2	Normal	T	1950	–	–	0.0	–	–	No	0	0	0
App. Lane 3	Normal	T	1950	–	–	0.0	2	–	No	0	0	0
App. Lane 4	Normal	R	1950	–	–	0.0	–	–	No	0	0	0
West	HW route 43 to Phattalung											
App. Lane 1	Continuous	L	1950	–	–	0.0	–	–	No	0	0	0
App. Lane 2	Normal	T	1950	–	–	0.0	–	–	No	0	0	0
App. Lane 3	Normal	T	1950	–	–	0.0	–	–	No	0	0	0
App. Lane 4	Normal	R	1950	–	–	0.0	1	–	No	0	0	0

Appendix II – 5: Input data for example case 1-hour of flyover situations (continue)

Geometry - Approach & Exit Lane Data

Lane Number	Lane Width m	Lane Length m	Grade %	SL Type
South	HW route #4135 to airport			
App. Lane 1	3.50	100.0	0.00	–
App. Lane 2	3.50	500.0	0.00	–
App. Lane 3	3.50	500.0	0.00	–
App. Lane 4	3.50	500.0	0.00	–
Exit Lane 1	3.30	500.0	0.00	–
Exit Lane 2	3.30	500.0	0.00	–
Exit Lane 3	3.30	500.0	0.00	–
East	HW route #43 to Phattani			
App. Lane 1	3.50	120.0	0.00	–
App. Lane 2	3.50	500.0	0.00	–
App. Lane 3	3.50	500.0	0.00	–
App. Lane 4	3.50	500.0	0.00	–
Exit Lane 1	3.30	500.0	0.00	–
Exit Lane 2	3.30	500.0	0.00	–
Exit Lane 3	3.30	500.0	0.00	–
North	HW route #4135 to HDY city			
App. Lane 1	3.50	100.0	0.00	–
App. Lane 2	3.50	500.0	0.00	–
App. Lane 3	3.50	500.0	0.00	–
App. Lane 4	3.50	500.0	0.00	–
Exit Lane 1	3.30	500.0	0.00	–
Exit Lane 2	3.30	500.0	0.00	–
Exit Lane 3	3.30	500.0	0.00	–
West	HW route 43 to Phattalung			
App. Lane 1	3.50	120.0	0.00	–
App. Lane 2	3.50	500.0	0.00	–
App. Lane 3	3.50	500.0	0.00	–
App. Lane 4	3.50	500.0	0.00	–
Exit Lane 1	3.30	500.0	0.00	–
Exit Lane 2	3.30	500.0	0.00	–
Exit Lane 3	3.30	500.0	0.00	–

Lanes are numbered from left to right in the direction of travel.

Geometry - Movement Definitions

To Approach	Movement Banned	Turn Desig.
From: South	HW route #4135 to airport	
West	No	L
North	No	T
East	No	R
South	Yes	–
From: East	HW route #43 to Phattani	
South	No	L
West	No	T
North	No	R
East	Yes	–
From: North	HW route #4135 to HDY city	
East	No	L
South	No	T
West	No	R
North	Yes	–
From: West	HW route 43 to Phattalung	
North	No	L
East	No	T
South	No	R
West	Yes	–

Appendix II – 5: Input data for example case 1-hour of flyover situations (continue)

Volumes

To Approach	Total veh	HV %	Peak Flow Factor %	Vehicle Occupancy pers/veh	Flow Scale %	Growth Rate %/year
From: South	HW route #4135 to airport					
West	79.0	5.00	95.0	1.20	100.00	2.00
North	600.0	7.00	95.0	1.20	100.00	2.00
East	925.0	8.00	95.0	1.20	100.00	2.00
From: East	HW route #43 to Phattani					
South	419.0	7.00	95.0	1.20	100.00	2.00
West	31.0	25.00	95.0	1.20	100.00	2.00
North	359.0	15.00	95.0	1.20	100.00	2.00
From: North	HW route #4135 to HDY city					
East	590.0	12.00	95.0	1.20	100.00	2.00
South	715.0	8.00	95.0	1.20	100.00	2.00
West	36.0	22.00	95.0	1.20	100.00	2.00
From: West	HW route 43 to Phattalung					
North	35.0	15.00	95.0	1.20	100.00	2.00
East	9.0	25.00	95.0	1.20	100.00	2.00
South	148.0	14.00	95.0	1.20	100.00	2.00

Path Data

To Approach	App. Cruise Speed km/h	Exit Cruise Speed km/h	App. Trav. Distance m	Negn Speed km/h	Negn Distance m	Downst. Distance m	Negn Radius m
From: South	HW route #4135 to airport						
West	60.0	60.0	500.0	–	–	–	–
North	60.0	60.0	500.0	–	–	–	–
East	60.0	60.0	500.0	–	–	–	–
From: East	HW route #43 to Phattani						
South	60.0	60.0	500.0	–	–	–	–
West	60.0	60.0	500.0	–	–	–	–
North	60.0	60.0	500.0	–	–	–	–
From: North	HW route #4135 to HDY city						
East	60.0	60.0	500.0	–	–	–	–
South	60.0	60.0	500.0	–	–	–	–
West	60.0	60.0	500.0	–	–	–	–
From: West	HW route 43 to Phattalung						
North	60.0	60.0	500.0	–	–	–	–
East	60.0	60.0	500.0	–	–	–	–
South	60.0	60.0	500.0	–	–	–	–

Appendix II – 5: Input data for example case 1-hour of flyover situations (continue)

Movement Data - General

Turn	Mov. ID	Queue Space LV m	Queue Space HV m	Vehicle Length LV m	Vehicle Length HV m	HVE	P.Deg. Satn	Movement Type	Movement Control
South	HW route #4135 to airport								
L	7	7.00	13.00	4.50	10.00	2.00	–	*Cont.*	–
T	8	7.00	13.00	4.50	10.00	2.00	–	*Normal*	–
R	9	7.00	13.00	4.50	10.00	2.00	–	*Normal*	–
East	HW route #43 to Phattani								
L	10	7.00	13.00	4.50	10.00	2.00	–	*Cont.*	–
T	11	7.00	13.00	4.50	10.00	2.00	–	*Normal*	–
R	12	7.00	13.00	4.50	10.00	2.00	–	*Normal*	–
North	HW route #4135 to HDY city								
L	1	7.00	13.00	4.50	10.00	2.00	–	*Cont.*	–
T	2	7.00	13.00	4.50	10.00	2.00	–	*Normal*	–
R	3	7.00	13.00	4.50	10.00	2.00	–	*Normal*	–
West	HW route 43 to Phattalung								
L	4	7.00	13.00	4.50	10.00	2.00	–	*Cont.*	–
T	5	7.00	13.00	4.50	10.00	2.00	–	*Normal*	–
R	6	7.00	13.00	4.50	10.00	2.00	–	*Normal*	–

Movement Type and Control parameters are set automaticly from Approach Control and Lane Type data in the Geometry dialog.

Movement Data - Signalised

Turn	Mov. ID	Signal Coord. Type	Signal Coord. PG %	Non-Actuated	Turn On Red	Turn Adjustment Type	Turn Adjustment Radius m	Pedestrian Effect Method	Pedestrian Effect St. Loss sec
South	HW route #4135 to airport								
L	7	–	–	–	–	Normal	–	–	–
T	8	3	–	–	–	Normal	–	–	–
R	9	3	–	–	–	Normal	–	St. Loss	0
East	HW route #43 to Phattani								
L	10	–	–	–	–	Normal	–	–	–
T	11	3	–	–	–	Normal	–	–	–
R	12	3	–	–	–	Normal	–	St. Loss	0
North	HW route #4135 to HDY city								
L	1	–	–	–	–	Normal	–	–	–
T	2	3	–	–	–	Normal	–	–	–
R	3	3	–	–	–	Normal	–	St. Loss	0
West	HW route 43 to Phattalung								
L	4	–	–	–	–	Normal	–	–	–
T	5	3	–	–	–	Normal	–	–	–
R	6	3	–	–	–	Normal	–	St. Loss	0

Priorities

Opposed Movement	Opposing Movements South	South East	East	North East	North	North West	West	South West
South	HW route #4135 to airport							
R	–	–	–	–	T	–	–	–
East	HW route #43 to Phattani							
R	–	–	–	–	–	–	T	–
North	HW route #4135 to HDY city							
R	T	–	–	–	–	–	–	–
West	HW route 43 to Phattalung							
R	–	–	T	–	–	–	–	–

Appendix II – 5: Input data for example case 1-hour of flyover situations (continue)

Gap Acceptance

Movement		Critical Gap sec	Follow-up Headway sec	End Departures veh	Exiting Flow Effect %
South	HW route #4135 to airport				
R		4.500	2.600	2.20	0
East	HW route #43 to Phattani				
R		4.500	2.600	2.20	0
North	HW route #4135 to HDY city				
R		4.500	2.600	2.20	0
West	HW route 43 to Phattalung				
R		4.500	2.600	2.20	0

Pedestrians

Mov. ID	Volume ped	Peak Flow %	Flow Scale %	Growth Rate %/year	Crossing Distance m	App. Trav. Distance m	Downst. Distance m	Walking Speed m/sec	Queue Space m	P.Deg. Satn	Satn Flow ped/h
South	HW route #4135 to airport										
P5	5.0	95.0	100.00	2.00	–	10.0	10.0	1.30	1.00	–	20
East	HW route #43 to Phattani										
P7	5.0	95.0	100.00	2.00	–	10.0	10.0	1.30	1.00	0.900	20
North	HW route #4135 to HDY city										
P1	5.0	95.0	100.00	2.00	–	10.0	10.0	1.30	1.00	–	20
West	HW route 43 to Phattalung										
P3	5.0	95.0	100.00	2.00	–	10.0	10.0	1.30	1.00	–	20

Phasing Data

Current Sequence: Split Phasing

Name	Phase Time	Yellow Time	All-Red Time	Dummy Movement Parameters			Movements Running in Phase							
				Specified	Min Green	Max Green	S	SE	E	NE	N	NW	W	SW
	sec	sec	sec		sec	sec								
A (W-E)	40	4	2	No	–	–	L	–	L	–	L,P1	–	LTR	–
B (E-W)	40	4	2	No	–	–	L,P5	–	LTR	–	L	–	L	–
C (N-S)	60	4	2	No	–	–	L	–	L,P7	–	LTR	–	L	–
D (S-N)	60	4	2	No	–	–	LTR	–	L	–	L	–	L,P3	–

Sequence Data

Current Sequence	Split Phasing
Cycle Time Option	Practical Cycle Time
Max Cycle Time	224 sec
Cycle Rounding	2 sec
Green Split Option	
Green Split Priority	No

Appendix II – 5: Input data for example case 1-hour of flyover situations (continue)

Movement Timing Data – Vehicles

Current Sequence: Split Phasing

Turn	Mov. ID	Start Loss sec	End Gain sec	Min Green sec	Max Green sec
South	HW route #4135 to airport				
L	7	3	3	–	–
T	8	3	3	–	–
R	9	3	3	–	–
East	HW route #43 to Phattani				
L	10	3	3	–	–
T	11	3	3	–	–
R	12	3	3	–	–
North	HW route #4135 to HDY city				
L	1	3	3	–	–
T	2	3	3	–	–
R	3	3	3	–	–
West	HW route 43 to Phattalung				
L	4	3	3	–	–
T	5	3	3	–	–
R	6	3	3	–	–

Movement Timing Data – Pedestrians

Current Sequence: Split Phasing

Mov. ID	Min Green sec	Max Green sec	Crossing Speed m/sec	Min Walk Time sec	Min Clearance Time sec	Clearance Time Overlap sec	Start Loss sec	End Gain sec
South	HW route #4135 to airport							
P5	–	–	1.20	5	5	2	2	3
East	HW route #43 to Phattani							
P7	–	–	1.20	5	5	2	2	3
North	HW route #4135 to HDY city							
P1	–	–	1.20	5	5	2	2	3
West	HW route 43 to Phattalung							
P3	–	–	1.20	5	5	2	2	3

Appendix II – 5: Input data for example case 1-hour of flyover situations (continue)

Model Settings - Options	
General Options	
Level of Service Method	Delay (HCM 2000)
Level of Service Target	LOS D
Performance Measure	Delay
Percentile Queue	95 %
Hours per Year	480 h
Gap Acceptance	
HV Method for Gap-Acceptance	Include HV Effect if above 5 per cent
Gap-Acceptance Capacity	SIDRA Standard (Akçelik M3D)
HCM Delay Formula	Yes
HCM Queue Formula	Yes
Downstream Short Lane Model	
Minimum Downstream Utilisation Ratio	20 %
Minimum Downstream Distance	30 m
Distance for Full Lane Utilisation	200 m
Calibration Parameter	1.2

Model Settings - Cost Parameters	
Vehicle Operating Cost	
Cost Unit	THB
Pump Price of Fuel	40.000 THB/L
Fuel Resource Cost Factor	0.500
Ratio of Running Cost to Fuel Cost	3.00
Vehicle Mass	
Light Vehicle Mass	1400.0 kg
Heavy Vehicle Mass	11000.0 kg
Heavy Vehicle Maximum Power	130 kW
Time Cost	
Average Income	35.00 THB/h
Time Value Factor	0.600

Demand & Sensitivity	
Analysis Method: Design Life	
Design Life Analysis Objective	Practical Capacity (v/c ratio = xp)
Growth Model	Uniform
Number of Years	20

Site Properties	
Site (Intersection) Type	Signals
Model Name	Standard Left
Drive Rule	Left-hand side of the road
New Zealand Rule	No
HCM Version	No
Units	Metric

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SIDRA INTERSECTION 5.1.9.2068
Project: E:\Data of Windows 2\In-Depth Case HDY 01.sip
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SIDRA INTERSECTION

Appendix II – 6: Output data for example case 1-hour of flyover situations (17:00 – 18:00), situations of fixed-time plan (244 sec/cycle)

INTERSECTION SUMMARY

Site: New Site - 1

HDY 01
Signals - Fixed Time Cycle Time = 224 seconds (User-Given Phase Times)
Design Life Analysis (Practical Capacity): Results for 0 years

Intersection Performance - Hourly Values

Performance Measure	Vehicles	Pedestrians	Persons
Demand Flows (Total)	4019 veh/h	6 ped/h	4829 pers/h
Percent Heavy Vehicles	12.9 %		
Degree of Saturation	1.565	0.509	
Practical Spare Capacity	-42.5 %		
Effective Intersection Capacity	2568 veh/h		
Control Delay (Total)	116.00 veh-h/h	0.12 ped-h/h	139.32 pers-h/h
Control Delay (Average)	103.9 sec	74.4 sec	103.9 sec
Control Delay (Worst Lane)	384.3 sec		
Control Delay (Worst Movement)	332.4 sec	91.1 sec	332.4 sec
Geometric Delay (Average)	4.5 sec		
Stop-Line Delay (Average)	99.4 sec		
Intersection Level of Service (LOS)	LOS F	LOS F	
95% Back of Queue - Vehicles (Worst Lane)	86.5 veh		
95% Back of Queue - Distance (Worst Lane)	594.3 m		
Total Effective Stops	3499 veh/h	5 ped/h	4204 pers/h
Effective Stop Rate	0.87 per veh	0.81 per ped	0.87 per pers
Proportion Queued	0.64	0.81	0.64
Performance Index	379.9	0.2	380.1
Travel Distance (Total)	2470.5 veh-km/h	0.2 ped-km/h	2964.8 pers-km/h
Travel Distance (Average)	615 m	37 m	614 m
Travel Time (Total)	158.7 veh-h/h	0.2 ped-h/h	190.6 pers-h/h
Travel Time (Average)	142.2 sec	102.6 sec	142.1 sec
Travel Speed	15.6 km/h	1.3 km/h	15.6 km/h
Cost (Total)	30785.69 Baht/h	10.25 Baht/h	30795.94 Baht/h
Fuel Consumption (Total)	535.2 L/h		
Carbon Dioxide (Total)	1346.0 kg/h		
Hydrocarbons (Total)	2.271 kg/h		
Carbon Monoxide (Total)	85.96 kg/h		
NOx (Total)	2.662 kg/h		

Level of Service (LOS) Method: Delay (HCM 2000).
Intersection LOS value for Vehicles is based on average delay for all vehicle movements.
Intersection LOS value for Pedestrians is based on average delay for all pedestrian movements.
SIDRA Standard Delay Model used.

Intersection Performance - Annual Values

Performance Measure	Vehicles	Pedestrians	Persons
Demand Flows (Total)	1,929,095 veh/y	2,880 ped/y	2,317,794 pers/y
Delay	55,680 veh-h/y	60 ped-h/y	66,876 pers-h/y
Effective Stops	1,679,494 veh/y	2,340 ped/y	2,017,733 pers/y
Travel Distance	1,185,819 veh-km/y	106 ped-km/y	1,423,089 pers-km/y
Travel Time	76,190 veh-h/y	82 ped-h/y	91,511 pers-h/y
Cost	14,777,130 Baht/y	4,918 Baht/y	14,782,050 Baht/y
Fuel Consumption	256,918 L/y		
Carbon Dioxide	646,088 kg/y		
Hydrocarbons	1,090 kg/y		
Carbon Monoxide	41,260 kg/y		
NOx	1,278 kg/y		

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Project: E:\In depth 12 hr\17-18.sip

SIDRA INTERSECTION

Appendix II – 6: Output data for example case 1-hour of flyover situations (17:00 – 18:00), situations of fixed-time plan (244 sec/cycle) (continue)

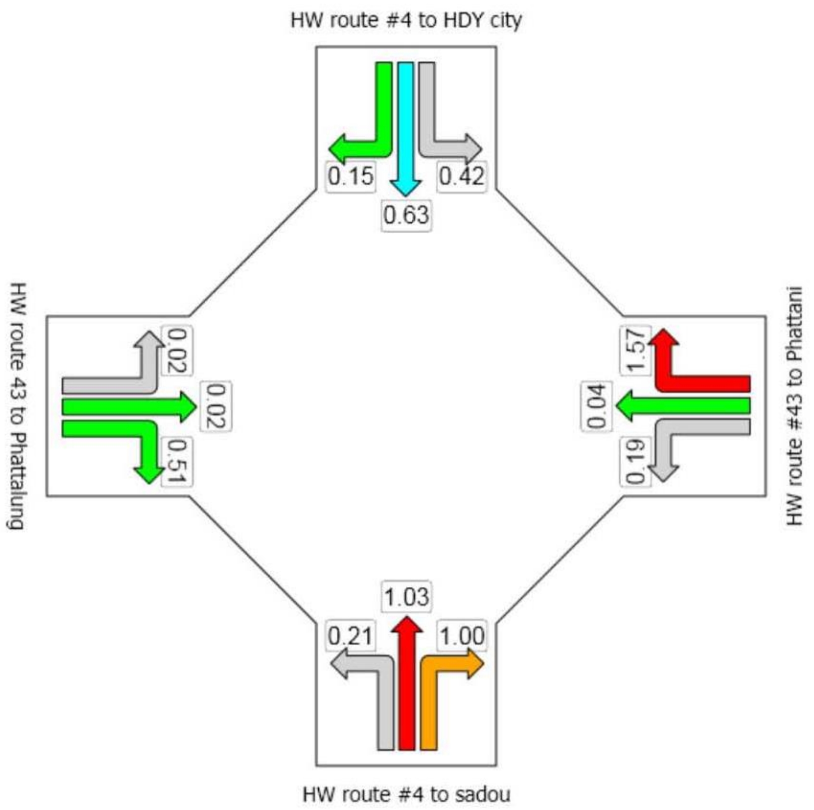
Unlicensed Trial Version

DEGREE OF SATURATION

Ratio of Demand Volume to Capacity (v/c ratio)

Site: New Site - 1

HDY 01
Signals - Fixed Time Cycle Time = 224 seconds (User-Given Phase Times)
Design Life Analysis (Practical Capacity): Results for 0 years



	South	East	North	West	Intersection
Degree of Saturation	1.03	1.57	0.63	0.51	1.57

Colour code based on Degree of Saturation

[< 0.6] [0.6 – 0.7] [0.7 – 0.8] [0.8 – 0.9] [0.9 – 1.0] [> 1.0] Continuous

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SIDRA INTERSECTION

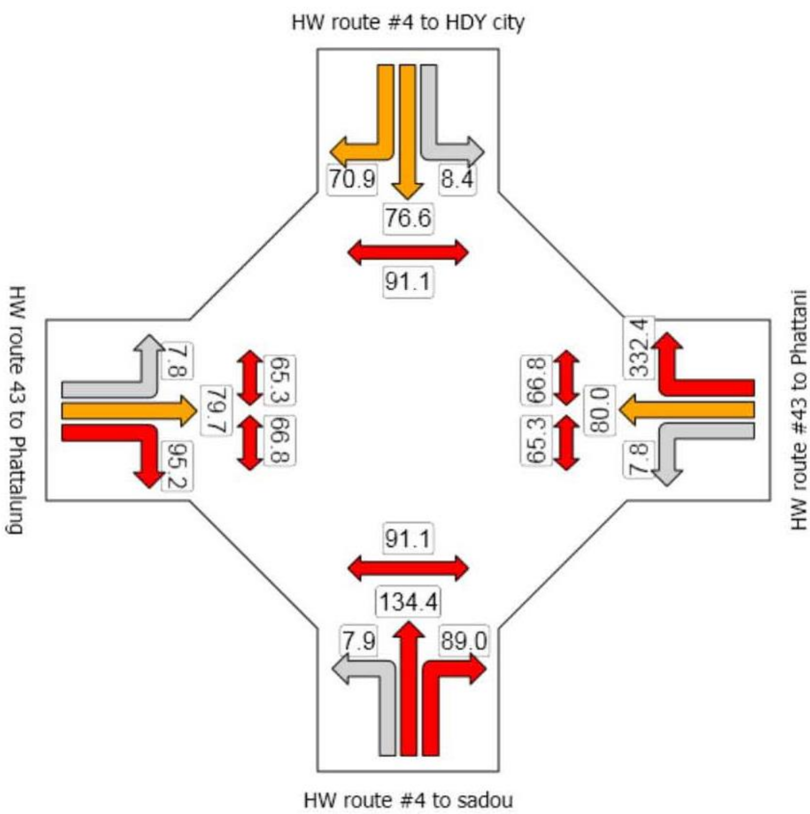
Appendix II – 6: Output data for example case 1-hour of flyover situations (17:00 – 18:00), situations of fixed-time plan (244 sec/cycle) (continue)

Unlicensed Trial Version

DELAY (AVERAGE) **Site: New Site - 1**

Average control delay per vehicle, or average pedestrian delay (seconds)

HDY 01
Signals - Fixed Time Cycle Time = 224 seconds (User-Given Phase Times)
Design Life Analysis (Practical Capacity): Results for 0 years



	South	East	North	West	Intersection
Delay (Average)	100.5	206.4	42.6	80.2	103.9
LOS	F	F	D	F	F

Colour code based on Level of Service

LOS A LOS B LOS C LOS D LOS E LOS F Continuous

Level of Service Method: Delay (HCM 2000)
Pedestrian Level of Service Method: SIDRA Pedestrian LOS Method (Based on Average Delay)
SIDRA Standard Delay Model used.

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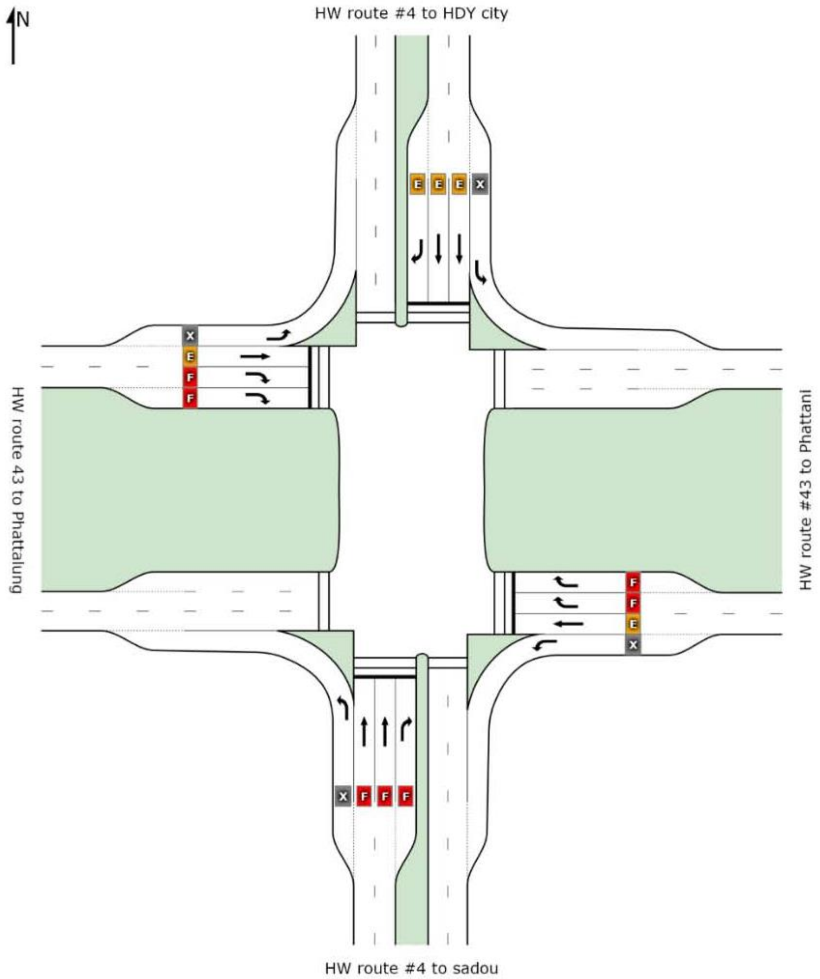
SIDRA INTERSECTION

Appendix II – 6: Output data for example case 1-hour of flyover situations (17:00 – 18:00), situations of fixed-time plan (244 sec/cycle) (continue)

Unlicensed Trial Version

LEVEL OF SERVICE SUMMARY Site: New Site - 1

HDY 01
Signals - Fixed Time   Cycle Time = 224 seconds (User-Given Phase Times)
Design Life Analysis (Practical Capacity): Results for 0 years

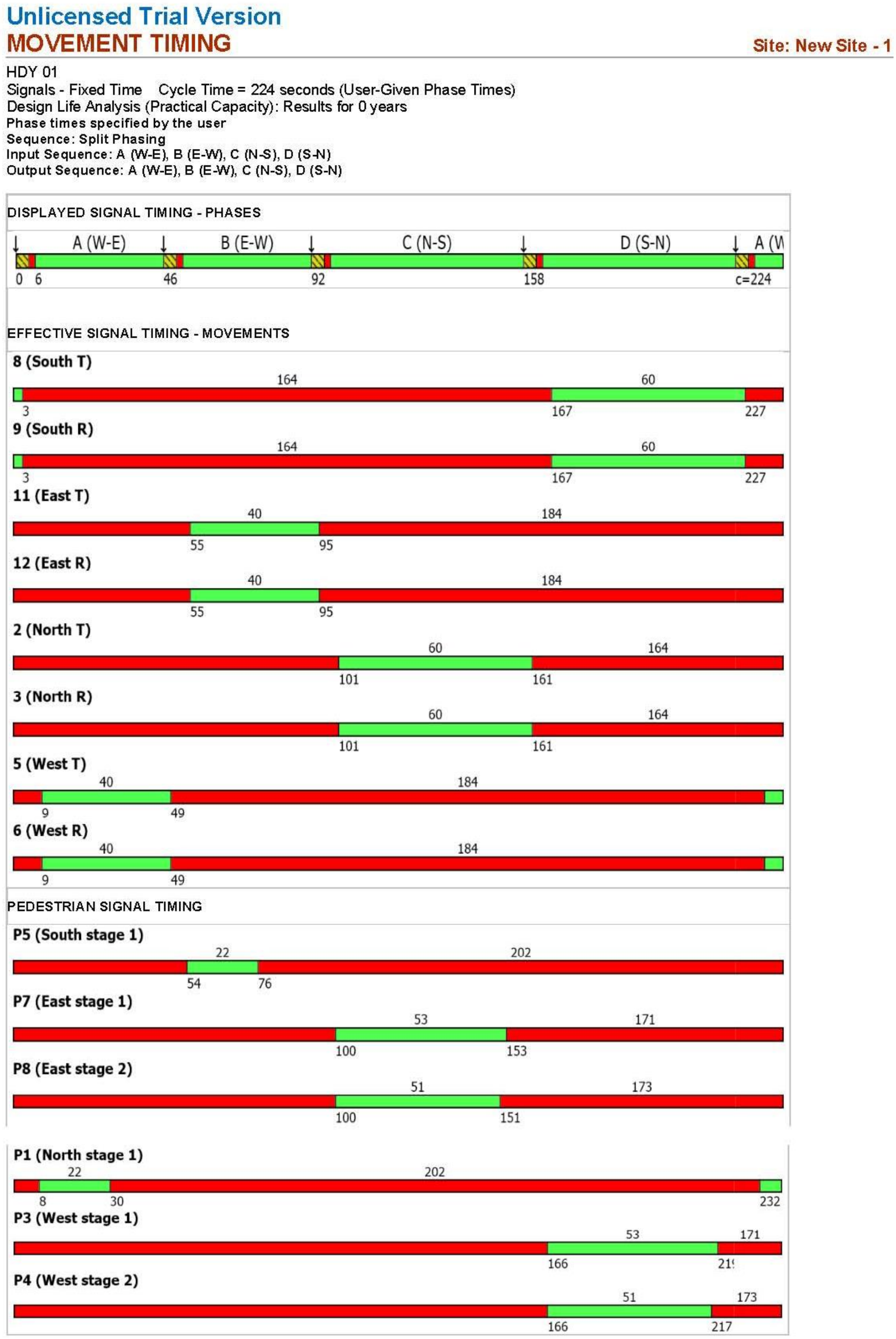


	South	East	North	West	Intersection
LOS	F	F	D	F	F

X: Not applicable for Continuous lane.

Level of Service (LOS) Method: Delay (HCM 2000).
Lane LOS values are based on average delay per lane.
Intersection and Approach LOS values are based on average delay for all lanes.
SIDRA Standard Delay Model used.

Appendix II – 6: Output data for example case 1-hour of flyover situations (17:00 – 18:00), situations of fixed-time plan (244 sec/cycle) (continue)



Appendix II – 6: Output data for example case 1-hour of flyover situations (17:00 – 18:00), situations of fixed-time plan (244 sec/cycle) (continue)

PHASING SUMMARY

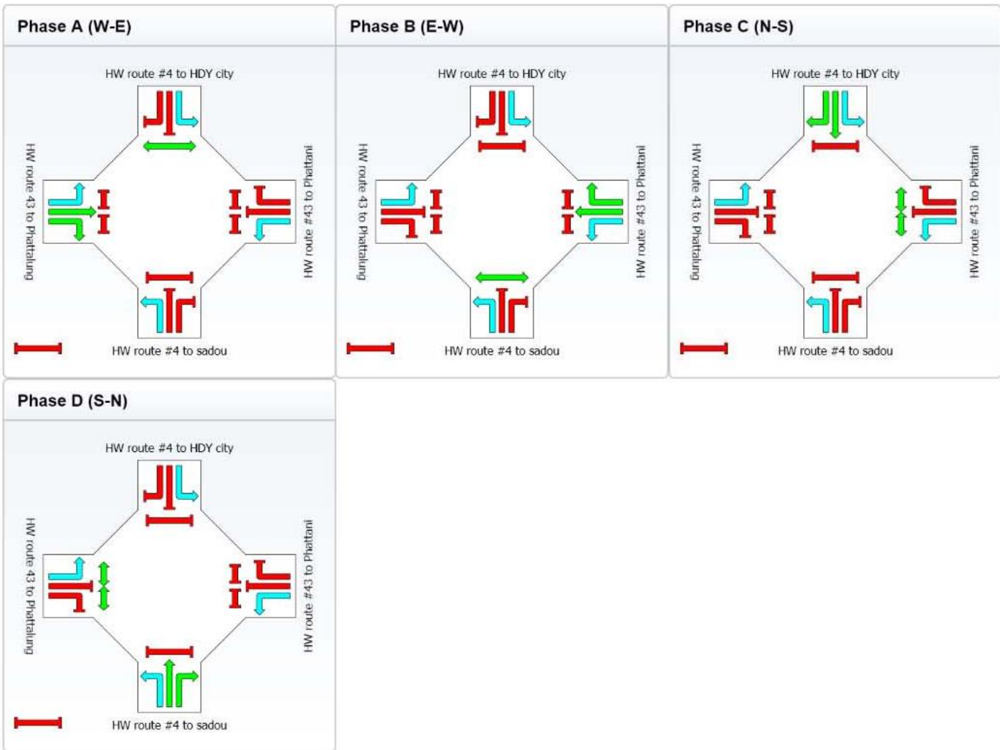
Site: New Site - 1

HDY 01
Signals - Fixed Time Cycle Time = 224 seconds (User-Given Phase Times)
Design Life Analysis (Practical Capacity): Results for 0 years

Phase times specified by the user
Sequence: Split Phasing
Input Sequence: A (W-E), B (E-W), C (N-S), D (S-N)
Output Sequence: A (W-E), B (E-W), C (N-S), D (S-N)

Phase Timing Results

Phase	A (W-E)	B (E-W)	C (N-S)	D (S-N)
Green Time (sec)	40	40	60	60
Yellow Time (sec)	4	4	4	4
All-Red Time (sec)	2	2	2	2
Phase Time (sec)	46	46	66	66
Phase Split	21 %	21 %	29 %	29 %



Normal Movement	Permitted/Opposed
Slip-Lane Movement	Opposed Slip-Lane
Stopped Movement	Continuous Movement
Turn On Red	Undetected Movement
	Phase Transition Applied

Processed: Sunday, July 13, 2014 11:52:08 AM
SIDRA INTERSECTION 5.1.9.2068

Appendix II – 6: Output data for example case 1-hour of flyover situations (17:00 – 18:00), situations of fixed-time plan (244 sec/cycle) (continue)

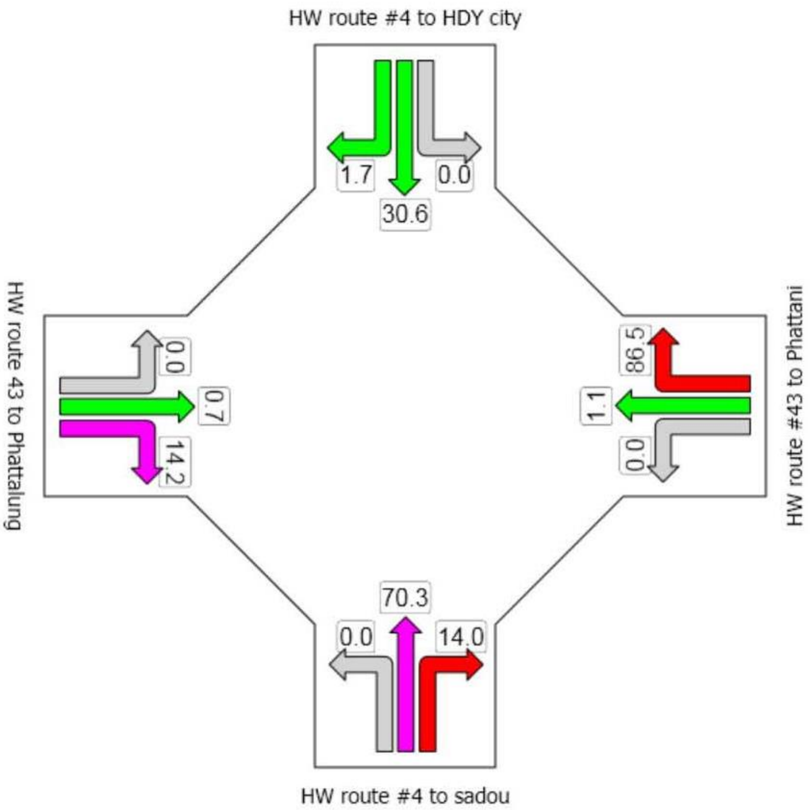
Unlicensed Trial Version

QUEUE

Site: New Site - 1

Largest 95% Back of Queue for any lane used by movement (vehicles)

HDY 01
Signals - Fixed Time Cycle Time = 224 seconds (User-Given Phase Times)
Design Life Analysis (Practical Capacity): Results for 0 years



	South	East	North	West	Intersection
Queue	70.3	86.5	30.6	14.2	86.5

Colour code based on Queue Storage Ratio

[< 0.6] [0.6 – 0.7] [0.7 – 0.8] [0.8 – 0.9] [0.9 – 1.0] [> 1.0] Continuous

Processed: Sunday, July 13, 2014 11:52:08 AM
SIDRA INTERSECTION 5.1.9.2068
Project: E:\In depth 12 hr\17-18.sip
UNLICENSED TRIAL VERSION

SIDRA INTERSECTION

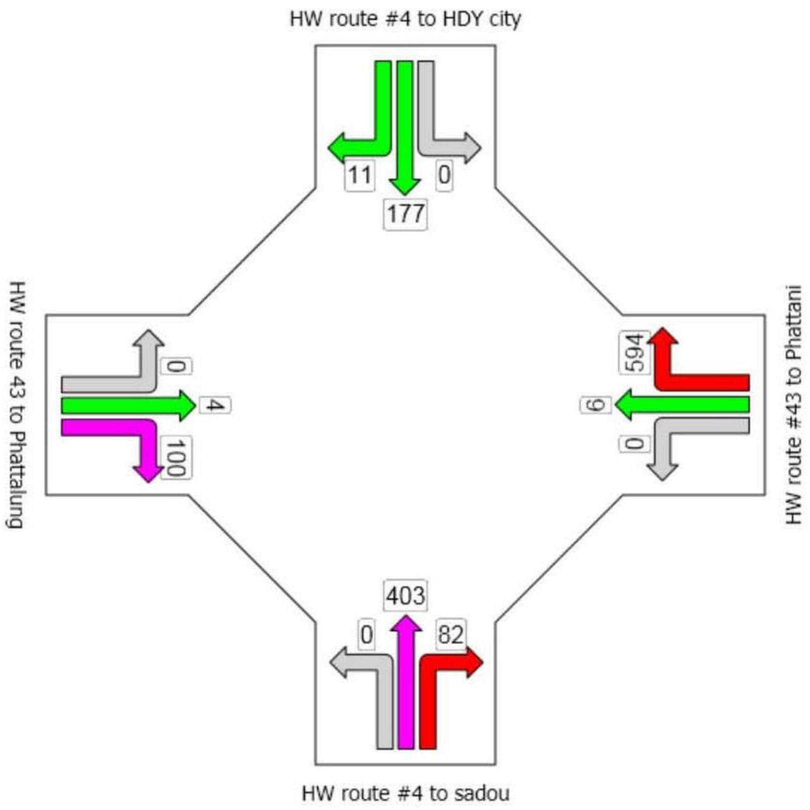
Appendix II – 6: Output data for example case 1-hour of flyover situations (17:00 – 18:00), situations of fixed-time plan (244 sec/cycle) (continue)

Unlicensed Trial Version

QUEUE DISTANCE **Site: New Site - 1**

Largest 95% Back of Queue for any lane used by movement (metres)

HDY 01
Signals - Fixed Time Cycle Time = 224 seconds (User-Given Phase Times)
Design Life Analysis (Practical Capacity): Results for 0 years



	South	East	North	West	Intersection
Queue Distance	403	594	177	100	594

Colour code based on Queue Storage Ratio

[< 0.6] [0.6 – 0.7] [0.7 – 0.8] [0.8 – 0.9] [0.9 – 1.0] [> 1.0] Continuous

Processed: Sunday, July 13, 2014 11:52:08 AM
SIDRA INTERSECTION 5.1.9.2068
Project: E:\In depth 12 hr\17-18.sip
UNLICENSED TRIAL VERSION

SIDRA INTERSECTION

Appendix II – 6: Output data for example case 1-hour of flyover situations (17:00 – 18:00), situations of fixed-time plan (244 sec/cycle) (continue)

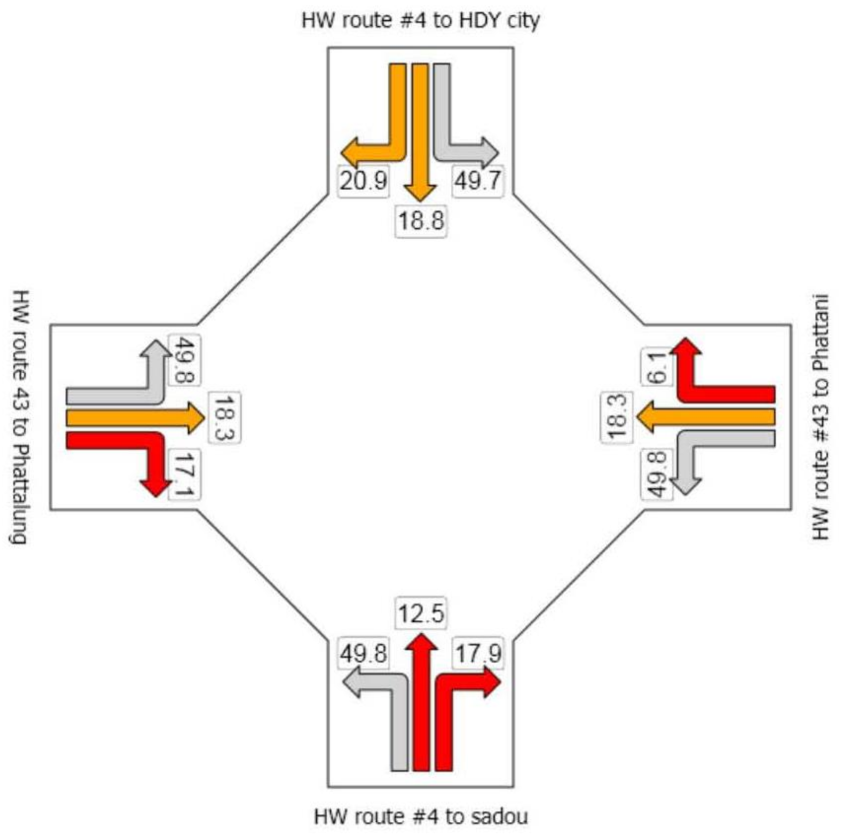
Unlicensed Trial Version

TRAVEL SPEED

Site: New Site - 1

Average travel speed including all delay effects (km/h)

HDY 01
Signals - Fixed Time   Cycle Time = 224 seconds (User-Given Phase Times)
Design Life Analysis (Practical Capacity): Results for 0 years



	South	East	North	West	Intersection
Travel Speed	15.7	9.2	27.3	19.2	15.6

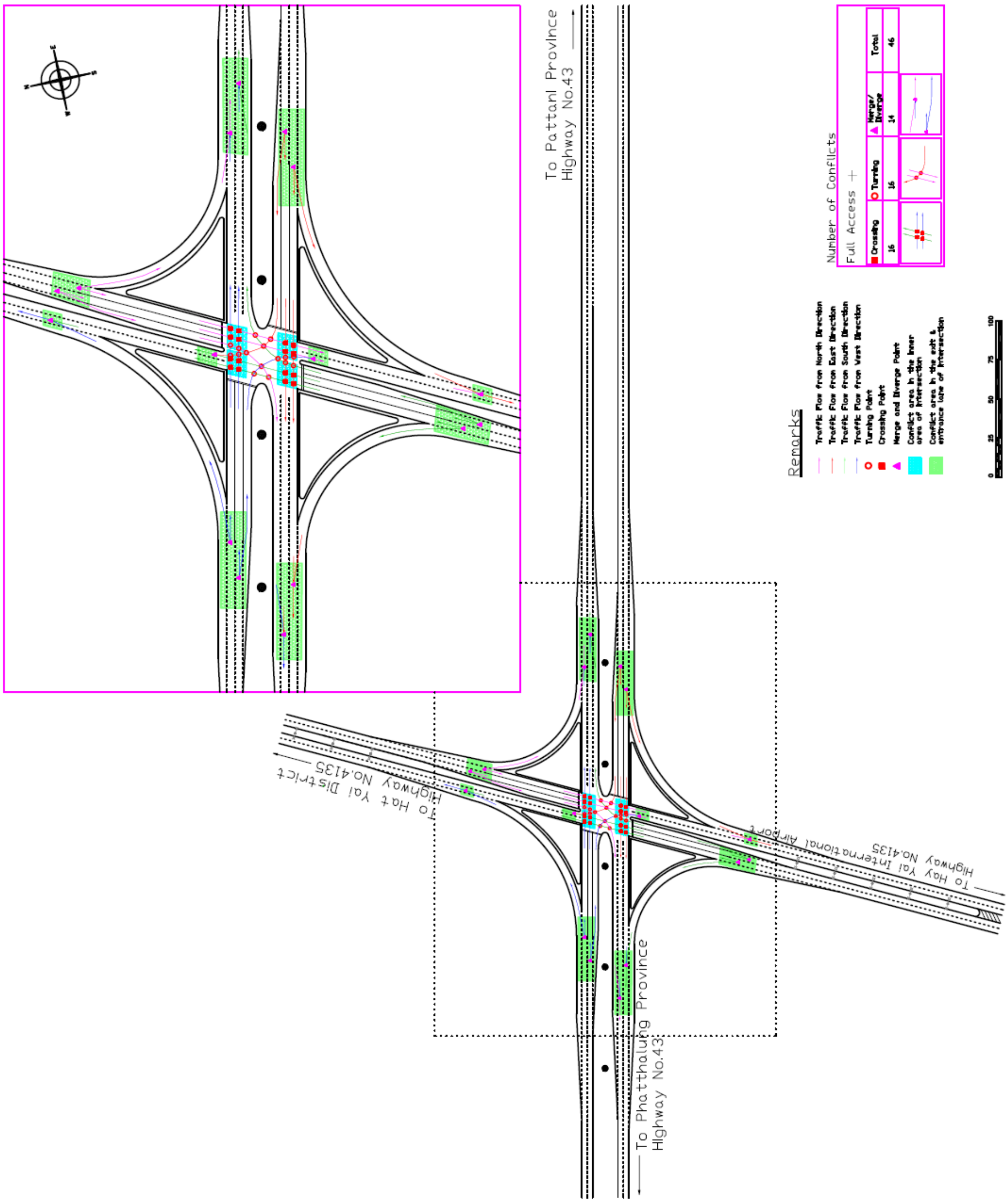
Colour code based on Speed Efficiency Ratio

[0.9 – 1.0] [0.8 - 0.9] [0.7 – 0.8] [0.5 – 0.7] [0.3 – 0.5] [0 - 0.3] Continuous

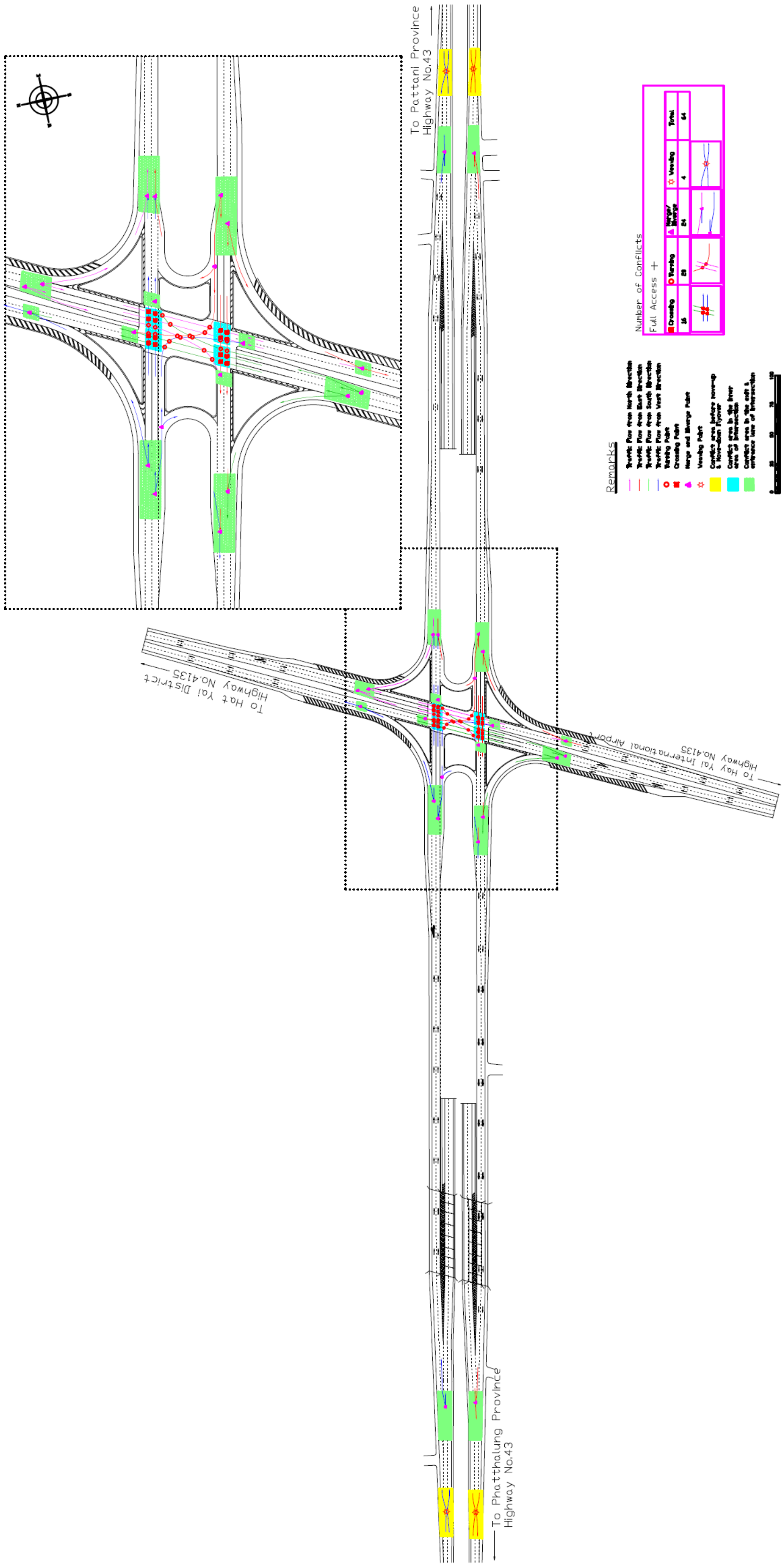
Processed: Sunday, July 13, 2014 11:52:08 AM
SIDRA INTERSECTION 5.1.9.2068
Project: E:\In depth 12 hr\17-18.sip
UNLICENSED TRIAL VERSION

SIDRA INTERSECTION

Appendix II – 7: Conflict Points of at-grade intersection

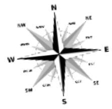


Appendix II – 7: Conflict Points of flyover intersection

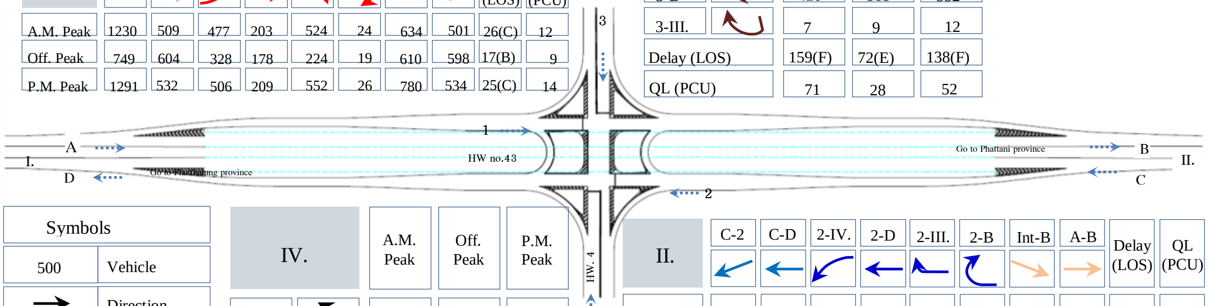


Appendix II – 8: Traffic volume, Delay, Queue length and level of service of 5 existing flyovers

III.	A.M. Peak	Off. Peak	P.M. Peak
3-B	340	315	720
3-IV.	912	1012	1859
3-D	420	383	552
3-III.	7	9	12
Delay (LOS)	159(F)	72(E)	138(F)
QL (PCU)	71	28	52



I.	A-1	A-B	1-III.	1-B	1-IV	1-D	Int-D	C-D	Delay (LOS)	QL (PCU)
A.M. Peak	1230	509	477	203	524	24	634	501	26(C)	12
Off. Peak	749	604	328	178	224	19	610	598	17(B)	9
P.M. Peak	1291	532	506	209	552	26	780	534	25(C)	14



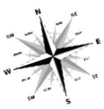
Symbols	
500	Vehicle
→	Direction
A.M. Peak	8:00 – 9:00
Off. Peak	12:00–13:00
P.M. Peak	17:00–18:00
20 (D)	Delay
10	Vehicle (PCU)

IV.	A.M. Peak	Off. Peak	P.M. Peak
4-D	160	165	156
4-III.	3815	824	1052
4-B	227	206	250
4-IV.	10	12	8
Delay (LOS)	105(F)	30(C)	75(E)
QL (PCU)	42	16	36

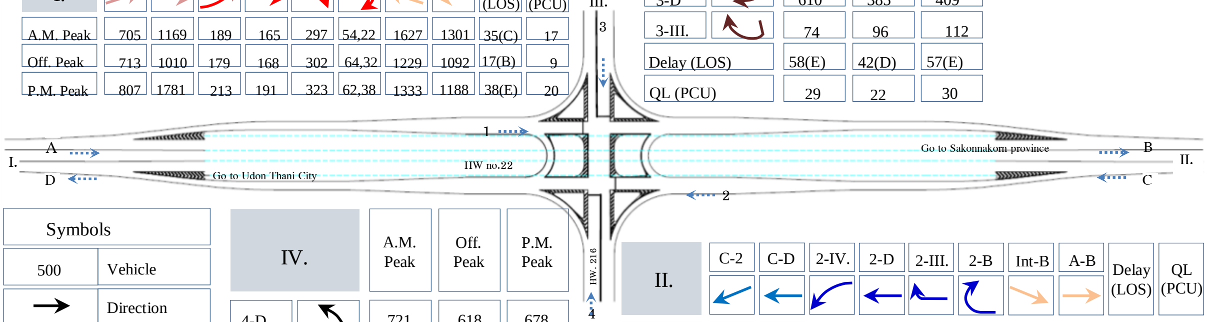
II.	C-2	C-D	2-IV.	2-D	2-III.	2-B	Int-B	A-B	Delay (LOS)	QL (PCU)
A.M. Peak	719	501	156	28	507	28	798	509	26(C)	12
Off. Peak	705	598	273	43	368	21	720	604	26(C)	12
P.M. Peak	793	534	320	48	402	23	1202	532	38(D)	15

Songkhla case study

III.	A.M. Peak	Off. Peak	P.M. Peak
3-B	214	315	397
3-IV.	643	588	620
3-D	610	385	409
3-III.	74	96	112
Delay (LOS)	58(E)	42(D)	57(E)
QL (PCU)	29	22	30



I.	A-1	A-B	1-III.	1-B	1-IV	1-D	Int-D	C-D	Delay (LOS)	QL (PCU)
A.M. Peak	705	1169	189	165	297	54,22	1627	1301	35(C)	17
Off. Peak	713	1010	179	168	302	64,32	1229	1092	17(B)	9
P.M. Peak	807	1781	213	191	323	62,38	1333	1188	38(E)	20



Symbols	
500	Vehicle
→	Direction
A.M. Peak	8:00 – 9:00
Off. Peak	12:00–13:00
P.M. Peak	17:00–18:00
20 (D)	Delay
10	Vehicle (PCU)

IV.	A.M. Peak	Off. Peak	P.M. Peak
4-D	721	618	678
4-III.	1124	884	994
4-B	312	488	556
4-IV.	102	103	144
Delay (LOS)	55(D)	46(D)	58(E)
QL (PCU)	30	25	31

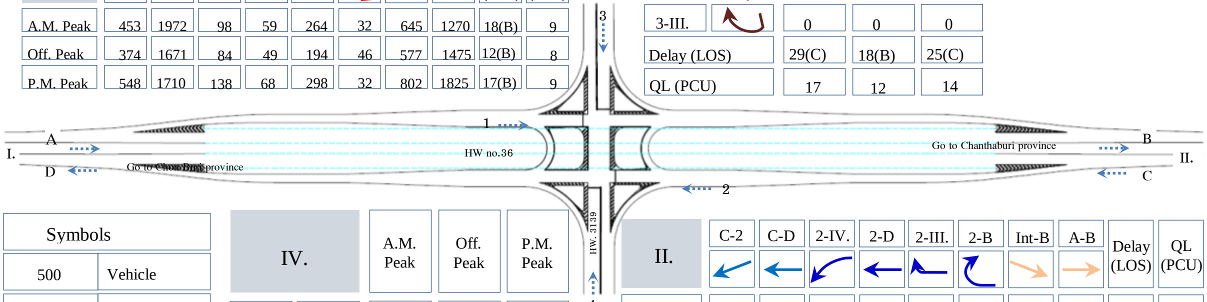
II.	C-2	C-D	2-IV.	2-D	2-III.	2-B	Int-B	A-B	Delay (LOS)	QL (PCU)
A.M. Peak	970	1301	224	242	472	32,44	723	1169	37(D)	21
Off. Peak	812	1092	201	162	411	38,56	1009	1010	21(C)	12
P.M. Peak	852	1188	206	234	404	48,57	1176	1781	26(C)	14

Udon Thani case study

Appendix II – 8: Traffic volume, Delay, Queue length and level of service of 5 existing flyovers (continue)

I.	A-1	A-B	1-III.	1-B	1-IV	1-D	Int-D	C-D	Delay (LOS)	QL (PCU)
A.M. Peak	453	1972	98	59	264	32	645	1270	18(B)	9
Off. Peak	374	1671	84	49	194	46	577	1475	12(B)	8
P.M. Peak	548	1710	138	68	298	32	802	1825	17(B)	9

III.	A.M. Peak	Off. Peak	P.M. Peak
3-B	313	207	341
3-IV.	402	254	411
3-D	371	276	384
3-III.	0	0	0
Delay (LOS)	29(C)	18(B)	25(C)
QL (PCU)	17	12	14



Symbols	
500	Vehicle
→	Direction
A.M. Peak	8:00 – 9:00
Off. Peak	12:00–13:00
P.M. Peak	17:00–18:00
20 (D)	Delay
10	Vehicle (PCU)

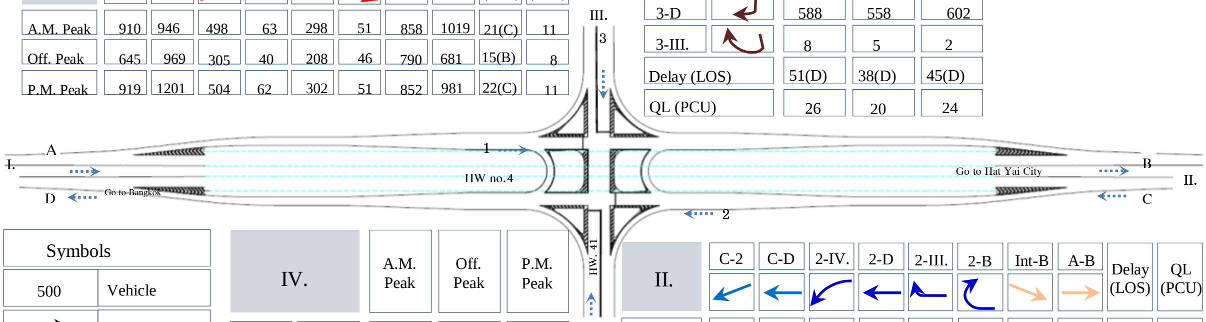
IV.	A.M. Peak	Off. Peak	P.M. Peak
4-D	201	223	381
4-III.	261	319	402
4-B	152	140	181
4-IV.	0	0	0
Delay (LOS)	19(B)	12(B)	17(B)
QL (PCU)	19	12	17

II.	C-2	C-D	2-IV.	2-D	2-III.	2-B	Int-B	A-B	Delay (LOS)	QL (PCU)
A.M. Peak	286	1270	89	41	132	24	548	1972	12(B)	8
Off. Peak	262	1475	76	32	115	39	435	1671	8(A)	5
P.M. Peak	493	1825	91	68	301	39	580	1710	10(A)	6

Rayong case study

I.	A-1	A-B	1-III.	1-B	1-IV	1-D	Int-D	C-D	Delay (LOS)	QL (PCU)
A.M. Peak	910	946	498	63	298	51	858	1019	21(C)	11
Off. Peak	645	969	305	40	208	46	790	681	15(B)	8
P.M. Peak	919	1201	504	62	302	51	852	981	22(C)	11

III.	A.M. Peak	Off. Peak	P.M. Peak
3-B	348	293	332
3-IV.	622	498	692
3-D	588	558	602
3-III.	8	5	2
Delay (LOS)	51(D)	38(D)	45(D)
QL (PCU)	26	20	24



Symbols	
500	Vehicle
→	Direction
A.M. Peak	8:00 – 9:00
Off. Peak	12:00–13:00
P.M. Peak	17:00–18:00
20 (D)	Delay
10	Vehicle (PCU)

IV.	A.M. Peak	Off. Peak	P.M. Peak
4-D	143	138	142
4-III.	542	412	501
4-B	369	297	345
4-IV.	11	8	12
Delay (LOS)	45(D)	37(D)	39(D)
QL (PCU)	29	17	22

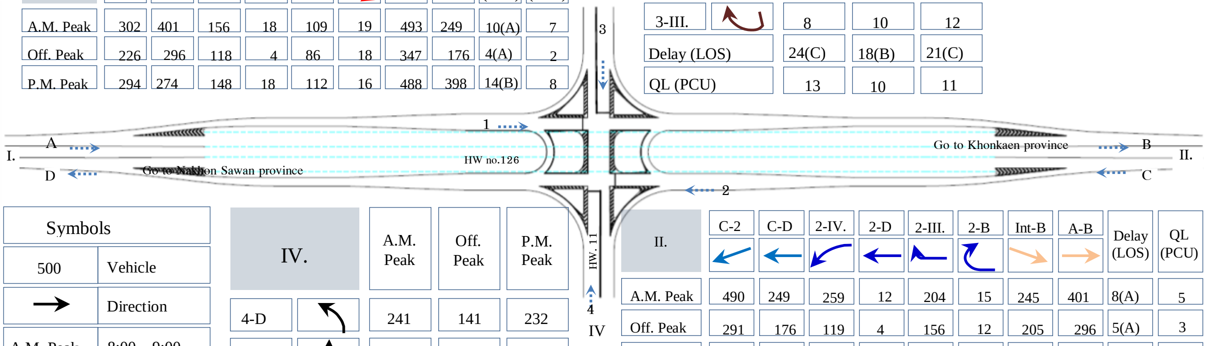
II.	C-2	C-D	2-IV.	2-D	2-III.	2-B	Int-B	A-B	Delay (LOS)	QL (PCU)
A.M. Peak	1074	1019	356	62	624	32	812	946	28(C)	16
Off. Peak	741	681	245	48	420	28	658	969	22(C)	12
P.M. Peak	960	981	298	57	571	34	773	1201	26(C)	16

Phatthalung case study

Appendix II – 8: Traffic volume, Delay, Queue length and level of service of 5 existing flyovers (continue)

III.		A.M. Peak	Off. Peak	P.M. Peak
3-B		184	172	192
3-IV.		62	48	57
3-D		221	184	241
3-III.		8	10	12
Delay (LOS)		24(C)	18(B)	21(C)
QL (PCU)		13	10	11

I.	A-1	A-B	1-III.	1-B	1-IV	1-D	Int-D	C-D	Delay (LOS)	QL (PCU)
A.M. Peak	302	401	156	18	109	19	493	249	10(A)	7
Off. Peak	226	296	118	4	86	18	347	176	4(A)	2
P.M. Peak	294	274	148	18	112	16	488	398	14(B)	8



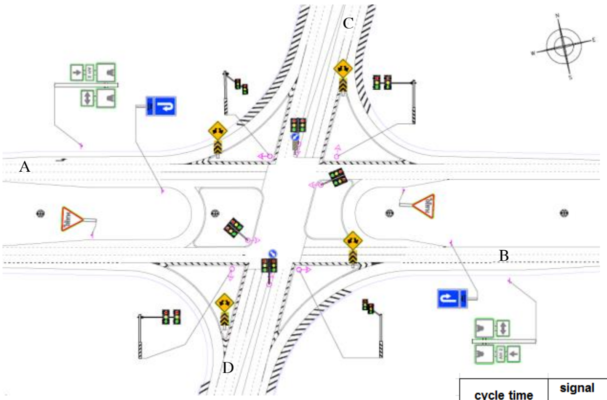
Symbols	
500	Vehicle
→	Direction
A.M. Peak	8:00 – 9:00
Off. Peak	12:00–13:00
P.M. Peak	
20 (D)	Delay
10	Vehicle (PCU)

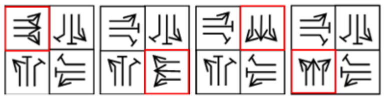
IV.		A.M. Peak	Off. Peak	P.M. Peak
4-D		241	141	232
4-III.		542	419	545
4-B		28	17	32
4-IV.		15	8	10
Delav (LOS)		19(B)	15(B)	28(C)
QL (PCU)		9	7	18

II.	C-2	C-D	2-IV.	2-D	2-III.	2-B	Int-B	A-B	Delay (LOS)	QL (PCU)
A.M. Peak	490	249	259	12	204	15	245	401	8(A)	5
Off. Peak	291	176	119	4	156	12	205	296	5(A)	3
P.M. Peak	512	398	221	19	254	18	260	274	12(B)	6

Phitsanulok case study

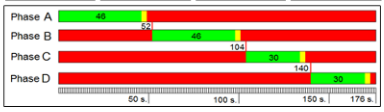
Appendix II – 9: Traffic signal data of 5 existing flyovers





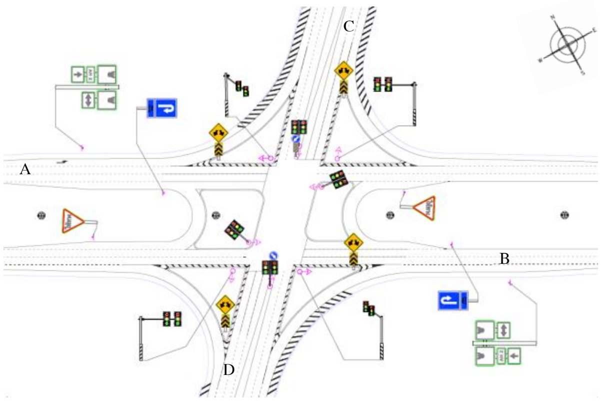
Phase	A	B	C	D
Green	30	30	46	46
Yellow	3	3	3	3
Red	142	142	127	127
All red	3	3	3	3

Light length: 176 second

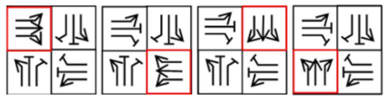


cycle time	signal program	time of operation (0 – 3 – 6 – 9 – 12 – 15 – 18 – 21)
178	S1	
Lights flashing	S1	

Songkhla case study

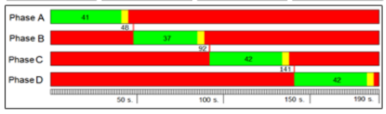


Timing information of traffic signals.



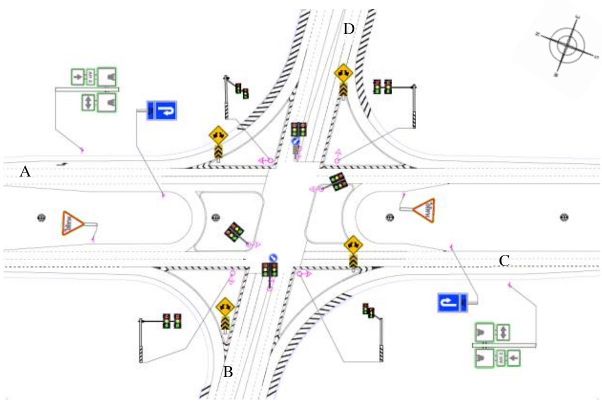
Phase	A	B	C	D
Green	41	37	42	42
Yellow	4	4	4	4
Red	130	134	129	129
All red	3	3	3	3

Light length: 190 second

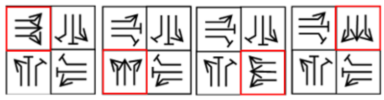


cycle time	signal program	time of operation (0 – 3 – 6 – 9 – 12 – 15 – 18 – 21)
178	S1	
Lights flashing	S1	

Udon Thani case study

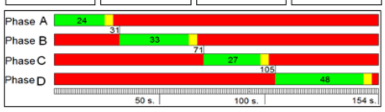


Timing information of traffic signals.



Phase	A	B	C	D
Green	24	33	27	48
Yellow	4	4	4	4
Red	117	108	114	93
All red	3	3	3	3

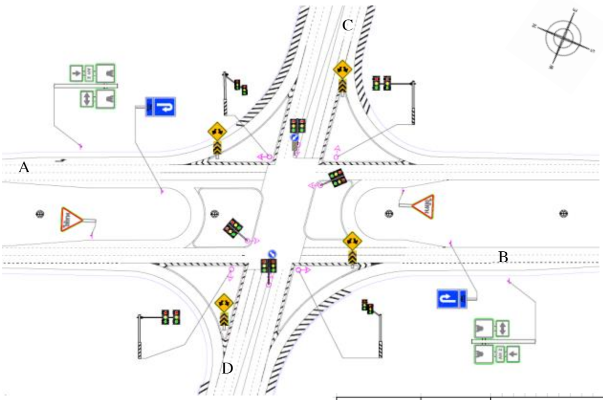
Light length: 148 second



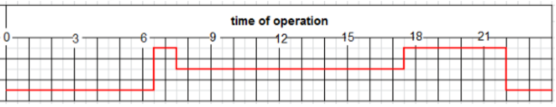
cycle time	signal program	time of operation (0 – 3 – 6 – 9 – 12 – 15 – 18 – 21)
148	S1	
Lights flashing	S1	

Rayong case study

Appendix II – 9: Traffic signal data of 5 existing flyovers (continue)

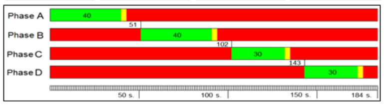


cycle time	signal program	time of operation
184	S1	
144	S2	
Lights flashing	S3	



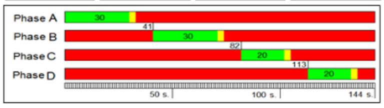
S1

Phase	A	B	C	D
Green	40	40	30	30
Yellow	3	3	3	3
Red	133	133	123	123
All red	8	8	8	8
Light length: 184 second				

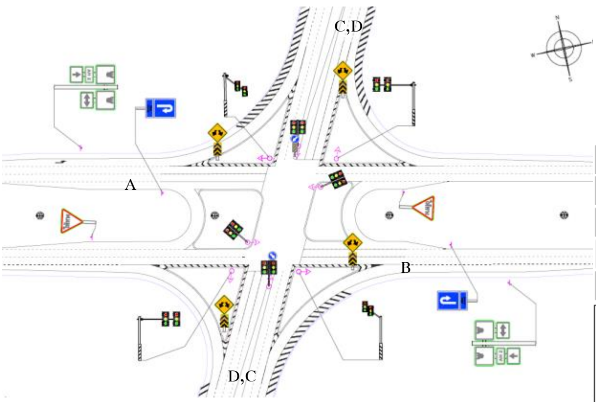


S2

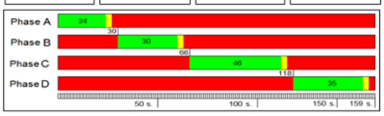
Phase	A	B	C	D
Green	30	30	20	20
Yellow	3	3	3	3
Red	103	103	113	113
All red	8	8	8	8
Light length: 144 second				



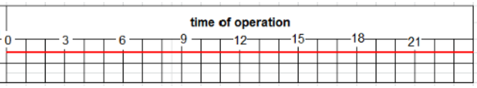
Phatthalung case study



Phase	A	B	C	D
Green	24	30	46	35
Yellow	3	3	3	3
Red	129	123	107	118
All red	3	3	3	3
Light length: 159 second				



cycle time	signal program	time of operation
159	S1	
Lights flashing	S1	



Phitsanulok case study

Appendix II – 10: Accident statistics in 2010 – 2012

Accident statistics of Songkhla case study

No	Zone	D/M/Y of accident	Hw/Sta (km.) Point of accident	Vehicle types of accident	Collision Diagram	Time			Number of Casualty			DOH damage	PDO	Cause
						Day	Night	Rain	Injury	Serious	Death			
1	2	1-Jan-10	1268+332	Motorcycle and Motorcycle	301		20:15		3			1,000		Violating speed limit
2	1	22-Jan-10	1269+305	10 wheels	703	11:30						30,000		Road materials Damaged
3		23-Jan-10		Motorcycle	707		22:42		1					Crash itself
4		1-Feb-10		10 wheels + Motorcycle	604		22:22		1					Crash itself
5	3	15-Mar-10		Motorcycle	-		20:29		1					Crash itself
6	2	28-Mar-10	1268+449	Passenger Pick-up	708		4:50					51,000		Violating speed limit
7		8-April-10		Motorcycle	-		20:57		1					Crash itself
8	1	15-April-10		Car + Motorcycle	307	7:35			1					Violating speed limit
9		12-May-10		Pick-up+ Motorcycle	309	12:20			1					Violating speed limit
10		12-Aug-10		Motorcycle + a dog	607		21:08		1					Motorcycle crash a dog
11	3	29-Aug-10		10 wheels + Motorcycle + Pick-up	306	11:52					1			Careless road user
12		1-Sep-10		Motorcycle	-	14:26			1					Crash itself
13	3	12-Sep-10		Motorcycle + Pick-up	307		19:16				1			Careless road user
14		23-Sep-10		Motorcycle + Pedestrian	009		19:07		1					Motorcycle hits Pedestrian
15	2	3-Oct-10	1269+047	Pick-up and Pick-up	708	10:20						14,000		Violating speed limit
16	3	7-Oct-10	1267+802	10 wheels	708		1:00					51,000		Violating speed limit
17	3	14-Nov-10	1267+706	Pick-up	604		22:20					8,000		Violating speed limit
18	3	20-Nov-10	1267+716	Pick-up	708	17:10			3			46,000		Violating speed limit
19	3	4-Jan-11	1246+710	Motorcycle +Pick-up+ Trailer	609	16:00			1	1				Violating speed limit
20	2	2-Mar-11	000+526	Car	803	18:00						17,586		Violating speed limit
21	3	1-Jan-12		Pick-up + Trailer	608		4:24		2					Brake system failure
22	1	19-Jan-12		Pick-up + Motorcycle	101		22:36		1					Violation of traffic signals
23	2	15-May-12	000+450	Pick-up	804	11:00						5,148		Violating speed limit
24	3	4-June-12	000+525	Car	704	10:00			1			9,970		Violating speed limit
25		9-July-12		Motorcycle	-		19:10		1					Crash itself
26	2	31-July-12		Van + Motorcycle	306	11:49			1					Careless road user
27	1	8-Aug-12		Car + Motorcycle	101		21:52		2					Violation of traffic signals

Appendix II – 10: Accident statistics in 2010 – 2012 (continue)

Accident statistics of Udon Thani case study

No	Zone	D/M/Y of accident	Hw/Sta (km.) Point of accident	Vehicle types of accident	Collision Diagram	Time			Number of Casualty			DOH damage	PDO	Cause
						Day	Night	Rain	Injury	Serious	Death			
1		29-Oct-12		Motorcycle and car	101	13:00			1					Violating speed limit
2		29-Oct-12		Third cycles	701	10:00								Crash itself
3		30-Sep-12		Pick-up and Motorcycle	202	13:00			1	1				Violation of traffic signals
4		16-Sep-12		Motorcycle	708	6:30			1					Careless road user
5		12-Sep-12		Motorcycle and Pick-up	101	13:00			1					Violation of traffic signals
6		30-April-12		Car and Motorcycle	304	8:00			1					Violating speed limit
7		21-Apri-12		Pick-up and Motorcycle	101		18:00			1				Violation of traffic signals
8		4-Mar-12		Motorcycle	701	4:50				1				Violating speed limit
9		23-Feb-12		Motorcycle	-	17:30			1					Crash itself
10		26-Jan-12		Motorcycle and Pick-up	101		18:00			1				Violation of traffic signals
11		5-Oct-11		Car and Trailer	303	13:20			2					Careless road user
12		31-Aug-11		Third cycles and Trailer	601		5:30				1			Careless road user
13		17-Aug-11		Motorcycle	-	8:10								Crash itself
14		15-aug-11		Motorcycle and Pick-up	101	17:00			1					Violation of traffic signals
15		7-July-11		Motorcycle	-		23:30			1				Crash itself
16		29-June-11		Motorcycle	-	15:45				1				Crash itself
17		23-June-11		Third cycles and Pick-up	601		18:10				1			Careless road user
18		15-June-11		Motorcycle and Pick-up	202		18:20			1				Violation of traffic signals
19		2-Feb-11		Motorcycle and Third cycles	303		19:30			1				Violating speed limit
20		12-Jab-11		Motorcycle and Pedestrian	-	3:30				1				Motorcycle hits Pedestrian
21		2-Dec-10		Motorcycle and Pedestrian	-	17:00			1					Motorcycle hits Pedestrian
22		24-Nov-10		Motorcycle and Pick-up	101	13:10				2				Violation of traffic signals
23		22-Oct-10		Motorcycle	-		20:30		1					Crash itself
24		11-Oct-10		Motorcycle	-	7:30				1				Crash itself
25		2-Oct-10		Motorcycle and Motorcycle	101	14:00			1					Violation of traffic signals
26		1-Oct-10		Motorcycle and Motorcycle	101	10:05			1					Violation of traffic signals
27		20-Sep-10		Motorcycle and animal	607	7:00								Motorcycle hits animal
28		6-Sep-10		Motorcycle	-	6:00								Crash itself
29		18-July-10		Motorcycle and Motorcycle	302	12:00			1					Violating speed limit
30		16-July-10		Motorcycle and a car	101	3:35				1				Violation of traffic signals
31		23-June-10		Motorcycle and Pick-up	101		21:10		1	1				Violation of traffic signals
32		16-May-10		Motorcycle and Motorcycle	101		19:40		1					Violation of traffic signals
33		27-April-10		Motorcycle	-		21:30		1					Crash itself
34		18-April-10		Motorcycle and Motorcycle	305	12:00			1					Careless road user
35		10-April-10		Third cycles	801	13:50								Slippery roads
36		24-Mar-10		Trailer	-		21:10							Fall Down from truck
37		22-Mar-10		Pick-up and Trailer	403		18:00							Careless road user
38		22-Feb-10		Motorcycle	601	17:30			1					Careless road user
39		9-Feb-10		Pick-up and Pick-up	306	17:00			1					Careless road user
40		7-Feb-10		Pick-up and Pick-up	307	17:00			1					Careless road user

Appendix II – 10: Accident statistics in 2010 – 2012 (continue)

Accident statistics of Rayong case study

No	Zone	D/M/Y of accident	Hw/Sta (km.) Point of accident	Vehicle types of accident	Collision Diagram	Time			Number of Casualty			DOH damage	PDO	Cause
						Day	Night	Rain	Injury	Serious	Died			
1		25-Jan-10		Pick-up	703	9:30								Crash itself
2		16-Jan-11		6 wheels + Electric Column	704		1:00							Hits the Electric column
3		27-July-11		Pick-up	-	11:47			1					-
4		9-Jan-12		Motorcycle	-	15:12			1					Crash itself
5		10-Jan-12		Motorcycle + Pick-up	101		4:49		1	1				No controller
6		17-Jan-12		Pick-up + Electric column	604	6:20					1			Drunkenness
7		28-Jan-12		Car	701				1	1				Crash itself
8		29-Jan-12		Motorcycle + Pick-up	601					1				Violating speed limit
9		2-Feb-12		Motorcycle	-	6:08			1					Crash itself
10		15-Feb-12		Motorcycle + Pick-up	101	13:21			1					Violation of traffic signals
11		18-Feb-12		Motorcycle	-	12:22			1					Crash itself
12		17-Mar-12		Motorcycle + Car	101		4:33			1				No controller
12		19-Mar-12		Motorcycle + Motorcycle	101		3:12			1				Violation of traffic signals
14		9-May-12		Motorcycle	701	9:14				1				Drunkenness
15		12-June-12		Motorcycle + Car	601	9:03				1				Motorcycle hits a Car
16		7-July-12		Car + Pick-up	-		4:12			1				No controller
17		13-July-12		Motorcycle + Pick-up	-		0:13		1					No controller
18		15-July-12		Motorcycle + Motorcycle	207	16:14					1			Motorcycle hits Motorcycle
19		1-Aug-12		Pick-up + Truck	202		5:44		1					Pick-up hits Truck
20		2-Aug-12		Motorcycle	701		19:10		1					Drunkenness
21		6-Aug-12		Motorcycle + Motorcycle	508		19:14							Motorcycle hits Motorcycle
22		7-Sep-12		Motorcycle + Pick-up	-		0:13		1					No controller
23		20-Oct-12		Motorcycle + Motorcycle	508		20:40		1					Motorcycle hits Motorcycle
24		4-Nov-12		Motorcycle + Car	-	10:55			2					Motorcycle hits a Car
25		10-Nov-12		Motorcycle + Motorcycle	101		3:32							No controller
26		16-Nov-12		Motorcycle + Car	-	14:33								Motorcycle hits a Car
27		28-Nov-12		Motorcycle + Motorcycle	-		19:54		2	1				Motorcycle hits Motorcycle
28		8-Dec-12		Motorcycle + Pick-up	-		0:20		1	1				No controller
29		10-Dec-12		Motorcycle + Car	-		22:28		1					Motorcycle hits a Car
30	3	29-Dec-12	36(55+600)	Motorcycle + Van	904	14:00			2		1			Van hits Motorcycle on the diverge zone

Appendix II – 10: Accident statistics in 2010 – 2012 (continue)

Accident statistics of Phatthalung case study

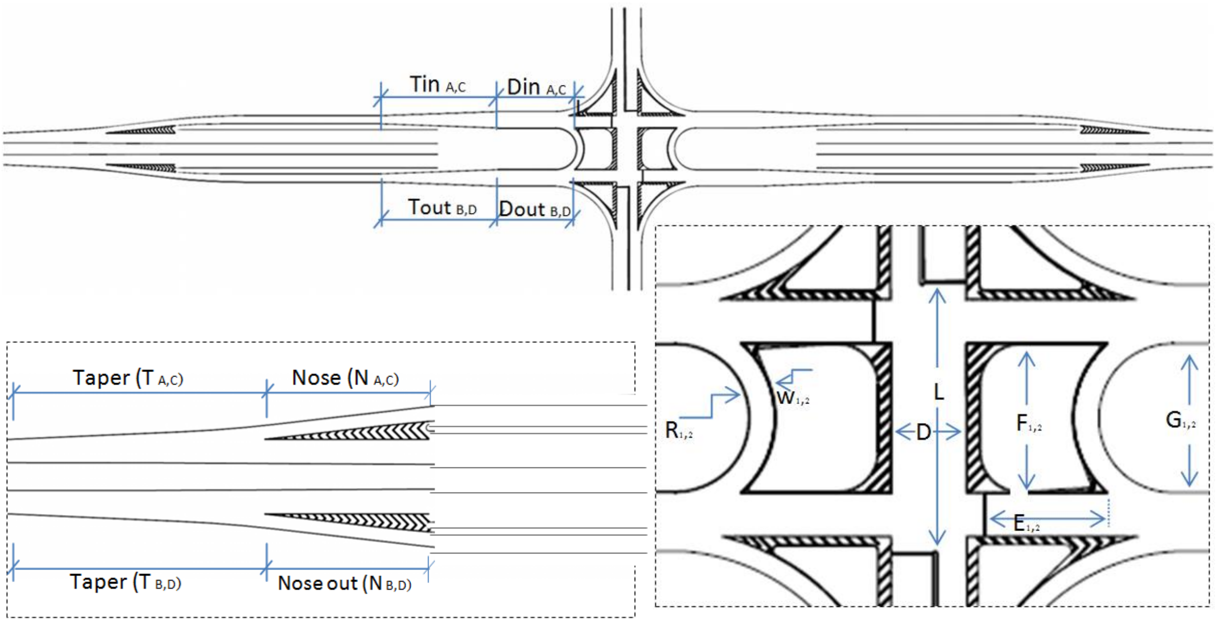
No	Zone	D/M/Y of accident	Hw/Sta (km.) Point of accident	Vehicle types of accident	Collision Diagram	Time			Number of Casualty			DOH damage	PDO	Cause
						Day	Night	Rain	Injury	Serious	Died			
1		10-May-10	41(86+200)	Motorcycle	701	12:30			2					Crash itself
2		20-May-10	4285(0000+100)	Pick-up	708		0:20				1			Violating speed limit and Drunkenness
3		21-July-10	4285 (2+250)	Three wheels + Truck	301	15:30			2					Violating speed limit
4		4-Aug-10	41(86+930)	Motorcycle + Car	101	8:30				1	1			Violation of traffic signals
5		2-Jan-11	4(1157+350)	Motorcycle	704	16:45			2					Violating speed limit and Crash itself
6		18-Mar-11	4(1157+350)	Car + Electric Column	604			13:00	1					Hits the Electric column (Drunkenness)
7		13-Apr-11	41(0086+900)	Motorcycle + Car	104			23:50		1				Driving in reverse direction
8		19-Apr-11	4(1157+770)	Pick-up	604	6:00								Violating speed limit and hit road materials
9		12-June-11	4(1158+200)	Motorcycle + 10 wheels	303		21:40				1			Violating speed limit (Motor hits 10 wheels)
10		29-Dec-11	4/(1157+700)	Motorcycle	-			8:30	1					Crash itself
11		29-Dec-11	4/(1157+700)	Motorcycle	904			21:30		1				Hits road materials (Drunkenness)
12		29-Dec-11	4/(1157+700)	Motorcycle	-		1:15		1					Crash itself
12		29-Jan-12	4(1158+520)	Car	801		5:55				2			Drowsiness
14		8-Mar-12	41(86+920)	Pick-up + Pick-up	202		5:50		1			130,636		Violation of traffic signals
15		20-July-12	4 (1158+360)	Trailer	703	14:15						49,510		Drowsiness
16		11-Aug-12	41 (86+890)	Pick-up	708		23:50		2			28,600		Hits the Electric column
17		29-Dec-12	4(1158+120)	Motorcycle + 10 wheels	301		23:00			1				Careless road user

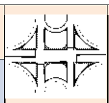
Appendix II – 10: Accident statistics in 2010 – 2012 (continue)

Accident statistics of Phitsanulok case study

No	Zone	D/M/Y of accident	Hw/Sta (km.) Point of accident	Vehicle types of accident	Collision Diagram	Time			Number of Casualty			DOH damage	PDO	Cause
						Day	Night	Rain	Injury	Serious	Died			
1		21-Jan-10		Motorcycle	702		3:47		1					Drunkenness
2		17-Feb-10		Car + Motorcycle	202	10:30			2					Violation of traffic signals
3		20-Feb-10		Car + Motorcycle	306	8:09			1					Violation of traffic signals
4		11-Mar-10		Motorcycle + Motorcycle	307		4:45		1					Violation of traffic signals
5		8-May-10		Truck + Motorcycle	101		19:48				2			Violation of traffic signals
6		19-Aug-10		Car + Motorcycle	207	16:01			1					Violation of traffic signals
7		19-Aug-10		Bus + Motorcycle	806	17:15								Careless road user
8		23-Sep-10		Pick-up + Pick-up	601		21:37		1					Careless road user
9		1-Jan-11		Motorcycle	-		2:13		2					Crash itself
10		10-Jan-11		Car + Pick-up	601	17:45				1				Violation of traffic signals
11		15-Jan-11		Motorcycle	703		21:46		1					Slippery roads.
12		26-Jan-11		Motorcycle	604		0:10		1					No controller
13		8-Feb-11		Motorcycle + a dog	607		19:18		1					Motorcycle hits a dog
14		10-Feb-11		6 wheels + Pick-up	601		01:19		1					No controller
15		10-Feb-11		10 wheels + Pick-up	601		2:38		1					No controller
16		20-Feb-11		Motorcycle	-		22:21		1					Crash itself
17		23-May-11	0003+718	6 wheels + Pick-up	101		21:00		1	4	3			Violation of traffic signals
18		29-May-11		Pick-up	-		18:22		1					Crash itself (Drunkenness)
19		29-May-11		Pick-up + Electricity post	708		22:24		1					Drunkenness
20		29-May-11		Motorcycle + Pick-up	308		0:30		1					No controller
21		16-June-11		Pick-up + Motorcycle	306		20:35		2					Violation of traffic signals
22		5-July-11		Pick-up + Motorcycle	308		20:19		1					Violation of traffic signals
23		13-Nov-11		Pick-up	-	11:38			1					Crash itself
24		30-Nov-11		Pick-up + trailer	308		21:30		8					Violation of traffic signals
25		16-Dec-11		3 wheels + Pick-up	-		22:33		1					Careless road user
26		27-Feb-12		Pick-up + Truck	601		19:17		1					Careless road user
27	1	6-April-12		6 wheels + Motorcycle	101	17:05				1				Violation of traffic signals
28		26-May-12		Motorcycle + Motorcycle	307	8:23			1					Careless road user
29		23-June-12		Motorcycle + Motorcycle	202		19:27		2					Violation of traffic signals
30		7-July-12		Motorcycle	-	10:21			1					Crash itself
31		13-Oct-12		Motorcycle	-	16:19			1					Violating speed limit
32		13-Nov-12		Trailer + Motorcycle	306		18:08		1					Violation of traffic signals
33		16-Nov-12		3 Pick-up + 2 cars	308	15:23			-					Violation of traffic signals
34		20-Nov-12		Motorcycle	701		20:10		1					Drunkenness
35		24-Nov-12		Motorcycle	-		21:50		-					Crash itself
36		27-Nov-12		Pick-up + car	307	17:29			1					Drunkenness
37		29-Nov-12		Motorcycle	-		21:11		1					Crash itself

Appendix II – 11: Dimension of 5 existing flyovers



	T				N				Tin				Din					L	D	E		F		G		W		R	
	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D				1	2	1	2	1	2	1	2	1	2
Case no.1	32	25	272	287	90	60	70	75	109	120	126	124	44	70	64	70		54	25	20	32	31	31	31	31	6	6	12	12
Case no.2	79	77	135	135	150	150	191	172	78	210	85	111	-	-	-	-		54	25	35	35	21	21	24	24	8.7	8.7	10	10
Case no.3	277	284	180	208	161	179	179	181	38	27	43	44	55	44	57	50		75	19	45	41	54	54	45	45	6.7	6.7	22	22
Case no.4	88	88	109	109	111	111	111	111	96	94	94	96	87	87	72	72		64	18	32	29	35	35	35	35	6	6	17	17
Case no.5	196	193	223	242	134	115	127	127	90	90	106	16	71	48	55	61		38	18	21	21	27	27	22	22	6	6	15	15

Appendix II – 12: Accident Statistics Analysis (in-depth case)

Table 1 Time of accident and number of casualties of 3 situations

Situations	Time of accident			Number of Casualties			DOH Damage	PDO
	Day	Night	Rain	Injury	Serious	Death		
Before	2	5	-	17	8	-	-	84,000
During	9	8	6	39	23	6	701,400	3,408,500
After	3	6	-	9	1	-	-	-

Table 2 Region of accident and number of vehicles in a case of 3 situations

Situation/Region	1	2	3	On Bridge	No. of vehicle in case	1	2	3	4	No. Accidents
Before	17	-	-	-	Before	5	12	-	-	17
During	33	11	7	-	During	18	30	3	2	53
After	2	1	3	3	After	6	3	1	1	9

Note: Region 1 is on crossroad

Region 2 is between region 1 and region 2

Region 3 is at the approaching and existing of the bridge

Table 3 Vehicle types of accidents of 3 situations

Vehicle Type	Bicycle	Tricycle	Motor	Car	Pick-up	Van	Bus	4 wheel truck	6 wheel truck	10 wheel truck	Heavy trucks	Other
Before	-	1	15	3	10	1	1	-	-	1	-	-
During	-	-	29	19	24	1	-	-	2	5	7	1
After	-	-	9	1	1	-	-	-	-	1	-	-

Table 4 Cause of accidents and collision diagram codes of 3 situations

Situation	Collision	Collision diagram code / number of each code												
Before	Code	-												
	Number	-												
During	Code	301	701	708	704	604	200	804	801	703	303	202	107	101
	Number	6	4	2	2	2	2	1	1	1	1	1	1	1
After	Code	701	306	307	702									
	Number	5	2	1	1									

Note: from the recorded did not show the cause of accidents

Appendix II – 12: Accident Statistics Analysis (in-depth case) (continue)

Table 5 Cause of accidents of 3 situations

Situation	Cause of accidents	Number
Before	- No recorded	
	- No recorded	
	- No recorded	
During	Highest speed limit	15
	Slippery roads	5
	Drowsiness	2
	Violating speed limit	2
	Drunkenness	1
After	Slippery roads	6
	Violating speed limit	2
	Vision is not clear	1

Note: from the recorded did not show the cause of accidents

Appendix II – 13: Accident Statistics Analysis (5 existing flyovers)

Table 1 Time of accident and number of casualties of 5 locations

Case no.	Time of accident			Number of Casualty			DOH Damage	PDO
	Day	Night	Rain	Injury	Serious	Death		
1	12	15	0	24	1	2	233,704	27
2	27	13	0	21	14	2	-	37
3	13	15	0	20	10	3	-	33
4	6	7	4	12	4	5	208,746	21
5	12	25	0	42	6	5	-	53
Sum	70	75	4	119	35	17	442,450	171

Table 2 Region of accident and number of vehicles in a case of 5 locations

Case No./Region	1	2	3	No. of vehicle in case	1	2	3	5	No. Accident
1	4	6	9	Case No.1	13	12	2	-	27
2	-	-	-	Case No.2	14	26	-	-	40
3	-	-	1	Case No.3	8	22	-	-	30
4	-	-	-	Case No.4	10	7	-	-	17
5	1	-	-	Case No.5	12	24	1	-	37
Sum	-	-	-	Sum	57	91	3	-	151

Table 3 Vehicle types in accidents case of 5 locations

Vehicle Type Case No.	Bicycle	Tricycle	Motor	Car	Pick-up	Van	Bus	4 wheel truck	6 wheel truck	10 wheel truck	Heavy trucks	Other
1	-	-	17	4	11	1	-	-	-	4	-	-
2	-	4	31	4	12	-	-	-	-	-	2	2
3	-	2	23	7	11	1	-	-	1	-	-	2
4	-	2	9	4	4	-	-	-	-	2	1	1
5	-	2	24	8	19	-	1	1	2	1	1	1
Sum	-	10	104	27	57	2	1	1	3	7	4	6

Appendix II – 13: Accident Statistics Analysis (5 existing flyovers) (continue)

Table 4 Cause of accidents and collision diagram codes of 5 locations (top 13 rates)

Case No.	Collision	Collision diagram code / number of each code												
1	Code	708	604	307	306	101	804	803	707	704	703	609	608	607
	Number	4	2	2	2	2	1	1	1	1	1	1	1	1
2	Code	101	601	701	303	202	801	708	607	403	307	306	305	304
	Number	11	3	2	2	2	1	1	1	1	1	1	1	1
3	Code	101	701	601	508	904	704	703	604	207	202			
	Number	5	3	2	2	1	1	1	1	1	1			
4	Code	708	604	301	904	801	704	703	701	303	202	104	101	
	Number	2	2	2	1	1	1	1	1	1	1	1	1	
5	Code	601	308	307	306	101	202	806	708	703	702	701	607	604
	Number	5	4	3	3	3	2	1	1	1	1	1	1	1

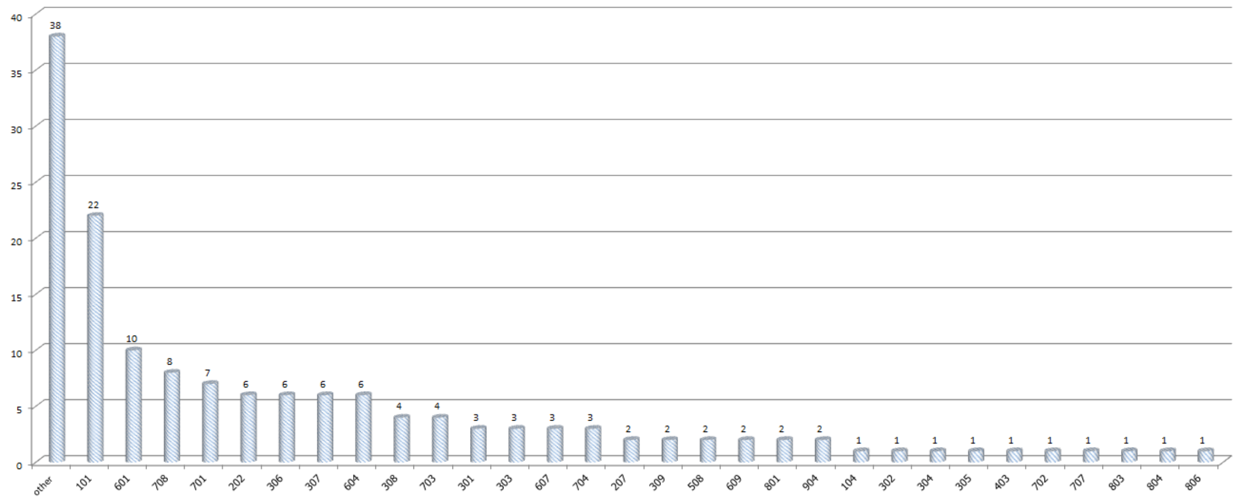


Figure 1 Cause of accidents and collision diagram codes of 5 locations

Appendix II – 13: Accident Statistics Analysis (5 existing flyovers) (continue)

Table 5 Cause of accidents of 5 locations

Cause of accidents/Case No.	1	2	3	4	5	Sum
Not specified	6	9	5	3	7	30
Drunkenness	-	-	3	4	4	11
Violation of traffic signals	2	12	2	2	14	32
Violations of speed limits	12	5	1	5	1	24
Careless road user	3	9	-	1	5	18
No controller	-	-	7	-	4	11
Slippery roads	-	-	-	-	1	1
Hits the Electric column	-	-	-	2	-	2
Fall Down from truck	-	1	-	-	-	1
Road materials Damaged	1	-	-	-	-	1
Brake system failure	1	-	-	-	-	1

And in the figure 2 shows the causes of each accident and involved vehicles with the accidents.

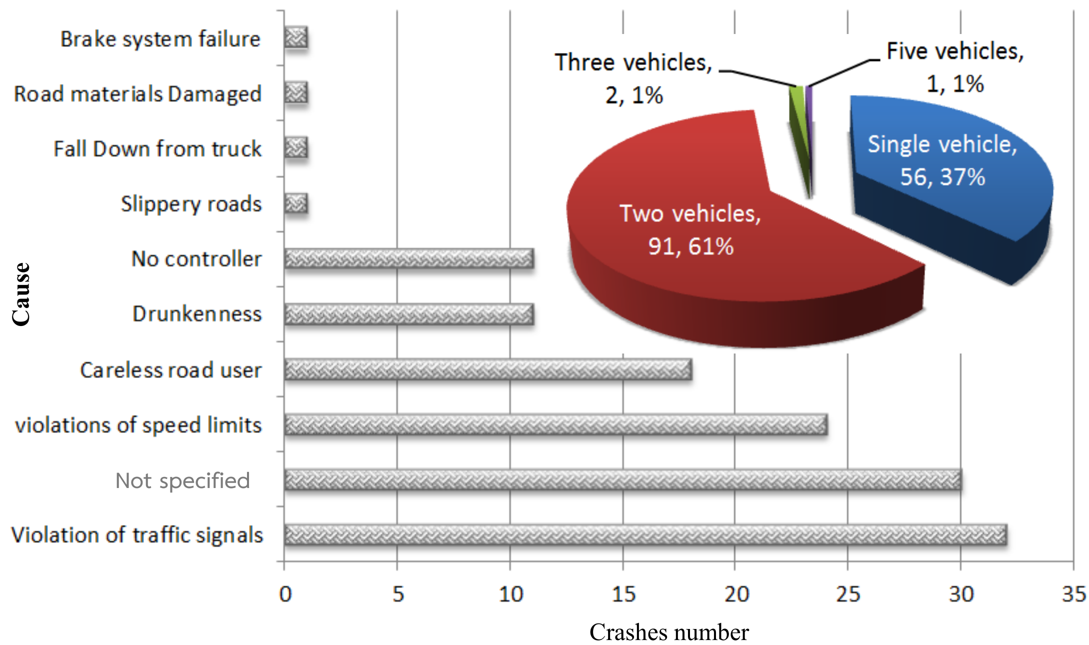


Figure 2 Causes of accidents and involved vehicle with 5 existing flyovers (3 year recorded)

Appendix III

Papers published during the PhD study period (7 papers)

1) ***Study of safety measures during construction work of GSJ*** (APTE 8^{th})
2) ***Road safety study during construction work of an at grade intersection converting it to a flyover*** (Acta Technica Jaurinensis, Szechenyi Istvan University)
3) ***A re look at of the signalized intersection under the flyover junction: A case study*** (NCCE 18^{th})
4) ***Assessment of benefits of flyover over signalized intersection: A case study*** (ATRANS 6^{th})
5) ***Assessment of traffic flow benefits of flyovers: A case study*** (JSTS)
6) ***A study of the flyover-bridge – improved intersection*** (EJ journal, 2015)
7) ***An evaluation of flyover-improved intersections: A case study of airport intersection*** (TSTS 4^{th})

STUDY OF SAFETY MEASURES DURING CONSTRUCTION WORK OF GSJ AT IDENTIFIED LOCATION

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Abstract: The traffic jam and accidents at junctions are chronic trouble. A way can solve the mentioned traffic problems is grade separation construction (Flyover). It has been under construction at highway road number 43 cross pass road number 4135 in Hat Yai District, Songkhla province by Department of Highway (DOH). 558 days are required for this building process. The serious issue is that all vehicles can travel along the road as usual despite the construction. In order to reduce the hazards and to protect all road users, every stage of construction control and construction management should be inspected by Road Safety Audit (RSA).

Key Words: *grade separation, fly over, road safety audit*

1. INTRODUCTION

Accidents in Thailand

The traffic accident record of the Police Information System Center, The Royal Thai Police, indicated that a number of road crashes increased dramatically from 77,616 in 2001 to 124,530 in 2004 when the graph reached a peak. After that, accident cases decreased continuously to 83,093 in 2010. For the economic loss due to the road accidents, 11,652 people were killed in 2001. The record showed that the number of fatality climbed steadily during 2002 to 2004 before it started going down from 13,766 in 2005 to 6,602 in 2010. During this same period, a number of injured people plummeted from 53,960 in 2001 to 17,367 in 2010. (Figure 1)

According to academic researches of the Asian Development Bank (ADB), the accident rates of 10 countries in Asia in 2003 were compared. Officially, Thailand was ranked 2nd in having fatal accidents when the death rate from accidents of 100,000 population were compared and was placed 5th when 10,000 registered vehicles were compared.

Traffic accidents on highway by accident location classification since 2006-2010 are shown in Figure 2. According to stated result, most of the accidents occur on straight areas, curved areas, intersections, and median opening; it is obvious that these areas cause the accidents. This problem should certainly be resolved.

Significance of Problem

From the traffic data at major junctions on highways, it was found that the traffic congestion, traffic accident, and traffic control are ubiquitous problems.

The authority's standard treatment for these issues is to build a flyover. However, the infrastructure is not the right answer to the problems as there are still accidents at the junctions. Traffic control by traffic signals is still applied at flyovers and junctions. The point is that some vehicles enter an intersection against a red traffic light. Many road users have to wait for the green signal so long. Some stuck in a traffic jam for an hour. All these kind of problems measure the efficiency of the flyover. It reflects that new type of the grade separation needs to be created to get rid of the mentioned trouble road users have to face.

One of the southern provinces of Thailand, Songkhla, is approximately 950 km by road from Bangkok, with an area of 7,765.323 sq.km. It is ranked 27th in Thailand in term of size, and the third in the south.

In transport sector, Songkla has a total of 750.748 km route length and 22 train stations for railway; the airport is 9 km from downtown Hat Yai and can support 1,505,906 passengers in 2010. There are more 750,000 registered vehicles per years.

To support traffic volume, the concept of grade separation construction was created by Department Of Highway in Hat Yai. It is located at intersection of highway route number 43 and number 4135 in Songkhla province. It becomes an interesting case. This intersection is an at-grade separated intersection before a flyover was recently constructed at a cost about 250 million baht, at station 24+489.400 km. and 967.00 meter in length of bridge and 558 days of construction time in this project.

Highway road number 43 is 104.268 km. it links road from Phatthalung province along the road to Pattani province. And Highway road number 4135 is 9.965 km. it link road from 414 junction highway route along the road go to Hat Yai International Airport.

In this research, the author will study problems associated with at-grade junction, and flyover at the junction. Traffic movements at this location. The key parameters will include vehicle delay, risk of accidents and investment cost. The cost of providing a junction control is compared for various types of junctions. A recommendation will be made as regards the most appropriate type of junction on highways.

Hat Yai, which is one of the districts in Song Khla province, is an important center for transport and economic growth of the southern provinces, particularly, the transport of passengers and goods in the three deep southern borderland provinces and between Thailand and the neighboring countries like Malaysia and Singapore. Definitely, the transport of passengers and goods are efficiently provided and facilitated by Hat Yai International Airport. And physical data of study area (shown in Figure 3)

2. OBJECTIVE

- To study Road Safety Audit during construction stage of Flyover
- To suggest management and controlling systems during the construction of Flyover

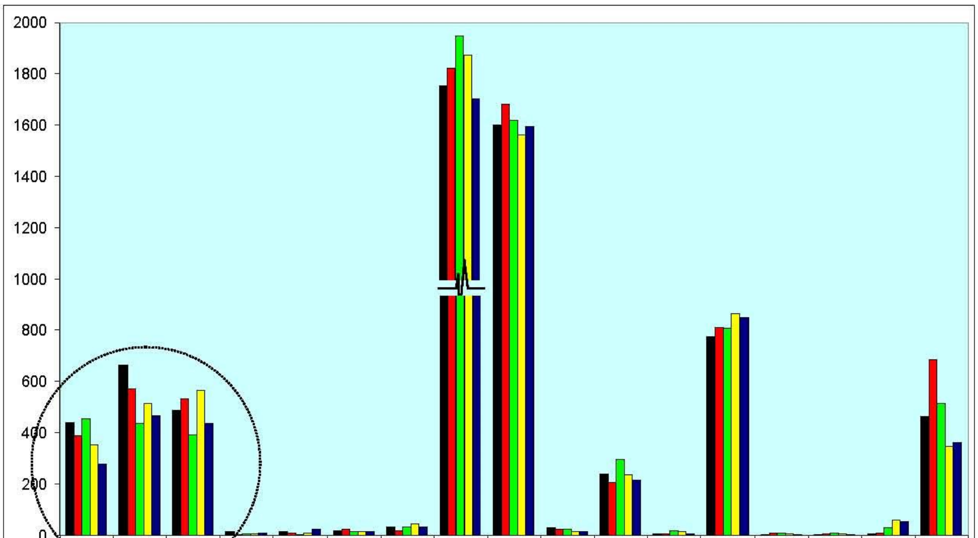
3. LITERATURE REVIEW

- **Definitions of Road Safety**

Road Safety Audit is a formal safety performance examination of an existing or future road or intersection by an independent audit team.
Source: *FHWA Office of Safety*

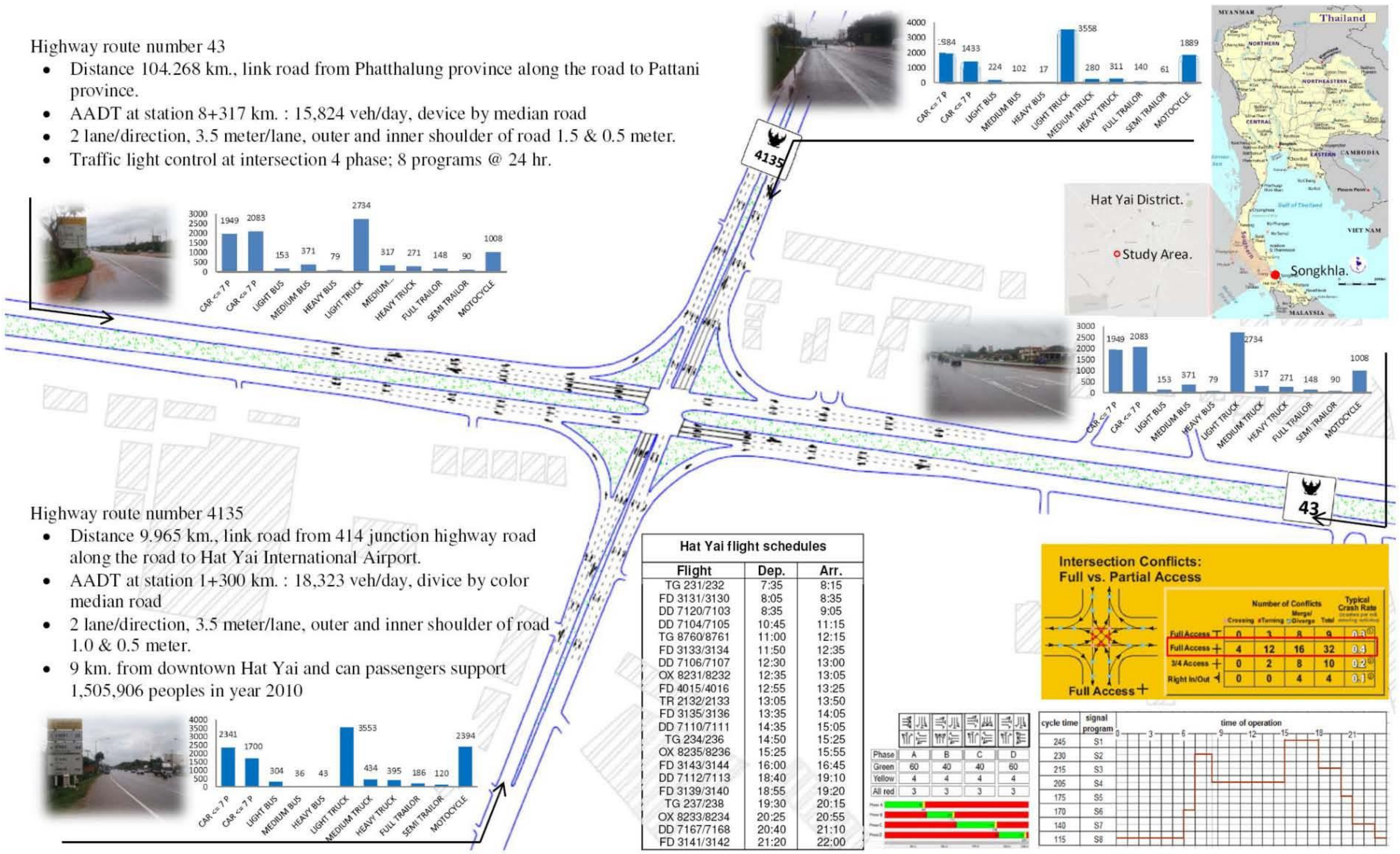
"Road Safety Audit" means an independent detailed systematic and technical safety check relating to the design characteristics of a road infrastructure project. And covering all stages from planning to early operation.
Source: *Andreas Vesper, 2011 (European Commission, 2008)*

Figure 1 Road Traffic Accident in Thailand (1987-2010)
Source: Bureau of Highways Safety, Department of Highways 2010



	+ Intersection	Y ot T Intersection	Othre Intersection	Roundabout	Maim Load Exit	Acess Intersection	Acess Building	Straight	Curve	Crest	Bridge	Detour	Median Opening	Change Lane Width	Railway Crossing	Interchange	Others
2006	443	665	490	14	14	20	34	8102	1603	29	243	7	775	4	4	7	464
2007	391	570	535	4	12	25	19	8646	1683	26	209	6	811	11	8	12	685
2008	458	438	395	8	3	13	35	9655	1620	25	296	19	808	11	10	28	514
2009	353	515	569	6	12	14	43	9048	1563	13	237	14	865	7	6	60	349
2010	279	466	437	11	27	14	32	7680	1597	14	215	7	849	3	2	57	364

Figure 2 Traffic Accident on Highway by accident location in Thailand (2006-2010)
Source: Bureau of Highways Safety, Department of Highways 2010



Hat Yai flight schedules

Flight	Dep.	Arr.
TG 231/232	7:35	8:15
FD 3131/3130	8:05	8:35
DD 7120/7103	8:35	9:05
DD 7104/7105	10:45	11:15
TG 8760/8761	11:00	12:15
FD 3133/3134	11:50	12:35
DD 7106/7107	12:30	13:00
OX 8231/8232	12:35	13:05
FD 4015/4016	12:55	13:25
TR 2132/2133	13:05	13:50
FD 3135/3136	13:35	14:05
DD 7110/7111	14:35	15:05
TG 234/236	14:50	15:25
OX 8235/8236	15:25	15:55
FD 3143/3144	16:00	16:45
DD 7112/7113	18:40	19:10
FD 3139/3140	18:55	19:20
TG 237/238	19:30	20:15
OX 8233/8234	20:25	20:55
DD 7167/7168	20:40	21:10
FD 3141/3142	21:20	22:00

Figure 3 Collected data at study area location

Road Safety Audit is to examine the formal aspects of road traffic in the future or existing road by a qualified independent auditor. This will be reported the potential for accidents and safety of the project or the street.
Source: *Thailand Road Safety Audit Manual, 2009 (Austroads, 2002)*

Road Safety Audit is the method is used to evaluate potential for accidents and safety in the use of construction new road projects, improve and maintain the existing road projects.
Source: *Thailand Road Safety Audit Manual, 2009 (Institution of Highway and Transportation, IHT (2002))*

Road Safety Inspection means an ordinary periodical verification of the characteristics and defects that require maintenance work for reasons of safety.
Source: *Andreas Vesper, 2011 (EU Directive 2008/96/EC [2008])*

"Road Safety Audit: RSA" is a method that is used to evaluate the potential for accidents and safety in the use of new construction project. And projects to improve and maintain the existing road. The road safety audit can contribute to increased safety in two ways;

- Eliminating elements that do not fit that may cause accidents, which can be prevented.
- Reduce the impact of the problem remains or has remained the same. Using appropriate equipment or tools to reduce accidents

Source: *Thailand Road Safety Audit Manual, 2009 (Austroads, 2002),*

■ **The advantages of road safety audit**

- To ensure that the construction of new roads can be used in a safe way
- To reduce the risk and severity of accidents that may occur
- To reduce the overall cost of the project
- To promote the consideration of safety in all stages of the project, including the planning, design, construction, and maintenance.

■ **Basic Principles: Road Safety Audit (RSA)**

"Prevention is better than cure"
"Drive, Ride, Walk in Safety"

■ **Various stages of a project to make safety audits**

Auditor can manage road safety audit in any period of times under a project as follows:

- Feasibility Stage
- Preliminary Design Stage
- Detailed Design Stage
- During Construction Stage
- Pre-Opening to Traffic and
- Existing Roads

■ **Reasons of inspection during all stages of grade separated intersection construction**

- Construction areas are often limited. There are machines and low-speed trucks, compared with high-speed vehicles; this can cause accidents.
- Traffic management by both contractor and employer during the construction is not well considered in safety aspect.
- To check the installation of traffic markers and temporary traffic control signs if they are standard. Generally, they are not of an acceptable standard, for instance, non-reflective signs or traffic sign shortage.
- To inspect safety of related roads if they can be used effectively and in a safe way while the main road is under the construction
- To gain safety for employees working in a construction area and increase good effects for all road users

4. METHODOLOGY

When there is a road construction project that may affect the traffic flow, it also increases the risk of driving. In the each step of construction must be managed/ controlled and planned well to reduce the bad effects of this project in every step. Risk may be increased during every stage of the construction if the traffic is not managed well enough. The process of this study is shown in Figure 4.

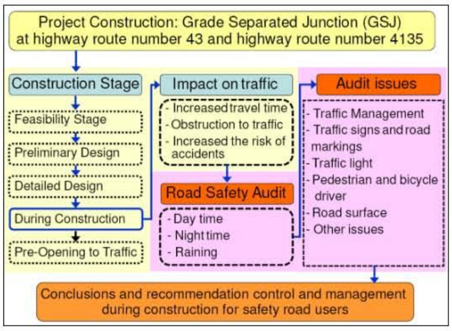


Figure 4 Road safety process during construction stages

5. FIELD STUDIES

Field audit can be checked 3 periods of time: day-time, night-time and raining-time. There are problems under construction; author can explain data from audit findings. Issues and recommendations are shown as below.

5.1 Traffic managements

■ **Traffic Control**

Audit Findings:

- Concrete Blocks are not covered throughout construction zone and road lanes and they are not in the same dimension.
- The installation of temporary traffic signs is not stable.
- Streets warning lights before the construction area are not turned on or sometimes they are only turned-on at night-time.
- The area at turning point from 3 lanes to 2 lanes is difficult for road users.
- In - out zone between construction area and road lanes are not controlled.
- Temporary U-Turn at route number 43 is surrounded by flooding and potholes.
- Temporary traffic signs are installed inappropriately (as shown in Figure 5)

Recommendations:

- Set up the concrete blocks at suitable positions for dividing road lanes and construction area.
- Install warning traffic sign at the location 1 km. before entering the construction area at four directions along the road to be clearly seen at night. They must be reflective. Speed limit warning traffic signs and flashing lights, further, are recommended to install.

Figure 5 Issues: Traffic management

- The temporary traffic signs should be stable, standard, can be easily moved, and can be seen clearly.
- Install street lights along the concrete blocks near construction area and at the shoulder of road.
- Construct the temporary U-turn at new location because this U-turn is very near construction site. New road surface should be paved.

■ **Speed control and management**

Audit Findings:

- There is only one speed limit sign found.
- Project signage is damaged.
- There is a shortage of traffic signs; Traffic notices are installed at inappropriate locations.

Recommendations:

- Speed limit signs in each of the lanes for four directions should be provided before construction zone.
- Traffic signs should be installed at appropriate positions.

■ **Access control in construction area**

Audit Findings:

- Vehicles can always travel around construction site.
- Sections of road and construction are not divided clearly.

Recommendations:

- Installation the Concrete Blocks at appropriate position for divide construction area and lane road to separated

5.2 Traffic signs and Road markings

■ **Traffic signs**

Audit Findings:

- Traffic signs are not reflective at night.
- Background color (brown) and text (black) in traffic sign cannot be seen clearly
- Traffic signs are installed inappropriately.
- Traffic signs have been damaged
- There are traffic signs with different characteristics (as shown in Figure 6)

Recommendations:

- The same standard temporary traffic signs should be designed so that drivers can see them easily at night while GSJ is being constructed.
- There must be the staff turning on and off the street lights every single night.

■ **Reflective equipment and Road markings**

Audit Findings:

- Traffic signs are not reflective.
- Street lights are not turned on and they are seedy.
- Traffic signs are installed inappropriately and they are not enough (as shown in Figure 6)

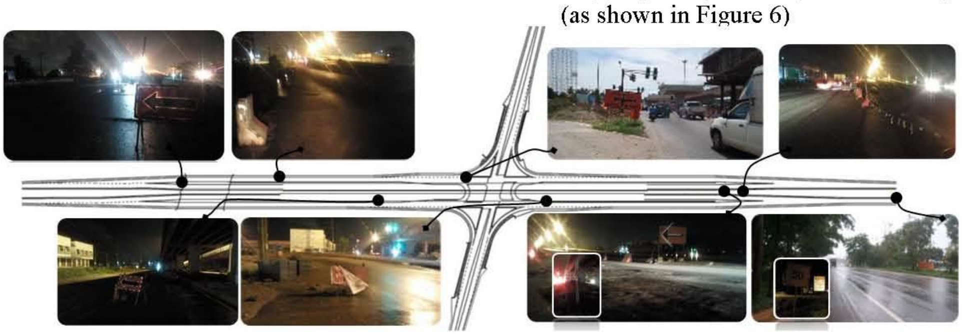


Figure 6 Issues: Traffic signs and road markings

Recommendations:
- Electric lights beside the road and traffic signs should be set up at the right position.
- Damaged traffic signs should be repaired and every traffic sign must be reflective.

5.3 Traffic light

■ **The temporary traffic light**

Audit Findings:
- It lacks of temporary warning traffic lights.
- The Program of phase and the traffic lights are still directed by the old control.

Recommendations:
- Install enough temporary warning traffic lights at construction area.
- Change the phase of traffic control signal during construction to support traffic volume with delay of vehicles waiting at junction.

Recommendations:
- Access control for pedestrians, working people and motorcycle/ bicycle.
- Create temporary stopping lines for bicycle and other vehicles at junction.
- Remove the scraps and raw aggregates from shoulder and surface of road. Also, improve surface road.

5.5 Road Surface

■ **Damage of road surface**

Audit Findings:
- Road surface is not smooth and bumpy.
- There is water covering on road surface.
- Mud mound, soil, and raw aggregates are found on the sidewalk and shoulder of road. (as shown in Figure 7)

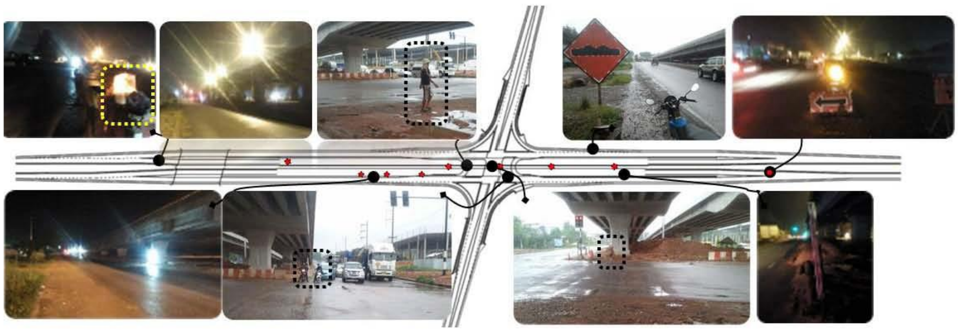


Figure 7 Issues: Pedestrians, bicycle and road surface

5.4 Pedestrians and bicycle

Audit Findings:
- There are not stopping lines for motorcycles and bicycles at junction.
- Potholes and scraps are found on shoulder of road and surface of road.
- There are loose aggregates that reduce skin resistance.

Recommendations:
- Improve new road surface for easy driving.
- Get rid of the mud mound on the sidewalk and shoulder of road to prevent vehicles from sliding at road surface when it is raining.

Figure 8 Issues: other issues

5.6 Other issues

Audit Findings:
- There are no traffic materials for adsorbing energy at edge of the bridge.
- There is a shortage of traffic tools that make dividing area between road surface and road side to prevent vehicles from falling down.
- There are still fixed solid materials near road surface. (as shown in Figure 8)

Recommendations:
- Build the barriers for protecting road users.
- Install the concrete blocks between road and road side at the different level of road surface.
- Provide the street lights at shoulder of road and road side for warning drivers that the road surface are in different level at night or when it is raining.

6. CONCLUSION

Flyover is built and traffic flow at intersection is controlled at the same time within 588 days under construction. Between construction area and road lanes, traffic is managed and controlled. So traffic systems at various positions in the construction zone will be different.

According to Road Safety Audit (RSA), it was found that there were significant issues affecting road users which are:

- Temporary traffic signs before into construction zone has not enough, install at not appropriate position, not reflective at night and with difference characteristics.
- There is a shortage of Concrete Blocks for separating installation between construction zone and road lanes and shoulder of road and road side. Are not installed consecutively and are not in the same dimension
- Temporary traffic signs are not in an acceptable standard. They aren't in the same pattern. They were made by hand. Furthermore, there is a shortage of traffic signs; Traffic notices are installed at inappropriate locations. Importantly, they are not reflective at night.
- Street lights are not enough and they are installed at inappropriate locations.
- There are scraps on shoulder of road, surface of road undulation, potholes. There are loose aggregates and reduced skin resistances.
- Mud mound, soil, and raw aggregates are on the surface and shoulder of the road.

7. RECOMMENDATIONS

Every building project affecting people's life is needed to be controlled and managed systematically in which both of road users and project owner can understand the traffic system exactly to be sustainably safe.

During construction steps the author recommends the staff controlling and managing traffic and construction because they have impacts on drivers who travel through the mentioned area. Moreover, by during so it offers project owner advantages and gain safety to the drivers. The stated recommendations are shown in the Field Studies topic of this paper.

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Road Safety Study during Construction Work of an at Grade Intersection Converting it to a Flyover

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Abstract: A flyover was constructed for solving the traffic problems, to improve the traffic flow at an intersection, to reduce the delays and accidents. 25 traffic accidents occurred during the construction work. This study will point out the issues that might be the cause of all these accidents around the construction area and in the conclusion the data of road safety evaluation (accident costs) will be shown.

Keywords: road safety, flyover construction, accident cost

1. Introduction

To solve the traffic problems at intersections on bypass roads such as traffic volume, accidents (as shown in Figure 1) and delays etc., the flyover is one of the tools to solve these problems. Normally in Thailand, the flyover is constructed at junctions on bypass roads near big cities.

A flyover is the special bridge constructed above existing at-grade intersections. It allows for the free flow of traffic on different levels, with the main goal of for reducing traffic conflicts, whereas the intersection is still the same old signal controlled.

Hat Yai City is an important center of the transport sector and economic growth of the southern provinces, particularly, the transport of passengers and goods in the three borderland southern provinces and between Thailand and neighboring countries like Malaysia and Singapore. Definitely, the transport of passengers and goods are efficiently provided and facilitated by the transport sector; Songkhla has a total of 750.748 km. of route length, 22 train stations and Hat Yai International Airport (9 km from the downtown of Hat Yai city) can support 1,505,906 passengers in 2010.

In 2009 the Government hired the Department of Highway (DOH) to construct a flyover at Sanambinnai Intersection. It was constructed on a length 1+325.570 kilometers above the old intersection by an investment of 249,597,672.5 THB. There were about 12,500 vehicles per day (DOH, 2008) travelling as usual despite the construction and 25 accidents occurred (DOH, 2011) during construction work. This

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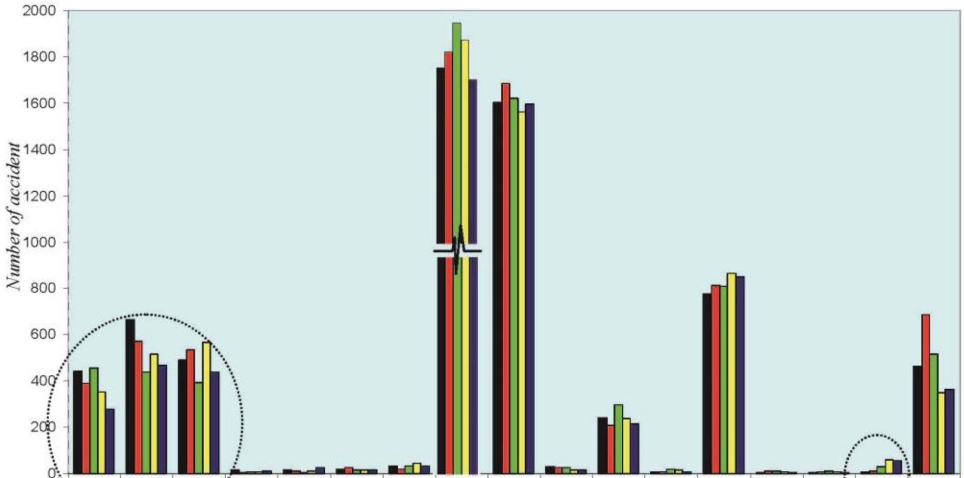
study will point out the issues that might be the cause of all these accidents around the construction area and in the conclusion the data of road safety evaluation (accident costs) will be shown.

2. Study area details

The study area consists of Highway route number 43 and Highway route number 4135 in Songkhla province. The intersection was an at-grade one before a flyover was recently constructed at station 24+489.400 km (a schematic map of Hat Yai city is shown in Figure 2), and 967.00 meters of length of bridge and 540 days of construction time (increased to 929 days due to the natural disaster).



	+ Intersection	Y ot T Intersection	Othre Intersection	Roundabout	Maim Load Exit	Acess Intersection	Acess Building	Straight	Curve	Crest	Bridge	Detour	Median Opening	Change Lane Width	Railway Crossing	Interchange	Others
2006	443	665	490	14	14	20	34	8102	1603	29	243	7	775	4	4	7	464
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2009	353	515	569	6	12	14	43	9048	1563	13	237	14	865	7	6	60	349
2010	279	466	437	11	27	14	32	7680	1597	14	215	7	849	3	2	57	364

Location

Figure 1. Traffic accidents on highways by accident location in Thailand [4]

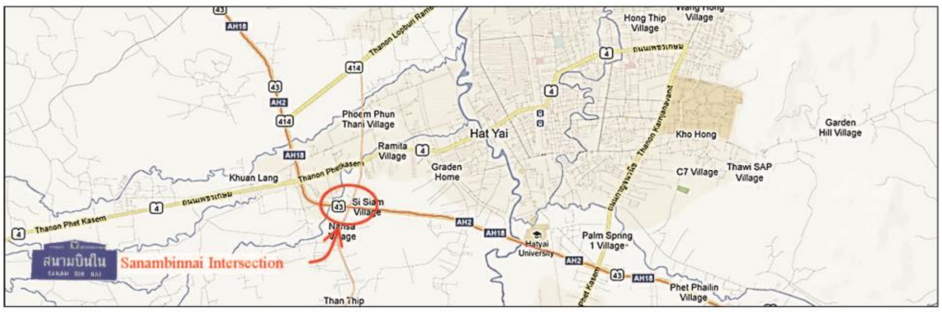

Figure 2. A schematic map of Hat Yai city with the study area marked

This intersection is situated at 6˚59'13.00" N latitude and 100˚25'42.93" E longitude and the physical data of the two important roads are;

Highway route number 43

- The distance is 104.268 km, link road from Phatthalung province along the road to Pattani province,
- AADT at station 8+317 km: 15,824 vehicles/ day and lane separated by an island, and
- 2 lanes/ direction, 3.5 meter/ lane, outer and inner shoulders of the road are 1.0 & 0.5 meter, respectively.

Highway route number 4135

- The distance is 9.965 km, link road from the Sanambinnok intersection along the road to Hat Yai International Airport.
- AADT at station 1+300 km: 18,323 vehicles/ day and lanes separated by yellow markings, and
- 2 lanes/ direction, 3.5 meter/ lane, outer and inner shoulders of the road are 1.0 & 0.5 meters respectively.

The signal control at the intersection was fixed time type, 4 phases, 2 programs a day; the first program has a cycle length of 244 seconds, it was operating from 06:00 am to 12:00 pm and the second program was flashing amber, it was used from 00:00 am to 06:00 am, the data as shown in Figure 3.

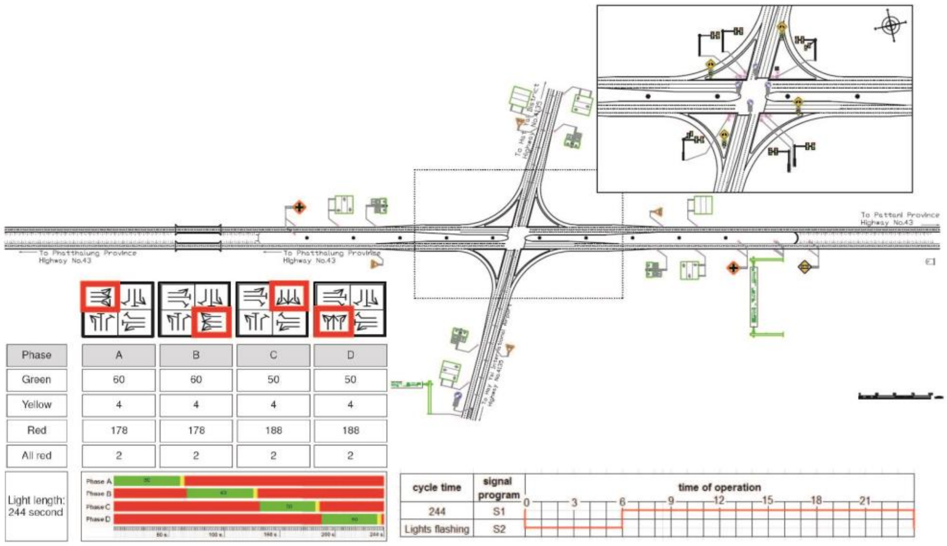

Figure 3. Physical data of highway route no 43 and highway route no 4135 (before construction) and the signal control program

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3. Methodology

This study will point out the traffic problems during the construction work between the construction zone and road users since the first to the last day of this project.

3.1. Stages of construction

During the stages of construction, there were 3 main steps for protecting the road users travelling through this intersection (shown in the figure 4). The project owner planned and installed traffic signs, flashing beacons and other informational signs.

In Zone 1 the river bridge was constructed, the road was extended to 3 lanes and the pillar for a special bridge was constructed on the road island. Concrete blocks and traffic cones were installed for dividing road users from the work zone, but sometimes it was divided explicitly, but sometimes it was not installed to protect and temporary U-turn was constructed by soil material near the river bridge.

In Zone 2 the pillar of the special bridge was constructed, this process was implemented simultaneously with zone 1 and the management process was similar to that of zone 1.

Zone 3 was the last area to work on, after all pillars of the special bridge were constructed in zone 1 and 2. The traffic signals were operating like the old signals (fixed time type, 4 phases, 2 programs a day, but changed the cycle time of the first program from 244 to 254 seconds, it was operating from 06:00 am to 12:00 pm and the second program (flashing amber), was used from 00:00 am to 06:00 am.

24 accidents occurred in the zone no 1 and zone no 2 and all accidents were registered.

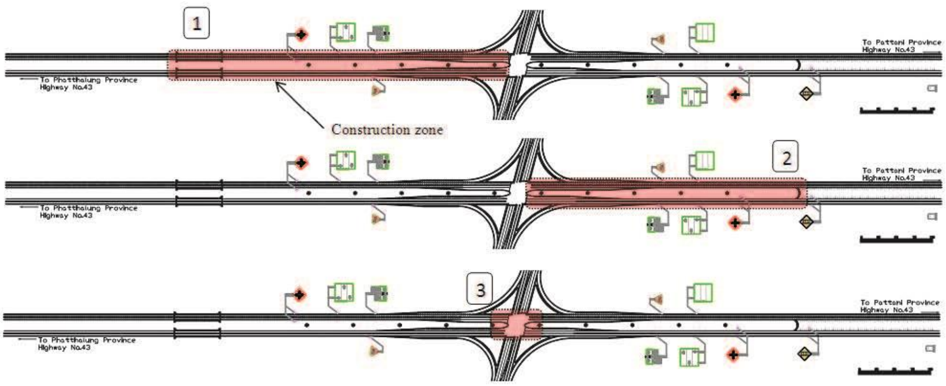


Figure 4. Stage during construction management

3.2 Road Safety Audit

Road Safety Audit under construction stage covers the following items [9];

- ❖ Traffic Management,

- ❖ Traffic signs and road markings,
- ❖ Traffic signals,
- ❖ Pedestrians and bicycles,
- ❖ Road surface, and
- ❖ Other issues.

Field audit was conducted during 3 periods: day-time, night-time and raining. The following issues were found during on-site audits:

- ❖ Traffic Managements

The picture of traffic management issues are shown in Figure 5

- The temporary traffic signs were installed at inappropriate locations,
- Did not have the staff to protect 2 zones,
- Auditor found only one of the speed limit signs (50 km/h); it was installed on the HW route 43 before entry to intersection 300 meters,
- Concrete blocks did not cover the construction zone, they did not protect the road users and construction zones, on the contrary, they raised problems for the road users because of their different sizes and, installed at inappropriate locations,
- Street lights according to the guideline of road lane direction were not turned on every night, and
- Road sections and construction zones were not divided clearly, so vehicles could enter and cross construction zones.

- ❖ Traffic signs and Road markings

The pictures of traffic signs and road marking issues are shown in Figure 6

- The installation of temporary traffic signs was not stable, not enough and insufficient,
- Traffic signs were not reflective at night and some traffic signs were damaged,
- Background (brown) and text (black) in traffic signs could not be seen clearly,
- There were traffic signs with different characteristics, and
- Road markings at intersection could not be seen clearly.

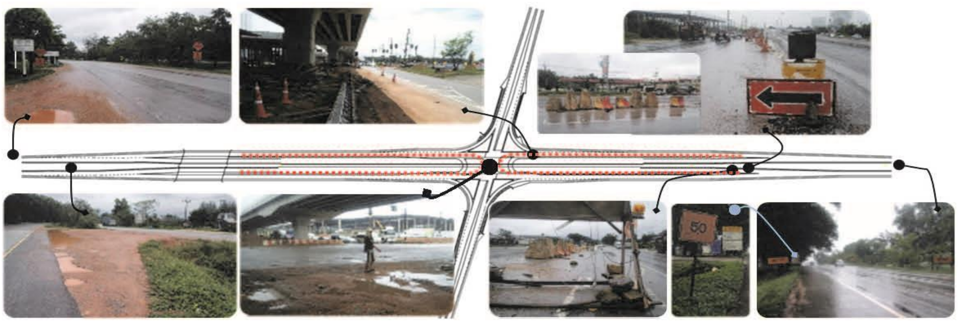


Figure 5. Traffic management issues

❖ Traffic lights

- The traffic signal control was using 4 phases, it consisted of 2 programs a day; the first program had a cycle of 254 seconds, it was operating from 06:00 am to 12:00 pm. During peak time (7:45-8:00 am) average queue length of the 4 legs were 48 vehicles (PCU). The second program was flashing amber, it was used from 00:00 am to 06:00 am.

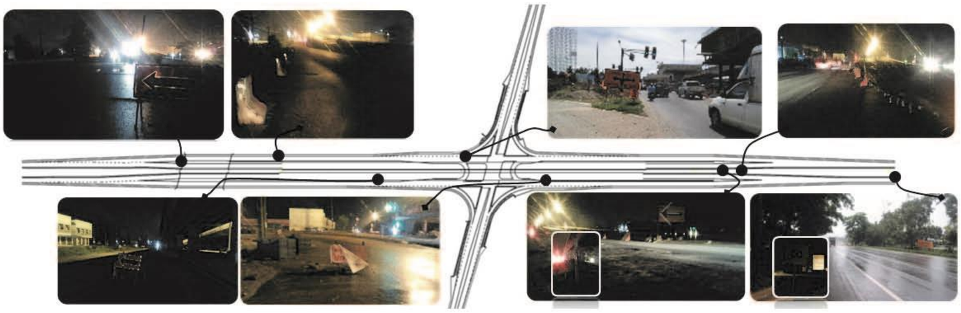


Figure 6. Traffic signs and road marking issues

❖ Pedestrians and bicycles

The pictures of pedestrians and bicycle issues are shown in Figure 7

- There were no stopping lines for motorcycles and bicycles at the intersection,
- There were scraps on the shoulder of the road, the bicycle cannot bike on this area, and
- There were loose aggregates that reduce skid resistance around this construction zone.

❖ Road Surface

The pictures of road surface issues are shown in Figure 7

- Road surface was not smooth and bumpy,
- There was water covering the surface of road after rain, and
- Mud mound, soil, and raw aggregates were found on the sidewalk and on the shoulder.

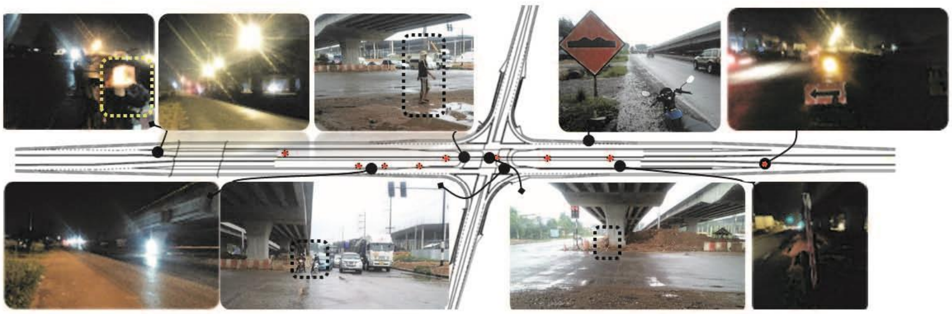


Figure 7. Pedestrians, bicycles and road surface issues

❖ Other issues

The pictures of other issues are shown in Figure 8

- There were no energy absorbing devices at the edge of the river bridge,
- There were no guardrails or concrete blocks between the road surface and roadside area to prevent the vehicles from falling down the road, and
- There were fixed rigid objects near the road surface.

Figure 8. Other issues

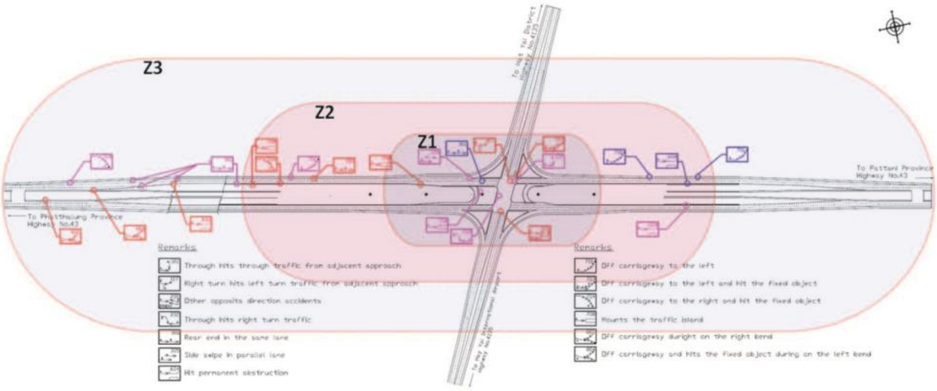
3.3. Accident statistics

As for accident statistics during construction work, this study collected data from the Department of Highways (DOH) and from the project owner. During the 929 days of construction, 52 accidents were found, of which 25 were sufficiently documented. Data cover such as spot of accidents, collision diagram, number of casualties, property damage only and cause of the accident.

4. Results and discussions

This intersection was improved by an investment costing about 250 million THB. The intersection was audited according to the road safety manual. In accidents statistic the top three causes of accidents were rear-end in the same lane (6 cases), hit with fixed solid objects (3 cases) and vehicle hits vehicle at intersection (3 cases) respectively. Vehicle types of the top three of the accidents are first one is car (13 vehicles), second is pick up (11 vehicles) and third is trailer (8 vehicles) respectively. On 15th April 2012 the new flyover was opened, under the flyover it is still the old junction controlled by traffic signals.

All of the 25 accidents where the data on the spot of accident and time of the accident are consistent with the time of management of each zone are shown in Figure 10. Accident costs were calculated as follows;



Accident: 25 times/ 929 days (Z1: 9, Z2: 9, Z3: 7)

Time of Accident				Number of Casualty			Property Damage Only
Dry		Wet		Injury	Serious	Died	
Day	Night	Day	Night				
8	11	6	-	20	6	6	1,353,900

Legend

Dry/Day Time
Wet/Day Time
Dry/Night Time
Wet/Night Time

Figure 10. Spot of accident at intersection area and collision diagram

5. Accident costs (AC)

Used to describe the combined effect of number and severity of the accidents [8]

Annual average accident cost ACa [€/year]:

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

where: A is number of accidents (acci),

MCA is the mean cost per accident (€/acci) as shown in table 1, and

t is the period of time under review (year).

$$ACa(F+SI+LI+PDO) = \frac{(6\times 5{,}178{,}000)+(6\times 151{,}500)+(20\times 29{,}750)+1{,}353{,}900}{(929/365)} = 13{,}329{,}336\ Baht$$

Table 1. The mean cost per accident for various severities [5]

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

6. Conclusion

According to Road Safety Audits under construction stage, the issues of on-site audits can be summarized as follows;

- The number of "temporary traffic signs" was not enough, no maintenance during construction, installed at improper locations, not reflective at night and made by hand (different styles and dimensions),
- "Concrete Blocks" not covered the construction zone, they did not protect the road users and construction zones, on the opposite, they caused problems for the road users because of their different sizes and inappropriate locations,
- "Street-lights" were not installed consecutively and not turned on every night,
- "Road surfaces" were not smooth but bumpy, the mud mound on the shoulder of the road made always a problem when raining, and
- There were no guard rails or concrete blocks between the road surface and roadside area to prevent the vehicles from falling down the road, although there were fixed rigid objects near the road.

Accident statistics during construction work is a reflection of construction management; there were 52 accidents (this 52 accidents were collected by 3 agencies) of 929 days. Because the sufficiency of accident data from 3 agencies is different, this study only used accidents data from Department of Highway (25 accidents). The cost of these 25 accidents occurred is equivalent to 13,329,336 THB in 2011.

7. Recommendations

In terms of Road Safety, the recommendations of this study are the followings;

- The "temporary traffic signs" should use standard signs, installed at appropriate and sufficient locations "Road surface" should not have pothole and soil aggregates on the road surface.
- "Street-lights" should be installed consecutively and turned on every night
- "Concrete Blocks" should be installed at appropriate locations, they should clearly show which are road user, roadside and construction zones. They should be installed covering the project construction area without gaps.
- Traffic signal control during construction and open road should follow traffic volumes of each leg and period of the day, and

- Field works should have traffic engineering staff for controlling or checking the possibility of accidents.

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A re look at of the signalized intersection under the flyover junction: A case study

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Abstract

Traffic signalization for an intersection often uses the same fixed time control plans, even after the intersection has been converted to a flyover. This paper presents a study of the performance of a flyover intersection in Hat Yai, South Thailand. The flyover bridge was constructed to increase capacity of traffic flow in two directions on one of the main road. It was found that about 35-40% of the total traffic volume was diverted to the flyover. However, traffic flows underneath the flyover still experience long delay and queue length similar to the 'before' situation. This paper points out the remaining problems of the signalized intersection including long delays and queue lengths. The SIDRA software was used to determine key parameters in terms of level of service, delay, queue length, fuel consumption and phase timing.

Keywords: Flyover, Traffic congestion, Signalized intersection, Vehicle delay

1. Introduction

The flyover is a bridge that constructed on a highway road over the at-grade junction. It allows the traffic volume for the free flow on the bridge.

The flyover is one of the methods that is often applied to solve problems at junctions on highway roads such as traffic congestion, delay and queue length etc.

There are 29 locations of this flyover model in Thailand (https://maps.google .co.th, 2012) as shown in figure 1, the flyovers mostly constructed at the junctions on the bypass highway roads near the big city.

The efficacy of the flyover is still not much different from the old signal controlled at-grade junction, the flyover can reduce the traffic congestion in its direction of the bridge that constructed, but the infrastructure cannot fully solve the problems like delay and queue length under flyover.

Hat Yai is the prominent City center of the south of Thailand. The total route length of Songkhla province there are 750.748 Km, 22 train stations and one Hat Yai International Airport (9 km from the downtown Hat Yai City) which can support 1,505,906 passengers in 2010.

The flyover which was constructed at an old intersection of the highway and crossing roads near Hat Yai City, Thailand was found that about 35-40% of the total traffic volume is diverted to the flyover, which results in a reduction of about 45% in the total delay. Using the flyover resulted as much as 60–70% saving in travel time.

This intersection which was converted to be the flyover cost about 250 million THB, paid by the Government who hired Department of Highway (DOH) to construct.

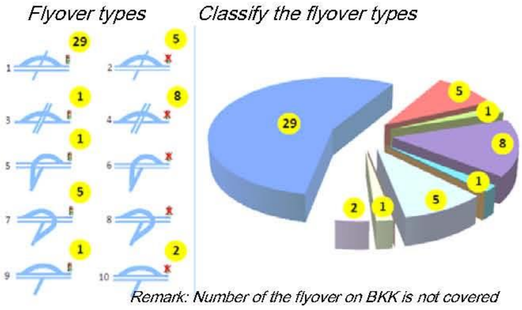


Figure 1. Number of the flyovers at junctions in Thailand (2012)
(Source: https://maps.google.co.th, 2012)

2. Study area

Study area consists of highway route number 43 and highway route number 4135 in Hat Yai City, Songkhla province, Thailand. This intersection was constructed and converted to a flyover at station 24+489.400 km., on a highway route number 43 (main road), 967.00 meters of the bridge length; it crosses pass an old at-grade intersection. The schematic map of the Hat Yai City with study area marked as shown in figure 2.

Figure 2. A schematic map of Hatyai City with study area marked

This intersection situated at 6˚59'13.00" N latitude and 100˚25'42.93" E, a longitude of 20 meters above the sea level, the physical data consists of two main roads which are;

Highway route number 43: the road is 104.268 km., linked road from Phatthalung province along the road to Pattani province, the AADT has 15,824 vehicles per day (two directions, checked at station 8+317 km.). The road is divided into 2 lanes by the traffic island, 3.5 meters per lane . Outer and inner of the shoulders of the road are 1.0 & 0.5 meters, respectively.

Highway route number 4135: the road is 9.965 km., linked road from the Sanambinnok intersection along to Hat Yai International Airport, the AADT has 18,323 vehicles per day (two directions, checked at station 1+300 km.), the yellow color lines divide the road direction, 2 lanes per direction, 3.5 meters per lane; outer and inner of the shoulders of the road are 1.0 & 0.5 meters, respectively.

3. Collected field data

These collected data took place on Tuesday, 18th Oct 09 (before construction) and Tuesday, 17th July 12 after construction, about 2 years and 9 months are the period of data counted on-site between first time and second time, the collected data were summarized and shown on figure 4.

3.1 Traffic movement count

The traffic movement at both the ends of the flyover on HW #43 and at-grade intersection under the flyover (HW #43 and HW #4135) counted manually on 24 hours for checking the traffic movement a day (24 hour). The traffic movement counted location marked as A, 1, B, C, 2 and D on the main road (HW #43) and secondary road (HW #4135) as 3 and 4. The vehicles categorized mainly under five categorizes; 2-wheelers (MC), 3,4-wheelers (PC), 6-wheelers (MB), Bus (B) and Heavy-duty (L). The traffic volume of all vehicle data changed to passenger car unit (PCU) by the factor of each type as follows are 0.33, 1.0, 1.75, 2.25 and 2.25, respectively. Figure 4 shows (graph) the traffic volume and delay.

The traffic movement on the at-grade intersection (before construction) collected on the 18th of Oct , 2009 by the department of highway (DOH) then the researcher adapts it for study. The vehicles on the highway route number 4135, from "South" approaching to an intersection is 17,316 PCUs/day, from "North" approaching to an intersection is 16,894 PCUs/day, and on the highway route number 43, from "East" approaching to an intersection is 17,284 PCUs/day, from "West" approaching to an intersection is 17,225 PCUs/day.

Traffic movement on the flyover (under the bridge), (after constructing); this collected data took place on the 17th of July 2012. The vehicles on the road number 4135, from "South" approaching to an intersection there are 21,075 PCUs/day, from "North" approaching to an intersection there are 19,944 PCUs/day, and on the road number 43, from "East" approaching to an intersection there are 17,621 PCUs/day, from "West" approaching to an intersection there are 3,663 PCUs/day, and the traffic movement to the flyover from "East" to "West" are 19,161 PCUs/day and 15,958 PCUs/day of opposite direction.

3.2. Delay

The delay on-site survey of both times counted in 24 hours it was counted with the traffic movements. The results of both types depend on the signal control, junction type, and travel demand. The delay on the at-grade intersection is 44,223.96 minutes/day (95.4 Sec/cycle) and the delay of the flyover is 30,774.69 minutes/day (91.8 Sec/cycle). If compare between the total traffic vehicles stopped the flyover can distribute vehicle more than an at-grade intersection. The vehicles stopped ratio for waiting green time of flyover and at-grade intersection are 21% and 40% respectively.

On 3 peak time a day of the flyover; the delay on the main road (HW # 43) and secondary road (HW # 4135) there are 19.64 minute/cycle and 41.41 minute /cycle by an average, respectively. The level of service is B and D level, respectively.

3.3. Queue length

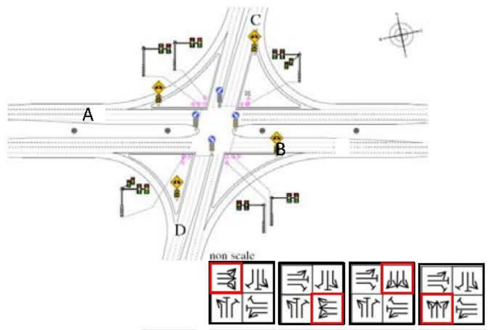
The queue length was checked simultaneously with the traffic movement count, to check the length of vehicles that stopping waiting the green phase at the at-grade intersection, a cycle time of the flyover has 224 seconds there are vehicles stopped 48 vehicles (count only one lane per direction that the vehicle stopped more than each lane) on the most direct way. This data can also set the time phases of a cycle.

3.4. Travel time and vehicle speed

The average speed of the vehicles was checked by the radar-gun in 4 areas on crossing areas under the flyover, 2 areas of the diverge zone before entering to under and upon the flyover and 2 areas of the merging zone on the opposite of the diverge zone. The recorded travel time and estimated average vehicle speed for each of the observations taken by the radar-gun can free flow plotted. 50 PCUs per areas in the each zone checked and used 85 percentile of speed for analysis.

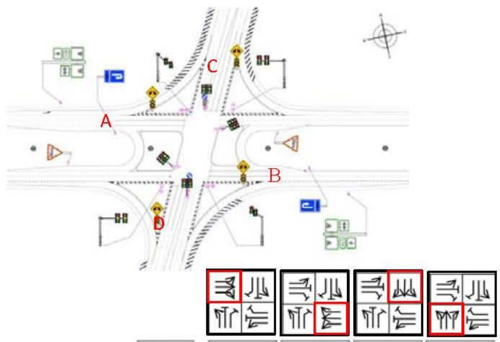
3.5. Traffic signal control

Traffic signal control at the intersection of both models controlled by fixed-time type. There are two programs a day; the first one of light length is 244 seconds which was controlled during 06:00 am to 12:00 pm (4 phases per one cycle), and second program which was controlled by lights flashing was collected during 00:00 am to 06:00 am. After the flyover constructed it still employed the same signal control, but it only changed a cycle time of the first program is 224 seconds, as shown the before and after of both data on figure 3.



Phase	A	B	C	D
Green	60	60	50	50
Yellow	4	4	4	4
Red	178	178	188	188
All red	2	2	2	2
Light length: 244 second				

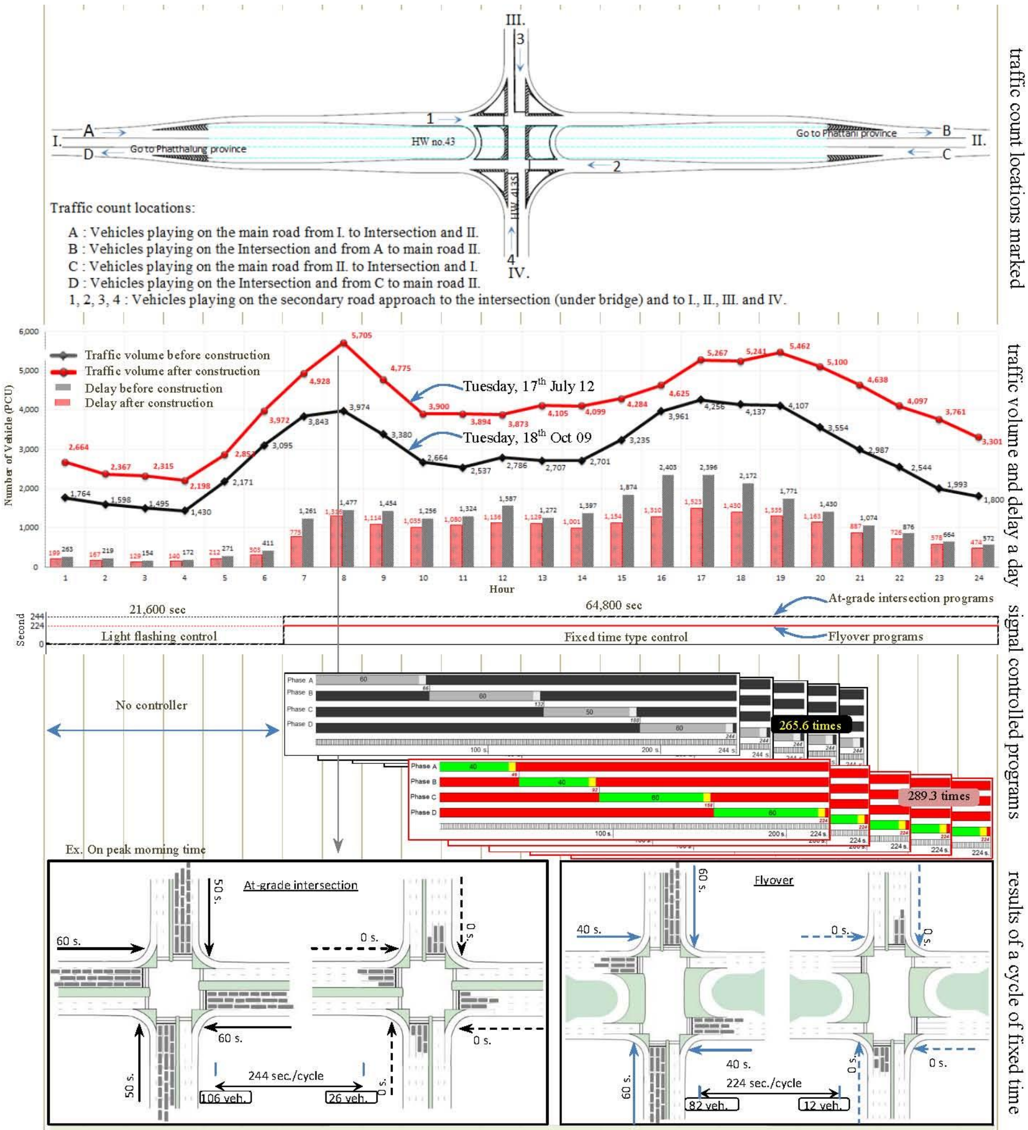
cycle time	signal program	time of operation
244	S1	
Lights flashing	S2	



Phase	A	B	C	D
Green	40	40	60	60
Yellow	4	4	4	4
Red	178	178	158	158
All red	2	2	2	2
Light length: 224 second				

cycle time	signal program	time of operation
224	S1	
Lights flashing	S2	

Figure 3. Traffic signal control of before and after construction



Comparison of both types

Before construction	Items/type of junction	After construction
68,719	Total Traffic volume (PCUs/day)	97,423
27,750 (44223.96 minute/day)	Total Delay (vehicles)	
[27,750x(97,423/68,719)]=39,341	[Delay compared with the total traffic volume of flyover]	20,316 (30774.69 minute/day)
40,969	Variance of the vehicle data (traffic volume -vehs stopped)	77,107
[(1/68,719) X 27,750] = 0.40	Risk of vehicles stopped = Frequency x Impact	[(1/97,423) X 20,316] = 0.21
95.4	Delay (second/vehicles/cycle)	91.8

Figure 4. Collected field data of both type control

The summary data as shown above in figure 5 consist of the traffic count locations marked, traffic volume and delay, signal control programs, results of a cycle of fixed time and comparison of traffic volume of both types.

4. Results and discussions

4.1. Traffic flow reduction

The flyover can support traffic flow only on the main road. The total traffic movement is 97,423 PCUs per day; the total traffic volume was diverted to the flyover is 35,120 PCUs per day, it is 36.05% of all traffic volumes especially heavy trucks and trailers.

At-grade intersection under the bridge supported only the residue of traffic volume is 56,404 PCUs per day, but amount 75-80% of all vehicles play on highway route number 4135.

4.2. Delay reduction

The flyover can only support traffic flow on the main road, but on at-grade intersection under the bridge still have the traffic congestion and delay, especially on the highway route number 4135 of both directions. Refer from figure 5, we found the delay reduction is 19,025 PCUs per day or reduced to 48.36%.

The risk of both types are reductions of delay, on the at-grade intersection is 40% and at the flyover is 21% or it reduced to 47.5%. While waiting at traffic signals, often the commuters have to keep their vehicle engines on, that result in the undue combustion of precious fuel.

4.3. Fixed time type controller

The fixed time model of signalized at-grade intersection under the flyover serve the traffic volume amount 56,404 PCUs per day. This model designed for controlling during 06:00 am to 12:00 pm, 224 second of one cycle.

In one cycle of the program, there are 4 phases which are the green time on highway route number 43 is 40 second of both directions and 60 seconds of the both directions on highway route number 4135. These fixed-time does not depend on the number of vehicles per cycle. The yellow time is 4 seconds of all directions. The traffic volume per day that are collected was designed per hour of a day as shown in table 1.

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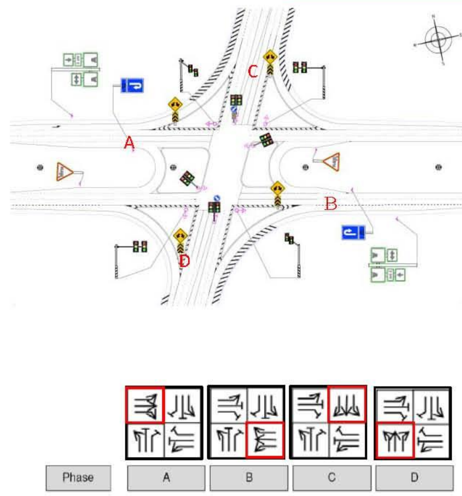
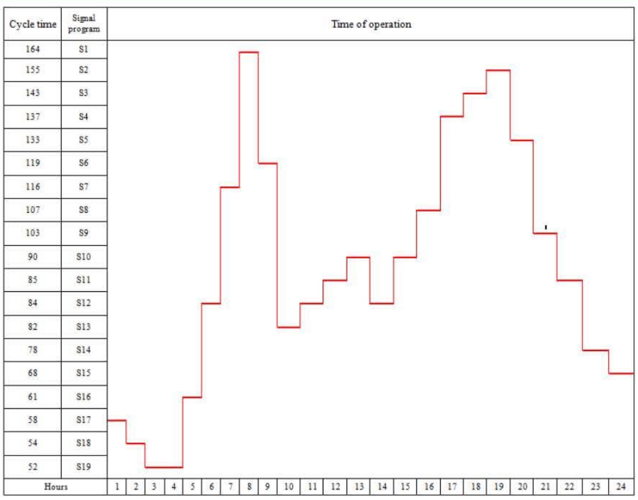
Table 1. A signal program designed per hours of a day

Hour		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Traffic volume	1	109	97	86	89	114	149	187	208	183	160	164	168	153	135	154	188	173	191	201	189	156	145	141	123
(PCU)	2	472	425	389	425	511	742	845	898	920	691	675	656	730	755	758	760	913	983	1001	992	879	771	743	687
	3	544	483	438	398	577	798	1082	1342	1063	875	845	815	737	785	834	880	980	1092	1123	1012	985	891	767	598
	4	593	511	472	454	655	871	988	1064	976	806	878	950	1073	890	956	1163	1254	1098	1132	1087	912	788	779	725
	Sum	1718	1516	1385	1366	1857	2560	3102	3512	3142	2532	2562	2589	2693	2565	2702	2991	3320	3364	3457	3280	2932	2595	2430	213
Clitical Lane Volume on each phase	CLV1	55	49	43	45	57	75	94	104	92	80	82	84	77	68	77	94	87	96	101	95	78	73	71	62
(PCU/lane)	CLV2	236	213	195	213	256	371	423	449	460	346	338	328	365	378	379	380	457	492	501	496	440	386	372	344
	CLV3	272	242	219	199	289	399	541	671	532	438	423	408	369	393	417	440	490	546	562	506	493	446	384	299
	CLV4	297	256	236	227	328	436	494	532	488	403	439	475	537	445	478	582	627	549	566	544	456	394	390	363
	Sum (CLVt)	859	758	693	683	929	1280	1551	1756	1571	1266	1281	1295	1347	1283	1351	1496	1660	1682	1729	1640	1466	1298	1215	106
Required Greentime, Rg	CLVt *	1374	1213	1108	1093	1486	2048	2482	2810	2514	2026	2050	2071	2154	2052	2162	2393	2656	2691	2766	2624	2346	2076	1944	170
where : Headway = 1.6 sec.	Headway																								
Available Lost time, Alt	3600 - Rg	2226	2387	2492	2507	2114	1552	1118	790	1086	1574	1550	1529	1446	1548	1438	1207	944	909	834	976	1254	1524	1656	189
Lost Time per Cycle, LTpC	(3+6)*4	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36
where : veh acceleration time = 3 sec.																									
: veh stopping time = 6 sec.																									
Number of Cycle, NC in hour	Alt /LTpC	61.82	66.31	69.22	69.64	58.73	43.11	31.07	21.96	30.18	43.73	43.07	42.47	40.16	43.00	39.96	33.53	26.22	25.24	23.18	27.11	34.84	42.33	46.00	52.6
	Approximation	62	66	69	70	59	43	31	22	30	44	43	42	40	43	40	34	26	25	23	27	35	42	46	53
Cycle Length, C	3600 / NC	58	54	52	52	61	84	116	164	119	82	84	85	90	84	90	107	137	143	155	133	103	85	78	68
Cycle Split per cycle																									
(CLVn * C)/CLVt	1	11	11	11	11	11	12	14	17	14	13	13	13	12	12	13	14	15	16	17	16	13	12	12	11
Gi is (>) Lost Time per direction	2	16	15	15	16	17	24	32	42	35	22	22	21	24	25	25	27	38	42	45	40	31	25	24	22
Green time, Gi = green + amber	3	18	17	16	15	19	26	40	63	40	28	28	27	25	26	28	32	41	46	50	41	35	29	25	19
	4	20	18	18	17	22	28	37	50	37	26	29	31	36	29	32	42	52	47	51	44	32	26	25	23
Possibility data of each phase checking																									
(Gi-Li)/h * true NC	1	77	83	87	87	73	81	97	110	94	109	108	106	75	81	100	105	98	110	116	119	87	79	86	66
	2	270	258	243	308	289	410	438	452	489	368	351	331	384	420	406	383	471	515	521	528	479	430	429	429
	3	365	344	322	264	369	459	610	736	591	532	500	469	390	447	470	473	517	588	601	542	560	534	451	335
	4	429	385	377	356	463	523	542	558	529	470	529	587	671	539	571	686	702	592	606	593	504	445	463	469
Amber Time, Ai=t + 0.5(v/a) + ((w+L)/v)																									
where : Ai = amber time	1	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
t = decision time = 1 sec	2	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
v = approach speed (25= 1,2), (32.5= 3,4)	3	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
a = acceliration = 5 m/sec	4	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
w = width of int (25= 1,2), (52.5= 3,4)																									
L = length of vehicle (3.6 m)																									
All reds is 1/3 of Ai	1,2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
	3,4	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Red phases	1	47	43	41	41	50	72	102	147	105	69	71	72	78	72	77	93	122	127	138	117	90	73	66	57
	2	42	39	37	36	44	59	84	122	84	60	62	63	65	59	65	80	100	101	110	93	72	60	54	46
	3	40	37	36	37	42	57	75	101	79	54	56	58	65	58	62	76	97	96	105	92	69	56	54	49
	4	38	36	34	35	40	55	79	114	82	56	55	54	54	55	58	66	85	96	104	89	71	59	53	45





4.3. Project evaluation

To evaluate the cost-benefit of the flyover and the effect of flyover reducing delay to traffic flow, the economic analysis (Garber and Hoel, 1997) are the Net Present Value (NPV), Benefit–Cost Ratio (BCR) and Internal Rate of Return (IRR). According to invested cost about 250 million Baht, this project have to assessment of benefits in terms of traffic volume and delay after construction.

- ❖ Investment cost = -249,597,672.5 Baht
- ❖ Maintenance cost = -27,000 Baht/year

Delay (After-Before) per year; compare with before and after flyover was constructed, two of all for checking the cost reducing before construction, consists of fuel consumption and time cost.

➢ Fuel Consumption (Fuel consumption during running and idling at the signals); while waiting at traffic signals, often the commuters have to keep their vehicle engines on, that result in the undue combustion of precious fuel. Fuel consumption in traveling waiting at the intersection (under the flyover), the average fuel economy and fuel consumption during idling conditions of vehicles, S. K. Goyal, S. Goel and S. M. Tamhane (2009) said "It may be necessary to point out that there are different types (make & model) of 2-wheelers and 4-wheelers, wherein the fuel economies vary considerably. For example for good condition vehicles, the fuel economy for 2-wheelers varies from 35 km/L to 70 km/L. Similarly, for 4-wheelers, the fuel economy varies from 10 km/L to 22 km/L. The fuel economy will depend on a number of factors, including the engine design, fuel quality, vehicle operating characteristics, maintenance of vehicles, road conditions etc. Similarly, fuel consumption during idling shall also vary with different types and makes of vehicles", in this study used an average of of PCU type is 0.20 cc. /Minute (http://www.sahavicha.com), Fuel cost: 1,000 cc. = 37.83 Baht. (http://www.pttplc.com/th/Pages/home.aspx, on 22/1/13), the average of the vehicle (PCU) stopped 1 minute = 20 cc. = 0.757 Baht.

➢ Time cost (vehicle stopped at the intersection, with the fixed-time type of signal control); the minimum wage is 300 Baht per 8 hours., so 1 minute = 0.625 Baht. The AADT on this location increase 6.7% per year and the vehicle increase 6.60% per year of Songkhla province. (average during 2010 to 2012, http://www.dlt. go.th/th/ index.php)

- ❖ i = 10 % per year
- ❖ n = 30 years

Net Present Value (NPV): this method is defined as the sum of the present values (PVs) of the individual cash flows of the same entity, by the equation as shown below (1);

$$NPV = (B_0 - C_0) + \frac{B_1 - C_1}{(1+i)} + \frac{B_2 - C_2}{(1+i)^2} + \frac{B_3 - C_3}{(1+i)^3} + \ldots + \frac{B_n - C_n}{(1+i)^n}$$

Where,

- C_0 : initial investment cost,
- B_t : Benefit cost t year,
- C_t : investment cost t year,
- i : interest rate per year (% per year)
- n : number of years

$$NPV = (-249{,}597{,}672.50) + (-27{,}000)\frac{[(1+0.1)^{30} - 1]}{0.1 \times (1+0.1)^{30}} + \sum_{n=1}^{t} \frac{reduction\ of\ delay_n}{(1+0.1)^n}$$

$NPV = 302{,}212{,}963.84\ THB$ *Ans.*

Benefit–Cost Ratio (BCR): a ratio attempting to identify the relationship between the cost and benefits of a proposed project, by the equation (2) and the resulted as shown on below;

$$BCR = \frac{Benefits}{Cost}$$

$$BCR = \frac{386{,}583{,}656.20 + 319{,}174{,}088.67}{(249{,}597{,}672.50 \times (0.1(1+0.1)^{30})) + (27{,}000 \times 30)} = 1.$$

Ans.

Internal Rate of Return (IRR): the discount rate often used in capital budgeting that makes the net present value of all cash flows from a particular project equal to zero, by the equation (3) and the resulted as shown on below;

$$IRR = (NPV)_i = C_0 - \sum_{n=1}^{t} \frac{B_n - C_n}{(1+i)^n} = 0 \qquad (1)$$

$$IRR = NPV = (-249{,}597{,}672.50) + (-27{,}000)\frac{[(1+i)^{30} - 1]}{0.1 \times (1+i)^{30}} + \sum_{n=1}^{t} \frac{reduction\ of\ delay}{(1+i)^n}$$

So, at the *i* = 14.78% will make the NPV equal to Zero Ans.

There are 4 variables in this research included in the invested cost, annual maintenance costs, fuel consumption and time cost. For checking the benefits of the next 30 years, these results as shown in table 2 and on the figure 5.

Table 2. Resulted of delay reduction and benefits-cost data per year (1-30 years)

Year (1)	+ Reduction of delay (minute/day) (2)	Fuel consumption: 1L.=37.83 thb stopped 1 min= 20 cc.=0.757 thb (3) = (2)*0.757	Fuel consumption: * 365 days (4) = (3)*365	Fuel consumption: P(1+i)^n (i=10%) (5)=(4)*[1+0.1]^(1)	Time cost: 300 thb/ 8 hr 1 min=0.625 thb (6)=(2)*0.625	Time cost: * 365 days (7)=(6)*365	Time cost: P(1+i)^n (i=10%) (8)=(7)*[1+0.1]^(1)	NPV	B/C
1	13,449	10,181.10	3,716,100.55	3,716,100.55	8405.79	3,068,114.72	3,068,114.72	-243,454,749.53	0.247
2	14,350	10,863.23	3,965,079.28	4,361,587.21	8968.98	3,273,678.40	3,601,046.25	-236,896,374.77	0.263
3	15,312	11,591.07	4,230,739.60	5,119,194.91	9569.90	3,493,014.86	4,226,547.98	-229,895,065.31	0.281
4	16,338	12,367.67	4,514,199.15	6,008,399.07	10211.09	3,727,046.85	4,960,699.36	-222,421,464.86	0.299
5	17,432	13,196.30	4,816,650.49	7,052,057.99	10895.23	3,976,758.99	5,822,372.84	-214,444,221.11	0.319
6	18,600	14,080.45	5,139,366.07	8,277,000.46	11625.21	4,243,201.85	6,833,719.00	-205,929,854.71	0.340
7	19,847	15,023.85	5,483,703.60	9,714,715.44	12404.10	4,527,496.37	8,020,735.99	-196,842,619.09	0.363
8	21,176	16,030.44	5,851,111.74	11,402,161.51	13235.17	4,830,838.63	9,413,937.84	-187,144,350.82	0.387
9	22,595	17,104.48	6,243,136.23	13,382,716.96	14121.93	5,154,504.81	11,049,138.84	-176,794,309.60	0.413
10	24,109	18,250.48	6,661,426.36	15,707,294.90	15068.10	5,499,856.64	12,968,374.26	-165,749,007.45	0.441
11	25,724	19,473.27	7,107,741.92	18,435,652.02	16077.66	5,868,347.03	15,220,980.86	-153,962,026.29	0.471
12	27,448	20,777.97	7,583,960.63	21,637,924.78	17154.87	6,261,526.28	17,864,865.24	-141,383,823.03	0.502
13	29,287	22,170.10	8,092,085.99	25,396,432.31	18304.24	6,681,048.54	20,967,992.33	-127,961,521.66	0.536
14	31,249	23,655.50	8,634,255.76	29,807,792.61	19530.63	7,128,678.79	24,610,132.60	-113,638,691.11	0.572
15	33,343	25,240.41	9,212,750.89	34,985,406.18	20839.18	7,606,300.27	28,884,912.63	-98,355,108.18	0.610
16	35,577	26,931.52	9,830,005.20	41,062,371.23	22235.40	8,115,922.39	33,902,221.96	-82,046,504.53	0.651
17	37,960	28,735.93	10,488,615.55	48,194,905.12	23725.18	8,659,689.19	39,791,037.91	-64,644,296.57	0.695
18	40,504	30,661.24	11,191,352.79	56,566,360.14	25314.76	9,239,888.37	46,702,741.20	-46,075,297.16	0.742
19	43,217	32,715.54	11,941,173.43	66,391,936.89	27010.85	9,858,960.89	54,815,007.34	-26,261,407.95	0.791
20	46,113	34,907.49	12,741,232.05	77,924,216.33	28820.58	10,519,511.27	64,336,374.12	-5,119,291.04	0.844
21	49,202	37,246.29	13,594,894.60	91,459,652.71	30751.56	11,224,318.52	75,511,602.30	17,439,981.45	0.901
22	52,499	39,741.79	14,505,752.53	107,346,194.38	32811.91	11,976,347.87	88,627,967.62	41,511,301.34	0.962
23	56,016	42,404.49	15,477,637.95	125,992,228.35	35010.31	12,778,763.17	104,022,645.60	67,195,923.42	1.026
24	59,770	45,245.59	16,514,639.70	147,877,078.41	37356.00	13,634,940.30	122,091,379.14	94,601,891.32	1.095
25	63,774	48,277.04	17,621,120.56	173,563,326.93	39858.85	14,548,481.31	143,298,651.69	123,844,491.93	1.169
26	68,047	51,511.60	18,801,735.63	203,711,276.82	42529.40	15,523,229.55	168,189,627.49	155,046,740.29	1.247
27	72,606	54,962.88	20,061,451.92	239,095,925.60	45378.87	16,563,285.93	197,404,165.79	188,339,897.02	1.331
28	77,471	58,645.40	21,405,569.20	280,626,887.88	48419.25	17,673,026.09	231,693,269.39	223,864,020.47	1.420
29	82,661	62,574.64	22,839,742.34	329,371,778.30	51663.34	18,857,118.84	271,938,390.28	261,768,555.83	1.516
30	88,200	66,767.14	24,370,005.07	386,583,656.20	55124.78	20,120,545.80	319,174,088.67	302,212,963.84	1.617

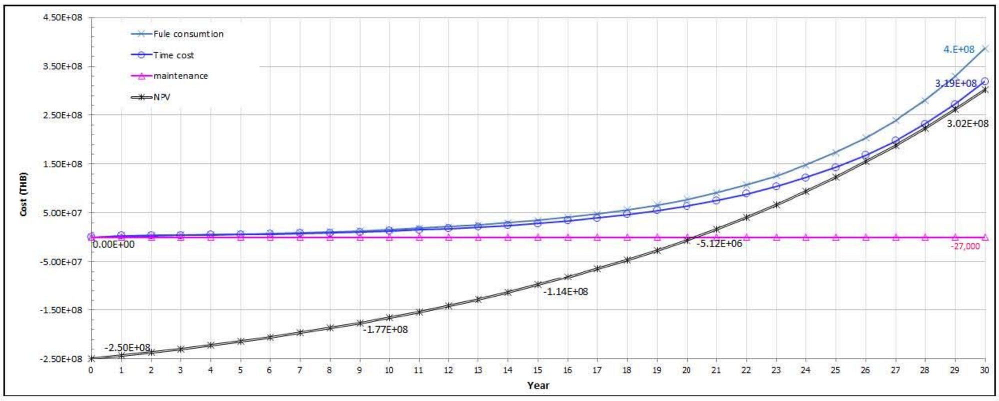
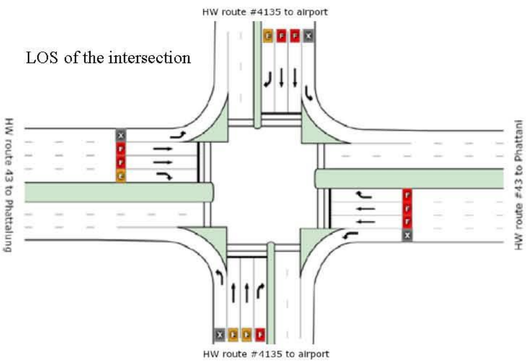


Figure 5. Benefits and Costs per year (1-30 years)

4.4. Assesses the junction data by SIDRA software

The (SIDRA) Signalized (and unsignalized) Intersection Design and Research Aid INTERSECTION software are an advanced micro-analytical tool for evaluation of alternative intersection designs in terms of capacity, level of service and a wide range of performance measures including delay, queue length and stops of vehicles and pedestrians, as well as fuel consumption, pollutant emissions and operating cost.

The old at grade intersection and the flyover was compared with the data that's collected on-site, by the results of this software as shown in figure 6, 7 and 8 as below;



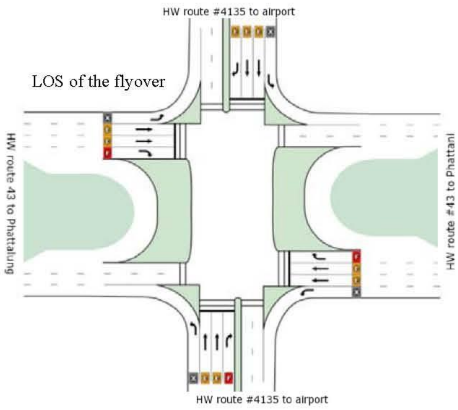


Figure 6. Level of service of the old at grade intersection and the flyover

Phase Timing Results of the intersection

Phase	A (W-E)	B (E-W)	C (N-S)	D (S-N)
Green Time (sec)	53	48	49	50
Yellow Time (sec)	4	4	4	4
All-Red Time (sec)	2	2	2	2
Phase Time (sec)	59	54	55	56
Phase Split	26 %	24 %	25 %	25 %

Phase Timing Results of the flyover

Phase	A (W-E)	B (E-W)	C (N-S)	D (S-N)
Green Time (sec)	38	39	62	61
Yellow Time (sec)	4	4	4	4
All-Red Time (sec)	2	2	2	2
Phase Time (sec)	44	45	68	67
Phase Split	20 %	20 %	30 %	30 %

Figure 7. Phase timing determined by the software of the intersection and the flyover

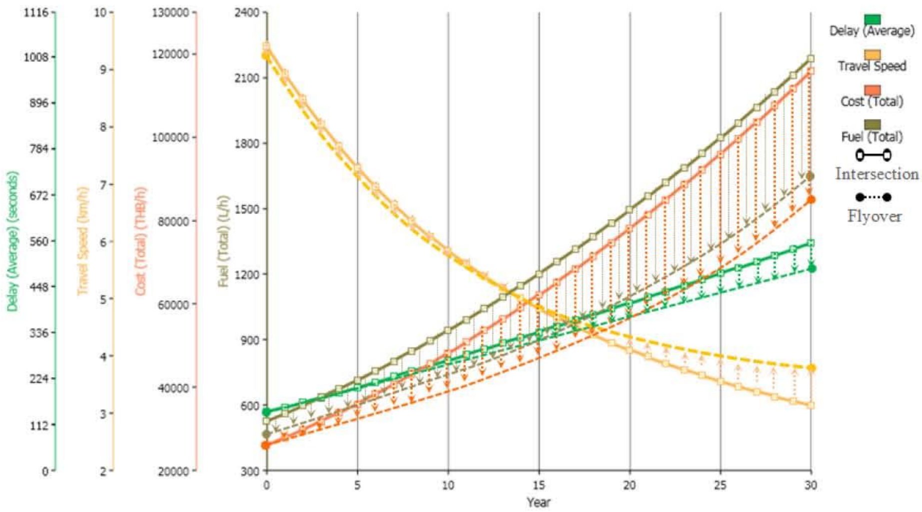


Figure 8. Graph showing the trend of each variable at this intersection (during 1-30 years)

5. Conclusion

This intersection was improved by investing cost about 250 million THB, for reducing the traffic flow and delay. The total traffic movement on the flyover is 97,423 PCUs per day. It was diverted to the flyover which is 35,120 PCUs per day or 36.05% of all traffic volumes and found the delay reduction is 13,449 minutes per day or reduced to 30.41% if compared with the old at-grade intersection. The risk of vehicles stopped of both types which are at the at-grade intersection is 40% and at the flyover is 21% or it reduced to 47.5% compared with old type and approximate 75-80% of traffic volume which is 56,404 PCUs/day play on under the flyover on highway route number 4135.

While waiting at traffic signals, often the commuters have to keep their vehicle engines on, that result in the undue combustion of precious fuel, to solve this problem the traffic volume on the 24 hours that collected was designed per hour of a day (as shown in table 1).

Assessment of benefits to traffic flow compared between the flyover and the old at-grade intersection at the same location. The economic analysis of the next 30 years is the net present value which is +302,212,963.84 Baht. The benefit cost ratio (BCR) is +1.617 and the internal rate of return (IRR) is i=14.78%, by the conclusion of this investmented will be a positive result on time considered.

The SIDRA software as processed and determined by using the collected average data of 3 peak times a day is level of service (LOS), delay, fuel consumption and phase timing as shown these data on figure 6 to 8.

6. Recommendations

To support the vehicle approaching an at-grade intersection (under the bridge) the traffic signal control should be design, depending on the traffic volume per hour on a day or install the loop detector and install CCTV as well. The benefits of using a computerized traffic control system include: providing efficient traffic flow, reducing travel time, fuel costs, vehicle emissions and rear end collisions.

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Assessment of benefits of flyover over signalized intersection: A case study

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Abstract

The flyover-bridge was constructed on the old at-grade intersection to increase capacity of traffic flow in two directions on one of the main road. Under the bridge, the traffic signalization for an intersection often uses the same fixed time control plans, even after the intersection has been converted to a flyover. However, traffic flows underneath the bridge still experience long delays and queue length similar to the situation 'before'. The purpose of this research is to evaluate the benefit of the flyover. This paper presents the study of the performance of an at-grade intersection converted to the flyover, and points out the remaining problems including long delays under the bridge and cost of accidents, in terms of traffic flow was found that about 35-40% of the total traffic volume that diverted to the flyover, saving the cost accidents 542,776 THB and this project plan is a good benefit.

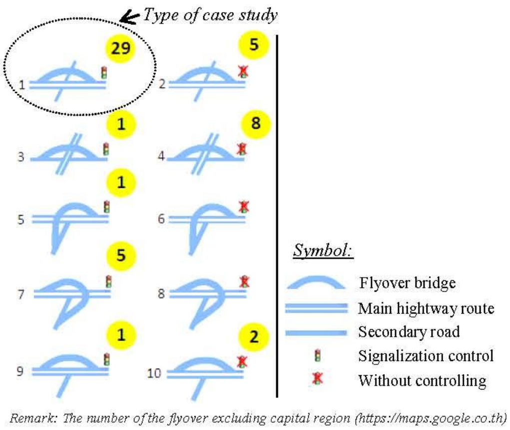
Keywords: *Flyover, Signalized intersection, cost-benefit analysis, Vehicle delay, Accident cost*

1. Introduction

The flyover is a bridge that constructed along a highway road in both directions over at the at-grade junction area. It allows the traffic volume to be free flow on the bridge. The flyover is one of the methods for solving the traffic problems at the at-grade junctions on highway roads such as traffic capacity, traffic congestion, long delay and queue length. The traffic signalization for an intersection often uses the same fixed time control plans, even after the intersection converting to a flyover. Moreover, the road user having same behavior as before situation.

Most of the flyovers in Thailand are constructed at the junctions on the bypass highway roads near the big city passes on the main road. There are approx 52 flyovers in Thailand (excluding capital region), (figure 1). Among various layouts, 29 flyovers are bridge cross-passes the at-grade intersection in both directions on one of the main road and under the bridge is controlled by fixed time control plans of traffic signal (figure 2).

To assess the benefit of the flyover, the study case is an at-grade intersection converted to the flyover. It is still not much different from the old at-grade intersection, it only facilitates the traffic volume in the directions of the bridge and the infrastructure cannot fully solve the problems, such as traffic congestion, long delay, queue length and road accidents. After the flyover constructed, the total traffic volume diverted upon the bridge about 35-40%, total delay reduced to about 40-45% and about 45–55% saving the travel time per day.



Remark: The number of the flyover excluding capital region (https://maps.google.co.th)

Fig.1. Number of the flyover at junctions in Thailand (2012)

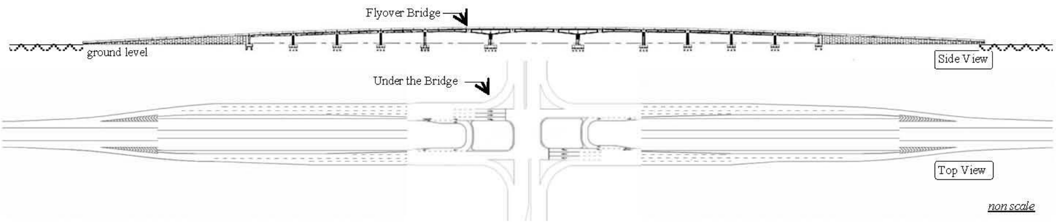


Fig.2. The scheme of Flyover intersection (case study type)

2. Study areas

There is an important case to study which is an at-grade intersection converting to the flyover. This location located in regional areas on Highway route no 43 and highway route no 4135, Songkhla province,Thailand.

3. Research framework

The study focus on two types of cases which are before and after flyover construction. The research framework consists of six steps (figure 3). First, focus on the implicated literature review such as intersection designing, flyover construction layout, road safety, traffic accident costing and SIDRA software. Second, the selection of case study locations; (1) case of an intersection converted to the flyover (during this study). Third, collection field data and implicated data. Fourth, evaluation step; assessments the benefit of the project. Fifth, conclusion step. And finally, will be recommended and pointed out about the effect of the flyover such as the traffic flow, vehicle delay and other problems that still exist.

4. Data collection

Field data were collected before (Tuesday, 18th Oct 09) and after (Tuesday, 17th July 12) construction of flyover (on working days in 2009 and 2012). These data were used to analyze the benefit by comparing before and after situations, the required data consists of the traffic movement, time delay, signal control plans, and flyover construction cost (Table 1).

4.1 Traffic movement count

For at-grade intersection; the traffic movement was counted at each of the legs/directions that vehicles entering to the intersection, at locations marked as 1, 2, 3 and 4 in figure 4 (A).

Table 1 Collected field data (in-depth case)

Time period / Items	Intersection converting to the flyover		
	Before	During	After
1. Flyover location	Highway route no 43 and highway route no 4135		
2. Traffic movement	✓	✓	✓
3. Delay	✓	-	✓
4. Queue length	✓	-	✓
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. Distance	✓	-	✓
8. Conflict points	46 points	-	55 points
9. Road Safety Audit	✓	✓	✓
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		

For the flyover; the traffic movement counted at locations marked as A, 1, B, C, 2 and D on the main road and secondary road at 3 and 4 (figure 4(a)). The vehicles categorized in five; 2-wheelers (MC), 3 and 4-wheelers (PC), 6-wheelers (MT), Bus (B) and Heavy-duty (L), [10]. The traffic volume were converted to equivalent_ passenger car unit (PCU) by the unit factor 0.33, 1.0, 1.75, 2.25 and 2.25 [20], respectively.

The traffic volume before construction of flyover, on the highway route number 4135; from "South" entering to an intersection is 17,316 PCU/day, from "North" entering to an intersection is 16,894 PCU/day and on the highway route number 43; from "East" entering to an intersection is 17,284 PCU/day, from "West" entering to an intersection is 17,225 PCU/day.

Traffic volume after flyover constructed, at the at-grade level: on the highway route number 4135; from "South" entering to an intersection is 21,075 PCU/day, from "North" entering to intersection is 19,944 PCU/day, on the highway route number 43; from "East" entering to intersection is 17,621 PCU/day, from "West" entering to intersection is

3,663 PCU/day, and the traffic upon the bridge from "East" to "West" is 19,161 PCU/day and 15,958 PCU/day of opposite directions (figure 4(b)).

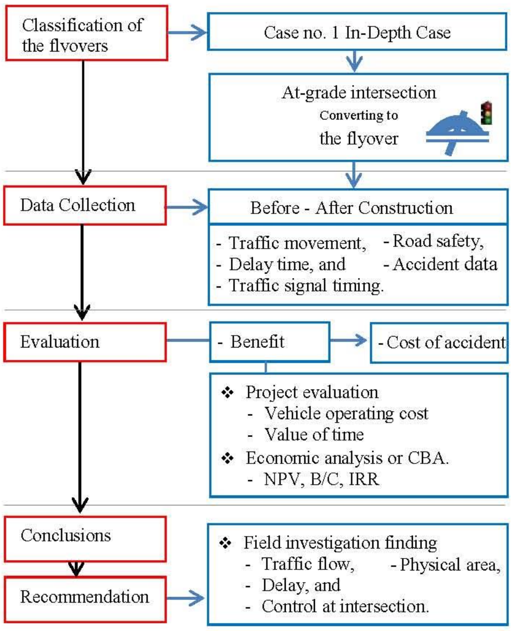


Fig.3. Research framework

4.2. Traffic Signal

The traffic signalization at at-grade level of both situations was controlled by fixed time control plans. There are two programs a day, first; the length of one cycle is 244 seconds (figure 5(a)), is controlled during 06:00 a.m. to 12:00 a.m. (4 phases per one cycle), and second; the cycle plan is controlled during 00:00 a.m. to 06:00 a.m. by traffic flashers. Even after the construction of the flyover, it has the same old controlled plans, but the length of cycle time is changed to 224 seconds per cycle (figure 5 (b)) [6]. The before and after construction of the traffic signal control plans are shown in figure 5 (c).

4.3. Delay at intersection

The delay of both situations were measured with the traffic volume counted. The results of both types depend on the signal control plans, the delay of before construction is 44,223.96 minutes/day (95.4 second per vehicle-cycle by average) and after construction is 30,774.69 minutes/day (91.8 second per vehicle-cycle by average). If comparing with the situation before and after, the percentage of vehicles stopped at intersection for waiting the green phase time of cycle are 40% and 21%, respectively.

4.4. Accident statistics

The accidents statistics were collected from 3 agencies, which are the Department of Highway (DOH), Police and Emergency Medical Services System (EMS).

5. Flyover evaluation

The objectives of this evaluation were to analyze cost, benefit and economic value analysis of the flyover project as follows;

5.1. Project evaluation

The project evaluation considered by comparative analysis at an intersection of the case that without a project and have a project, to assess the benefits when the project is constructed by a height investment value. The benefit includes the value of time (VOT), vehicle operating cost (VOC) and cost of accidents as follows;

- *Value of time (VOT)*

Value of time means the cost (equivalent to money) that lost in the travel, but when the intersection is improved more efficiency will save in time of trips and road user can use this time to do another activity to have an economic value increase, by calculating the value of time in the area (province) of case study consists of the gross province product (GPP), number of employed and average hours of work (Table 2).

Table 2 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 (2013), [15]

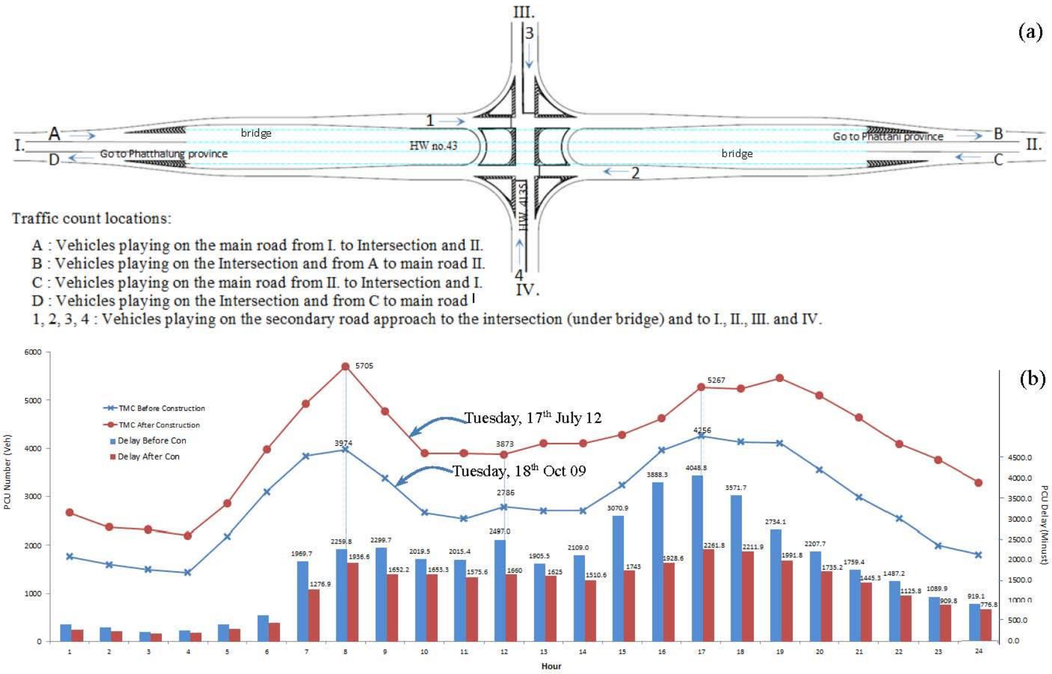


Fig.4. Traffic movement counted at locations marked and traffic volume and delay per day

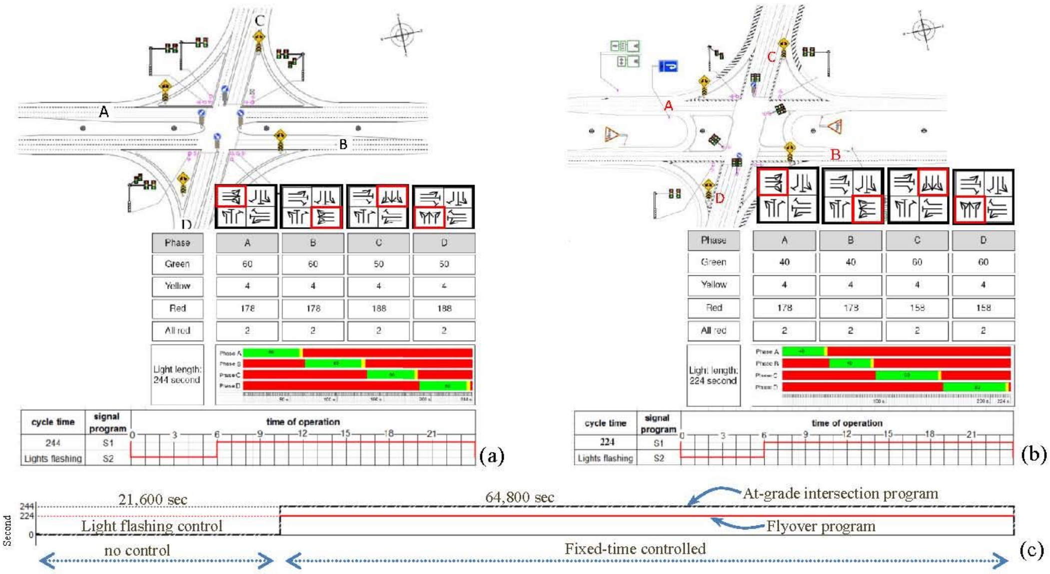


Fig.5. Traffic signal control plans of both situations

According to the value of time in Songkhla province is 83.86 Baht/PCU/hour in 2011, to adjust by the growth rate in 2007 to 2011 (0.31), so the value of time in 2013 is 84.38 Baht/ PCU/hour.

The collected data used for comparing with both situations (Table 3), which consists of the vehicle delay (loss of time and fuel consumption) and type control (supportable the traffic volume).

Table 3 The results of both situations

Items	Situation		Result
	Before	After	
- Traffic volume (pcu/day)	68,719	97,423	+29.46%
- Delay (minute/day)	44,224	30,775	-30.41%

Extrapolation the traffic volume in the future (Table 4), from the equation by DOH in 2006 [12], Eq (1);

$$T = \left[(1+\frac{P}{100})(1+\frac{G}{100})^{e} \right] x100-100 \qquad (1)$$

Where,

T: escalation rate of traffic volume per year

P: escalation rate of population in the area (7.02)

G: escalation rate of GPP per capita (0.75)

e : elasticities value of escalation rate of traffic volume per income (constant: 1.738)

Table 4 Results of the extrapolation the traffic volume in the future

Year	Traffic volume (PCU/day)			Time Delay (Minute-day)		
	Before	After	Variance	Before	After	Variance
2009	68719	76468	7,749	44223.96	24152.75	20,071.21
2014	102892	114494	11602	66211.36	36163.73	30,047.62
2019	154060	171432	17,371	99137.77	54147.69	44,990.08
2024	230673	256683	26010	148438.24	81074.93	67,363.31
2029	345385	384330	38,945	222255.47	121392.89	100,862.59
2034	517142	575454	58,312	332781.46	181760.66	151,020.80
2038	714259	794797	80,538	459625.86	251041.33	208,584.53

- *Vehicle operating cost (VOC)*

The vehicle operating cost consists of the fuel cost, lubricant cost, idling of engine and operation cost, these correlated with number, type, vehicle speed and traffic volume [23], when the vehicles are waiting for green signal at the intersection stop line and turn on the engine (idling of engine), that resulted in the undue combustion of precious fuel and the fuel consumption during idling shall also vary with different types of vehicles [10]. The variance traffic volume between case without project and have a project, change to be the cost (equivalent to money) that saving in the vehicle increase of both controllers at an intersection. This study used an average the fuel cost of passenger car unit (PCU) to consider (1,000 cc. = 37.18 Baht (6/08/2013), (http://www.pttplc.com/th/Pages/home.aspx)), and used the average passenger car unit (PCU) that stopped and idling of engine 1 minute = 20 cc. (http://www.sahavicha.com/?name=knowledge&file=readknowledge&id=1623), or loss of the money is 0.75 Baht per minute.

The results of benefit evaluation of a project (in case of having a project) are shown in Table 5 and 6.

- *Cost of accidents*

The accident cost depends on the mean cost per accident for various severities from the Department of Highway in 2012. Author uses the mean data cost of other provinces in Table 7 for calculating.

Table 5 Value of benefits of the project

Year	Value of time (VOT)				Vehicle operating cost (VOC)	
	Loss of time 84.83 Baht/PCU/hr (1.41 Baht/Minute)		Fuel Consumption 0.75 Baht/PCU/Min		Vehicle increase by type controller (traffic volume data of "Flyover - At-grade")	
	At-grade	Flyover	At-grade	Flyover	Save loss of time	Save fuel consumption
2009	62355.7	34055.4	33477.5	18283.6	28300.4	15193.9
2014	93358.0	50990.9	50122.0	27375.9	42367.2	22746.1
2019	139784.2	76348.3	75047.3	40989.8	63436.0	34057.5
2024	209297.9	114315.6	112367.7	61373.7	94982.3	50994.0
2029	313380.2	171163.9	168247.4	91894.4	142216.3	76352.9
2034	469221.9	256282.5	251915.6	137592.8	212939.3	114322.7
2038	648072.5	353968.3	347936.8	190038.3	294104.2	157898.5

Table 6 Total benefit per year of project evaluation

Year	Cost of situations before and after		Cost of vehicle increase by type controller	Total cost per year (Million Baht)
	At-grade	Flyover		
2009	28.7	15.7	13.0	26.1
2014	43.0	23.5	19.5	39.1
2019	64.4	35.2	29.2	58.5
2024	96.5	52.7	43.8	87.6
2029	144.5	78.9	65.6	131.1
2034	216.3	118.2	98.2	196.4
2038	298.8	163.2	135.6	271.2

Because some case of accident statistics from 3 agencies did not record the number of disabled people on the accident report, the author used the percent of the serious injury and disability number of crash severity in Thailand (2004), [2], [19] to modify the accident cost of Thailand 2012 [4] and created a new value for checking the cost of a disability person case.

Table 7 New average unit cost of crash severity

Severity	Other Provinces (Baht)		New unit cost (Baht)	
Fatality	Fal	5,509,000	Fal	5,509,000
Disability	Dis	6,012,000	SI_2	365,785
Serious Injury	SI	161,000		
Slight Injury	SL	38,750	SL	38,750
Property Damage Only	PDO	52,000	PDO	52,000

Source: Adapted from Department of Highway, Thailand (2012), [4]

For changing the average unit cost of crash severity in three situations, the number of casualties are calculated by 4 equations below (Eqs (2), (3), (4) and (5)), and the results of the average value of accident unit costs (Avg AcUC) as shown in Table 8.

$$\text{Avg AcUC}_{(Fal)} = [\text{No.of Fal} * (\text{AcCS}_{(Fal)} + \text{AcCS}_{(SI2)} + \text{AcCS}_{(SL)} + \text{AcCS}_{(PDO)})] \quad (2)$$

$$\text{Avg AcUC}_{(SI2)} = [\text{No.of SI}_2 * (\text{AcCS}_{(SI2)} + \text{AcCS}_{(SL)} + \text{AcCS}_{(PDO)})] \quad (3)$$

$$\text{Avg AcUC}_{(SL)} = [\text{No.of SL} * (\text{AcCS}_{(SL)} + \text{AcCS}_{(PDO)})] \quad (4)$$

$$\text{Avg AcUC}_{(PDO)} = [(\text{No.of PDO} * (\text{AcCS}_{(PDO)})) + \text{On-site damage cost}] \quad (5)$$

Table 8 Average unit cost of 3 situations

AcUC	Cost of situations before, during and after construction		
	At-grade	During constructing	Flyover
Fal	5,509,000	8,460,143	5,509,000
SI2	308,773	452,199	712,785
SL	101,318	106,987	95,594
PDO	52,000	68,500	52,000

And, for checking the accident cost at this intersection, depending on the number of severity and year consider, Eq (6) [4], and the accident costs of three situations as shown below;

$$AgAC = \frac{A(F)*M(F) + A(SI_2)*M(SI_2) + A(SL)*M(SL) + A(PDO)*M(PDO)}{t} \quad (6)$$

Where

$AgAC$: average of accident cost ($/year),

A : number of accidents (accident),

M : the mean cost per accident ($/accident) (Table 9), and

t : the period of time under review (year).

Average of accident cost at this intersection of three situations are 2,175,681.0 , 27,585,771.0 and 1,632,905.0 Baht/Year, respectively.

- *Assesses data from SIDRA software*

The software is an advanced micro-analytical tool for evaluation of alternative intersection designs in terms of capacity, level of service and a wide range of performance measures including delay, queue length, as well as fuel consumption, pollutant emissions and operating costs [1]. In this study, this software to help, to present and points out the before and after situations which are the delay, travel speed, cost and fuel in 30 years (figure 6).

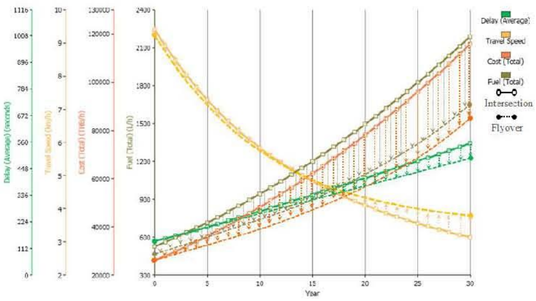


Fig.6. Assesses data from the SIDRA software

5.2. Cost-benefit analysis (CBA)

CBA is the method to calculate all benefits and costs of outcomes, can help decision makers to make their choice for a (road infrastructure) measure or a combination of measures. To analyze the benefit of the flyover construction project, the economic analysis will be considered by three important equations which consisting of the Net Present Value (NPV), Eq (7), Benefit–Cost Ratio (BCR), Eq (8) and Internal Rate of Return (IRR) [9], by the items of each cost as shown in Table 9.

In this study used the interest rate per year (i) = 12% [12] and 30 years (n) of time of the project.

Table 9 Cost and Benefits for improvement plans with respect to existing conditions

Items (present time data:2013)	Cost (Thai Baht)
- Investment cast	249,597,672.5
- Maintenance cost per year	27,000.0
- Cost of accident during construction	27,585,771.0
- Saving in accidents per year	542,776.0
- Benefits evaluation of the project PV= (FV:Total Cost per Year$_n$)/(1+0.12)^n	421,654,886.1

- *Net Present Value (NPV):*

This method is defined as the sum of the present values of the individual cash flows of the same entity, Eq (7);

$$NPV = \sum_{t=0}^{n} \frac{(B_t - C_t)}{(1+i)^t} \quad (7)$$

Where,

n : number of years (that consider)
B_t : Benefit in year t
C_t : Cost emerged in year t
i : interest rate per year (% per year)

$$NPV = -249{,}597{,}672.5 - 27000 - 27{,}585{,}771 + 542{,}776 + 421{,}654{,}886.06$$

NPV = 144,987,218.56 Baht. *Ans.*

- *Benefit–Cost Ratio (BCR):*

A ratio attempting to identify the relationship between the cost and benefits of a proposed project, Eq (3);

$$BCR = \frac{Benefits}{Cost} = \frac{542{,}776 + 421{,}654886.06}{249{,}597{,}672.5 + 27000 + 27{,}585{,}771} \quad (8)$$

BCR = 1.52 *Ans.*

- *Internal Rate of Return (IRR):*

The discount rate often used in capital budgeting that makes the net present value of all cash, solve for the value of interest rate for which NPV = 0.

So, i = 15.742 % *Ans.*

So, at the i = 15.742% will make the NPV equal to zero. Since IRR is greater than 12 percentages, this project is benefiting the investment.

The information of cost-benefit analysis of this project per year is as shown in figure 7.

6. Conclusion

At-grade intersection converted to the flyover by investment cost about 249.5 million THB, to increase capacity of traffic flow and for reducing time delay and long queue at the at-grade level. The results obtained of the situation after (controller by the flyover); the traffic volume increased to +29.46%, and time delays reduced to -30.41%.

In terms of cost-benefit analysis (CBA) for assessing the economic at 12% interest rate per year and 30 years of time of the project; the Net Present Value (NPV) = 144,987,218.56 Baht., Benefit–Cost Ratio (BCR) = 1.52 and Internal Rate of Return (IRR) = 15.742%.

The project evaluation in terms of value of time (VOT) and vehicle operation cost (VOC) saves cost about 421.65 Million Baht (present value), and saves the cost of accident = 542,766 Baht. So, this project plan is a good benefit.

The traffic signalization at the at-grade level of two types (at-grade and flyover intersection) had been being controlled by fixed time control plans, it still has long queue and time delay especially on the secondary road.

7. Recommendations

The results of this location in three situations (before, during and after construction), these information were considered in terms of traffic volume, delay reduction and traffic signal control as follows;

7.1. Traffic flow on the flyover

Although the flyover can be able to serve more traffic capacity, total traffic on the flyover is 97,423 PCU/day, diverted to the bridge is 35,120 PCU/day or 36.05% and the remaining traffic volume on the at-grade level is 62,303 PCU/day and amount 75-80% of traffic volume on an at-grade level flowed on the secondary road.

7.2. Delay

The vehicles on the at-grade intersection (under the bridge) still has been being congested—long delay, especially on the secondary road, because it depends on the fixed time plans of signalized. The delay of the before construction is 44,223 minutes/day and 30,774 minutes/day of the delay after construction, if comparing with both situations before and after, it reduced to 30.41%, but most of the delay is still on the secondary road, because the behavior and trips of road users are still the same.

7.3. Control at intersection

The fixed time plan was installed and used to control the traffic movement of each direction (at-grade level), about 3-4 minutes for one cycle, an average vehicle stopped is about 90-100 seconds per a cycle (day time data). This is an important consideration when the vehicles are served by this plan. And in terms of road safety, when the road safety approaching to a signalized intersection faced with on an amber signal indication, must decide whether to cross or to stop [13], because, most of the cause of the accident happened by violation of traffic signal.

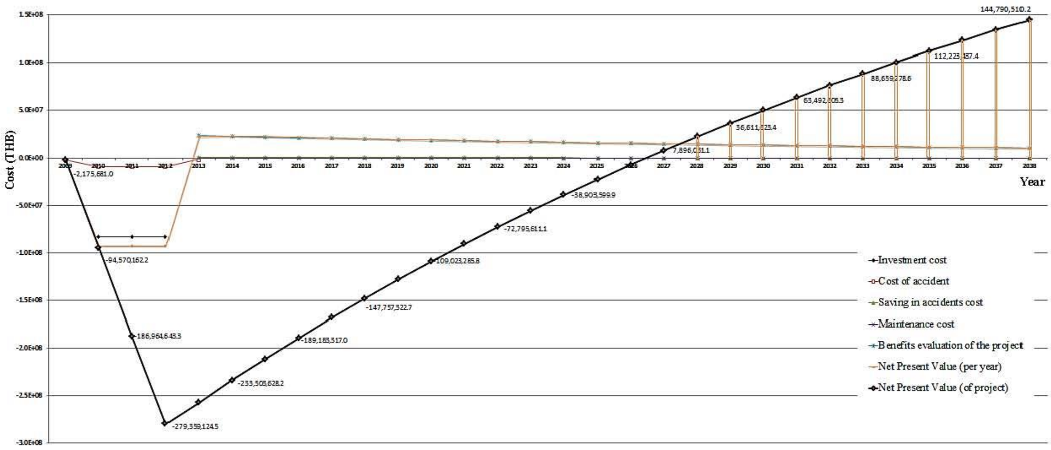


Fig.7. Information of cost-benefit analysis (CBA) per year, (1-30 years)

7.4 Existing problems

The flyover can support to increase capacity of traffic flow only two directions on one of the main road, but it still has the problems under the bridge which is the fixed time control plans of traffic signal control, in preliminary plan it should be designed new of the signal timing phase by depending on the traffic volume and directions control plans (as shown the example of each cycle lengths in the day in figure 8). Chang and Park., [3] used a real-time traffic control system on the basis of Vehicular Ad-hoc Networks—this system estimates the queue lengths in each lane and determines cycle lengths and green splits for a traffic signal controller, or install the loop detector or CCTV—the benefits of using a computerized traffic control system are provided efficiently of traffic flow, reducing travel time, fuel costs, vehicle emissions and rear end collisions.

- *Physical layout of flyover*

The area of the flyover bigger than the at-grade intersection about 2 times, the hazardous zones have still found at the beginning and exiting of the flyover area (merge and diverge zone); these zones should newly designed such as add the length of the auxiliary lane and painted or highlighted the line of road lane to guide the road user. Wall and Hounsell., [21] said "With the Parallel diverge (Taper + auxiliary lane), drivers wishing to leave the motorway should stay in lane 1 and then move into the auxiliary lane that feeds into the exit slip road. An auxiliary lane (sometimes called a parallel lane) provides extra capacity, reducing the risk of traffic blocking back onto the main carriageway".

The space at center at-grade level (under the bridge) is very wide (52x25 m^2), it should be painted the road-line for guiding to road user drive the vehicle of all directions.

The radius at kerb corner should newly designed by depending on turning radius of the trailer.

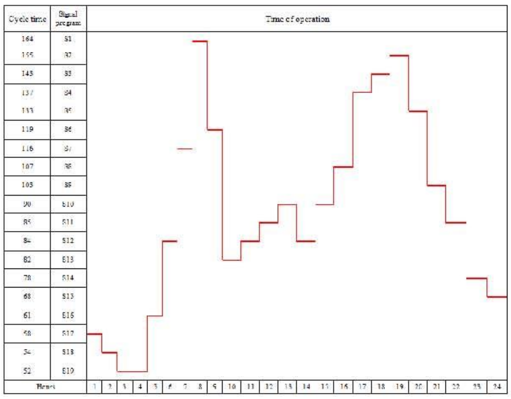


Fig.8. The cycle length programs were calculated by depending of the traffic volume per hour

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ASSESSMENT OF TRAFFIC FLOW BENEFITS OF FLYOVERS: A CASE STUDY

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ABSTRACT:

This paper describes the results of a pilot study of the benefits of a flyover bridge which was constructed over an existing at-grade intersection to increase capacity of traffic flow in two directions on one of the main highway. Under the flyover, the existing traffic signalization for the intersection still uses the same fixed time control plans. This is a main reason why traffic flows underneath the flyover still experience long delays and queue length similar to the situation 'before'. The purpose of this research is to evaluate the benefits of the flyover. The paper presents the performance of the flyover upgraded intersection and points out the remaining problems including long delays under the flyover. It was found that about 35-40% of the total traffic volume diverted to the flyover, and despite an increase in traffic volume of +29.46%, at the intersection, the vehicle delays were reduced by 30.41% over the same period; the saving in travel time and vehicle operating costs amounted to 421.65 Million Baht.

KEYWORDS: *Flyover, Signalized intersection, cost-benefit analysis, Vehicle delay*

1. INTRODUCTION

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 upgraded intersection often 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 52 flyovers in Thailand, excluding the ones in Bangkok and its vaciniy. Twenty nine of these flyovers are bridges constructed on one of the main highway over existing at-grade fixed-time control signalized intersections

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). Figure 2 shows layout of the flyover.

Figure 1. Case study location (near Hat Yai airport, Songkhla)

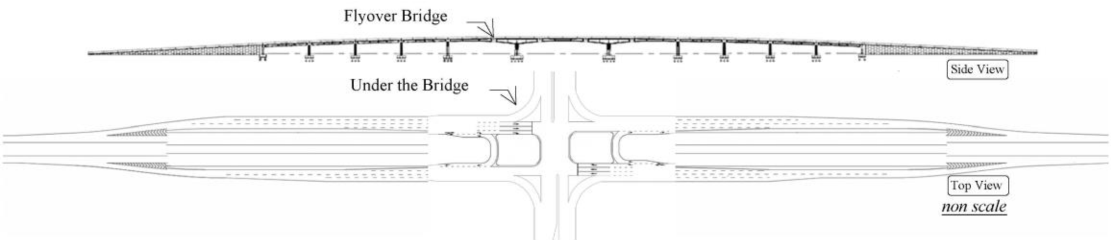

Figure 2. Layout of the flyover intersection

2. STUDY AREA

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

3. RESEARCH FRAMEWORK

The study focuses on two situations, before and after flyover construction. The research framework consists of six steps (Figure 3). First, focus on the review of relavant literature such as intersection design, flyover construction layout, road safety, traffic accident costing and SIDRA software. Second step involves the selection of case study location. Third, step is data collection. Fourth step is the evaluation step, assessing benefits and costs of the project. Fifth step is the conclusions. And the last step is the recommendations on how to improve the intersection in terms of traffic flow, vehicle delays and other problems that still exist.

4. DATA COLLECTION

Field data were collected before and after construction of the flyover (on working days in 2009 and 2012). These data were used to analyze the benefits by comparing before and after situations, the required data consist of traffic movement, vehicle delay, signal control plans, and flyover construction cost (Table 1).

4.1 Traffic movement count

For at-grade intersection; the traffic movement was counted at each of the legs/directions that vehicles entering to the intersection, at locations marked as 1, 2, 3 and 4 in Figure 4 (A).

Table 1. Collected field data over three time periods

Items \ Time period	Intersection converting to the flyover		
	Before	During	After
1. Flyover location	Highway route no 43 and highway route no 4135		
2. Traffic movement	✓	✓	✓
3. Delay	✓	-	✓
4. Queue length	✓	-	✓
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. Distance	✓	-	✓
8. Conflict points	46 points	-	55 points
9. Road Safety Audit	✓	✓	✓
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		

For the flyover, the traffic movement were counted at locations marked as A, 1, B, C, 2 and D on the main road and secondary road at 3 and 4 (Figure 4 (a)). Vehicles were categorized in five groups: 2-wheelers (MC), 3 and 4-wheelers (PC), 6-wheelers (MT), Bus (B) and Heavy-duty (L) (Goyal, S. K., Goel, S., & Tamhane, S. M. (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 traffic volume before construction of the flyover, on the highway 4135; from "South" entering to the intersection was 17,316 PCU/day, from "North" entering to the intersection 16,894 PCU/day and on the highway 43; from "East" was 17,284 PCU/day and from "West" 17,225 PCU/day.

Traffic volume after flyover was constructed, at ground level: on the highway 4135; from "South" direction was 21,075 PCU/day, from "North" 19,944 PCU/day, on the highway 43; from "East" direction 17,621 PCU/day, and from "West" direction 3,663 PCU/day. On the flyover, the traffic from "East" to "West" was 19,161 PCU/day and 15,958 PCU/day for the opposite direction (Figure 4 (b)).

4.2. Traffic Signal

The traffic signalization for both situations was controlled by fixed time control plans. There are two programs, the first applies during 0600 to 2400 hr (4 phases per one cycle) and the cycle time of 244 seconds (Figure 5 (a)), and the second applies during 0000 to 0600 hr and control by flashing light. Even after the construction of the flyover, it has the same fixed time control plans, but the length of cycle time is changed to 224 seconds (Figure 5 (b)) (DOH, 2011). The before and after flyover construction of the traffic signal control plans are shown in Figure 5 (c).

4.3. Delay at intersection

The delay for both situations was measured. The results of both types depend on the signal control plans, the delay of before construction is 44,223.96 minutes/day (95.4 second per vehicle on average) and after construction 30,774.69 minutes/day (91.8 second per vehicle on average). Comparing the situation before and after the flyover operation, the percentage of vehicles stopped at intersection waiting for the green phase are 40% and 21%, respectively, a significant reduction.

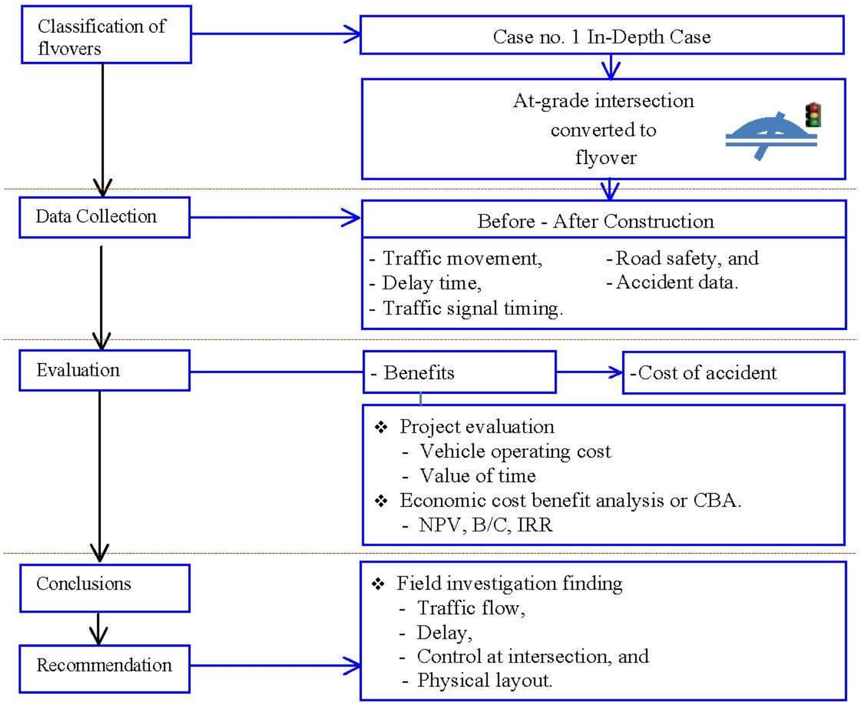

Figure 3. Research framework

5. FLYOVER EVALUATION

The objectives of this evaluation were to analyze costs, benefits and economic value analysis of the flyover project as follows;

5.1. Project evaluation

The project evaluation compares the cases 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 cost of accidents. Details are as follows;

5.1.1 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 efficiency will save travel time and road users can use this time to do another activity. Value of time in the area (province) of case study can be calculated from the gross province product (GPP), number of people employed and average hours of work (Table 2).

Table 2. Value of time (VOT) in Songkhla province

Year	GPP (Million THB)	Employments	Avg of hours work (per 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 (2013) and NESDB., 2013

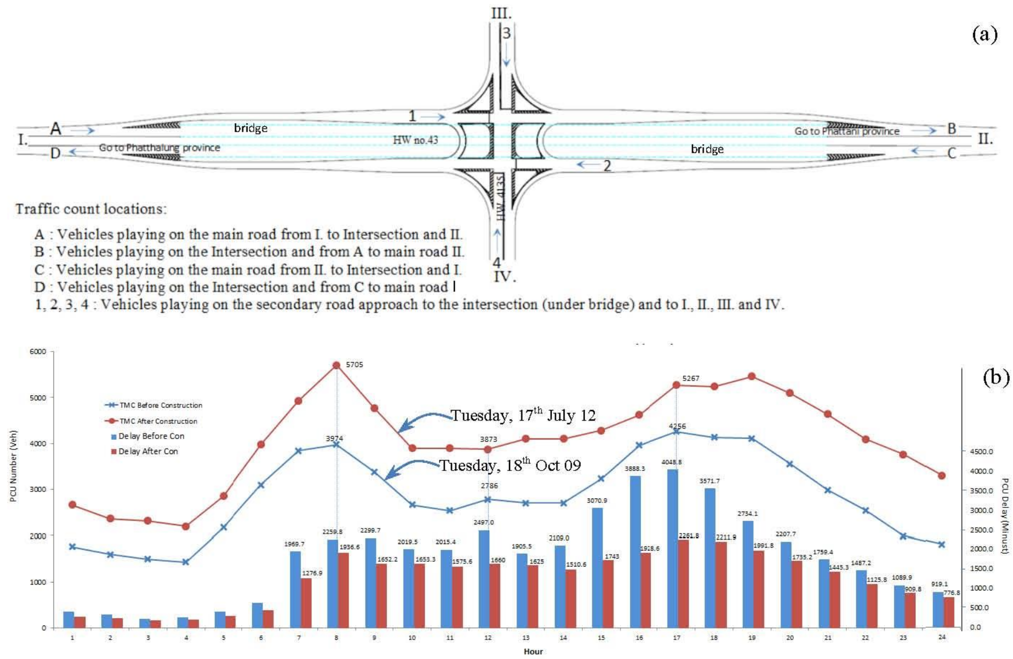

Figure 4. Traffic movement counted at locations marked and traffic volume and delay per day

Accordingly, the value of time in Songkhla province was 83.86 Baht/PCU/hour in 2011. Adjustment of factors for 2013 gives the value of time for 2013 at 84.38 Baht/ PCU/hour.

Table 3 shows a significant improvement in the total vehicle delay by 30.41 % despite an increase of 29.46% of traffic volume over the same period.

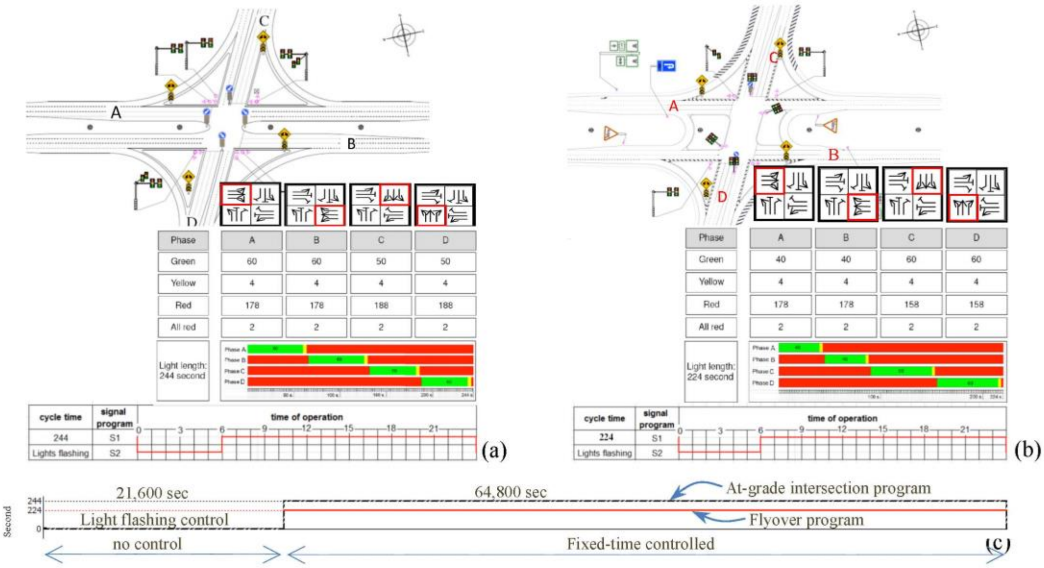

Figure 5. Traffic signal control plans for both before and after situations

Table 3. Reduction in vehicle delay after construction of the flyover

Item	Situation		Difference
	Before	After	
- Traffic volume (pcu/day)	68,719	97,423	+29.46%
- Delay (minute/day)	44,224	30,775	-30.41%

To calculate future benefits and costs, an extrapolation of future traffic volume is required using the equation developed by DOH in 2006 as shown in Eq (1) (Luophongsok, et al., 2011).

$$T = \left[(1+\frac{P}{100})(1+\frac{G}{100})^{e}\right]x100 - 100 \qquad (1)$$

Where,

T: escalation rate of traffic volume per year
P: escalation rate of population in the area (7.02)
G: escalation rate of GPP per capita (0.75)
e : elasticities value of escalation rate of traffic volume per income (constant: 1.738)

Table 4. Results of extrapolated future traffic volume

Year	Traffic volume (PCU/day)			Vehicle delay (Minute per day)		
	Before	After	Variance	Before	After	Variance
2009	68719	76468	7,749	44223.96	24152.75	20,071.21
2014	102892	114494	11602	66211.36	36163.73	30,047.62
2019	154060	171432	17,371	99137.77	54147.69	44,990.08
2024	230673	256683	26010	148438.24	81074.93	67,363.31
2029	345385	384330	38,945	222255.47	121392.89	100,862.59
2034	517142	575454	58,312	332781.46	181760.66	151,020.80
2038	714259	794797	80,538	459625.86	251041.33	208,584.53

5.1.2 Vehicle operating costs (VOC)

Vehicle operating costs comprise the cost of fuel, lubricant cost, idling of the engine and operation cost, these correlated with number, type, vehicle speed and traffic volume (Watcharin, V., (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 case without and with project can be converted to equivalent monetary term. This study used an average fuel cost of a passenger car unit (PCU) of 1,000 cc. = 37.18 Baht (6/08/2013), (http://www.pttplc.com/th/Pages/home.aspx)), and the fuel consumption of an average passenger car unit which stops and idles for 1 minute = 20cc.(http://www.sahavicha.com/?name=knowledge&file=readknowledge&id=1623). This amounts to a monetary loss of 0.75 Baht per minute.

The results of benefit evaluation of a project shown in Tables 5 and Table 6.

Table 5. Value of time and Vehicle operating cost saving from the project

Year	Value of time (VOT)				Vehicle operating cost saving	
	Loss of time 84.83 Baht/PCU/hr)		Fuel Consumption (0.75 Baht/PCU/Min)		Vehicle increase by type controller (traffic volume data of "Flyover - At-grade")	
	At-grade	Flyover	At-grade	Flyover	Saving in time	Saving in fuel consumption
2009	62355.7	34055.4	33477.5	18283.6	28300.4	15193.9
2014	93358.0	50990.9	50122.0	27375.9	42367.2	22746.1
2019	139784.2	76348.3	75047.3	40989.8	63436.0	34057.5
2024	209297.9	114315.6	112367.7	61373.7	94982.3	50994.0
2029	313380.2	171163.9	168247.4	91894.4	142216.3	76352.9
2034	469221.9	256282.5	251915.6	137592.8	212939.3	114322.7
2038	648072.5	353968.3	347936.8	190038.3	294104.2	157898.5

Table 6. Total road user benefits per year from improved traffic flow

Year	Cost of situations before and after		Saving	Total saving per year (Million Baht)
	At-grade	Flyover		
2009	28.7	15.7	13.0	26.1
2014	43.0	23.5	19.5	39.1
2019	64.4	35.2	29.2	58.5
2024	96.5	52.7	43.8	87.6
2029	144.5	78.9	65.6	131.1
2034	216.3	118.2	98.2	196.4
2038	298.8	163.2	135.6	271.2

5.1.2 Calculation of flow performance

The SIDRA software is an advanced micro-analytical tool for evaluation of alternative intersection designs in terms of capacity, level of service and a wide range of performance measures including delay, queue length, as well as fuel consumption, pollutant emissions and operating costs (Akcelik and Associates Pty Ltd., (2011)). In this study, the software was used to analyse traffic flow performance before and after the flyover was instlled (Figure 6).

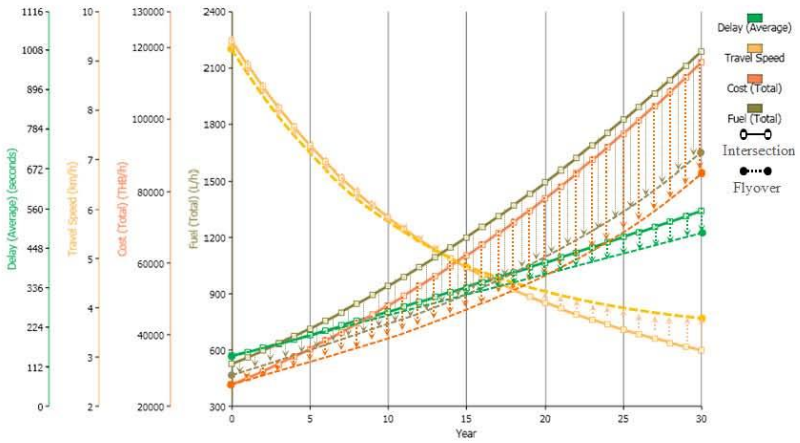

Figure 6. Analysis of intersection flow by SIDRA software

6. CONCLUSIONS

An at-grade intersection was upgraded with an installation of a flyover at a cost of about 249.5 million THB, to increase capacity of the intersection and reduce vehicle delay and long queue at the at-grade level. The study results show that despite an increase in traffic volume of +29.46%, at the intersection, the vehicle delays were reduced by 30.41% over the same period.

Benefits of the flyover in terms of saving in travel time and vehicle operation cost amount to 421.65 Million Baht. However, traffic signalization for both the existing at-grade situation and flyover upgraded situation has been and is still controlled by fixed time control plans, there is still long queue and delay especially on the airport access highway.

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Article

A Study of a Flyover-Bridge - Improved Intersection

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Abstract. To reduce traffic congestion at an at-grade intersection near a big city, one method is construction a flyover bridge at the old junction in two directions on one of the main highways. The flyover facilitates the traffic flow in the directions of the bridge, but the infrastructure cannot fully solve all of the problems especially on the secondary road. Under the bridge, although it relieves the traffic congestion at the intersection; the traffic signal still uses the same control as the "before" situation, that is the fixed time control plan. With the flyover bridge in place, it was found that about 30-35% of all traffic volumes diverted to the bridges, and time delay reduced by 30% over the same period. This paper which is one part of the first author's thesis, presents the issues that still exist at the flyover-improved junction and makes suggestions to increase the benefits of the flyover such as creating a new cycle and phase times and improving the physical area under the bridge. The SIDRA software is used to determine the appropriate fixed time plans, and using the process of Road Safety Inspection (RSI) to audit the safety of the site and presents the improvements to the remaining problems.

Keywords: Flyover-bridge intersection, SIDRA, RSI, signalized intersection, time delay.

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1. Introduction

The flyover-bridge intersection is an intersection that has a special bridge constructed over an at-grade intersection to allow for the free flow in two directions on one of the main road – to increase capacity of traffic flow and reduce the traffic congestion in both of these directions, but underneath of the bridge, the existing traffic signalization is still used to control traffic as the situation before (Fig. 1). This model is used for increasing traffic capacity at a bigger intersection in suburb area, there are 29 flyover intersections in Thailand (excluding Bangkok and its vicinity) [24]. In this study 5 existing flyovers were selected covering all regions of Thailand.

According to the guidelines for controlling traffic at an intersection, [10] it used traffic volume as criteria to choose a type of junction, for traffic volume about 25,000 to 45,000 vehicles/day, two levels of control should be used. The flyover only facilitates traffic flows in the directions of the bridge, but the infrastructure cannot fully solve all of the problems especially on the secondary road. This research presents issues that still exist at the flyover intersection and recommend improvements to the problems

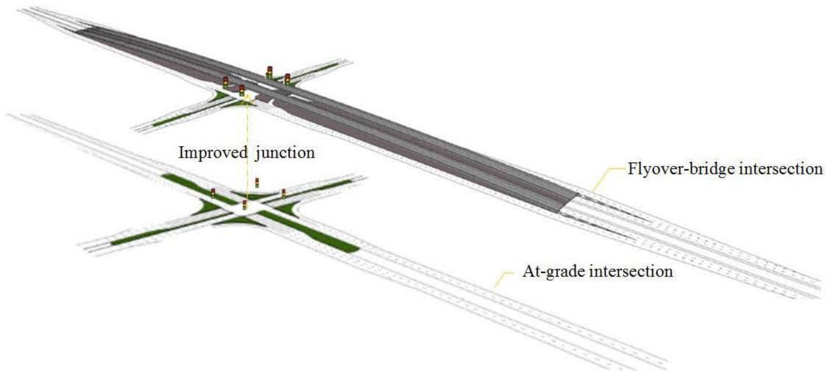

Fig. 1. The layout of an at-grade intersection converted to a flyover-bridge intersection.

2. Objectives

- To study the remaining traffic and road safety issues at the flyover-improved intersections
- To make suggestions to further improved the performance of existing flyover-bridge improved intersections

3. Scope of Study

- This study which is one part of author's thesis, presented the problems that could still be found at the flyover areas such as road safety and its consequence compared with "before" situation
- The Signalized (and unsignalized) Intersection Design and Research Aid (SIDRA) 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 [1]. In 2012, the latest versions of the software were in use by over 1350 organizations in 70 countries such as USA, Australia, South Africa, Canada, New Zealand, Malaysia, Singapore, as well as over 140 organizations in Europe. This study used SIDRA to analyze traffic data and determine an optimum cycle-phase time of three peak times traffic data of case studies,
- The process of Road Safety Inspection (RSI) was used to audit the sites and highlighted critical issues in the hazardous zone.

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4. Research Framework

A research framework consists of six steps (Fig. 2), the first is selecting 5 case studies covering all regions, the second is data collection consists of physical data, traffic data and accident statistics, the third is data assessment, fourth is data analysis and comparison data consists of the control at intersection, road safety, accident cost and used the SIDRA software to find the results in terms of traffic control such as phase times, time delay, vehicle queue length and level of service, then conclusion step and the last step is recommended to improve the case studies to better control.

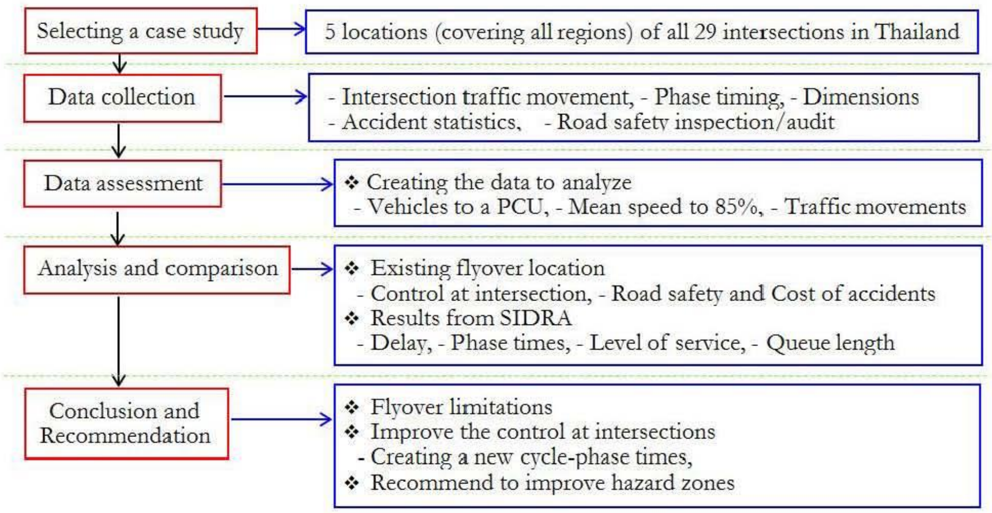

Fig. 2. Research framework.

5. Data Collection

Not only on-fields collected data, but also the important information such as the construction costs, number of casualties and flyover designs, in Table 1 shows these items of 5 example cases. Each location is different in the design and management because it is designed by depending on its physical locations, some locations must have an auditor for recording and inspection of these information more than six people such as at Udon Thani case study location – the dimension of the intersection is very big (it's located on the bypass highway), consequently, we need help with video record for checking traffic movement of each direction on the ground level, furthermore, author can also check and calibrate to the SIDRA software such as road user behavior and cycle phase time.

6. Data assessment

6.1. Traffic Data Collection

Under the bridge; the traffic movement is counted at each leg/direction that vehicles entering to the intersection, at locations marked as 1, 2, 3 and 4, on the bridge; the traffic movement counted at locations marked as A, B, C and D (Fig. 3). The vehicles were categorized into five groups; 2-wheelers (MC), 3 and 4-wheelers (PC), 6-wheelers (MT), Bus (B) and Heavy-duty (L) [19]. The traffic volume is converted to equivalent passenger car unit (PCU) by the unit factor 0.33, 1.0, 1.75, 2.25 and 2.25 respectively [22].

The timing of vehicle delay and queue length are counted in a cycle phase time of traffic signal on three peak times (as shown in Fig. 3).

The traffic signal programs used the same control as the situation of the at-grade intersection, 4 in 5 case studies are controlled by fixed-time control plan throughout the day (as shown in Fig. 4).

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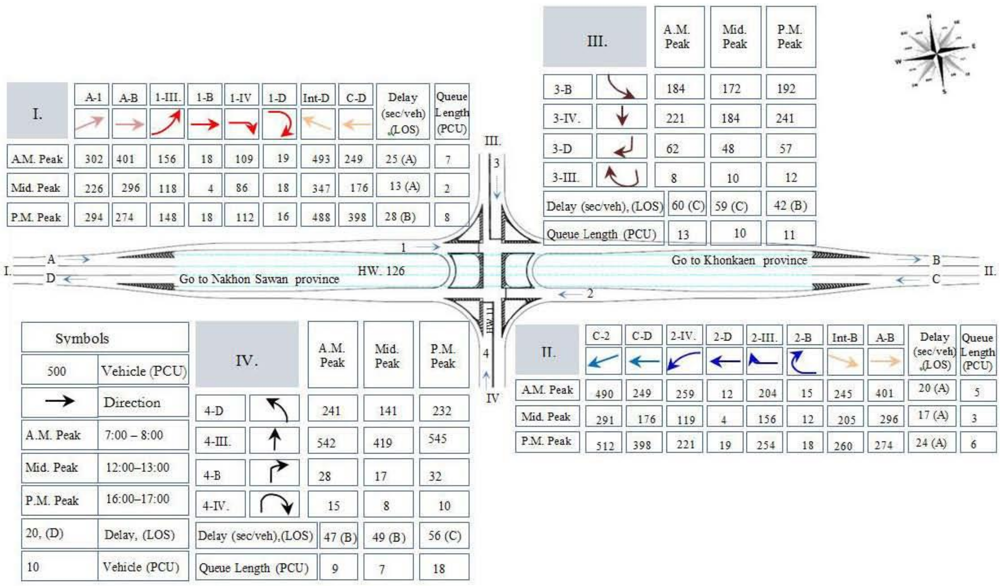
Table 1. Collected data of 5 existing flyover-bridge intersections.

Items \ Location	5 existing flyovers (province in Thailand)				
	Songkhla	**Udon Thani**	**Rayong**	**Phatthalung**	**Phitsanulok**
1. Flyover locations	HW# (4 + 43)	HW# (22+216)	HW# (36+3139)	HW# (4 + 41)	HW# (11+126)
2. Traffic survey - vehicle movement - delay and queue length	Collected data at three peaks-time a day (07:00 - 08:00 am., 12:00 am. – 01:00 pm., and 04:00 – 05:00 pm.) in a working day.				
3. Cycle times (fixed-time), (second/cycle)	176, 176, 176	178, 178, 178	160, 160, 160	184, 144, 184	159, 159, 159
4. Average speed (km/hr)	65	62	68	58	64
5. Dimension (Bridge length (meter))	390	750	340	410	670
6. Road Safety Inspection - Conflict points - No. of accidents (3 years)	64 27	64 40	40 30	64 17	66 37
7. Construction cost (Million Baht) and Opening date	117.00 Aug, 1996	242.20 2008	203.80 Aug, 2001	198.97 Sep, 2008	116.20 2002



Source: Applied from Traffic and Highway Engineering [11],

Fig.3. Traffic movement, Delay and Queue length information at 3 peak times (Phitsanulok case study)

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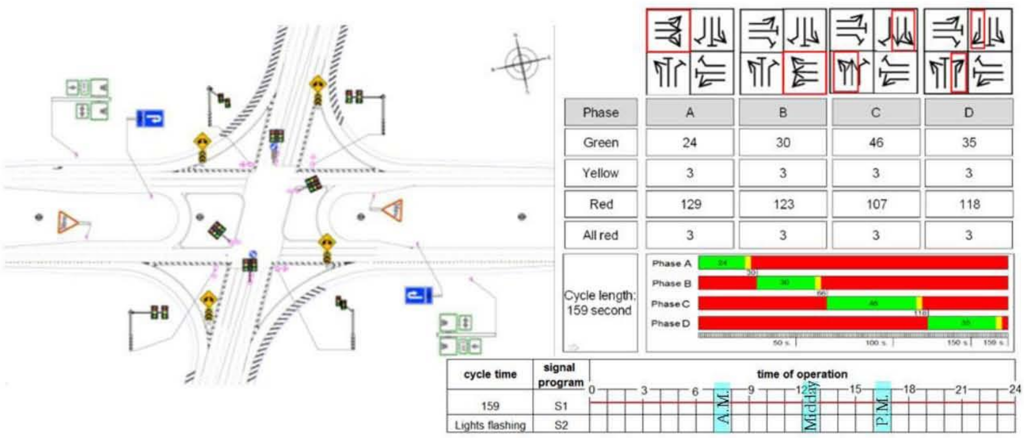

Fig.4. Traffic signal programs (Phitsanulok case).

Table 2 shows the passenger car units (PCU) data of both levels and cycle length of all case studies.

Table2. Passenger car units data per peak times and Cycle times.

Items \ Location		5 existing flyovers (province in Thailand)														
		Songkhla			Udon Thani			Rayong			Phatthalung			Phitsanulok		
Time period considers		A.M. (7:00-8:00)	Mid (11:00-12:00)	P.M. (16:00-17:00)	A.M. (7:00-8:00)	Mid (11:00-12:00)	P.M. (16:00-17:00)	A.M. (7:00-8:00)	Mid (11:00-12:00)	P.M. (16:00-17:00)	A.M. (7:00-8:00)	Mid (11:00-12:00)	P.M. (16:00-17:00)	A.M. (7:00-8:00)	Mid (11:00-12:00)	P.M. (16:00-17:00)
Cycle time (second)		176	176	176	190	190	190	160	160	160	184	144	184	159	159	159
PCU	on bridge	1802	1038	1538	2470	2102	2969	3242	3146	3535	1965	1710	2182	650	472	672
	at-grade level	5643	5566	6521	5213	4701	5225	2383	1970	3070	4492	3516	4120	2036	1464	2071

6.2. Accident Statistics

Accident statistics of each location were collected for 3 years (2010-2012) from 3 agencies in Thailand consisting of Department of Highways (DOH), Police records and Emergency Medical Services (EMS). The statistics were used for computing costs of accident that occurred at these existing locations. Table 3 shows the number of casualties in 3 years of accidents. Eq. (1) was used to find an annual average accident cost, to describe the combined effects of the number and severity of the accidents in these case studies.

Table 3. Number of casualties and time of accidents, 3 years (2010 – 2012).

Case studies (province)	Time of accident			Number of Casualties			DOH Damage	PDO
	Day	Night	Rain	Slight Injuries	Serious Injuries	Deaths		
Songkhla	12	15	0	24	1	2	-	27
Udon Thani	27	13	0	21	14	2	-	40
Rayong	15	15	0	20	10	3	-	30
Phatthalung	6	7	4	12	4	5	-	17
Phitsanulok	12	25	0	42	6	5	-	37
Sum	70	75	4	119	35	17	None	151

Source: Accident statistics at the flyover areas: DOH. (2010 - 2012) [3], *EMS. (2010 - 2012)* [4], [5], [6], [7], [8] *and Police records* [9], [12], [13], [14], [15]

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

Source: RIPCORD-ISEREST (2005), [17]

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where ACa: annual average accident cost ($/year);
A: number of accidents (acci);
MCA: mean cost per accident ($/acci) as shown in Table 4; and
t: the period of time under review (year).

The mean cost per accident in Thailand is used to estimate the accident cost, the number of casualties per unit is transformed to be the cost value (money), in this case used the mean value of the other provinces (in Table 4) to estimate.

Table 4. Mean cost per accident for various severities (2012).

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 *(Dis)*	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 *(LI)*	0.0386 - 0.0389	0.1731 - 0.1733	0.0297 - 0.0298
Property Damage Only *(PDO)*	0.052	0.164	0.039

Source: Mean cost of severities per road accident in Thailand: DOH. (2012), [2]

7. Data analysis

7.1. Description of Intersection Control

Although the control of intersection is improved by the installation of a flyover bridge, it still has many limits and can't fully solve the traffic problems that exist in similar situation of the at-grade intersection model such as vehicle delay, traffic congestion and road accidents. The bridge is just increasing the convenience for the road users in two directions on one of the two main roads while under the bridge, the same traffic control plans as the "before the flyover" were still in use. Even though it was found that about 30-35% of the total traffic volume diverted to the bridge and the vehicle delays reduced by 30% over the same period [18], the traffic flow situation on the secondary road is almost the same as that of the previous at-grade intersection.

The fixed-time cycle plan of the traffic signalization was used to control traffic volumes at ground level (4 in 5 case studies used only one plan of control throughout the day), it leads to an unnecessary loss of vehicle time. Table 5 further describes the issues relating to the flyover model that were found in this study, in terms of its advantages and disadvantages

Table5. Advantages and disadvantages of the flyover intersection.

Items	Disadvantages	Advantages
The bridge over an at-grade level	- The visual landscape is obscured, especially the commercial building that located near this area.	- Convenient for road users using the bridge, free flow on the bridge
Traffic capacity	- Small increase in traffic capacity for the secondary road	- Empowered to handle large traffic volume, especially on the main road
Delay & Queue length	- The delay and queue on secondary road are quite the same as the situation of the at-grade intersection	- Reducing a number of delays and vehicle queues in the direction of the bridge constructed (main road) - Saving travel time, increasing vehicle speed, especially, on the main road from 29.8 km/hr. to 52.5 km/hr. (at 85% vehicle speed)

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Items	Disadvantages	Advantages
Traffic control	- Traffic signalization still uses the fixed-time control plans as the previous situation of at-grade intersection, which does not fully utilize the benefits of having a flyover	- Reducing time for waiting at the intersection (by adjusting a new cycle time for flyover situation)
Road Safety	- In the flyover area, the hazard zone is spread to more zones, especially at the approaching and exiting zones of the bridge	- Reduce traffic conflict points at the junction - Reducing rear-end collisions
Cost and benefit	- During construction, road accidents and vehicle time delay incurred extra costs - Higher maintenance costs	- The flyover is an essential part of the highest type of highway, the expressway or freeway. It has cheaper construction cost than other types of grade separations. - No land needs to be expropriated.

7.2. Road Safety Inspection [16], [20], [21]

According to the physical data, the area of intersection has increased compared to the old one and under the bridge, the existing traffic signalization still uses the same previous fixed time control plans; hence, similar problems as those of the previous at-grade intersection still exist. Furthermore the hazardous zone has spread out to other zones in the flyover area (as shown in Fig. 10) as follows:

At the approaching and exiting zone of the bridge (bottleneck); road users behavior at an approaching zone may lead road crashes from weaving conflicts because the vehicles cutting in sharply from the right lane to the left lane before entering the auxiliary lanes or heading for the bridge. At the exiting zone, conflicts of vehicles merging can lead to road crash because some vehicles from the left auxiliary lane cutting across the chevron markings to the right lane of the main road abruptly (Fig. 5).

Fig. 5. Traffic conflicts at the approaching and exiting zones.

The drainage ditches on the median of the road, at the beginning of the bridge there are illegal paths that were used by motorists for crossing to opposite direction, when a high speed vehicle on the main road passes this area, a crash may occur as a result of the vehicles on the main road hitting the motorcycle emerging from the drainage median (Fig. 6).

Fig. 6. An illegal movement at the drainage ditches on the median of the road.

The U-turn under the bridge, it is located near the stop line markings on the bridge direction about 17 meters or 3-vehicle length. For Udon Thani case study, this type of U-turn which allows movements in two directions and becomes an illegal channel for motorcycles, could cause the right or left angle collisions and head-on collisions (Fig. 7).

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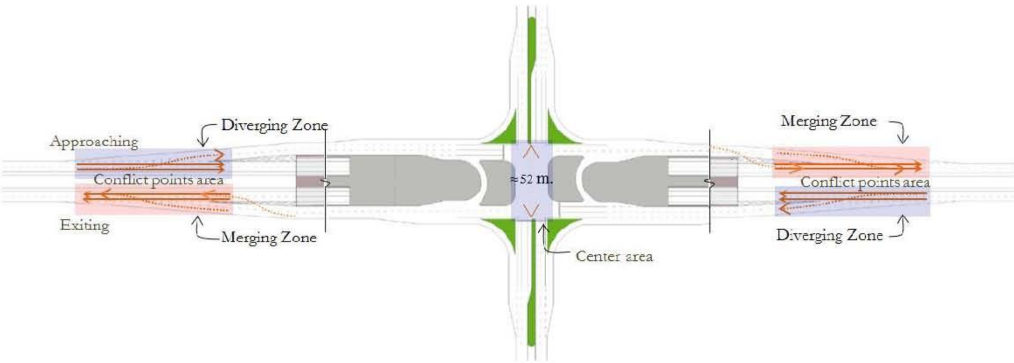
Fig.7. Illegal movements at U-turn under the bridge.

On the shoulder of the road, there are many heavy trucks that stop and wait for repair and recess. Some incidents may occur when motorcycles using the shoulder at night time and cannot see a truck in time, a rear-end collision could result (Fig. 8).

Fig. 8. A fixed object - heavy trucks stopped for repair and recess at the shoulder of the road near flyover intersection area.

Other problems near the flyover area, because the flyover model doesn't have a standard design, the Phitsanulok case study has a different traffic control for example the U-turn is opened on secondary road (Fig. 9(A)), for the Udon Thani case study, a supermarket is located near the flyover location (Fig. 9(B)) and for the Phatthalung case study, the U-turn has no auxiliary lane (Fig. 9(C)).

Fig. 9. Other problems near the flyover areas.



Source: Applied the conflict points from Traffic and Highway Engineering (page number 283) [11],

Fig. 10. Hazardous zones in the flyover intersection area.

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7.3. Cost of Accidents

To assess the accident cost at the existing flyover intersections (5 case studies), Eq. (1) is used to estimate the annual average accident cost.

Because the accident statistics from the 3 agencies did not record the number of people who were disabled by the accidents; the authors used estimate as given by Dr. Nima Asgari [23] who stated that "every crash of road accidents in one year will be one person's death, injured 20 people and 1 of 20 people become to a disabled person", so, if there are 100 injured people, 5 people may become disabled. For this reason this paper uses 5% of the slightly injured number as the number of disabled people.

Equation (1) is used to calculate an annual average accident cost (ACa) as shown in Table 6.

Table 6. Annual average accident cost of 5 case studies.

Mean cost per accident \ Locations		Number of casualties (3 years recorded)				
		Songkhla	Udon Thani	Rayong	Phatthalung	Phitsanulok
Fatal	5,178,000 Baht	2	2	3	5	5
Disabled	6,168,500 Baht	1.2	1.05	1.0	0.6	2.1
Seriously injured	151,500 Baht	1	14	10	4	6
Slightly injured	29,750 Baht	24	21	20	12	42
Property damage only	39,000 Baht	27	40	30	20	37
ACa [Baht/year]		6,558,900	7,046,225	8,327,500	10,444,700	14,148,450
		Avg ACa = **9,305,155** Baht/year				

7.4. Analysis Results from SIDRA

This software is an advanced micro-analytical tool used for evaluating of alternative intersection designs in many terms such as capacity, level of service, time delay, queue length, as well as fuel consumption, pollutant emissions and operating costs [1]. In this study, the software was used to analyse the performance of each flyover improved intersection and point out the average delay, average queue length and level of service (Table 7).

And to further improve the performance of the intersections, the same data were used to calculate the optimum cycle-phase times by using the lowest time delay as the indicator. Table 8 shows the optimum cycle time and its results for 3 time periods of the 5 case studies.

Table 7. Analysis of field data by SIDRA for 3 time periods.

Locations	Songkhla			Udon Thani			Rayong			Phatthalung			Phitsanulok		
Items \ Time	A.M.	Mid	P.M.	A.M.	Mid	P.M.	A.M.	Mid	P.M.	A.M.	Mid	P.M.	A.M.	Mid	P.M.
Cycle time (sec)	176	176	176	190	190	190	160	160	160	184	144	184	159	159	159
Average delay (sec/veh)	159	151	195	204	162	191	46	45	46	207	165	232	37	36	38
Average queue length (vehicle) and (meter)	83 & 543	80& 516	96& 563	72& 474	56& 375	63& 413	13& 77	11& 66	15& 87	66& 395	35& 216	65& 407	11& 66	9& 53	12& 67
Level of service	F	F	F	F	F	F	D	D	D	F	F	F	D	D	D

Table 8. Optimum cycle-phase time by SIDRA for 3 time periods.

Locations	Songkhla			Udon Thani			Rayong			Phatthalung			Phitsanulok		
Items \ Time	A.M.	Mid	P.M.	A.M.	Mid	P.M.	A.M.	Mid	P.M.	A.M.	Mid	P.M.	A.M.	Mid	P.M.
Cycle phase time (sec)	130	140	150	185	160	170	115	106	115	178	178	178	80	80	80
Average delay (sec/veh)	153	143	175	140	98	109	38	37	39	139	76	142	28	27	28
Average queue length (vehicle) and (meter)	65& 432	67& 446	86& 501	64& 422	44& 292	53& 336	10& 61	10& 57	13& 76	58& 347	32& 193	57& 357	10& 60	7& 43	9& 54
Level of service	F	F	F	F	F	F	D	D	D	F	E	F	C	C	C

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8. Conclusion and Recommendations

This study which is one part of the first author's thesis, presented the performance of the 5 case studies flyovers and suggested improvements to 29 flyover intersections in Thailand.

An at-grade intersection was upgraded with an installation of a flyover at a cost of about 175 million THB, to increase capacity of the intersection and reduce vehicle delay and long queue at the at-grade level, the flyover is one of the methods that supported traffic volume about 25,000 – 45,000 vehicle/day [10].

In terms of benefits (the second part study of the author's thesis: "a case study of an at-grade intersection converted to the flyover intersection") [18], it was found that about 35-40% of the total traffic volume diverted to the flyover, and despite an increase in traffic volume of +29.46%, at the intersection, the vehicle delays were reduced by 30.41% over the same period, and saving in travel time and vehicle operation cost amount to 421.65 Million THB.

The results of study, however, show that traffic signalization for both the existing at-grade situation and flyover upgraded situation has been and is still controlled by fixed time control plans, there is still long queue and delay especially on the secondary highways. Hazardous zones in the flyover area spread out to other zones which are at the approaching and exiting areas, at the drainage ditches on a median of roads, at the U-turn under the bridge and at the crossroad under flyover, furthermore, the conflict points increased from 50 points to 64 points. Accident cost is about 9.3 Million THB/year/flyover intersection, average accident number is about 30 crashes, 30 injured people and 1 person death per year.

To improve the performance of the flyover intersections, the SIDRA software (version 5.1) was used to calculate the optimum cycle-phase times based on the lowest time delay. In terms of road safety improvement, the Road Safety Inspection guideline was used for site inspections and recommendations are suggested as shown in Table 9.

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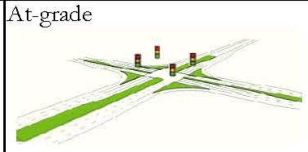
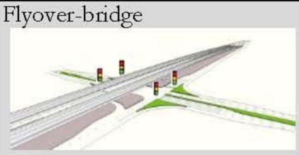
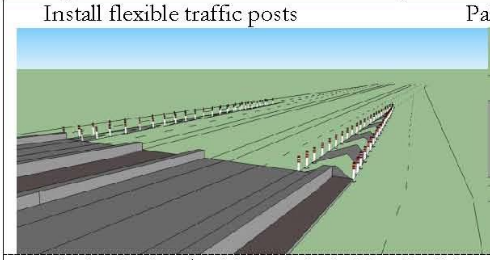
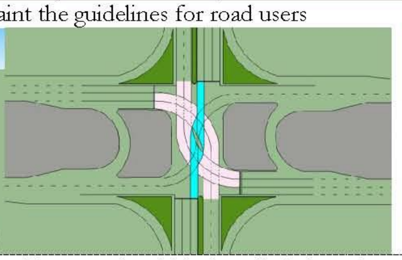
Table 9. Conclusion data and suggestion to improving an existing flyover intersection.

Items	Intersection		
- Figure	At-grade  Previous	Flyover-bridge  Present	Grade separation  Future
- Construction cost (approximate)	40,000 Baht/square^2	75,000 Baht/square^2 (Avg = 175.63 million THB)	80,000 Baht/square^2
- Traffic capacity of each type	≈1,500 – 25,000 vehicles/day	≈25,000 – 45,000 vehicles/day	> 45,000 vehicles/day
- Situations	Analysis of field data by SIDRA	Optimum cycle times by SIDRA	
· Phase time	Avg cycle phase time = 174 second/cycle	= 136 second/cycle (reducing to 38 second)	
· Delay	Avg Delay = 127 second/cycle	= 92 second/cycle (reducing to 27.5%)	
· Queue length	Avg Queue = 45 vehicles or 287 meters	= 29 vehicles or 245 meters (reducing to 14.0%)	
· LOS	between F to E	between F to D	
Accidents	Average number of accidents = 30 crash /location/year		
No.of injured	Average number of injured = 30 people /location/year		
Death	Average a number of deaths = 1 person /location/year		
Accident cost	Average accident cost = 9,305,155 Baht/year/location (285,724.09 USD)		
- Recommend to improve the existing flyover intersection	Install flexible traffic posts 	Paint the guidelines for road users 	
	- At the beginning/ exiting of the bridge flexible traffic posts should be installed along the line of the nose-ghost island, the direction arrows should be painted on the weaving zones, installation of traffic signs: speed limit sign, give way sign and intersection warning sign.		
	- At the drainage ditches on the median of the main road concrete barriers should be installed to close off the illegal paths		
	- At the U-turn under the bridge, one way traffic control should be used.		
	- At the junction underneath the bridge, guideline should be painted for road users in all directions.		
	- For a typical existing flyover intersection, around 60-80% time delay is on the secondary road, traffic engineer should design a new cycle-phase times of traffic signalization especially the yellow phase-time which should be appropriately designed in accordance with the size of the intersection.		

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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.

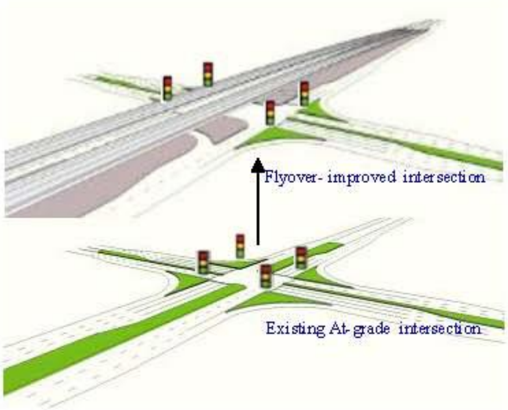


Figure 1. Layout of an at-grade intersection converted to a flyover-improved intersection

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)).

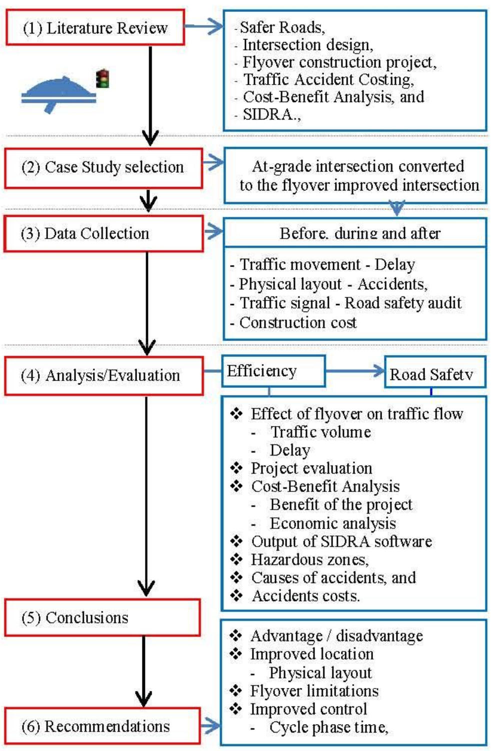


Figure 2. Research framework

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		

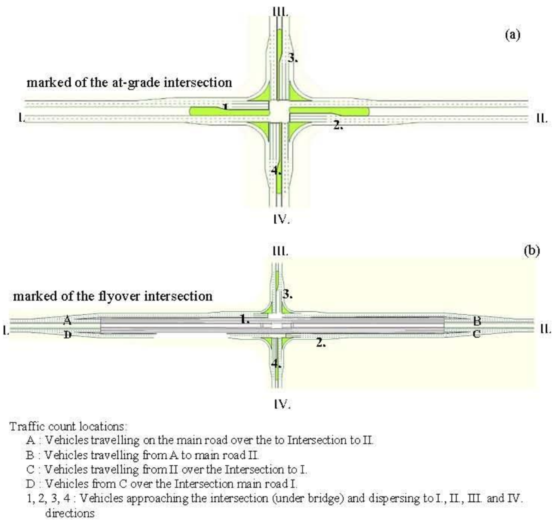


Figure 3. Turning movement count locations at the existing and flyover improved intersection

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.

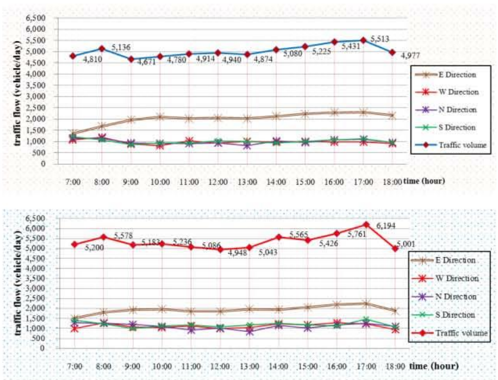


Figure 4. At-grade intersection traffic volume and Flyover intersection traffic volume

3.4 Traffic Signal

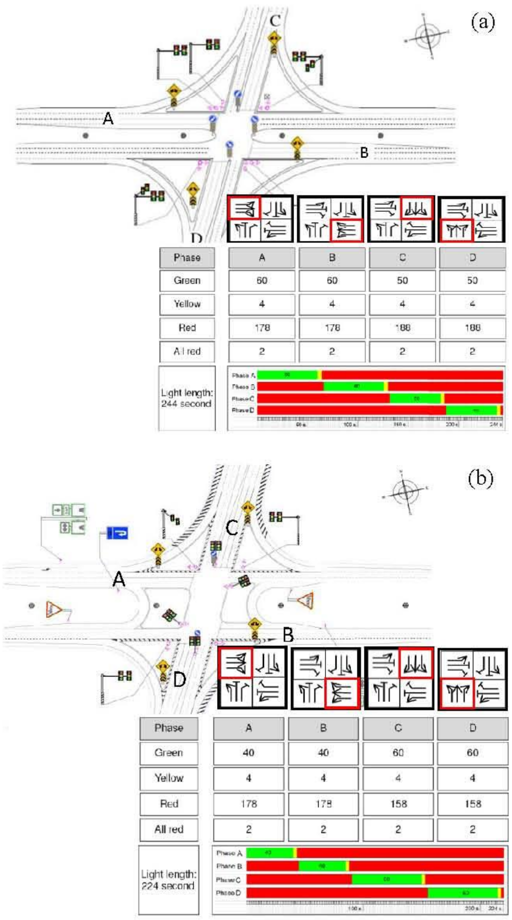
Traffic signal for both situations was controlled by fixed time plans. The before situation was controlled by two programs; the cycle time in the first program is 244 seconds (Figure 6 (a)), applied during 0600 to 2100 (4 phases per cycle), and the second program was flashing yellow, applied during 2100 - 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.



Phase	A	B	C	D
Green	60	60	50	50
Yellow	4	4	4	4
Red	178	178	188	188
All red	2	2	2	2

Phase	A	B	C	D
Green	40	40	60	60
Yellow	4	4	4	4
Red	178	178	158	158
All red	2	2	2	2

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

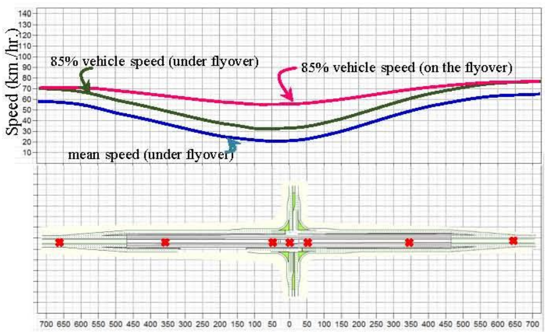


Figure 7. Vehicle speed at marked locations

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	Items: (units)	Intersection situation: At-grade	Intersection situation: Flyover		Results: Reduction		Results: 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		-		3,904	6.0%
				PCU	Truck				
				47,261	16,958				
				73.6%	26.4%				
	Under the flyover		60,351	39,915 (62.16%)		20,436	33.8%	-	
				PCU	Truck				
				32,837	7,078				
				82.2%	17.8%				
	On the flyover		-	24,304 (37.8%)		-		24,304 (37.8%)	
				PCU	Truck			PCU	Truck
				14,424	9,880			14,424	9,880
				59.4%	39.6%			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)

	Speed (kilometer per hour)											
VOC	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

Mean cost per accident \ Locations		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).

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

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

$NPV = 361{,}641{,}982$ Baht

5.2 Benefit–Cost Ratio (BCR)

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

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

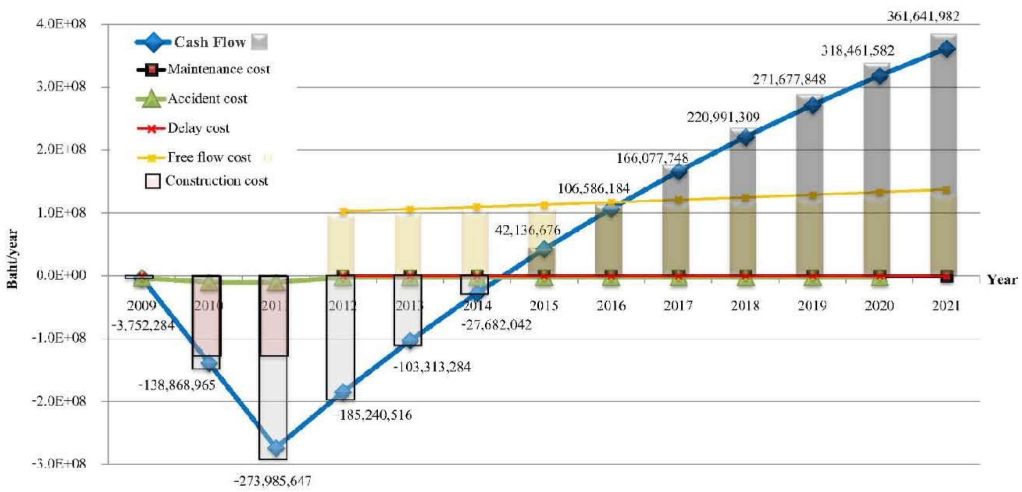
$BCR = 1.34$

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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VITAE

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List of Publication and Proceeding :

1) Institute : **National Convention on Civil Engineering (NCCE 14th)**
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2) Institute : **The National Transport Conference (NTC 6th)**
Article Title : ***In-Depth Traffic Accident Investigation: The Upper Part of Northeastern Region of Thailand.***
Article Number : NTC 12
Year : 2009

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3) Institute : **Asian Transportation Research Society "ATRANS" Symposium (3th)**
Article Title : ***The Study of In-Depth Traffic-Accident Investigation Procedures: The Example Case Studies in the Upper Northeastern Region.***
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Year : 2010

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4) Institute : **Asia Pacific Conference Transportation and the Environment (APTE 8th)**

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Article Number : TRP102

Year : 2013

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7) Institute : **Asian Transportation Research Society "ATRANS" Symposium (6th)**

Article Title : ***Assessment of benefits of flyover over signalized intersection: A case study***

Article Number : YRF13-028

Year : 2013

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8) Institute : **Journal of Society for Transportation and Traffic Studies (JSTS)**

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Article Number : Vol. 4 No.3, pp. 1-12

Year : 2013

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9) Institute : **ENGINEERING JOURNAL (EJ-CU, 2014)**

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Article Title : ***An Evaluation of Flyover-Improved Intersections: A case study of airport intersection***

Article Number : TSTS 07

Year : 2015