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.

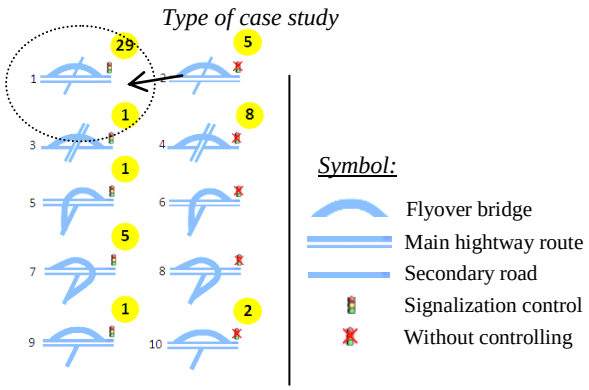
Keywords: *Flyover, Signalized intersection, cost-benefit analysis, Vehicle delay, Accident cost*

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)

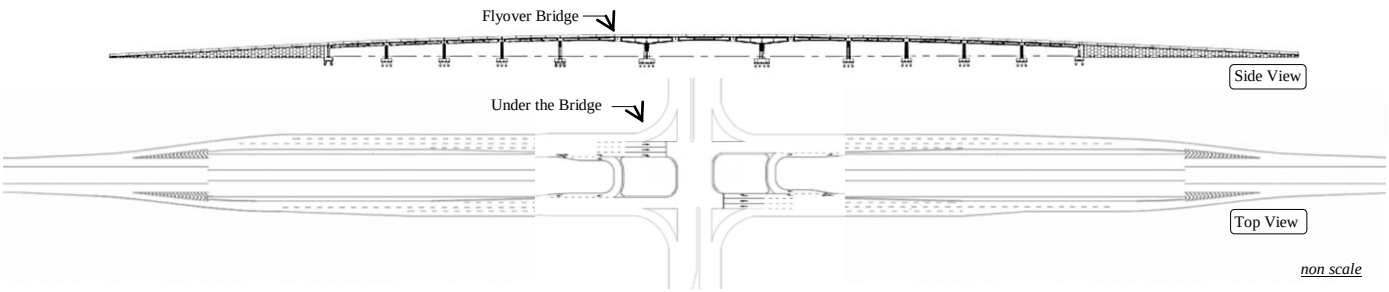


Fig.2. The scheme of Flyover intersection (case study type)

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)

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 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 is17,316 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)).

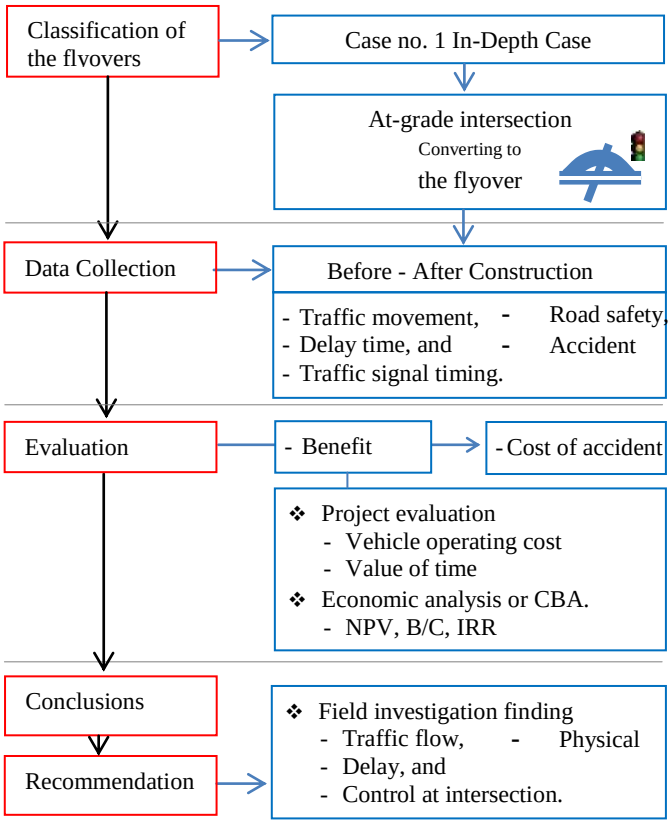


Fig.3. Research framework

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

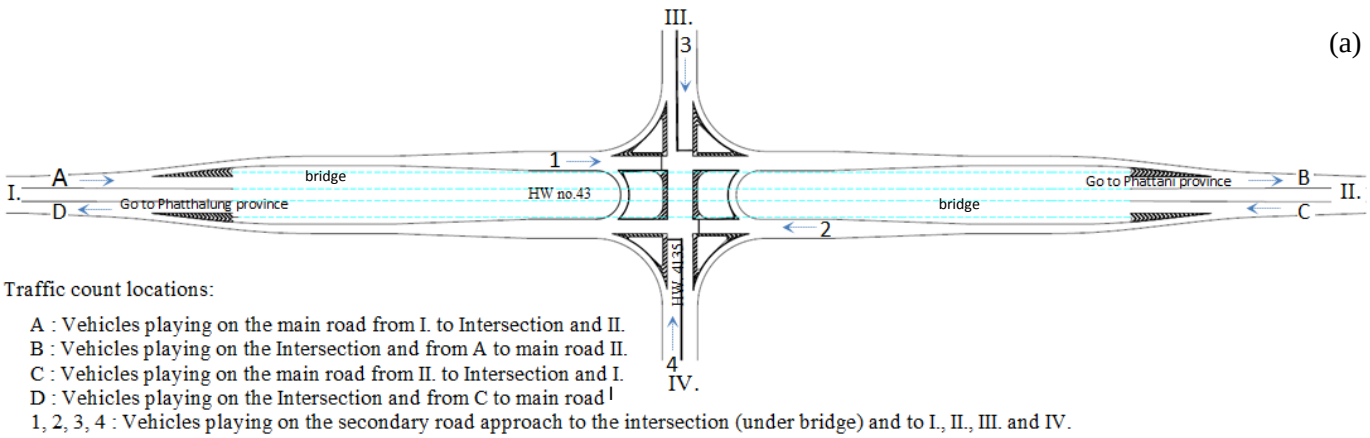
value increase, by calculating the value of time in the area (province) of case study consists of the gross province product (GPP), number of employed and average hours of work (Table 2).

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]

(a)



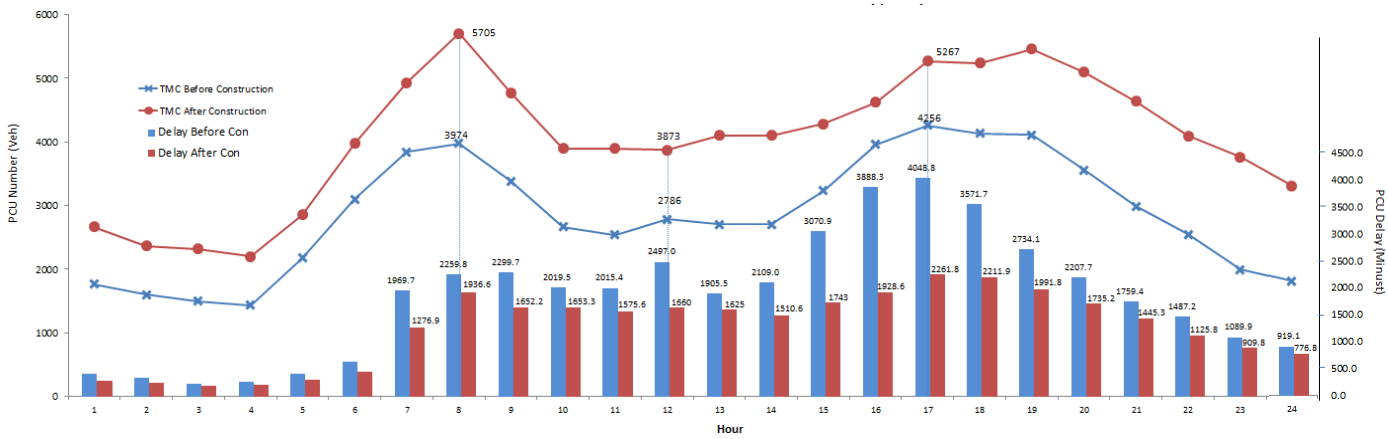
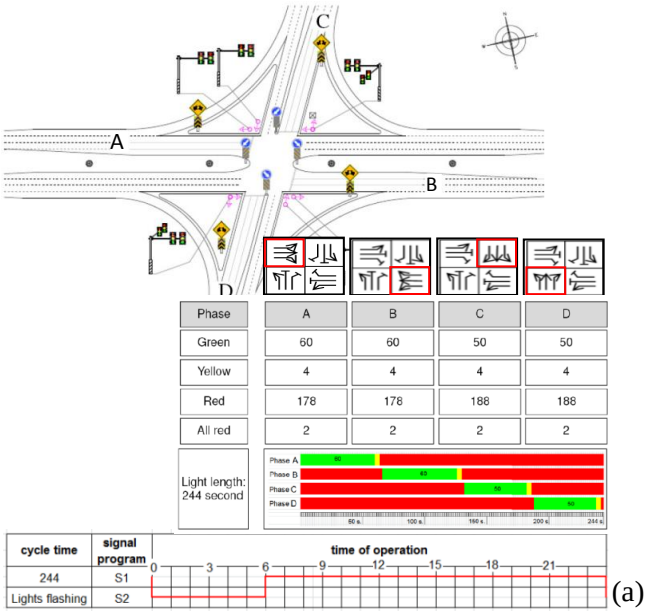
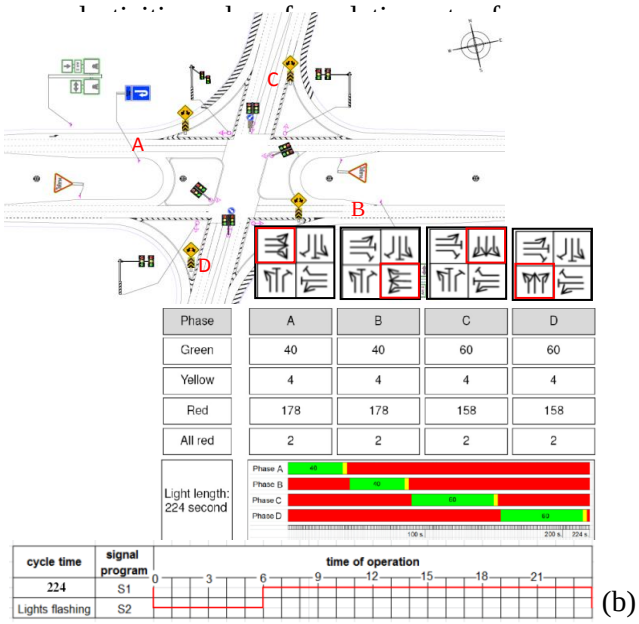


Fig.4. Traffic movement counted at locations marked and traffic volume and delay per day



(a)



(b)

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);

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

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)

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 (Million Ba
	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.

$$\text{Avg } AcUC_{(Fal)} = [\text{No.of Fal} * (AcCS_{(Fal)} + AcCS_{(SI2)} + AcCS_{(SL)} + AcCS_{(PDO)})] \quad (2)$$

$$\text{Avg } AcUC_{(SI2)} = [\text{No.of } SI_2 * (AcCS_{(SI2)} + AcCS_{(SL)} + AcCS_{(PDO)})] \quad (3)$$

$$\text{Avg } AcUC_{(SL)} = [\text{No.of SL} * (AcCS_{(SL)} + AcCS_{(PDO)})] \quad (4)$$

$$\text{Avg } AcUC_{(PDO)} = [(\text{No.of PDO} * (AcCS_{(PDO)})) + \text{On-site damage cost}] \quad (5)$$

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
*A*gAC : 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).

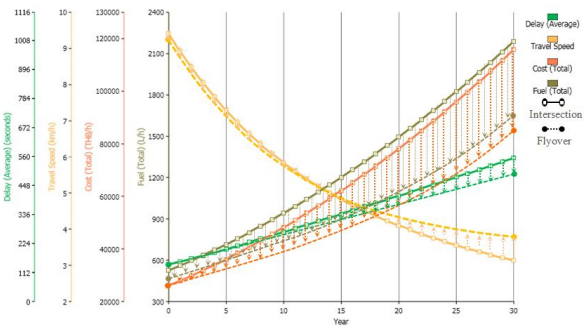


Fig.6. Assesses data from the SIDRA software

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. <u>*Ans,*</u>

- *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 <u>*Ans,*</u>

- *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.

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 directions.

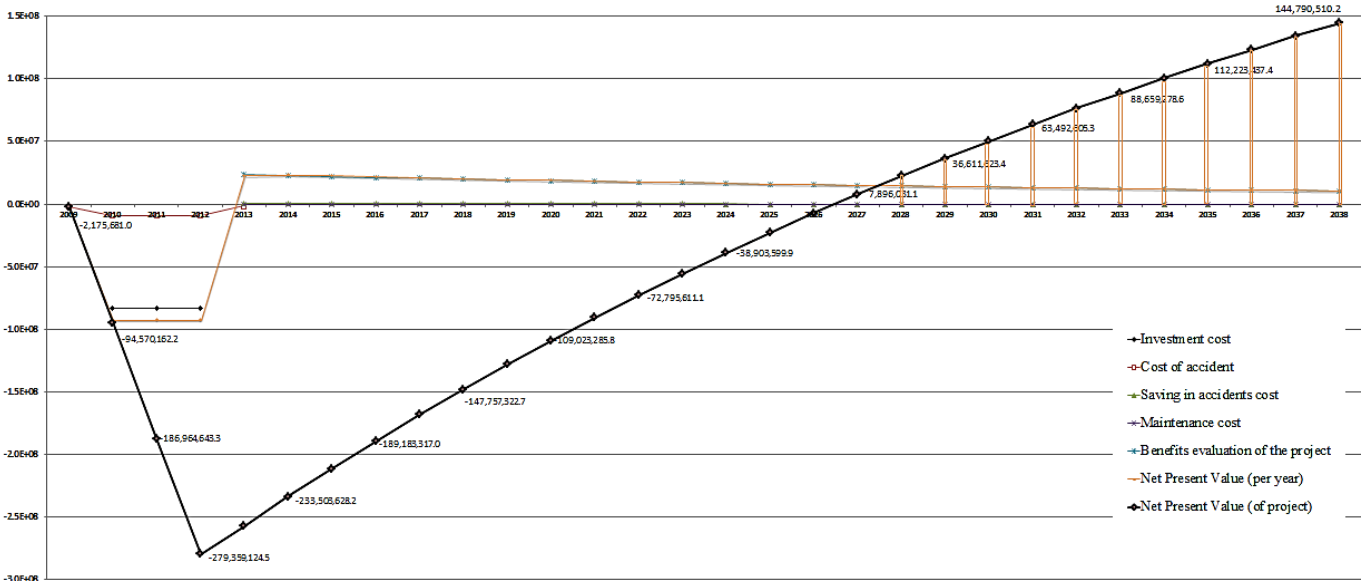


Fig.7. Information of cost-benefit analysis (CBA) per year, (1-30 years)

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

The radius at kerb corner should newly designed by depending on turning radius of the trailer.

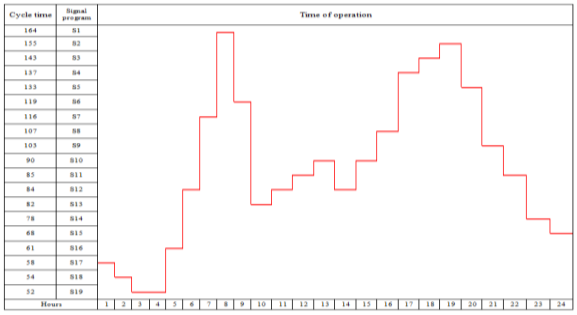


Fig.8. The cycle length programs were calculated by depending of the traffic volume per hour

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