Using aaSIDRA and PARAMICS in Evaluation of a Traffic Signal Coordination Development in Khon Kaen City, Thailand

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1. Introduction

In most cases, a level of delays and congestions in an urban road network is regularly related to the performance of traffic signals. A range of traffic signal coordination strategies has been developed and used in order to alleviate the situation. The fixed-time traffic signal coordination strategy is a proper alternative for improving urban traffic condition in Thailand because of three main reasons: compatible for most existing traffic signal controllers without additional equipment installation; requires shorter time spending for an implementation; and less expenditures compared to adaptive coordination strategies.

Focusing on the traffic engineering in Thailand, even though the benefits of traffic signal coordination and computer traffic simulation technology have been clearly proved, they have yet been a new knowledge and not widely used in Thailand. According to Thailand Ministry of Transportation (2004), the record of the ministry shows an excessive situation. The number of registered vehicles has annually been average 7% increasing since 1990s. The dramatic increasing of vehicle without improvement of road and traffic control facilities leads many serious traffic issues to Bangkok and other large cities in the country. In consideration of traffic signal controls in Thailand, most of them are now individual fixed timing system. Inadequately phase timing and unsynchronized among neighbor traffic signals in a network are the major cause of traffic issues.

2. Khon Kaen City

Khon Kaen is the capital city of north-eastern region of Thailand with total population of 1,750,000; ranks the third of the country. Central businesses district (CBD) is experiencing one of the fastest growth rates in Thailand. Since last decade, traffic condition in Khon Kaen CBD has massively changed. The number of vehicles becomes double. In such a situation, the traffic control and management system should be improved effectively to resolve the traffic congestion.

Considering the weakest areas in Khon Kaen CBD, Sri-Jan Road is one significant arterial road of Khon Kaen reaching unmanageable condition. The arterial is crossing the heart of CBD, and intersected by other three arterial roads. Within the considered area of 1.5 km approximately along the arterial, there are four signalized intersections. Those traffic signals operate at an individual pre-timed mode. The spacing between each intersection varies from 150 to 300 meters.

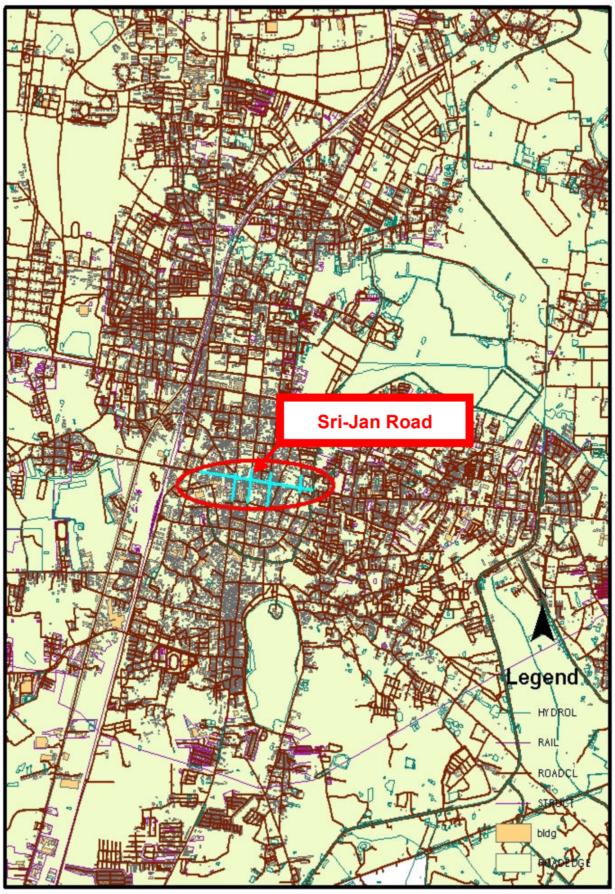

Figure 1: Khon Kaen CBD Map

A field observation was conducted in January, 2005. It found that congestions and queues along the corridor were often found during the day. In the morning and evening peak, oversaturated condition often happened along the corridor. It was believed that the traffic signals are the reason behind the issue. The existing cycle times and phase timings appeared unsuitable for the traffic demand at the intersections. Additionally, in the off-peak and inter-peak periods, the vehicles driving along the corridor still experienced delay and unnecessary stops even though the number of vehicles was not high and the traffic was not congested.

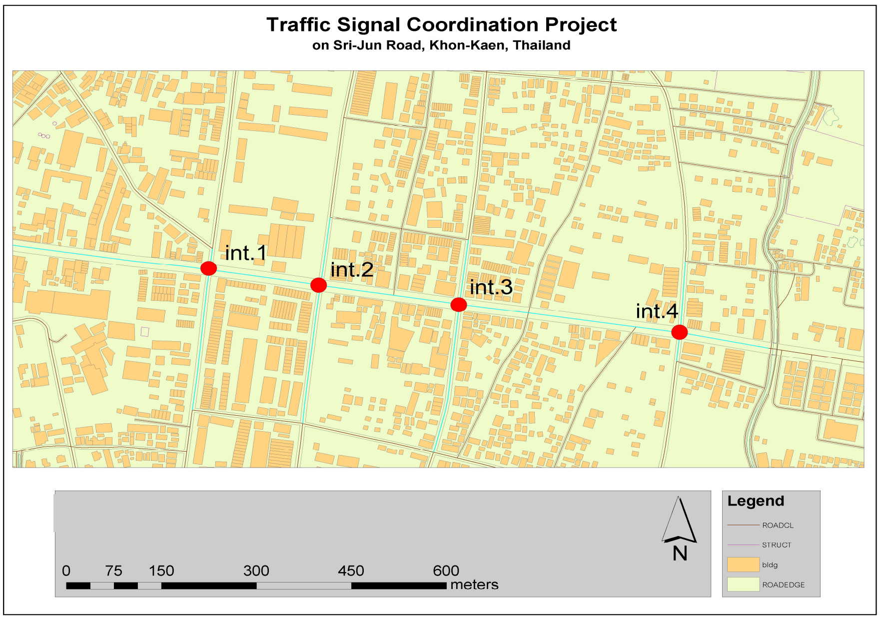

Figure 2: Layout of the Four Signalized Intersections

3. Traffic Signal Coordination

HVCEO Transport Planning (2005) states that the principal purpose of most arterial roads is to maximize effective road capacity, minimize delay, and provide safely at the same time. The major cause of delay and congestion along most arterial roads are regularly traffic signals. There are many times that traffic stream is required to make unnecessary stops because of no relationship between neighbor traffic signals in the area. This situation leads poor conditions and many issues to the road network such as longer travel times, increase vehicle emissions and fuel consumption, increase motorists frustration caused by unnecessary stops. Additionally, undue delay possibly leads a potential increasing of accidents.

Traffic signal coordination is a method to synchronize any numbers of adjacent traffic signals in an area by establishing the relationships using offsets between those adjacent traffic signals on an arterial road or a road network. An offset is defined as the time difference in the starting of green phase between adjacent traffic signals. Basically, when a group of neighbor traffic signals are synchronized, they can possibly produce more opportunities for motorists to travel along the corridor without experience unnecessary stops by any traffic signal. For an arterial road, the performance of traffic signal coordination is depended on several factors such as driving speed of vehicles along the corridor, spacing between traffic signals, traffic volume on arterial road and cross roads, and number of un-signalized intersections along the corridor (HVCEO Transport Planning, 2005).

According to CCIT (2004), there are many different levels of traffic signal coordination control developed and currently used for an arterial road, from simple to advance. Those can be basically classified to two classes: Progression Scheme; and Adaptive Scheme. A type of Progression Scheme named *Flexible Progression Scheme* is selected for Sri-Jan Corridor. The cycle lengths of all traffic signals along the corridor are equal. The relationship of the indications between intersections varies by the non-uniform spacings between intersections. The offset of each intersection is therefore different. The phasing plan and cycle length can be changed, related to the varieties of traffic patterns in each period. However, they must refer to the library only. This scheme can be applied to the existing signal controllers at all intersections on Sri-Jan Corridor and also does not require the additional equipments such as detectors. Therefore, this scheme benefits in term of implementation time spending and also financial arrangement.

4. Traffic Pattern on Sri-Jan Corridor

The intersection turning movements were counted at all intersections, between 6.30AM and 6.00PM on the two weekdays in February 2005. The traffic composition, queue length and mid block speed were also recorded. According to the survey, the traffic pattern on the first day and the second day were almost similar to one another day. These implied the high consistency of traffic demand pattern on Sri-Jan Corridor on any weekdays. Figure 3 shows the traffic demand on the days that the survey was conducted.

According to the Figure 3, the highest peak is in the morning, between 7.30AM and 8.30AM. The second peak is in the evening, between 4.30PM and 6.00PM. This study initially divides into seven periods (seven progression schemes):

Period 1:	Off Peak	between 6.45AM and 7.30AM	(45minutes)
Period 2:	Morning Peak #1	between 7.30AM and 8.30AM	(60minutes)
Period 3:	Morning Peak #2	between 8.30AM and 10.00AM	(90minutes)
Period 4:	Inter Peak #1	between 11.00AM and 12.30PM	(90minutes)
Period 5:	Inter Peak #2	between 12.30PM and 2.00PM	(90minutes)
Period 6:	Evening Peak #1	between 3.00PM and 4.30PM	(90minutes)

Period 7: Evening Peak #2 between 4.30PM and 6.00PM (90minutes)

For the Period 1, the traffic demand is very low, compared to other periods. Therefore, it is assumed that the traffic demand in the Period 1 also represents the traffic volume at night.

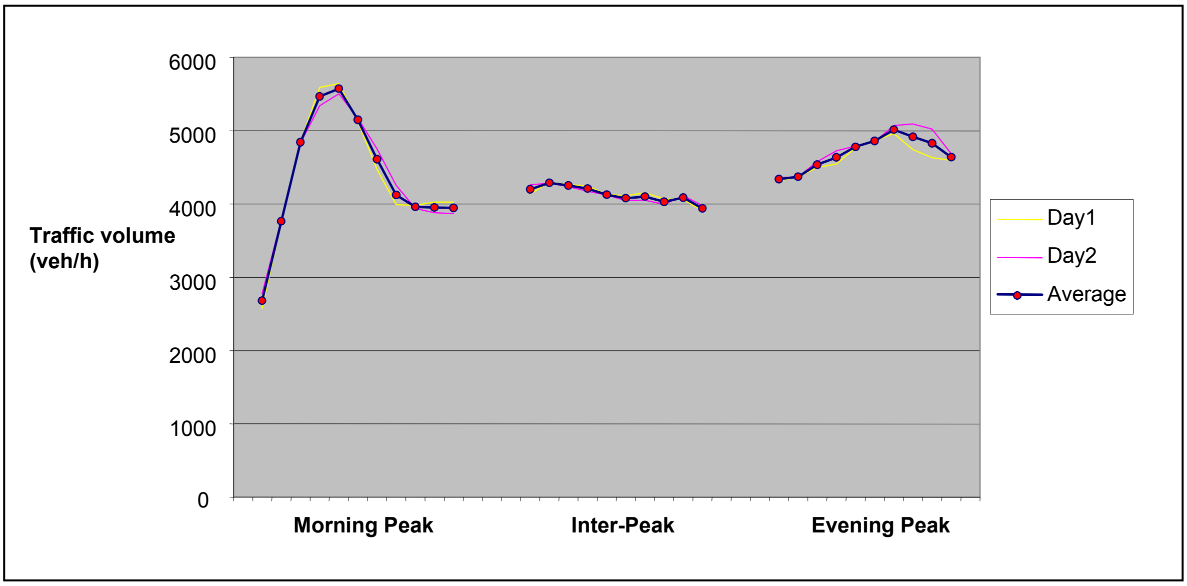

Figure 3: Traffic Demand on the Study Area (Excluding Motorcycle Demand)

5. Unique Traffic Behaviors and PARAMICS Model Calibration in Khon Kaen

In Khon Kaen, there are two factors which totally different from the traffic behaviors in developed countries. Those are motorcycle impacts and right-turn behavior factor, influence on the effectiveness of using traffic simulation software packages in the city. This section reviews some aspects relating to the factors and also reviews the PARAMICS model calibration and validation concepts used in this study.

5.1 Motorcycle Impacts

In Thailand, motorcycle is one factor which needs to be considered. Motorcycle ranks a high proportion of traffic composition on the roads in urban area. By the reason that PARAMICS does not provide motorcycle modeling function. This study therefore tries to deal with the motorcycle composition before starts using the model. The Passenger Car Unit (PCU) Method is initially used to calibrate the model. This assumption is experimented in the Period 2 that has the worst traffic condition. The PCU value used is 0.33, according to the Khon Kaen Traffic Master Plan Study (SIRDC, 2004).

Figure 4: Motorcycle Behavior in Thailand

As a result of the calibration, the total traffic volume after the PCU applied is 21.8% over the actual. The traffic conditions with motorcycle PCU are obviously poorer than the actual traffic condition. The cumulative queues at all intersections are much longer, especially on right-turn movements. Additionally, oversaturated condition happens.

In consideration of the real traffic in Khon Kaen, the characteristics and behaviors of motorcycle are totally different from passenger vehicles. Most motorcycles in Thailand are classified as a small type – its engine capacity varies between 80cc and 150cc. Small motorcycles usually use spacing between adjacent vehicles, do not therefore extensively affect to length of queue behind the stop line (as shown in the Figure 4). Moreover, more than one motorcycle can make a right-turn at the same time, and sometimes make a turn at the same time with a vehicle.

According to the experiment, the PCU Method which converts the number of motorcycles to personal vehicle unit leads the excessive number of personal vehicles on the corridor and causes longer queue length. Subsequently, the same number of personal vehicles requires longer time to cross an intersection and experiences more delay. Therefore the PCU Method may not be appropriate for calibrating the model with high proportion of motorcycles, for instance, in Thailand. The assumption may be more properly working, however requires further study. To deal with the motorcycle impacts, this study suggests a method to calibrate the model without motorcycle demand which will be discussed in the section 5.3.

5.2 Right-Turn Behavior

Another factor which is different from developed countries is the right-turn behavior. In developed countries and also in PARAMICS, the vehicles wish to make a right-turn at an intersection usually wait until all through movement vehicles have crossed the intersection or sufficient gap acceptance or until amber phase begins. In contrast, some of the right-turn movement vehicles at the beginning of the queue in Thailand, sometimes, do not give way to the through movement vehicles and snatch the opportunity to make a turn before the through movement vehicles reach the middle of the intersection. This behavior leads delay to the through movement vehicles and less number of through movement vehicles which are able to cross the intersection per one cycle time. However, the number of right-turn movement vehicles passing an intersection per one cycle time becomes higher.

For the PARAMICS model which is not specifically calibrated, the right-turn movement queue is longer and the through movement queue is shorter than the real situation. The difference is obviously found when the traffic demand is high such as in the morning peak. To deal with the right-turn behavior, this study develops a method to calibrate the model which will be discussed in the section 5.3.

5.3 PARAMICS Model Calibration and Validation for Khon Kaen

The purpose of model calibration and validation method is to adjust the model to be similar to reality as much as possible. As discussed, the motorcycle demand does not directly involve in the PARAMICS model, and also the unique right-turn behavior in Khon Kaen affects the queue lengths, delay and intersection capacity. Therefore, it is necessary to find out the way to cope with the factors. This section presents some concepts which are used for calibrating the model.

5.3.1 General Calibration

General parameters such as road and intersection geometric coding, next lane, stop line, turn arrow, traffic demand and composition, are base parameters which need to be calibrated until close to the real world as much as possible before start using the model.

5.3.2 Calibration of the Motorcycle Impacts

Motorcycle does not lead longer queue, however increases the driving friction to other vehicle types. Instead of motorcycles, the reducing of link speed limit and vehicle acceleration can increase the driving friction as well.

- The driving speed is calibrated by using Trial Method, until the average driving speed at the mid of each link on Sri-Jan Corridor is close to the speed collected by field survey. It was found that the link speed limit of 40 to 45 km/hr makes the driving speed on the simulation close to the real world for the Sri-Jan Corridor.

- According to the Klungboonkrong, P. Khompratya, T and Wooley, J. (2003), The acceleration of each type of vehicles which was studied in Khon Kaen and used in this study, is shown in the Table 1 below

The table 1: The vehicle accelerations studied in Khon Kaen (Klungboonkrong, P. Khompratya, T and Wooley, J., 2003)

```
vehicle types

type 1 car colour 0x00ffffff shape 1
      matrix 1 proportion 54.700 perturbation 5.0 familiarity 85.00

type 2 car top speed 35.00 kph colour 0x00ffffff shape 2
      matrix 1 proportion 38.400 perturbation 5.0 familiarity 85.00

type 3 LGV colour 0x00b469ff shape 3
      matrix 1 proportion 1.600 perturbation 5.0 familiarity 85.00

type 4 OGV1 colour 0x00b469ff shape 3
      matrix 1 proportion 0.300 perturbation 5.0 familiarity 85.00

type 5 car height 2.00 m top speed 40.00 kph dec -4.00 mpss colour
0x0000ff00
      matrix 1 proportion 3.200 perturbation 5.0 familiarity 85.00

type 6 car length 6.00 m width 2.20 m height 2.20 m top speed 40.00 kph
       acc 1.20 mpss dec -3.20 mpss colour 0x0000ff00
      matrix 1 proportion 0.400 perturbation 5.0 familiarity 85.00
```

5.3.3 Calibration of the Right-Turn Behavior

By the behavior, the number of through movement vehicles which are able to cross the intersection per cycle time is decreasing. Conversely, the number of right-turn movement vehicles passing an intersection per cycle time becomes higher. To calibrate the behavior, the right-turn priority phase without amber and inter-green time is addressed in the model, however the cycle time is the same, to allow a higher number of right-turn vehicles which is able to cross the intersection. The length of the right-turn priority phase is determined by using the Trial Method. On the display screen, it is found that the right-turn priority phase of 2 seconds allows one or two additional vehicles to make a turn per approach per cycle time.

5.3.4 Model Validation

To validate the PARAMICS model in this study, three parameters are used: average driving speed at the mid of each link on Sri-Jan Corridor; queue length on each approach by using PARAMICS Analysis Module; and travel time between point to point in the network. For the reason that traffic signal coordination directly relates to the synchronizing offsets. Therefore, the significant concern for the validation in this study is the travel time estimated between intersections in the model. It must be close to the reality as much as possible.

6. Traffic Signal Coordination Determined

This section presents the phasing time, cycle time and synchronizing offsets which are determined for the traffic signal coordination for Sri-Jan Corridor.

6.1 Phasing and Cycle Time

The phase timing and cycle times for traffic signal coordination determined are shown in the Table 2.

Table 2: Phase Timing and Cycle Time for Traffic Signal Coordination

Period	Intersection											
	1			2			3			4		
	B	A	Cycle Time	B	A	Cycle Time	B	A	Cycle Time	B	A	Cycle Time
Period 1 (18.00-7.30)	22	22	**44**	22	22	**44**	24	20	**44**	22	22	**44**
Period 2 (7.30-8.30)	27	23	**50**	22	28	**50**	27	23	**50**	27	23	**50**
Period 3 (8.30-10.00)	22	22	**44**	22	22	**44**	23	21	**44**	22	22	**44**
Period 4 (11.00-12.30)	22	22	**44**	22	22	**44**	25	19	**44**	22	22	**44**
Period 5 (12.30-14.00)	22	22	**44**	22	22	**44**	24	20	**44**	22	22	**44**
Period 6 (15.00-16.30)	22	22	**44**	22	22	**44**	25	19	**44**	22	22	**44**
Period 7 (16.30-18.00)	22	22	**44**	22	22	**44**	26	18	**44**	23	21	**44**

In most periods, the phase timing for the Intersection 1, Intersection 2 and Intersection 4 are constant, 22 seconds for both phases. However, the signal phase timing at the Intersection 3 varies in a small range. To provide less complicated and easier for service maintenances, the signal phase timing for the intersection 3 of the Period 1 and from Period 3 to Period 7 are reassigned as 20 seconds for phase A and 24 seconds for phase B constantly as shown in the Table 3.

Table 3: Phase Timing and Cycle Time for Traffic Signal Coordination after Grouping

Period	Intersection											
	1			2			3			4		
	A	B	Cycle Time	A	B	Cycle Time	A	B	Cycle Time	A	B	Cycle Time
Period 2 (7.30-8.30)	23	27	**50**	28	22	**50**	23	27	**50**	23	27	**50**
Other periods	22	22	**44**	22	22	**44**	20	24	**44**	22	22	**44**

Remarks: A is the phase for the approaches on Sri-Jan Road

B is the phase for the approaches on cross roads

6.2 Synchronizing Offsets

Two offset progression schemes are developed for the seven periods. The Period1 and from Period 3 to Period 7, the same progression schemes is applied. Table 4 shows the offset times of each progression scheme.

Table 4: Sets of Optimum Synchronizing Offsets Determined

Period	Synchronizing Offset			
	Intersection 1	Intersection 2	Intersection 3	Intersection 4
Period 2 (7.30-8.30)	0	2	25	0
Other Periods	0	22	43	21

For the Period 1 and Period 3 to Period 7, the beginning of phase cycle for any of two adjacent intersections is approximately half of cycle length. In contrast, in the Period 2 which is the busiest period and the cycle time is longer, the beginning of phase cycle of the Intersection 1, Intersection 2 and Intersection 4 are closely at the same time. Only the beginning of the cycle phase of the Intersection 3 is approximately half cycle length different from the others.

7. Evaluation of the Improvement

The evaluation of traffic condition in this study is using two methods: On-Screen Visualizing Observation; and Comparison of Measures of Effectiveness (MOEs) Produced by PARAMICS. The observation method is easy to acquire the qualitative findings, such as how smooth of driving, issues or weak points on the network. In contrast, the comparison of MOEs method measures the traffic condition in term of quantitative findings, which clearly illustrates whether the traffic condition is improved or not, and/or how much they are improved.

7.1 Evaluation of Improvement Using PARAMICS Visualization

Due to the existing traffic signals with non-coordination, one obvious issue is the unnecessary stops. The unnecessary stops often occur at all intersections. Major cause of the issue is the difference of cycle times and unsynchronizing of traffic signals along Sri-Jan Corridor. Another issue is found only in the Period 2 (7.30AM – 8.30AM) and Period 7 (4.30PM – 6.00PM), is the cumulative queues of right-turn movements, especially at the Intersection 1 and Intersection 2. The right-turn movements at the Intersection 1 and Intersection 2 in the Period 2 and Period 7 are normally able to make a turn while the amber phase and inter-green phase only. It is because a high volume of opposing through movement which has the higher priority while green phase.

In contrast, the first improvement which can be seen on the simulation display for the new traffic condition is the decreasing of unnecessary stops, in the off-peak and inter-peak period especially. Most vehicles driving along the corridor are able to pass through two intersections or more without stopping. The perfect traffic condition is on the link between Intersection 3 and Intersection 4. Queues behind the stop line can completely be cleared few seconds before the approaching platoon reaches the intersection, and the green phase left is sufficient to allow most vehicles in the approaching platoon to cross the intersection as well.

For the Intersection 1 and Intersection 2, the traffic volumes at the both intersections are very high at all time during the day. Sometimes, the approaching platoon reaches the intersection before the queues behind the stop line are completely cleared. The approaching platoons have to slow down or shortly stop and slightly experience delay. However, some vehicles in the approaching platoon are able to cross the second intersection. Another improvement is the queues of the right-turn movements which are shorter than the existing traffic condition. This is because the new cycle time is 36% to 45% shorter than the existing (count on PARAMICS Analyzer Module).

7.2 Evaluation of Improvement Using MOEs Determined by PARAMICS

According to the Table 5, the table compares the MOEs between before and after addressing the traffic signal coordination. In the Period 2, the number of vehicles using the corridor ranks the highest number of vehicles, 5000 vehicles per 50 minutes approximately. Conversely, Period 1 ranks the lowest number of vehicles, 2000 vehicles per 50 minutes approximately. For other periods, the numbers of vehicles are between 3800 and 4300 vehicles per 50 minutes.

The new traffic signal coordination improves traffic condition on Sri-Jan Corridor, by average 9% decreasing of mean delay, average 10% increasing of mean speed, and 50% to 80% decreasing of total all stoppage time, compared to the existing traffic condition. Total all stoppage time is significantly improved, particularly in the Period 1, Period 4 and Period 5 which the all stoppage time is over 70% decreased. This implies a well achievement of the new traffic signal coordination in term of producing smoothness of driving along Sri-Jan Corridor to motorists. In addition, the decreasing of mean delay advantages to the energy consumption and such environment impacts as emission and noise pollution indirectly.

Table 5: Comparison of MOEs determined before and after addressing of the new traffic signal coordination on Sri-Jan Corridor

Signal Timing Plan		Total Vehicle Mean Delay	Total Vehicle Distance (km)	Total Vehicle Count	Total Vehicle Mean Speed	Total All Stoppage
Period 1	Existing Signal Plan	74.32	1425.20	1990	34.0	1.18
	New Fixed 44sec. With Coordination	67.40	1423.68	1990	37.6	0.23
	Percentage of Improvement	**9%**	0%	0%	**11%**	**81%**
Period 2	Existing Signal Plan	84.51	3563.05	4981	29.6	5.31
	New Fixed 44sec. With Coordination	77.10	3558.09	4981	32.6	2.65
	Percentage of Improvement	**9%**	0%	0%	**10%**	**50%**
Period 3	Existing Signal Plan	79.06	2832.64	3894	32.4	2.51
	New Fixed 44sec. With Coordination	72.59	2829.92	3894	35.3	0.78
	Percentage of Improvement	**8%**	0%	0%	**9%**	**69%**
Period 4	Existing Signal Plan	79.28	2972.33	4083	32.1	2.94
	New Fixed 44sec. With Coordination	71.82	2972.29	4083	35.5	0.69
	Percentage of Improvement	**9%**	0%	0%	**11%**	**77%**
Period 5	Existing Signal Plan	80.16	2846.17	3874	32.2	2.63
	New Fixed 44sec. With Coordination	72.79	2841.35	3874	35.5	0.79
	Percentage of Improvement	**9%**	0%	0%	**10%**	**70%**
Period 6	Existing Signal Plan	80.44	3119.38	4300	31.6	2.90
	New Fixed 44sec. With Coordination	73.64	3120.67	4300	34.6	0.98
	Percentage of Improvement	**8%**	0%	0%	**9%**	**66%**
Period 7	Existing Signal Plan	84.98	3153.98	4217	30.8	4.07
	New Fixed 44sec. With Coordination	76.70	3149.12	4217	34.2	1.40
	Percentage of Improvement	**10%**	0%	0%	**11%**	**66%**

Remark: All simulation runs are 60 minutes. However, the first 10 minutes of the runs (unstable stage) are cut off and all results shown in the Table 5 is between 11th and 60th minutes of the runs.

7.3 Free Flow Speed Condition

According to the Table 5, it is interesting that the mean delay for the existing traffic condition in Period 2 (highest peak) is only 14% higher than Period 1 (off peak) even though other MOEs are quite different – the traffic volume in Period 2 is 2.5 times and total all stoppage time is 4.5 times over the Period 1, and the vehicle mean speed for the Period 1 is 10% faster than the Period 2. As well as the new traffic condition, the total mean delay for the new traffic condition in Period 2 is also 14% higher than Period 1 although other MOEs are quite different. By these evidences, it can be predicted that the mean delay for the free flow condition, such as late of night, on Sri-Jan Corridor should not be much different from the Period 1. In other words, it can be said that the Period 1 well represents the free flow condition on the corridor.

7.4 Why Short Cycle Time

Generally, some literatures suggest that the proper cycle time for urban area usually in between 60 and 120 seconds, however the cycle time determined in this study are 50 seconds or less. Consideration of the benefits of the short cycle time traffic signal, the short cycle time provides the shorter cumulative queue and better level of service to right-turn movements and pedestrians, however causes waste of time and lower capacity than long cycle time. As in the case of Sri-Jan Corridor which 20% to 30% of approach demand is the right turn movement, the SIDRA therefore gives a short cycle time to provide the better level of service to right-turn movement and minimize the total delay and keep the short queue length. In addition, a proper short cycle time improves the trust of road users on the traffic signal, including pedestrians.

7.5 Future Projection

The future projection and life time need to be considered in every development project. In this study, the Trial Method is used to forecast the future traffic condition and estimated life time of the traffic signal coordination determined. The future demand is projected by the intensification rate of registered vehicles in Thailand, and then modeled by PARAMICS to see the traffic condition year by year until the traffic condition is unacceptable (oversaturated condition happens). For the off peak and inter-peak periods, it is found that the new traffic signal coordination is possibly used for at least four years. Nevertheless, for the morning peak and evening peak periods, the phase and timing plans and synchronizing offsets need to be revised after next two years. The right-turn movement seems to be the major cause of unaccepted traffic condition in the future, particularly at the Intersection 2. To mend the issue, this study suggests that the right-turn priority phase, right-turn vehicle restriction (allows only public transport) or other alternatives are basically required.

8. Conclusion and Future Works

As a result of the study, the new set of traffic signal coordination possibly produces significant improvements on the traffic conditions of the Sri-Jan Road, reducing the total mean delay by 10%, total vehicle stoppage time by 50% to 80%, and increasing the average driving speed by 10%. The decreasing of mean delay and stoppage time also indirectly advantage to the energy consumption and such environment impacts as emission and noise pollution. Moreover, the new traffic signal coordination provides the better level of service to pedestrians and right-turn movement.

For the PARAMICS model calibration in this study, there are two factors which are totally different from developed countries and require specific calibration method: the motorcycle impacts; and right-turn behavior. For the calibration of motorcycle impacts, the increasing of frictions such as decreasing of speed limit and decreasing of acceleration is used. Beside, the right-turn behavior is calibrated by adding a short right-turn priority phase. To validate the PARAMICS model, three parameters are used: average driving speed at the mid of each link on Sri-Jan Corridor; queue length on each approach; and travel time between point to point in the network.

One recommendation of the study is the using SIDRA without specific calibration for the motorcycle impacts and right-turn behavior in Khon Kaen. The traffic signal phase timing determined by SIDRA may not optimize effectiveness of the traffic condition. Several phasing plan and cycle time adjustments on site may require for reaching the optimum traffic condition in reality.

For the future works following this study, the traffic signal coordination developed in this study will be addressed on Sri-Jan Corridor. A traffic survey will also be conducted to collect the new traffic condition. This is well opportunity to validate both PARAMCIS and SIDRA used in Khon Kaen City, and also to develop the more effective methods for calibrating and validating the software packages used in Thailand in the future.

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