International Transaction Journal of Engineering, Management, & Applied Sciences & Technologies

http://TuEngr.com

COORDINATED SIGNAL CONTROL UNDER VARYING TRAFFIC VOLUMES

Vanchai Kantonon [a], Winai Raksuntorn [a*], Boonsap Witchayangkoon [a], Nareenart Raksuntorn [b], and Songrit Chayanan [c]

[a] *Department of Civil Engineering, Thammasat School of Engineering, Thammasat University, THAILAND.*
[b] *Faculty of Industrial Technology, Suan Sunandha Rajabhat University, THAILAND*
[c] *Bureau of Highway Safety, Department of Highways, Ministry of Transportation, Royal Thai Government, THAILAND*

ARTICLEINFO

Article history:
Received 22 May 2018
Received in revised form 01 December 2018
Accepted 16 December 2018
Available online 19 December 2018

Keywords:
Traffic Signal Control, Coordinated Signal Control

ABSTRACT

This research studies and determines the suitable time to use the coordinated signal control at two intersections on Mahidol road, Chiang Mai Province, using traffic simulation models. This study reveals that the consideration of using the coordinated signal control does not only depend on volume to capacity ratio, distance between intersections, interference of the platoon, link volume, and average speed but also depends on coordinated direction traffic volume to total traffic volume ratio. The study also suggests that the coordinated signal control can be used effectively when volume to capacity ratio reaches 0.60. This is because of considerably low values of the coordinated direction traffic volume to total traffic volume ratios, between 20 to 43 percent.

1. INTRODUCTION

Signal coordination for intersection network is developed and operated on a limited number of predetermined time-of-day plans. For example, signal coordination plans are commonly programmed based on weekday and weekend peak periods. Signal Timing plans are also determined to suit traffic patterns in those specific time periods. During other time periods, traffic signals operate in fixed time, actuated, or adaptive modes based on capability of signal controllers. Even though the traffic on coordinated direction gains benefit from the signal coordination, minor road traffic usually experiences longer delays and longer queues. This indicates that the signal coordination does not have positive impacts on traffic on intersection network at all times.

As mentioned earlier, signal timing is used to coordinate signals during peak hour (A.M., and P.M. peak hours) and run operations in fixed time, actuated, or adaptive modes during off-peak hours. This approach comes from a principle that signal coordination should be implemented when traffic volume is high enough. Conversely, signal timing coordination is not only a function of traffic

*Corresponding author (W.Raksuntorn). Tel: +66-2-5643005 Ext3046 E-mail: rwinai@engr.tu.ac.th

volume but also it is a function of other parameters including signal spacing, platoon dispersion, traffic volume, and so on (Nevada Department of Transportation, 2012).

Several studies on appropriate signal spacing for signal coordination (Koonce et al, 2008; U.S. Department of Transportation, 2009; Henry, 2005) suggest that signals should be coordinated when traffic signals are within ¾ miles of each other. Other study (Chang and Messer, 1986) suggests that the signal coordination is preferred when travel time between two intersections is about one-third to one-half of its cycle length time.

Arrival pattern of flow is one of the most important parameters used to determine the necessity of the signal coordination. Manar and Baas (1996) show that dispersion is low at low traffic volume. The dispersion increases as traffic volume increases and reaches the maximum at volumes of 60 to 80 percent of the link capacity. This dispersion gets to zero near the capacity of the link. The delay minimization concept and a formalized platoon dispersion model is integrated as one of the basis of TRANSYT (Robertson, 1996). However, signal coordination during off-peak hours needs further examination.

Yogoda et al (1973) introduces the coupling index, ratio of the link traffic volume to distance between intersections, to determine the potential of coordination between two adjacent signals. Synchro (Trafficware, 2004) uses coordinatability factor based on travel time, signal spacing, link volume, vehicle platooning, vehicle queuing, and natural cycle length to determine a likelihood of using signal coordination. Current study (Hook and Albers, 1999) studied and compared the effectiveness of the two models, coupling index and coordinatability factor. The study shows that there is no absolute best factor for determining when signals should be coordinated.

Based on the literature, traffic management for intersection network using signal coordination is suitable in high traffic volume conditions (on coordinated direction) and short distance between intersections. Conversely, the signal coordination may cause more traffic problem (increase delays and queues) if traffic volume on coordinated direction is considerably low compared to total traffic volume on an intersection network. However, it is necessary to maintain continuous flow on main roads even though its traffic volume is low compared to total volume on a certain intersection network. Therefore, this research aims to determine at what time of day coordination plans should be implemented for such intersections.

2. MODELING STUDY AREA

Thailand uses Left-hand traffic (LHT). Data collection had been made on two intersections on Mahidol road, Chiang Mai Province, North of Thailand. These data are used for traffic simulation models. These two intersections are two hundreds and five meters apart *see* Figure 1. The road through the two intersections has four and six lanes. Daily traffic volume is more than 70,000 vehicles, while in rush hour more than 5,000 vehicles per hour get through the intersections. It is one of the arterial roads used to get to Chiang Mai City.

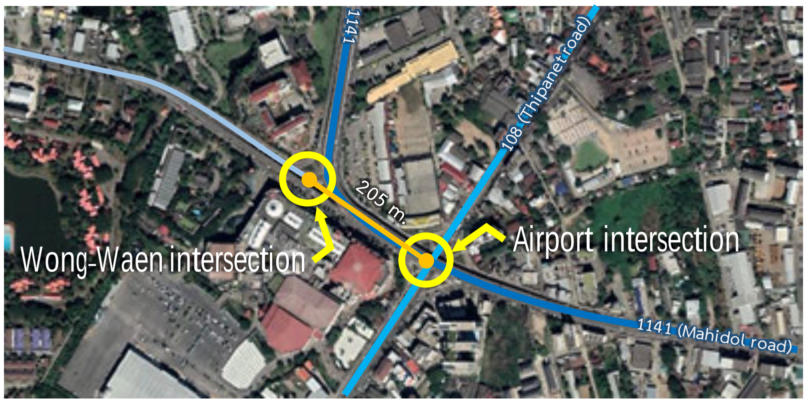


Figure 1: Study Area - Intersections on Mahidol road, Chiang Mai Province
(modification made to Google® Map, courtesy of Google®)

Wong-Waen intersection is characterized direction and detail of the traffic lanes as follows. (1) From Airport intersection (East- 1) has two through lanes and two lanes always-thru., (2) From Muang Chiang Mai (North- 1) has two right turn lanes and two lanes always-thru., and (3) From Chiang Mai International Airport (West-1) has two through lanes and two lanes always-thru. A recent study on traffic management at t intersections with always-thru traffic found that it was suitable for medium to high volume of traffic (Pananun, 2018).

Airport intersection is characterized direction and detail of the traffic lanes as follows.: (1) From Wong-Waen intersection (West-2) has a through lane, a share right turn lane, a right turn lane, and a left-turn lane always-thru., (2) From Hang Ya (North-2) has a through lane, a share right turn lane, a right turn lane, and a left-turn always-thru., (3) From Hang Dong (South-2) has a through lane, a share right turn lane, a right turn lane, and a left-turn always-thru., and (4) From Mahidol road (East-2) has a through lane, a share right turn lane, a right turn lane, and a left-turn always-thru. *see* Figure 2.

(a) Wong-Waen intersection (b) Airport intersection

Figure 2: Study Area - Intersections on Mahidol road, Chiang Mai Province
(modification made to Google® Map, courtesy of Google®)

Optional traffic volume data for modeling is total traffic volume per 15 minutes (Motorcycle 0.33 and Truck 3.00 converted into Passenger Car Unit (PCU)) including Airport intersection and Wong-Waen intersection on weekdays, Saturdays, and Sundays. Each day was divided into 12-time intervals, two hours each, *see* Figure 3, then selected the maximum traffic volume in each period of 36 sets of data.

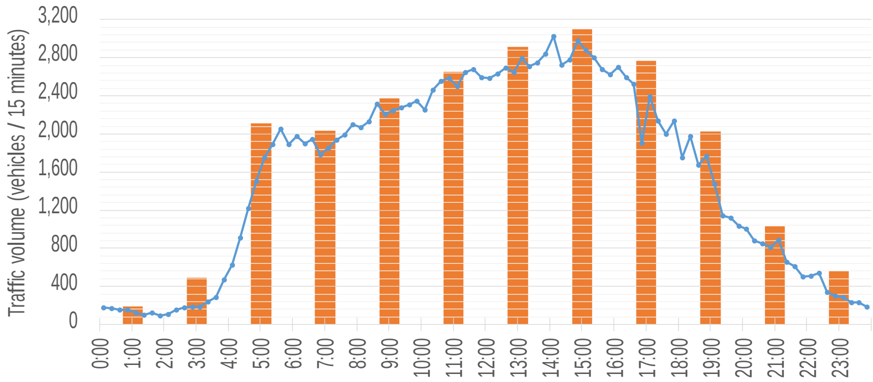


Figure 3: Example of traffic volume per 15 minutes on Monday March 19, 2018.

Average volume to capacity ratio of all interactions are used traffic volume per lane compared to ability to release cars through the intersection set at 1,800 cars per hour of intersection. In this study, Random selection various ranges of 17 sets for design of the signal and tested in traffic model.

Determine arterial traffic volume on the total traffic volume of all intersections. The critical traffic volume phase is coordinated direction traffic volume per lane compared average total critical volume of all intersections between 0.20 and 0.43 *see* Figure 4.

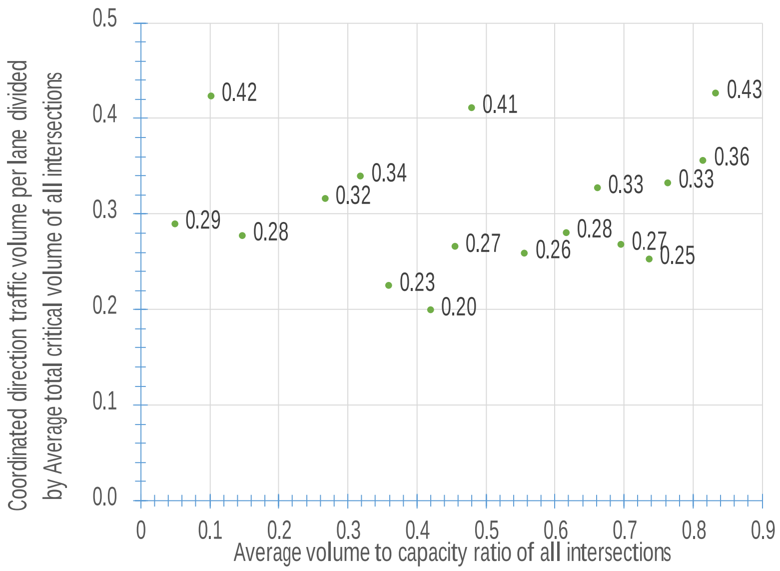


Figure 4: Coordinated direction traffic volume per lane divided by average total critical volume of all intersections

3. Aimsun® MODEL AND SIMULATION

In this study, Aimsun® models were used for detailed traffic volume modeling as follows: Type of traffic volume used for personal cars, road speed limit of 60 km/hr. Since the area is a metropolitan area, where the traffic volume on each side is 400 meters from the intersection, and there are seven of origin, *see* Figure 5.

(1) From Airport intersection (East-1)

(2) From Chiang Mai International Airport (West-1)

(3) From Hang Dong (South-2)

(4) From Mahidol road (East-2)

(5) From Hang Ya (North-2)

(6) From Wong-Waen intersection (West-2)

(7) From Muang Chiang Mai (North- 1)

Figure 5: Traffic model - Intersections on Mahidol road, Chiang Mai Province (modification made to Google® Map, courtesy of Google®)

The traffic light systems are included in the study models. Model A applies the Isolated Signal Control, a real-time adaptive traffic control system that enables traffic signals to immediately adapt to traffic demand. Model B operates the Coordinated Signal Control, a real-time adaptive traffic signal control system multiple traffic intersection.

Both traffic simulation models apply the same configurations. Traffic signal is pre-configured cycle is between 165 to 300 seconds, yellow time three seconds, all-red time four seconds, and minimum green time 30 seconds. Traffic signal system has been set up in the model. Traffic Signal for critical traffic volume of each direction and delay time in accordance with the method of the Highway Capacity Manual (2010).

Actuated system has detector intersection from stop line at 25 meters as a control. Turn on the traffic lights when the traffic is in the detection range and in the phase. If there is no traffic on the detection range at the beginning of the phase or the detection position is more than three seconds, then skip the phase and go to the next phase. Phase plan for intersection *see* Table 1-2.

Table 1: Phase plan in the Wong-Waen intersection

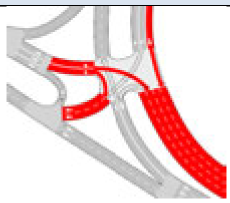
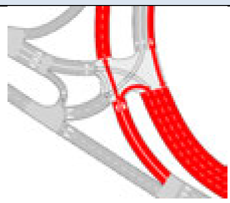
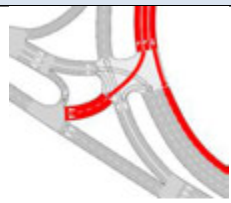
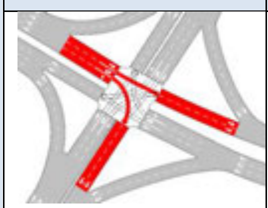
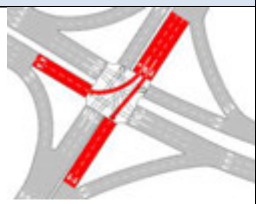
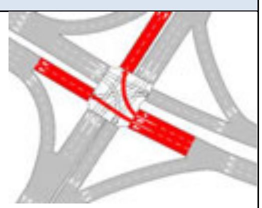
	Phase 1	Phase 2	Phase 3
Phase plan			

Table 2: Phase plan in the Airport intersection

	Phase 1	Phase 2	Phase 3	Phase 4
Phase plan				

*Corresponding author (W.Raksuntorn). Tel: +66-2-5643005 Ext3046 E-mail: rwinai@engr.tu.ac.th

Traffic simulation models take traffic volumes, geometric information, and traffic control plans as inputs. Then, they simulate the defined scenarios and report various measures of effectiveness (MOESs) as outputs. Typical MOES include: average intersection delay, number of stops, average queue, maximum queue, corridor speed, fuel consumption, total bandwidth, bandwidth efficiency, bandwidth attainability, and system throughput. Most traffic simulation models provide an estimate of several, if not all, MOEs. In fact, simulation models are able to tell how good or bad a given scenario is. The study used traffic simulation models are Aimsun®.

Model calibration is using the GEH (Geoffrey E. Havers) value from Design Manual for Roads and Bridges (DMRB) (Highways Agency et al, 2012) in the comparison of the processing volume 1 hour in each case study model and calibrate make data closer to actual survey intersection GEH <5.0.

4. ANALYSIS AND RESULTS

To analysis traffic simulation, the model data on Mahidol Road in the Chiang Mai Province comprises two intersections, the Wong-Waen intersection (Crossroads) and Airport intersection (the three-way split), which is 205 meters apart. The three parameters are queue length, travel time delay, and average speed in arterial roads is as follows *see* Figure 6.

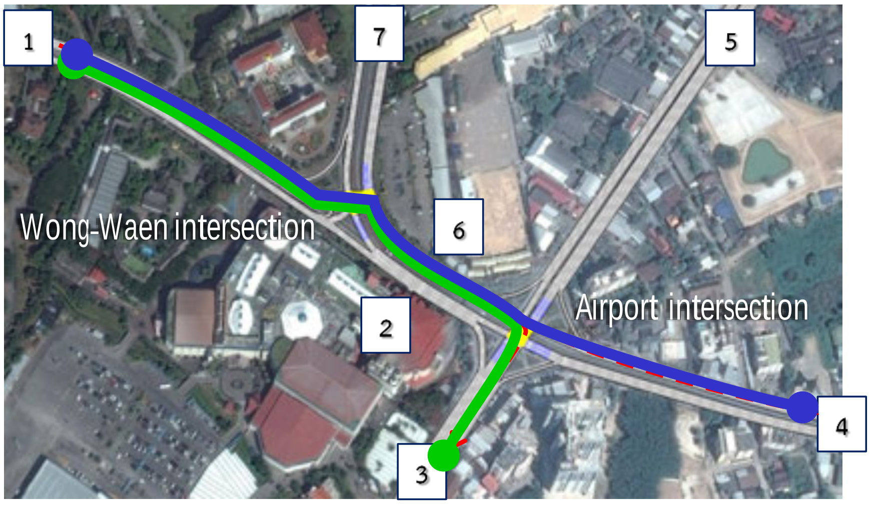
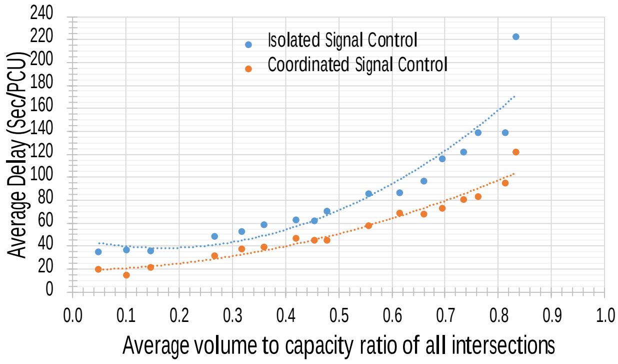
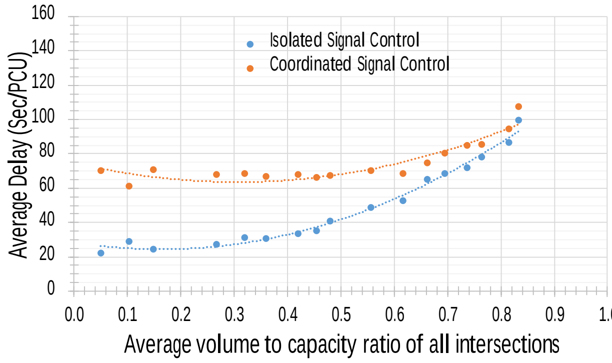


Figure 6: Arterial roads - Intersections on Mahidol road, Chiang Mai Province (modification made to Google® Map, courtesy of Google®)

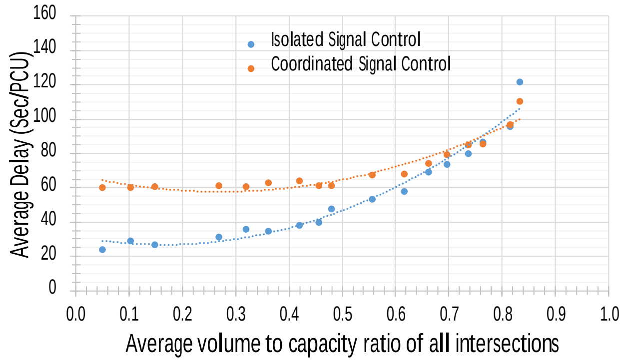
(1). Isolated signal control are average delays time in level of service does not exceed LOS D for traffic volume to capacity ratio of all intersections is less than 0.6. However, when the traffic volume to capacity ratio of intersections is more than 0.75, the coordinated signal control has the overall delay of traffic passing through traffic lights lower than isolated signal control. Average delay of secondary road direction with the isolated signal control is always less than the coordinated signal control, and the average delay of arterial roads coordinated signal control is lower than isolated signal control, *see* Figure 7.



(a) Average delay of arterial roads



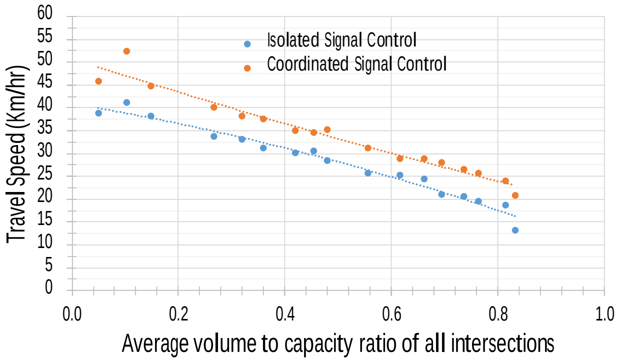
(b) Average delay of secondary road



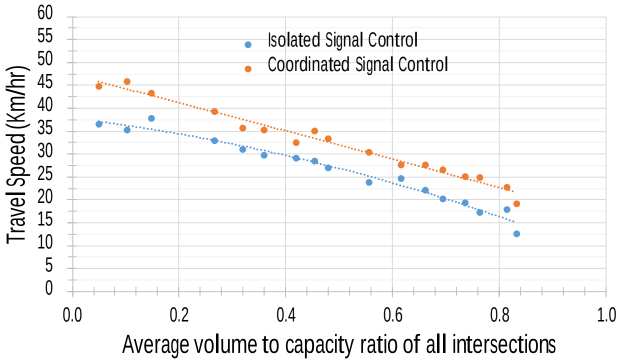
(c) Average delay of all intersections

Figure 7: Average delay time in traffic models

(2) The average speed in the direction of the coordinated signal control is faster than the isolated signal control all traffic volumes to capacity ratio of all intersections *see* Figure 8.



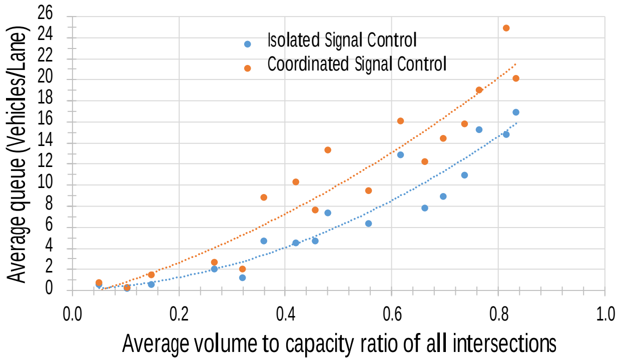
(a) Chiang Mai International Airport to Hang Dong



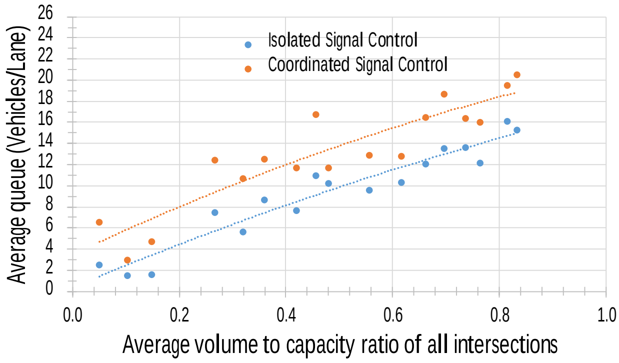
(b) Chiang Mai International Airport to Mahidol road

Figure 8: Travel speed of arterial roads in traffic models

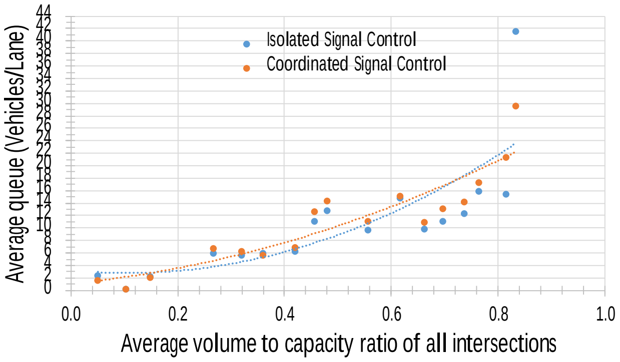
(3) Average queue in different ranges of traffic volume to capacity ratio of all intersections. Isolated Signal Control has an average value less than the Coordinated Signal Control, except in arterial roads Wong-Waen intersection (West-2). The adaptive isolated signal control has a longer queue length, and when the traffic volume to capacity ratio of all intersections is greater than 0.76, the potential for queues exceeds the length of the lanes that can accommodate the traffic (average of 30 cars per lane), *see* Figure 9-10.



(a) Average queue of Muang Chiang Mai (North-1)

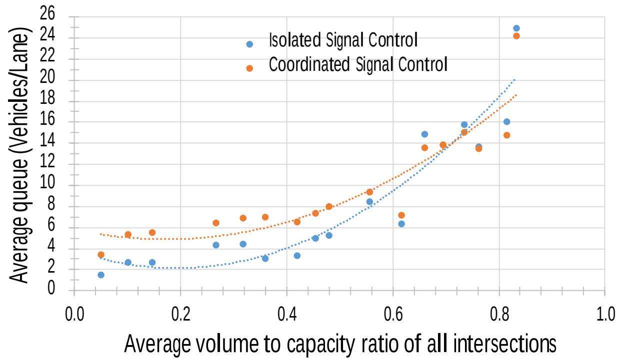


(b) Average queue of Airport intersection (East-1)

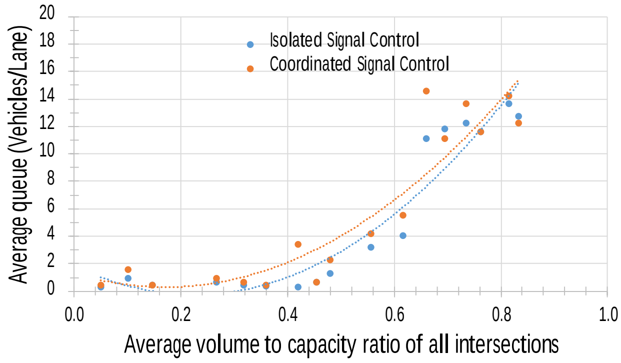


(C) Average queue of Chiang Mai International Airport (West-1)

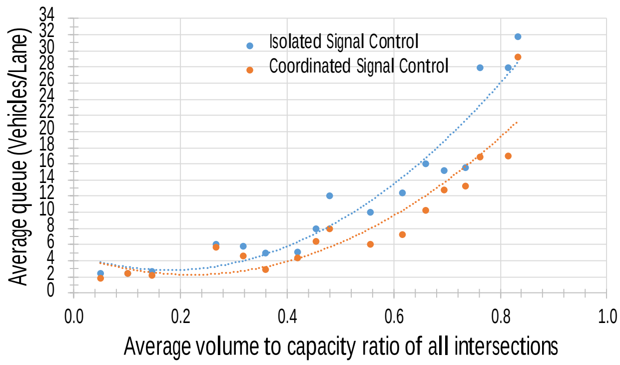
Figure 9: Average queue the Wong-Waen intersection



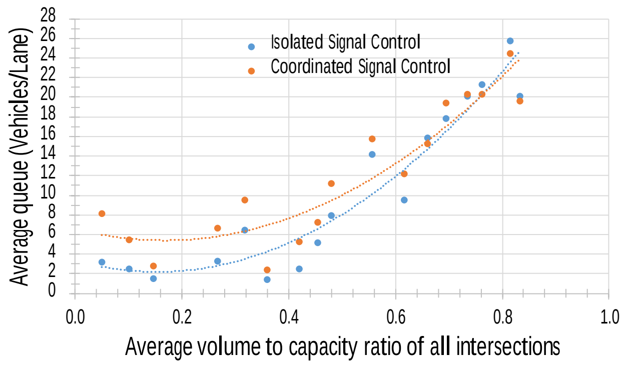
(a) Average queue of Hang Ya (North-2)



(b) Average queue of Mahidol road (East-2)



(c) Average queue of Wong-Waen intersection (West-2)



(d) Average queue of Hang Dong (South-2)

Figure 10: Average queue the Airport intersection

5. CONCLUSION

Based on the analysis of the highway network from the traffic model in the district intersections on Mahidol road, Chiang Mai Province, using a traffic simulation model. These two intersections are two hundreds and five meters apart.

(1) Coordinated signal control can be used effectively when volume to capacity ratio of all interactions reaches 0.60 because of considerably low values of the coordinated direction traffic volume to total traffic volume ratios, rather low (Between 20-40 percent)

(2) Mahidol Road is the main route and important to drain traffic from Chiang Mai International Airport. Coordinated signal control systems may be considered when average volume to capacity ratio of all interactions close to 0.5, overall travel time delay and queue length are more than Isolated Signal Control just a little.

This study has taken factors to consider in choosing continuous traffic signal control system in addition to the distance between intersections. The results show multi-factors to be considered including the proportion of traffic volume in the main direction that coordination with the traffic volume, signal phase, and geometry of intersection. Therefore, in order to set the automatically select the system by itself, more additional factors need to be further investigated, in order for the system can respond in selecting appropriate maximize traffic flow and optimize traffic management.

6. REFERNCES

Chang, E. C-P., and C.J. Messer. (1986) Warrants for Interconnection of Isolated Traffic Signals. FHWA/TX-86/67+293-1F, U.S. Department of Transportation.

Henry R. D. (2005). Signal Timing on a Shoestring. Publication FHWA-HOP-07-006. FHWA, U.S. Department of Transportation.

Hook, D., and A. Albers. (1999). Comparison of Alternative Methodologies to Determine Breakpoints in Signal Progression. Proc., of the ITE Annual Meeting, Kissimmee, Fla., ITE, Washington, D.C.

Highways Agency et al. (2012). Design Manual for Roads and Bridges (DMRB) Volume 12 Traffic Appraisal of Road and Schemes.

Koonce, P., L. Rodegerdts, K. Lee, S. Quayle, S. Beaird, C. Braud, J. Bonneson, P. Tarnoff, and T. Urbanik. (2008). Traffic Signal Timing Manual. Publication FHWA-HOP-08-024. FHWA, U.S. Department of Transportation.

Manar, A., and K.G. Baas. (1996). Traffic Platoon Dispersion Modeling on Arterial Streets. Transportation Research Record 1566.

Nevada Department of Transportation. (2012). Signal Timing and Coordination Strategies Under Varying Traffic Demands. NDOT Research Report: Report No. 236-11-803.

Pananun, W., Raksuntorn, W., Witchayangkoon, B., Raksuntorn, N., and Chayanan, S. (2018). Traffic Management at T Intersections with Always-Thru Traffic. International Transaction Journal of Engineering Management & Applied Sciences & Technologies, 9(5), 447-454.

Robertson, D.I. (1969) Transyt: A Traffic Network Study Tool. Report No. LR 253. Road Research Laboratory, Crowthorne, Berkshire, United Kingdom.

Trafficware. (2004). Synchro 6 User Guide. Albany, CA.

*Corresponding author (W.Raksuntorn). Tel: +66-2-5643005 Ext3046 E-mail: rwinai@engr.tu.ac.th

U.S. Department of Transportation. (2009). Manual on Uniform Traffic Control Devices for Street and Highways. Publication FHWA.

Yagoda, H.N, E.N. Principe, C.E. Vick, and B. Leonard. (1973). Subdivision of Signals Systems into Control Areas. Traffic Engineering, Vol. 43, No. 12, pp. 42-45.

Vanchai Kantanon is a Master degree student of Department of Civil Engineering, Thammasat School of Engineering, Thammasat University, THAILAND. He earned a Bachelor of Engineering and Management, Thammasat School of Engineering, Thammasat University. He is interested in traffic modeling analysis and management.

Dr. Winai Raksuntorn received his PhD (Civil Engineering) from University of Colorado, USA. He is currently an Assistant Professor in the Department of Civil Engineering, Faculty of Engineering, Thammasat University. His research interests include transportation safety analysis, traffic operations and management, traffic impact studies, traffic flow modeling, highway capacity analysis, advanced traffic management for intelligent transportation systems.

Dr. Boonsap Witchayangkoon is an Associate Professor in Department of Civil Engineering at Thammasat University. He received his B.Eng. from King Mongkut's University of Technology Thonburi with Honors. He continued his PhD study at University of Maine, USA, where he obtained his PhD in Spatial Information Science & Engineering. Dr. Witchayangkoon current interests involve applications of multidisciplinary and emerging technologies to engineering.

Dr. Nareenart Raksuntorn is an Assistant Professor at the Faculty of Industrial Technology, Suan Sunandha Rajabhat University. She received the B.Eng. degree in Electronics Engineering from King Mongkut's Institute of Technology Ladkrabang, Thailand, the M.S. degree in Electrical Engineering from the University of Colorado, and the Ph.D. degree in Electrical Engineering from the Department of Electrical and Computer Engineering, Mississippi State University. Her research interests include remote sensing image analysis, image processing, and pattern recognition.

Dr. Songrit Chayanan is Head of Traffic and Transportation Surveys, Bureau of Highway Safety, Department of Highways, Thailand. He earned his Bachelor of Engineering degree with Honors from Thammasat University, Thailand. He got his PhD from University of Washington, USA. His research is related to analysis of highways transportation and accidents.