Empirical Study on Maximum Traffic Throughputs at Intersections

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Abstract. Traffic congestion in big cities of Thailand has been a major problem seriously deterring economy growth. An average travel speed has become lower than 15 km/hour during peak-hour periods. One of the current major questions is how to find the most optimum green time that minimizes vehicle delay at an intersection. Since the identification of this optimum green time significantly depends on the knowledge of how fast vehicles can pass through an intersection, the information of the maximum traffic throughputs at intersections at different locations is indispensable. In this study, therefore, traffic counts were extracted manually from the videos recorded at 4 major intersections in Saensuk city. After the data were analyzed, the maximum traffic throughputs for different lane numbers and configurations were calculated and summarized. A better understanding of this maximum traffic throughput at intersections will lead to more accurate estimation of optimal green time.

1 Introduction

Traffic congestion in Thailand has been a major problem slowing down economy growth. With the number of vehicles exceeding the available roadway capacity in the network, traffic condition during rush hours becomes extremely congested. For example, at present, there are about 7 million registered vehicles in Bangkok but the current roadway capacity is only available for 2.5 million vehicles. The rush-hour periods expand longer each year mainly because of the increasing number of personal vehicles.

For last 20 years, to minimize traffic congestion, several new roads and expressways were built. However, there has been no sign of improvement on travel time in the area. Under bad economy for about a decade and the unsuccessful outcomes from previous traffic congestion mitigation strategies, most of major cities have limited budget and less support for new road construction projects from the communities. Therefore, an improvement on the current operations of existing traffic systems becomes more feasible option.

In 2015, after experiencing severe traffic congestion on major roads during peak hours, Saensuk city started a new traffic mitigation program. This new program's first phase started the work on major intersections with the highest congested level. The program emphasizes on the application of Intelligent Traffic Systems (ITS) to lessen the traffic congestion level. At the selected intersections, there was an attempt to use vehicle data collected from recorded videos to enhance an understanding of traffic congestion and identify the optimum green time that results in high intersection capacity. To be able to select the optimum green time, a good understanding of possible maximum traffic throughput at intersection is essential. As a result, the data on maximum traffic throughput for different lane numbers and configurations were collected and summarized in this study.

2 Literature review

There has been many researches with the effort to minimize vehicle delay at intersections. The work is related to important traffic parameters such as traffic capacity and saturation flow rate at an intersection. Samples of the researches can include the following works. In 1968, Miller [1] conducted a research to estimate capacity at signalized intersections in Australia. After that, Akcelik [2] analyzed not only capacity but also timing at signal intersections. Kimber et al. [3] developed a procedure to predict the saturation flow rate at an intersection that is controlled by traffic signals. Bester and Meyers [4] also worked on saturation flow rate at an intersection.

In recent years, non-motorized mode has become more popular. As a result, Li et al. [5] conducted a research on the saturation flow rate of shared non-motorized lane at intersections. Applying a better understanding of the traffic throughput at an intersection, many researchers had developed efficient ways to improve traffic throughputs, such as Liu and Chang who worked on an arterial signal optimization for intersections [6] and Li and Elefteriadou who worked on maximizing the throughput of turn bays at a signalized intersection [7]. Additional works may include the work from Zhou et al. [8], Wu et al. [9], and Chunhui et al. [10]. As advanced traffic-related and automobile technologies are rapidly growing and

increasingly play an important role in our present society, new research related to the reduction of vehicle delay at intersections has become broader.

3 Data source

Intersections with high traffic congestion level in the Saensuk city were selected for this study, which include 4 major intersections that are 1) Galaxy, 2) Burapa, 3) Kao Larm, and 4) Lam Tann. These intersections are on the major arterials in the city. Each intersection has different number of arms and lanes and/or lane configurations. For example, the Galaxy intersection is a three-way junction as shown in Fig. 1. The Southbound (SB) approach has 4 lanes. Similarly, the Northbound (NB) approach has 4 lanes. However, the Eastbound (EB) approach has 3 lanes. The lane type is also displayed by white arrows in Fig. 1.

Figure 1. Galaxy Intersection

The Burapa intersection is also a three-way junction with 2 lanes EB, 3 lanes WB, and 3 lanes NB (shown in Fig. 2). The special thing at this intersection is the rightmost u-turn lane of the WB approach. The last two intersections are Kao Larm and Lam Tann intersections, which are four-way junctions (Fig. 3 and 4, respectively). The Kao Larm intersection has 2 lanes EB, 4 lanes WB, 2 lanes NB, and 3 lanes SB. Similarly, for the Lam Tann intersection, there are 1 lane EB, 2 lanes WB, 2 lanes NB, and 3 lanes SB.

To collect traffic count data, the CCTV cameras were installed at these 4 major intersections (displayed in Fig. 2). Videos were recorded for 24 hours for the days with high traffic congestion. After the investigation of traffic condition, the time interval 16:00-20:00 has been identified as the time period with highest traffic volume. Therefore, the manual traffic count was conducted for this time period and the results are summarized in this study.

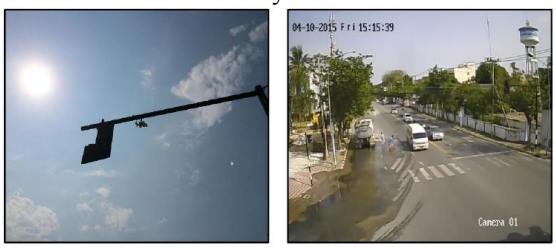

Figure 2. Installation of CCTV cameras and a snapshot of recorded videos

4 Maximum traffic throughout

To ensure the accuracy of the collected traffic data, vehicle counts were extracted manually for three signal cycles in every half hour between 16:00-20:00 and shown in Tables 1-4. Lane 1 is always the rightmost lane in each approach. According to Tables 1-4, the maximum number of vehicles that can pass an intersection on the left lane is always smaller than its adjacent right lane. For example, based on the median values of traffic counts on the NB Lanes 2 and 3 at the Galaxy intersection, the number of vehicles that could pass the intersection in the same time period on the left lane can be as low as 45% of the number of vehicles on the adjacent right lane on the same approach. Similarly, Lane 4 SB is the leftmost lane and the traffic count is only 548 vehicles compared to 1078 vehicles on Lane 3 SB.

Table 1. Maximum traffic throughput at Galaxy intersection

time	cycle	Galaxy								
		NB			SB				EB	
		lane 1	lane 2	lane 3	lane 1	lane 2	lane 3	lane 4	lane 1	lane 2
16:00	1	1,770	1,388	544	1,424	1,503	1,298	1,399	1,205	165
	2	1,536	1,587	1,204	1,425	1,929	1,597	943	1,283	908
	3	1,468	1,168	705	1,225	1,240	1,187	991	1,450	1,132
16:30	1	1,557	1,349	544	1,278	1,331	1,240	539	1,368	1,087
	2	1,651	1,531	1,350	1,422	1,271	1,326	792	780	1,072
	3	1,473	1,349	530	1,481	1,459	1,109	339	1,073	1,820
17:00	1	1,381	1,495	984	1,422	1,537	739	351	1,513	901
	2	1,705	1,643	1,138	1,305	1,439	1,320	307	1,295	819
	3	1,717	1,508	502	1,526	1,548	1,321	1,187	1,515	1,018
17:30	1	1,692	1,551	363	1,196	1,525	995	541	1,407	1,194
	2	1,607	1,200	643	1,313	1,268	1,091	360	1,194	1,520
	3	1,633	1,339	838	1,242	1,178	1,106	225	1,493	1,384
18:00	1	1,470	1,618	1,084	1,270	1,498	775	776	1,197	1,202
	2	1,014	625	568	1,481	1,037	881	881	1,484	1,017
	3	1,812	1,790	437	1,481	966	966	939	1,201	1,319
18:30	1	1,628	1,501	681	1,452	1,450	1,078	1,041	1,380	1,253
	2	1,623	1,483	610	1,172	1,398	884	548	1,220	1,293
	3	1,610	1,500	682	1,439	1,126	980	801	1,321	1,317
19:00	1	1,467	1,383	358	1,452	1,051	1,078	271	1,381	1,044
	2	1,659	1,504	406	1,172	1,350	894	597	1,220	1,282
	3	1,333	1,370	1,056	1,439	1,338	980	1,011	1,321	1,083
19:30	1	1,100	1,299	683	1,258	1,643	772	396	1,283	1,145
	2	983	1,118	702	1,418	1,389	886	974	1,428	1,470
	3	1,463	1,409	624	1,542	1,367	1,307	312	1,444	646
20:00	1	1,255	895	289	1,263	1,631	1,084	481	1,446	1,035
	2	735	808	230	1,386	1,541	1,226	477	1,268	1,847
	3	1,545	1,206	452	1,250	1,330	1,018	532	1,137	1,258
Average		1,477	1,355	846	1,359	1,402	1,079	701	1,337	1,283
Median		1,545	1,383	624	1,418	1,389	1,078	548	1,321	1,145

At the Burapa intersection, since Lane 1 is for through and U-turn traffic, its maximum traffic throughput is less than that of Lane 2, which is through-left-turn lane. At this intersection, traffic demands on Lane 3 NB, Lane 2 EB, and Lane 3 WB are significantly less than the capacity, so those lanes were not included in Table 2.

Table 2. Maximum traffic throughput at Burapa intersection

time	cycle	Burapa				
		NB		EB	WB	
		lane 1	lane 2	lane 1	lane 1	lane 2
16:00	1	1,559	556	1,345	1,147	1,134
	2	1,001	300	1,107	848	1,274
	3	1,179	468	983	1,173	1,152
16:30	1	952	528	1,559	642	1,084
	2	1,208	1,369	1,248	948	1,114
	3	1,207	—	328	1,110	1,291
17:00	1	1,289	944	1,137	678	1,063
	2	1,066	372	1,072	592	1,380
	3	1,312	1,533	1,250	835	1,346
17:30	1	1,228	—	719	1,124	1,251
	2	1,002	936	834	1,026	1,508
	3	1,009	1,318	208	881	1,388
18:00	1	681	506	1,231	626	1,395
	2	983	516	478	584	1,288
	3	1,267	375	454	918	1,232
18:30	1	1,127	—	1,044	826	866
	2	1,092	912	955	889	1,147
	3	1,279	574	1,227	569	1,020

19:00	1	1,211	—	822	877	1,272
	2	1,167	1,083	987	661	1,363
	3	1,159	554	608	823	1,407
19:30	1	985	—	1,024	929	1,075
	2	1,071	680	1,020	885	1,225
	3	1,071	570	1,137	777	699
20:00	1	1,246	879	569	566	1,100
	2	721	1,513	1,547	817	957
	3	1,084	1,057	1,391	831	869
ave.		1,168	1,057	1,134	836	1,181
median		1127	627	1024	835	1225

Figure 2. Burapa Intersection

Table 3. Maximum traffic throughput at Kao larm intersection

time	cycle	Kao Larm								
		NB		SB		EB		WB		
		lane 1	lane 2	lane 1	lane 2	lane 1	lane 2	lane 1	lane 2	lane 3
16:00	1	1,331	1,721	1,283	1,088	2,202	1,105	1,303	2,515	1,165
	2	1,505	1,297	1,101	683	855	—	809	740	1,597
	3	1,449	1,026	866	1,044	2,466	—	1,213	2,271	1,451
16:30	1	1,386	1,134	740	—	1,264	—	778	429	1,037
	2	2,074	1,236	1,304	715	1,957	—	1,231	1,610	—
	3	2,777	1,363	1,082	—	1,898	—	1,161	1,477	1,280
17:00	1	1,484	642	744	—	1,150	—	1,458	1,326	914
	2	1,693	1,282	1,958	—	1,656	—	1,383	1,802	1,163
	3	1,888	933	951	—	418	—	1,509	1,506	1,224
17:30	1	1,402	1,571	1,578	—	1,638	—	1,143	1,152	1,088
	2	1,822	1,481	3,081	1,111	1,154	—	1,619	1,628	737
	3	1,501	1,375	261	589	1,539	—	1,212	1,398	1,089
18:00	1	1,270	1,074	1,880	—	616	—	894	1,636	460
	2	1,567	774	1,510	1,105	1,270	—	1,087	1,477	547
	3	1,288	1,407	849	1,710	1,707	—	1,187	1,746	1,228
18:30	1	1,514	747	589	1,440	1,667	—	840	1,714	738
	2	1,512	1,388	1,487	2,001	1,708	—	1,044	1,469	465
	3	1,546	1,389	1,519	—	2,279	—	903	1,423	1,572
19:00	1	1,008	1,277	1,217	1,519	1,283	558	1,179	955	1,493
	2	1,956	420	929	—	446	—	1,458	1,593	954
	3	1,477	896	567	543	1,289	—	976	1,310	1,258
19:30	1	641	1,020	1,576	1,246	1,249	852	1,409	1,177	1,334
	2	1,698	1,533	606	639	1,546	496	1,224	1,001	1,284
	3	2,362	941	669	—	1,434	527	1,101	1,069	1,575
20:00	1	1,808	1,120	1,710	—	648	1,535	1,167	1,358	681
	2	966	1,223	1,852	473	1,906	—	746	542	—
	3	1,977	1,131	1,302	1,154	445	—	753	1,488	—
ave.		1,642	1,398	1,365	1,066	1,396	846	1,140	1,662	1,097
median		1512	1223	1217	1096.5	1434	705	1167	1469	1164

Figure 3. Kao Larm Intersection

Table 4. Maximum traffic throughput at Lam Tann intersection

time	cycle	Lam Tann					
		NB		SB		EB	WB
		lane 1	lane 2	lane 1	lane 2	lane 1	lane 1
16:00	1	1,403	1,165	1,353	562	1,572	525
	2	1,118	1,245	1,371	654	1,021	1,419
	3	1,494	1,601	1,387	782	1,447	1,347
16:30	1	1,372	1,611	—	—	1,089	1,745
	2	1,513	820	632	—	1,079	1,881
	3	1,289	585	—	—	758	1,148
17:00	1	1,320	1,365	1,527	—	1,789	1,511
	2	1,586	1,301	—	—	1,102	1,558
	3	1,406	790	1,191	—	1,579	1,747
17:30	1	1,305	628	1,356	—	820	1,749
	2	1,610	1,557	1,341	—	1,448	1,690
	3	1,345	1,429	706	—	1,316	1,705
18:00	1	1,267	1,061	1,085	—	435	1,596
	2	1,349	1,281	673	—	1,165	2,170
	3	1,364	1,163	600	—	1,990	1,802
18:30	1	1,368	945	1,462	634	1,619	1,730
	2	1,028	1,316	1,572	1,103	1,995	1,612
	3	1,645	1,581	1,531	886	1,184	2,504
19:00	1	649	719	1,504	—	1,906	971
	2	1,300	1,200	2,236	—	2,394	1,908
	3	1,258	890	1,314	—	2,154	1,125
19:30	1	1,163	1,273	1,498	—	2,772	861
	2	1,247	1,267	1,696	234	1,224	1,300
	3	932	1,221	1,117	1,155	2,587	716
20:00	1	1,403	1,165	1,353	562	1,572	525
	2	1,118	1,245	1,371	654	1,021	1,419
	3	1,494	1,601	1,387	782	1,447	1,347
		1,353	1,287	1,425	886	1,573	1,686
		1,345	1,245	1,363.5	654	1,447	1,558

Figure 4. Lam Tann Intersection

Because each traffic lane allows different kinds of movements (e.g., through, left turn, right turn) and maximum speed for each movement is different, we separated traffic lanes into 6 types: 1) through lane, 2) right-turn lane, 3) through-right-turn lane, 4) through-left-turn lane, 5) through-right-left-turn lane, and 6) through-U-turn lane. The possible maximum traffic throughputs for each lane type is summarized in Table 5.

The surprising finding is that the traffic throughputs on Type 1 lane is never higher than 1,500 vehicles/hour and the traffic throughputs for Types 2 and 3 lanes are always higher than that of Type 1 lane. According to Table 5, the medians of vehicle numbers passing through the selected intersection on Types 2 and 3 lanes are 1,310 and 1,402 vehicles/hour, but Type 1 lane has only 1,088 vehicles/hour.

Table 5. Traffic throughput by lane type

Intersection	Direction	Lane#	Type 1	Type 2	Type 3	Type 4	Type 5	Type 6
Galaxy	**NB**	1	1,477					
		2	1,355					
		3	846					
	SB	1	-	1,369				
		2	-		1,402			
		3	1,079					
		4	701					
	EB	1		1,337				
		2		1,283				
Burapa	**NB**	1	1,168					
		2	1,057					
	EB	1			1,134			
	WB	1						1,140
		2				1,181		
Kao Larm	**NB**	1			1,642			
		2				1,398		
	SB	1			1,365			
		2	1,066					
	EB	1			1,396			
		2				846		
	WB	1		1,140				
		2			1,662			
		3	1,097					
Lam Tann	**NB**	1			1,353			
		2	1,287					
	SB	1			1,425			
		2				886		
	EB	1					1,573	
	WB	1			1,686			
median			1,088	1,310	1,402	1,034	1,573	1,140

5 Conclusions and recommendations

In this study, the information of possible maximum traffic throughputs at major intersections was collected using the traffic count data extracted from the videos recorded by deploying CCTV cameras. Four major intersections with high traffic congestion in Saensuk city were chosen and afterward new CCTV cameras were installed at these intersections. Traffic throughput data were manually extracted from the recorded videos for the time period of 16:00-20:00 because, after the visual observation, this time period covers peak traffic hours.

The maximum traffic throughputs for different number of lanes and lane configurations at the chosen intersections were collected and analyzed. There are two 3-way and two 4-way intersections. Traffic throughputs for different lane types should be treated separately. With a better understanding of possible maximum traffic throughputs, the identification of optimum green time to minimize vehicle delay would become more accurate. In the future work, a statistical analysis to identify a relationship among important parameters, such as green time vs. maximum throughput will be conducted.

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