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ANALYSIS OF A BUSY SIGNALIZED INTERSECTION

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ABSTRACT. One way to alleviate traffic congestion at busy intersections in major cities is by building flyovers bridge (and or an underpass). The flyover facilitates the traffic flow in the directions of the bridge. Before construction, assessment study is needed to estimate the appropriate flyover dimension, as well as how well the flyover built accommodates high traffic demand in that area. One of the busiest intersections in Bandung City was chosen here as a case study, it is the Buah Batu-Kiara Condong intersection. The effectiveness of the proposed flyover construction was evaluated for varying levels of traffic volume by comparing the average delay, and the average queue length. To avoid a secondary problem, traffic operations for roads underneath a flyover was also discussed. Further, simulations of the congested and uncongested vehicles pattern behind a signalized intersection were provided; the long vehicles queue, exceeding 0.5 km before flyover construction would be reduced to less that 0.1 km, if there is a flyover. These results showed the effectiveness of the proposed layout. Furthermore, assessment study implemented here can serve as an example to be applied to other intersections.

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1. INTRODUCTION

Oftentimes, in densely populated cities, the proportion of road area to the city area is relatively low. Without adequate public mass transportation, along with high population mobility needs, the existing roads will be overloaded. This will result in traffic congestion, which get worse day by day. In order to reduce traffic congestion and to maximize traffic flow, engineer often need to make decision whether to change a two-way road to a one-way street, where to construct entrances, exits, and also flyover. Such a policy also includes how many lanes to build for a new highway or to develop alternate forms of transportation. In order to make such decisions, traffic engineers need to access real situation and conduct a thorough assessment study.

The city of Bandung has total area of 167.67 km^2. The city has more than 1.5 million urban residents, and surrounded by scattered rural population. Bandung is the third of Indonesias most populated cities. Traffic congestion in Bandung were observed on daily basis, which increasingly deteriorate. Here, we present a case study from one of the busiest intersections in Bandung; Buah Batu and Kiara Condong intersections. High traffic demand at

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this intersection occurs regularly, especially during peak hours on weekdays and weekends. Long cycle times of traffic signals installed at these intersections often result in very long traffic jams. Similarly, studies about busy intersections in urban areas were also found in literature [4, 8, 15, 16]

In this paper we examine the data of traffic load at Buah Batu and Kiara Condong intersections, provided by Institut Teknologi Bandung transportation management system [7]. We use the critical lane and time budget concepts to determine the optimal cycle time for both intersections. Indeed, under such heavy traffic demands, the cycle times were longer than 5 minutes for both intersections. However, 5 minutes cycle time for a traffic light is certainly too long, and the long vehicle queues will cause another problem, as well. For these kind of intersections, building a flyover is probably the only feasible solution at this moment. To simplify the presentation, in further discussions, Buah Batu, Kiara Condong will be abbreviated as BB, KC, respectively.

The organization of this paper is as follows. We start the discussion with a review of several concepts about signalized intersection; optimum cycle time and delay, these are discussed in Section 2, and Section 3, respectively. In Section 4, traffic load data collected form BB - KC intersections area was used to conduct assessment study for the construction of a flyover. We also compare cycle time and delay time between situations with and without flyover. In Section 5, a graphical method based on shock wave and rarefaction wave solutions of the kinematic equation is used to simulate the queue length formed behind a traffic signal, before and after flyover construction. Finally, conclusion is given in Section 6.

2. Optimum cycle time in a four phase intersection

Consider a junction which is the intersection of two main roads, so that there are four road segments (say legs) connected to this intersection. Assuming that the four legs all have the same traffic intensities. When a traffic light is installed on this intersection, logically each leg should have an equal turn. Assuming there is no time lost between changing phase, then for a given cycle length C, the length of green light turn is approximately one third of the red light turn. This is perceived by vehicles on each leg of that intersection.

The next issue is determining the cycle length C of a traffic light. The most suitable cycle length can be determined by a method which is essentially based on time budgeting. This formula is resumed here. Consider a particular location at the intersection, where vehicles of all four legs pass through it alternately, as time progresses.

$$V_C \equiv \frac{3600}{h}\left(1 - \frac{Nt_L}{C}\right). \tag{1}$$

The value of V_C is known as *the critical lane volume*, it denotes the number of maximum vehicles per lane (in total for all legs) that can be accommodated by an $N-$phase traffic light with cycle length C. After some algebra, the formula (1) can be re-written as $C = Nt_L/(1 - \frac{V_C h}{3600})$. From the description above we can conclude that in order to accommodate the critical lane V_C, traffic light should be operated with the minimum cycle length C. Therefore, the use of notation C_{min} is preferred, and hence the formula for the minimum cycle length is

$$C_{min} = \frac{Nt_L}{1 - \frac{V_C h}{3600}}. \tag{2}$$

The cycle length formula (2) is too ideal to be implemented. Commonly, signal/ traffic light is timed using the *optimum cycle-time*

$$C_{opt} = \frac{Nt_L}{1 - \frac{V_C h}{3600.PHF.q/c}}. \tag{3}$$

This formula C_{opt} is similar with the previous (2), but it accommodates two new parameters: PHF the peak hour factor, and q/c the desired volume to capacity ratio. The peak hour factor measure the fact that on averaged traffic density is less than what is measured during the very peak hour, therefore its value is less then one. The parameter q/c is a measurement on how dense the traffic is. A fully compact traffic means $q/c = 1$, but of course this situation is undesirable. Typically $q/c \in [0.8, 0.99]$. Authors [17] conduct investigation on determining the optimum cycle times, that takes into account vehicle delay time, pedestrian crossing time, and drivers anxiety, see also [2].

3. Delay

On a signalized intersection with fixed cycle length C, by assuming a fixed arrival rate, we can determine the averaged delay time using a well known Webster formula. For the sake of clarity, here we will review a variant of the Webster delay time formula.

Depending on the cause, delay can be divided into two types: the overflow delay (due to excessive traffic density), and the uniform delay (due to obstacles, e.q. traffic signal). First, we will discuss how to compute the uniform delay experienced by vehicles which cross the signalized intersection with fixed cycle length C. In predicting delay, our approach is deterministic, whereas for stochastic approach, readers are referred to [5, 9, 10].

This delay time can be obtained by computing the number of arrival vehicles minus the leaving vehicles. Figure 1 (a) shows a diagram of cumulative vehicles versus time. Assuming a constant arrival rate q, the straight blue line represents the number of arrival vehicles as a function of time. The orange lines represent the number of vehicles leaving the site via the signalized intersection. During red light (R), there is no passing vehicles, hence the orange line is horizontal, whereas during green light (G), vehicles leave

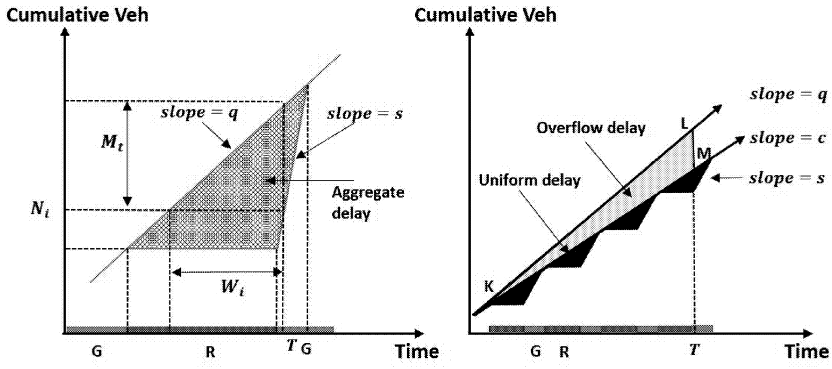

FIGURE 1. (Left) Cumulative vehicles diagram to compute Webster uniform delay. (Right) Illustration of overflow delay over a certain period of time.

with a constant saturation flow rate, s. Also we can interpret that, the waiting period of the vehicle N_i is W_t. Moreover, area of the shaded triangle in Figure 1 (a) represents the total amount of delay for all vehicles. Note that the *average delay* can be obtained from the total delay divided by the total number of vehicles.

In reality, calculating delay for an intersection can be complicated. Let q denote arrival flow rate (veh/hr) and c is the capacity of intersection (veh/hr). Depending on the ratio of q/c, two different situations can be distinguished: $q/c < 1$ (rather quiet intersection) and $q/c > 1$ (busy intersection). In the case of $q/c < 1$, vehicles only experience *uniform delay*, with the *aggregate-uniform delay* (AUD) formula

$$AUD = \frac{1}{2}\left[C\left(1 - \frac{G}{C}\right)\right]^2 \left(\frac{qs}{s-q}\right), \tag{4}$$

which is in fact the area of the triangle area in Figure 1 (a). Then, the average uniform delay (UD) is calculated from

$$UD = \frac{1}{2}C\frac{\left[1 - \frac{G}{C}\right]^2}{\left[1 - \frac{q}{c}\right]}, \tag{5}$$

which can be obtained from (4) after divided by qC.

In the case of a very busy intersection with $q/c > 1$, besides the uniform delay, vehicles will experience an additional overflow delay, the shaded area of triangle KLM in Figure 1 (b). Here we do not present formulas for overflow delay, since for our case study, the BB and KC intersections, there is only uniform delay. We refer to [14] for further reference about commonly used formulas for predicting delay. Extensive researches on models for predicting delay are for instance [1, 6, 3].

4. A case study: BB - KC intersection

Intersection in Indonesia are mostly four-leg. Typically, a four-leg intersection contains twelve vehicular movements and four crossing pedestrian movements. Focusing only on traffic volumes of vehicular signalized intersection, in this paper we adopt the critical volume concept and time budget concept to determine the optimal cycle time. Buah Batu (BB) and Kiaracondong (KC) are two busy intersections in Bandung. Both intersections are four-leg intersections, located next to each other. Everyday, especially during weekdays, there were long queues on that intersections. To reduce traffic congestion on these areas, construction of flyover was planned.

Based on field measurement data of traffic fluxes of all legs of the BB - KC intersections, here we will conduct analysis with the aim of proposing the most suitable scenario for flyover construction at BB - KC area. We also compare the performance of BB - KC intersections before and after the flyover construction.

4.1. **The optimum cycle time of current situation.** By using traffic flux data along the E(ast), W(est), N(orth), S(outh) of the BB and KC intersections, here we compute the optimum cycle time. Take a close look at Table 1 (top left), using the traffic flux data q of the BB intersection during weekend, we computed traffic flux per lane q/N. Then, the critical volume V_C is just the sum of q/N from all four legs. Next, the minimum cycle time C_{min} is computed using equation (2), and further the optimum cycle time C_{opt} is computed using equation (3). Here, we used parameters $t_L = 2\ sec$, $PHF = 1$, and $q/c = [0.88, 0.98]$. Further, the average delay time is computed using equation (5). Similarly, we compute the optimum cycle time C_{opt} for the other three cases: BB during weekdays, and KC during weekends and weekdays. The results are resumed in Table 1. It shows that the optimum cycle time C_{opt} of the KC intersection during weekends exceeds 5 min, which indeed a very long cycle time of a signalized intersection. Meanwhile, the BB intersection during weekdays has even longer cycle time, i.e. more than 12 minutes.

Moreover, it is interesting to compare the q/N ratio for each leg in Table 1, the high ratio of q/N are marked with circles. This ratios show which leg is more busy than the others. So here we know that East leg is the most heavy leg for both intersections. The fact that the East-West road for both intersections are more busy than the North-South road, lead us to conclude that East-West is the *major road* for both intersections. This East -West road is Jl. Soekarno Hatta. Therefore, it is reasonable to build a flyover over this Jl. Soekarno Hatta, crossing along the BB - KC intersections as illustrated in Figure 2.

4.2. **Performance after a flyover construction.** To overcome the long duration of cycle length and delay time, the performance of flyover layout shown in Figure 2 will be assessed. Here, we will conduct several assessment

TABLE 1. Traffic data along E(ast), W(est), N(orth), S(outh) of BB and KC intersections during peak hours on weekends and weekdays, the critical lane volume V_C and the optimum cycle time C_{opt}.

BB on Weekend	E	W	S	N
q	2269	1320	1570	1288
N (Lane)	4	4	4	3
q/N	567.25	330	392.5	429.33
Vc (veh/hr)	1719.08			
Cmin (sec)	168			
Copt (sec)	305			
Average delay	52.19	60.10	51.99	50.27

KC on Weekend	E	W	S	N
q	3489	2410	1047	1681
N (Lane)	7	7	3	3
q/N	498.43	344.29	299.14	480.29
Vc (veh/hr)	1622.14			
Cmin (sec)	205			
Copt (sec)	**372**			
Average delay	70.07	77.74	74.38	62.71

BB on Weekday	E	W	S	N
q	2677	931	2020	1250
N (Lane)	4	4	4	3
q/N	669.25	232.75	505	416.667
Vc (veh/hr)	1823.67			
Cmin (sec)	398			
Copt (sec)	**722**			
Average delay	60.84	78.32	58.54	63.46

KC on Weekday	E	W	S	N
q	3030	1231	1086	1521
N (Lane)	7	7	3	3
q/N	432.86	175.86	362	507
Vc (veh/hr)	1477.71			
Cmin (sec)	72			
Copt (sec)	131			
Average delay	45.17	57.12	47.01	41.13

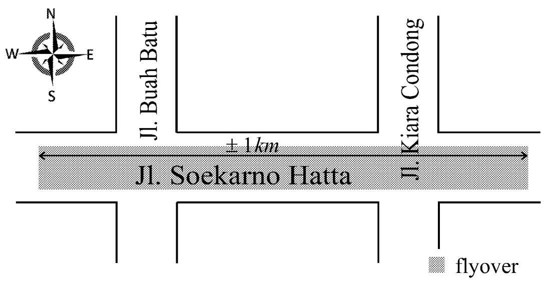

FIGURE 2. The proposed flyover layout built ± 1 km over the BB-KC intersections, along Jl. Soekarno Hatta - Bandung.

analysis to compare the performance of BB-KC intersection before and after the flyover construction. Three performances will be compared: cycle time, delay time, and queue length.

From our private communication with Insitut Teknologi Bandung Transportation Engineering Research Group, the BB - KC flyover will accommodate vehicular coming from West to East, and the other way around, and each will have two lanes. With the presence of a flyover, vehicles coming from the East headed to the West do not need to pass the signalized intersection. The existence of this flyover will reduce the volume of traffic that must pass through the intersection, and therefore reduce the critical volume V_C.

With the addition of two extra lanes from the East and the West part of the BB flyover, V_C decreases from 1719.08 veh/hr to 1420 veh/hr on weekends and from 1823.67 veh/hr to 1523 veh/hr on weekdays. Then,

TABLE 2. In the presence of flyover, the reduced traffic volumes along E(ast), W(est) of Buah Batu intersection results in the reduction of V_C, C_{opt}, and averaged delay.

BB on Weekend	E	W	S	N
q	2269	1320	1570	1288
N (Lane)	4 → 6	4 → 6	4	3
q/N (veh/hr)	567.25 → 378.17	330 → 220	392.5	429.33
Vc (veh/hr)	**1719.08 → 1420**			
Copt (sec)	**305 → 115**			
Red period (sec)	209 → 88	249 → 99	239 → 87	233 → 85
Average delay (sec)	110.01 → 51.81	131.42 → 59.37	125.00 → 51.18	121.53 → 48.98
Reduced delay (%)	47.09	45.18	40.94	40.30

BB on Weekday	E	W	S	N
q	2677	931	2020	1250
N (Lane)	4 → 6	4 → 6	4	3
q/N (veh/hr)	669.25 → 446.16	232.75 →115.17	505	416.67
Vc (veh/hr)	**1823.67 → 1523**			
Copt (sec)	**722 → 147**			
Red period (sec)	463 → 108	632 → 133	526 → 103	561 → 111
Average delay (sec)	235.71 → 60.66	321.48 → 77.10	268.56 → 57.66	285.16 → 61.62
Reduced delay (%)	25.73	23.98	21.47	21.61

using equation (3), will directly result in the reduction of C_{opt}, see Table 2. Thus, having a flyover will yield in reduced traffic volume of the intersection, and directly lead to smaller C_{opt}. As we shall see here, the extreme C_{opt} on weekdays at BB intersection is reduced from 722 *sec* to 147 *sec*. Using equation (5) we can compute delay time for each leg, i.e. it is reduced to $21-26\%$, see Table 2. Further, during weekends, C_{opt} at BB intersection is reduced from 305 *sec* to 115 *sec*, which results in a reduction in delay time to only $40-47\%$. This new performance of the BB intersection is clearly substantial. Similarly, a trend of C_{opt} and delay time being reduced is also observed at the KC intersection, see Table 3. During weekends and weekdays, the cycle time is reduced from 372 *sec* to 165 *sec*, and from 131 *sec* to 99 *sec*. Whereas the averaged delay on weekends and on weekdays are reduced to $45-50\%$ and $78-85\%$, respectively.

5. Vehicles queue behind a signalized intersection

Let us consider one leg road from a signalized intersection. A top view observation towards the road section will show a pattern of congested and uncongested vehicles as a result of an alternating red and green light turn of the traffic signal. Soon after the traffic signal turn red, vehicles queue starts to develop, and this queue will get longer as time progresses. This is actually a shock wave in traffic flow. When traffic signal turn green, this vehicles queue starts to relax in the form of a rarefaction wave. When the light turn red again, the cycle repeats. It may happen that vehicle queue from the previous red light still remain, which make this second red light

TABLE 3. In the presence of flyover, the reduced traffic volumes along E(ast), W(est) of Kiara Condong intersection results in the reduction of V_C, C_{opt}, and averaged delay.

KC on Weekend	E	W	S	N
q	3489	2410	1047	1681
N (Lane)	$7 \to 9$	$7 \to 9$	3	3
q/N (veh/hr)	$498.43 \to 387.67$	$344.29 \to 267.78$	349	560.33
Vc (veh/hr)	**$1622.14 \to 1564.77$**			
Copt (sec)	**$372 \to 165$**			
Red period (sec)	$271 \to 128$	$302 \to 139$	$301 \to 132$	$258 \to 111$
Average delay (sec)	$140.40 \to 70.07$	$156.98 \to 77.41$	$156.55 \to 71.59$	$134.20 \to 61.35$
Reduced delay (%)	49.91	49.31	45.73	45.72

KC on Weekday	E	W	S	N
q	3030	1231	1086	1521
N (Lane)	$7 \to 9$	$7 \to 9$	3	3
q/N (veh/hr)	$432.86 \to 336.67$	$175.86 \to 136.78$	362	507
Vc (veh/hr)	**$1477.71 \to 1342.44$**			
Copt (sec)	**$131 \to 99$**			
Red period (sec)	$97 \to 78$	$117 \to 90$	$103 \to 76$	$91 \to 67$
Average delay (sec)	$55.03 \to 46.60$	$67.28 \to 56.73$	$57.55 \to 46.25$	$51.86 \to 40.51$
Reduced delay (%)	84.68	84.32	80.38	78.11

turn bring about a longer traffic queue.

To study congested and uncongested traffic dynamics, here we apply a continuum approach. In this approach, three main variables are used: traffic flux q, traffic density k, and the averaged velocity v. As a rule of thumb, these variables are related to each other as $q = kv$. Assuming traffic velocity v depends solely on traffic density k, hence $q(k) = kv(k)$. Further, traffic dynamics is governed by the kinematic model

$$k_t + q_x = 0, \tag{6}$$

which is a nonlinear convective equation. Here we will show that this simplest kinematic wave model can adequately describe vehicle queue pattern behind a traffic light. Further study on this kinematic wave model together with its discrete model can be obtained in [12] and [13].

Consider (6) with a chosen concave flux function $q(k)$, and equipped with an initial condition

$$k(x,0) = \begin{cases} k_A, & x < 0 \\ k_B, & x \geq 0. \end{cases} \tag{7}$$

Its solution will evolve into

$$\text{a shock wave if } k_A < k_B, \quad \text{and a rarefaction wave if } k_A > k_B. \tag{8}$$

In Figure 3 (left) we sketch a shock wave solution with $k_A < k_B$, i.e. traffic density on the downstream side is higher than traffic density on the upstream side. As time progresses, the discontinuity in the shock wave solution will propagate with velocity that follows from the Rangkine-Hugoniot formula [11]

$$\text{shock speed} = \frac{q_B - q_A}{k_B - k_A}. \tag{9}$$

Note that formula (9) is just the gradient m_{AB} of the segment line on the flux curve function in Figure 3 (right). Here, a shock wave can have both negative as well as positive shock speed. In further discussion, the shock wave will be represented only by a shock line on the $xt-$plane, see the red line on Figure 3 (left). Similarly, rarefaction wave can also be represented as a line on the $xt-$plane. On the other way around, to determine a given segment line on the flux curve represents a shock wave or rarefaction wave, we can just use (8). Therefore, this simple qualitative graphical method can completely described any type of shock wave and rarefaction wave existing in the kinematic wave model (6). Moreover, this holds for any concave flux function $q(k)$.

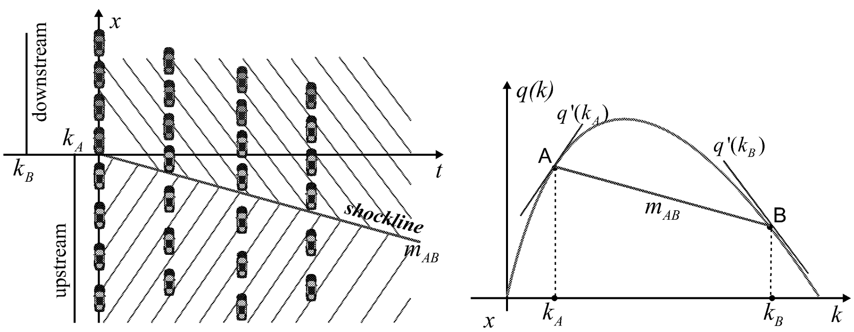

FIGURE 3. (Left) Shock wave and queue tail. (Right) A curve of the traffic flux $q(k)$ with a segment line AB which gradient m_{AB} represents the shock velocity.

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For a relationship between velocity v and traffic density k, there are several options, here we use the Greenberg model which is

$$v(k) = v_m \ln\left(\frac{k_{jm}}{k}\right) \quad \text{and} \quad q(k) = k v_m \ln\left(\frac{k_{jm}}{k}\right). \tag{10}$$

Implementing the graphical method to a road segment with traffic signal will yield a traffic density pattern as depicted in Figure 4. This result were obtained using Greenberg model (10) with normalized parameters $v_m = 1$, $k_{jm} = 1$, and cycle time 60 minutes, with the green/red ratio $= 1/3$. It shows congested traffic during red light and uncongested traffic during green light. In this simulation, the queue of vehicles caused by red light is not all released during the green light, thus the queue of vehicles is getting longer and longer. Next, this method will be used to assess the vehicle queue at BB-KC intersection.

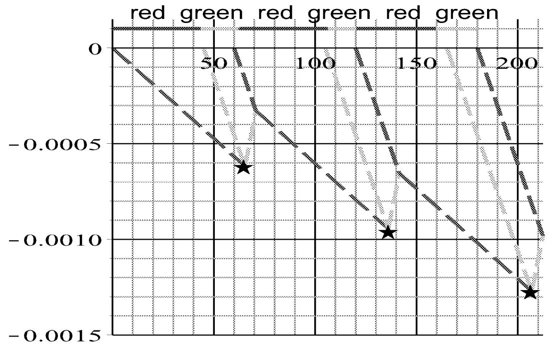

FIGURE 4. Graphical method to describe the congested and uncongested vehicles pattern behind a traffic signal. The stars indicate the farthest queue in each red light period.

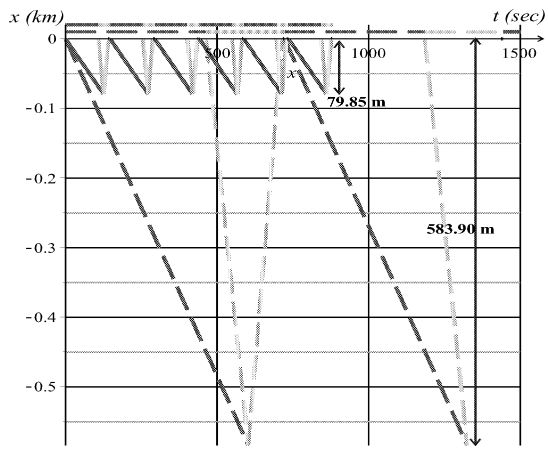

FIGURE 5. Illustration of the queue length dynamics due to traffic signal at Buah Batu (BB) intersection, under conditions: without flyover (dashed lines), and with flyover (solid lines).

Here we analyze the queue length formed along the East West legs of BB - KC intersections, along Jl. Soekarno Hatta. We compare situations before and after the flyover construction. Using traffic flux data of BB intersection during weekdays, we implemented graphical method to describe the formation of vehicles queue due to traffic signal. Result is shown on Figure 5; dashed lines represent condition without flyover, whereas solid lines represent condition after building a flyover. Different cycle times used $C_{opt} = 372\ sec$ (without flyover) and $C_{opt} = 162\ sec$ (with flyover) leads to strikingly different situations. Without flyover, the longest queue reach $583.9\ m$. Assuming that each car is five meter long, that means a queue of 115 cars (per lane) were lining up along Jl. Soekarno Hatta, this happens every single cycle of the traffic signal. Note that, if there is a residual car

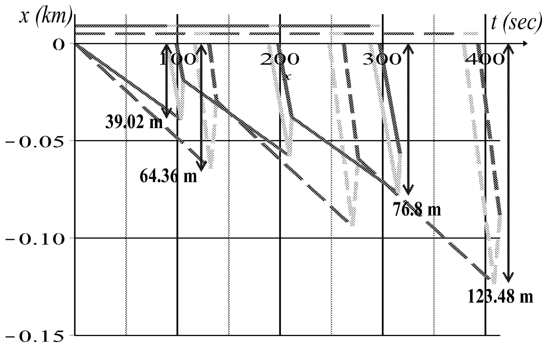

FIGURE 6. Illustration of the queue length dynamics due to traffic signal at Kiara Condong (KC) intersection, under conditions: without flyover (dashed lines), and with flyover (solid lines).

TABLE 4. Queue length results with and without flyover for BB and KC intersection during weekends and weekdays.

BB Weekend	E	W	S	N
Q_A	2269	1320	1570	1288
	Without Flyover			
Number of lanes	4	4	4	3
G:R	96 : 209	56 : 249	66 : 239	72 : 233
Queue length (m)	211.2	130.4	153.2	166.2
Residual Queue	-	-	-	-
	With Flyover			
Number of lanes	6	6	4	3
G:R	27 : 88	16 : 99	28 : 87	30 : 85
Queue length (m)	57.9	34.20	58.90	64.50
Residual Queue	-	-	-	-

BB Weekday	E	W	S	N
Q_A	2677	931	2020	1250
	Without Flyover			
Number of lanes	4	4	4	3
G:R	259 : 463	90 : 632	196 : 526	161 : 561
Queue length (m)	583.90	223.81	458.36	386.25
Residual Queue	-	-	-	-
	With Flyover			
Number of lanes	6	6	4	3
G:R	39 : 108	14 : 133	44 : 103	36 : 111
Queue length (m)	79.85	31.21	96.80	81.08
Residual Queue	-	-	-	-

KC Weekend	E	W	S	N
Q_A	3489	2410	1047	1681
	Without Flyover			
Number of lanes	7	7	3	3
G:R	101 : 271	70 : 302	71 : 301	114 : 258
Queue length (m)	232.3	166.12	168.20	256.68
Residual Queue	-	-	-	-
	With Flyover			
Number of lanes	9	9	3	3
G:R	37 : 128	26 : 139	33 : 132	54 : 111
Queue length (m)	87.02	60.27	77.37	120.43
Residual Queue	5.18	2.12	-	-

KC Weekday	E	W	S	N
Q_A	3030	1231	1086	1521
	Without Flyover			
Number of lanes	7	7	3	3
G:R	34 : 97	14 : 117	28 : 103	40 : 91
Queue length (m)	83.15	64.36	57.56	90.53
Residual Queue	1.19	29.56	-	-
	With Flyover			
Number of lanes	9	9	3	3
G:R	21 : 78	9 : 90	23 : 76	32 : 67
Queue length (m)	53.03	39.02	44.55	72.69
Residual Queue	6.58	18.89	-	-

between the traffic cycles, this queue of cars would be longer. Meanwhile, having the flyover built along Jl. Soekarno Hatta, the queue length has reduced to become 79.85 m, which is only 16 cars (per lane) lined up waiting for the lights to turn green.

Similarly, at the KC intersection, because of the flyover, the cycle time has reduced from $C_{opt} = 131$ sec (without flyover) to $C_{opt} = 99$ sec (with flyover). As shown in Figure 6 dashed lines represent condition without flyover, whereas solid lines represent condition after building a flyover. The longest queue length during first cycle is reduced from 64.36 m to 39.02 m. But in this case, there are residual cars from the previous cycle, and hence every cycle, the queue length increases as time progresses. Note that 64.36 m of queue length on KC-West road is much less then the queue length on BB-East road, but with constant arrival flow, the queue length will reach more than 600 m within an hour. We conducted this analysis for all legs of both BB - KC intersection and the results are resumed in Table 4.

6. Conclusion

In this article, the critical lane and time budget concept have been used to obtain the optimal cycle time of a busy intersection in Bandung. Real traffic load data is used, which lead us to an optimal cycle time that exceed 5 minutes for both intersections. This could be the reason for the urgency of building a flyover. With the proposed layout of the flyover, the optimal cycle time were reduced to only ± 2 min for both intersections. Moreover, expected delay time were reduced to 85% or less. This situation would happen during weekdays and also weekends. The queue length formed along BB-East and KC-West road before and after flyover construction were also presented. In this way, we show the effectiveness of the proposed layout.

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