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Improving Urban Traffic Flow at Congested Signalized Intersections in Phnom Penh: Case Study of Neakvaon Intersection

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Abstract: Traffic congestion is one of the most serious problems facing by not only the developed countries, but also by developing countries, including Cambodia. Efforts have been made to minimize urban traffic congestion in order to improve the traffic flow. This paper intends to provide the best alternative solutions to improve traffic flow at a busy intersection in Phnom Penh, Cambodia—i.e., Neakvoan intersection. Three alternative solutions were proposed based on redesign of road geometry and reconfiguration of one-way traffic road, and analyzed queue length and delay via a micro-simulation environment (i.e., PTV VISSIM) using actual data from traffic count survey. Results showed that, compared with the existing conditions, the third alternative solution performed better than other alternatives, by improving the traffic flow at Neakvoan intersection up to 39% with a reasonable level of service D. The proposed alternative solution was evaluated and accepted for implementation by the government.

Keywords: Level of service; One-way traffic; Signalized intersection; Traffic flow; Traffic simulation

1. INTRODUCTION

Infrastructure development in Cambodia has increased quickly in recent years. Population come to the city for their living, business and education. The more population come to live in the city, the more urban traffic congestion becomes. Phnom Penh is now home for more than 2 million citizens [1], while the number of registered vehicles keeps increasing. As a result, traffic congestion has become an unavoidable social problem in Phnom Penh and its suburban areas. Transport engineers have a duty to help minimize this problem to ensure that road capacity and traffic light time balance with the population in the city. PTV VISSIM is the most sophisticated and widely used microscopic traffic simulation program, according to Gai [2]. He addressed VISSIM's modules, features, and application area, as well as the possibility of expanding its use in China. VISSIM was used by Qin and Xiong [3] to test some schemes in the scientific research of traffic renovation in Kunming, China. They suggested a new concept for testing traffic management schemes under complex traffic conditions by simulating one-way schemes, and they showed that VISSIM can provide some decision-making basis for traffic management departments. Microsimulation traffic models have the potential to greatly enhance the efficiency of urban road network planning and design. When various strategies are evaluated and compared, they can be used as part of the decision-making process.

The objective of this study is to improve the overall traffic flow at the area around Neakvoan intersection, one of the busiest intersections in Phnom Penh. We analyzed both the geometry and traffic movement at this intersection using data from a traffic count and topography survey. Three alternative solutions were considered based on the existing geometry and traffic movement. The better alternative solutions were analyzed in a micro-simulation environment using the geometry and traffic data. The best alternative solution was then suggested based on its optimal queue length and level of service.

2. METHODOLOGY

2.1. Road inventory data

Initially, inventory surveys of the selected intersections and roads are conducted. The goal of the road inventory studies is to gather information on the existing features of the chosen intersections, as well as the current pavement condition and the

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conditions of road marking, traffic signal timing and the presence of crossing traffic [4]. Surveys were conducted for collection of Oueue length data from field and comparison is made with the data obtained from simulation form the PTV VISSIM software. The survey includes collection of hourly traffic volume of the selected intersection and also the turning movement counts. The following information was collected as the part of the survey: presence of crossing traffic (vehicle), hourly traffic volume (to identify peak hour at day time), width of the roads, road shoulders and sidewalks, number of lanes, road marking details and traffic signal timing. The methodology used in this study is the intersection count method. Intersection count method is used to determine vehicle classification through movements and turning movement at intersection. Counted data are used to analyse the level of service, design phase lengths of traffic signal, cycle time of signalized intersection. Traffic counting is done manually at several road junction at the area around Neakvoan intersection, in Phnom Penh city. Traffic counting was carried out to identify which route often travelled, the traffic volume per unit of time (veh/h) and composition of the vehicle passing through the streets such motorcycle, Bajaj, Remork, car, bus and truck. In addition, traffic counting also identify the environment of intersection as well as the geometry of the road.

2.2. Traffic data collection

The traffic volume count was carried out at the selected intersection for the morning peak hours (6:30am to 9:30am) and afternoon peak hours (16:00pm to 19:00pm) during the workdays on 14th February 2020. The method of traffic count is conducted by two ways: (1) directly count the traffic by enumerators and re-count the traffic by using video recorded at the same day for different directional traffic. Each direction was counted for all vehicles that passthrough intersection such as motorcycle, car, bajaj, remork, bus and truck. The period of the volume counting is divided into 30 minutes intervals on each movement at the selected intersection.

2.3. Data conversion

Traffic volume should be converted into the Passenger Car Unit (PCU), thus all different types of vehicles become one standardized vehicle for simulation study. The conversion factors are used to convert the virous classes of vehicles to passenger car unit [5].

2.4. One-way traffic

One-way traffic is an efficient utilization of the existing roads space that is the key to solve various problems of traffic. Along narrow streets, curb side parking has resulted in difficulty for opposing traffic streams to pass through, thus creating serious traffic congestion. To overcome this problem, one of the solutions is to convert such narrow street into one-way streets.

This measure can help in more efficient usage of the limited road space by increasing its operational capacity for a smoother traffic flow while reducing traffic accident. The following are the basic functions of a one-way traffic system [5]:

- 1) One-way traffic system capable of increasing the traffic processing capacity of narrow and congested street.
- 2) In principle, one-way traffic system will not be introduced to the major arterial roads in the city.
- 3) All the existing one-way traffic streets are to be retained as they are.
- 4) The existing routes are basically extended or expanded to those routes or areas included in the Public Experiment Study Area.
- 5) Streets that are close-by, parallel and of similar class and length can be paired up.
- 6) Any extension of route should not be too short and in principle should function as the connecting road between arterial street.
- 7) Each pair of one-way streets must be basically within 300 m of each other.
- 8) Routes are selected only if they do not cause exceptionally long detours.
- 9) Routes that may cause further complication to the travel pattern will not be selected.

Table 1 Vehicle type and PCU Ratio	,
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ID	Vehicle Type	PCU Ratio
1	Motobike/Motodop	0.3
2	Tuk-tuk	0.75
3	Motorumork	1.25
4	Sedan, Wagon, Van	1
5	Taxi	1
6	Minibus	2
7	Medium and Large Bus	3
8	Light Truck /Pick up	2
9	Truck (2 axles)	2.5
10	Heavy Truck (3 Axles more)	3

2.5. Level of service

Intersection level of service is a qualitative metric that defines operating conditions within a traffic stream based on service measures like speed and travel time, traffic interruptions, comfort, and convenience. There are several methods to find out the level of service at signalized intersections. Some of the methods are: Highway Capacity Manual method, Webster's method, Norman method and so on. Level of service for signalized intersections is defined in term of control delay, which is a measure of driver discomfort, frustration, fuel consumption, and increase travel time (HCM, 2000).

$$d_I = \frac{\sum d_A V_A}{\sum V_A}$$

Where d_I is delay per vehicle for intersection (s/veh), d_A is delay for approach (s/veh), V_A is adjustment flow rate for approach (veh/h).

2.6. Traffic simulation

Traffic modelling and simulation is one of the frequent tools used on road infrastructure design. Software tools designed for traffic simulations are an important supportive tool in decision-making and in choosing the optional solution. We use PTV VISSIM software (version 11.0) in the purpose of simulation traffic flow, with input data from traffic counting (see Fig. 1).



Fig. 1. Flowchart of a simulation study

3. RESULTS AND DISCUSSION

3.1. Study area

Neakvoan intersection is a four-leg signalized intersection, located to Khan Toul Kok of Phnom Penh city. It interlinks Russian Blvd., St.132 and St.221. This intersection has seven different directions of movement of traffic. Russian Blvd. inbound city (Techno-kdan2) has 2 movements (through, rightturn), Russian Blvd. outbound city (Kdan2-Techno) has 2 movements (through, right-turn) and St.132 has 3 movements (through, right-turn). Just remind that St.221 is oneway street. Fig. 2 shows the location of Neakvoan area.

3.2. Data collection

3.2.1. Traffic data

The traffic volume data of the selected intersections was carried out for 3 hours in the morning (6:30 to 9:30) and 3 hours in the evening (16:00 to 19:00) during the workdays, 14th February 2020. Fig. 3 shows the total traffic volumes during the counted period. The highest traffic volume was found to be between 17:00 and 18:00, the time of off-work and off-school. Method of collecting data were collected using both video graphic method and counting direct. The period of volume counting is divided into 30 minutes intervals.

Fig. 4 shows the modal share of traffic passing Neakvoan intersection. Majority was motorcycle, accounting for 72.1%. The share of paratransit modes (Remork and Bajajs) was 12.2%, which is comparable to the share of cars (16.1%). There were few trucks (0.2%), i.e., mainly construction vehicles because trucks are generally banned from entering the city centers.



Fig. 2. The location of Neakvoan area

3.2.2. Speed

The average speed of vehicle was measured by a mobile phone app (i.e., Speed Gun). The period of measuring speed is divided into two times interval in the morning (6:30 to 9:00) and evening (17:00 to 18:30). Fig. 5 reports these averages speed. Speed of vehicles were measured for 3 different types of vehicles near the intersection (both departing and arriving vehicles): motorcycles, Remorks/Bajajs, and cars. It shows that the average speeds for these vehicles slower in the evening than morning hours. For example, the average speed of motorcycles and cars reduced from 26.1 km/h to 22.5 km/h and from 22.0 km/h to 19.9 km/h, respectively.



Fig. 3. Hourly traffic volumes (veh/h)



Fig. 4. Share of vehicles passed Neakvoan intersection

The average speed of vehicle was measured by a mobile phone app (i.e., Speed Gun). The period of measuring speed is divided into two times interval in the morning (6:30 to 9:00) and evening (17:00 to 18:30). Fig. 5 reports these averages speed. Speed of vehicles were measured for 3 different types of vehicles near the intersection (both departing and arriving vehicles): motorcycles, remorks/bajajs, and cars. It shows that the average speeds for these vehicles slower in the evening than morning hours. For example, the average speed of motorcycles and cars reduced from 26.1 km/h to 22.5 km/h and from 22.0 km/h to 19.9 km/h, respectively.

3.2.3. Lane width

The number of traffic lanes and lane widths of the roads in the studied area were measured manually. Table 2 shows these road measurements. The lane widths at this intersection were 3.25 m. Table 2 tabulates the width of lanes and roads.



Fig. 5. Average speed at Neakvoan intersection

3.2.4. Traffic signal timing

The traffic signal timing was also recorded (Table 3). The signal timing of the existing intersection has two phases with 120 s of fixed cycle length, giving the priority time to major road of Russian Blvd. for 90 s and 30 s to St.132. All-red is 2 s for these two phases, 4 s of yellow time applied on Russian Blvd., and 3 s of yellow time applied to St.132.

Table 2 Width of lanes and roads

Road Name	Lane	Road Width	Lane Width
Russian	4	17.7 m	3.25 m
St.132	4	16 m	3.25 m
St.221	1	7.2 m	3.25 m
St.225	1	7.2 m	3.25 m

 Table 3 Step timing at Neakvoan intersection

Phase	Phase 1	Phase 2
Traffic flow	East-West	South-North
Green time (s)	84 s	32 s
Red time (s)	32 s	84 s
Yellow time (s)	4 s	4 s
Fixed cycle (s)	120 s	120 s

3.3. Data analysis

3.3.1. Data conversion

All vehicles type that obtained from traffic count volume were converted passenger car unit (PCU). All converted PCU volumes are classified as a group direction. Fig. 6 shows the volume in PCU at Neakvoan intersection during the peak hour at this intersection





3.3.2. Peak hour volume (PHV)

An excel program is used to analyse the traffic account to specify the peak hour. From the site investigation and traffic count, the following conclusions were observed that peak hour at Neakvoan intersection is found to be between 17:00 to 18:00. The total traffic volume during this hour is 6,693 pcu/h. Motorcycle is the highest volumes that passthrough intersection during peak hour and bus is the lowest volumes. This volume and peak hour (17:00 to 18:00) is significant in the use of analyse the level of service, design traffic signal and do simulation.

3.3.3. Peak hour factor (PHF)

Peak hour factor (PHF) is the hourly volume during the maximum-volume hour of the day divided by the peak 15-minute flow rate within the peak hour. Table 4 shows peak hour factor of each directions.

3.3.4. Saturation flow rate

Saturation flow rate represents the main parameter that has a major effect in the capacity of intersection or represents the equivalent hourly rate at which previously queued vehicles can traverse an intersection approach under prevailing conditions, assuming that the green signal is available at all times and no lost times are experienced, in vehicles per hour or vehicles per hour per lane.

Table 4 Peak	hour	factor	(PHF)
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Direction	Movements	PHF
	LT	0.96
Russian Blvd (from Techno)	TH	0.98
	RT	0.95
Russian Blvd (from Kdan2)	RT	0.96
	TH	0.95
	LT	0.62
St.132	TH	0.79
	RT	0.99

Note: LT: Left-turn; TH: Through; RT: Right-turn

Table 5 Saturation flow rate by direction

Direction	Saturation flow rate (veh/h)
Russian Blvd. (From Techno)	5577
Russian Blvd. (From Kdan2)	5496
St.132	5253

4. Alterative solutions

In this study, we are searching for a better solution to reduce the traffic congestion at Neakvoan intersection. Based on the possibility of redesigning geometry and changing the directional traffic flow at this intersection, we considered 3 alternative solutions below for comparing with the existing traffic condition (Alternative 0).

4.1. Alternative 1

The first proposed alternative solution is suggested to: provide left turn movement on Russian Blvd. in the direction form Techno to Kdan2. Fig. 7.a shows the conceptual redesign of this alternative solution.

4.2. Alternative 2

The second proposed alternative solution is suggested to: (1) provide left turn movement on Russian Blvd in the direction from Techno to Kdan2 and (2) provide left turn movement on Russian Blvd in the direction from Kdan2 to Techno. Fig. 7b shows the conceptual redesign of this alternative solution.

4.3. Alternative 3

The third proposed alternative solution is suggested to: (1) provide left turn movement on Russian Blvd in the direction from Techno to Kdan 2, (2) invert existing one-way on St.221, (3) lengthen one-way road 200m of St.221, connecting from

Kampuchea Krom Blvd. to Russian Blvd. and direction respectively and (4) change St.225 to one-way road with the length of 265m, connecting from Russian Blvd. to Kampuchea Krom and direction respectively. Fig. 7c shows the conceptual redesign of this alternative solution.

Table 6 Simulation re	sults of	Queue	length	and 7	Гime	delay
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Indiastor	Direc	Alternative Solutions			
mulcator	-tion		Alt.1	Alt.2	Alt.3
	EB	267.9	248.5	258.8	105.3
Queue	WB	273.3	204.2	271.5	197.1
(m)	SB	88.1	87.2	85.9	81.4
(III)	NB	0.0	0.0	0.0	234.8
	FB	10.8 (B)	231 2 (F)	296.5	39.3
	LD	10.0 (D)	231.2 (I)	(F)	(D)
Time	WB	15.1(B)	146.8 (F)	323.8	43.0
Delay				(F)	(D)
(a/wah) SP		193.7	60.6(E)	60.6	33.6
(s/ven)	30	(F) $00.0(E)$	(E)	(D)	
	NB	None	None	None	52.4
	IND	None	None	None	(C)
Note:					

EB: East Bound (from Techno)

WB: West Bound (from Kdan2)

NB: North Bound (from St.132)

SB: South Bound (from St.132)

SB: South Bound (from St.221

Table 7 Finalized results of Queue length and LOS

	Queue	Level of	Service	
Option	Length(m) Improve (%)		Delay (s/veh)	LOS
Existing	629 m	0.0%	50	D
1	540 m	14.2%	159	F
2	616 m	2.1%	261	F
3	384 m	39.0%	40	D

The simulation was run for 3600 s to find the optimal Queue length and Level of Service at Neakvoan intersection. The traffic data used as input is that during the evening peak hour (17:00-18:00). Traffic volumes (PCU) are input to all movements of the road such as left-turn, through and right-turn. Simulation run as a system with the proposed one-way street. Signal timing also is set in simulation to figure out the shortest Queue length and the reasonable Level of Service of each alternative solutions. The results in table below indicate the values of queue length and time delay that we obtained from simulation (VISSIM) in 3600 s. The three proposed alternative solution improve traffic flow by reducing the queue length of vehicle that passthrough the intersection.



Fig. 7. The conceptual redesign of Neakvoan intersection: Alternative 1 (a), Alternative 2 (b), and Alternative 3 (c)

5. CONCLUSION

The results of the traffic analysis of the area round Neakvoan intersection, it is noticed that the problem is concentrated in all the directions of the intersection. To improve the traffic performance operation of this area, it is necessary to adopt several alternatives to reduce queue length, delay time and improve the level of service. The traffic volume on road Russian Blvd., from Techno to Kdan2, is very high and phasing design of existing traffic signal need to be changed for balancing the traffic flow. One-way traffic on St.215 also caused the problem.

In conclusion, the results revealed that proposed solution with alternative 3 is the best solution among three. The level of service (LOS) D improves better than the existing, queue length is shorter and traffic flow at intersection improve up to 39% compares to the existing. Therefore, the road geometry would provide left-turn on Russian Blvd., direction from Techno to Kdan2. Traffic signal is changed to balance with the present traffic volumes, the existing one-way traffic direction on St.221 is inverted the direction and St.225 is changed to one-way street to the pair with St.221.

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