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Reducing traffic congestion during flyover construction: A case study of flyover construction at the intersection 2004, Phnom Penh, Cambodia

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Abstract: *The issue of traffic congestion in Phnom Penh, exacerbated by rapid population growth and construction of flyovers, underscores the need for effective traffic management strategies. In particular, efforts to mitigating congestion during flyover construction, is equally critical for ensuring smoother traffic flow and minimizing disruptions for commuters. This study proposed and evaluated several alternative solutions to minimize traffic congestion during the flyover construction period at busy intersection (i.e., Intersection 2004) in Phnom Penh. Traffic and related data were collected in October 2023 and a micro traffic simulation software was used to analyze traffic data and to evaluate alternative solutions. Results showed substantial reduction in the traffic congestion during flyover construction at Intersection 2004, lowering overall queue length by 30% to 40% and also improving vehicle travel time, compared with the common practices of flyover construction. The findings provide insights into urban traffic management planning, thus help optimizing traffic congestion, enhancing road safety, and improving overall commuter experience during construction process of major intersections in city.*

Keywords: Traffic congestion, Flyover construction, Phnom Penh, Traffic simulation, Traffic management

1. INTRODUCTION

1.1 Overview

Phnom Penh is the capital city of Cambodia and is home for 2.35 million population in 2024, the population increased by 3.13%, compared to 2023 [1]. In Phnom Penh, there are over 500,000 cars and around 2 million motorbikes [2]. The more population increases, the more congestion become. Traffic congestion becomes more serious issue in Phnom Penh, especially during peak hours, both in the morning and in the evening, due to the rapid population growth, vehicle growth, illegal parking, poor driving behavior, limited roadway capacity, and inadequate transport infrastructure. Traffic congestion yield several negative impacts, including waste of time, delays in transportation, accidents, fuel consumption, and pollution to the environment. Furthermore transport infrastructure have been constructed in recent years, including flyovers, roads, airports, ports, and railways to supply the growth of population and vehicles. In urban areas, construction of flyovers are helpful for managing traffic flow at major intersections because they shorten travel time, reduce congestion, increase pedestrian safety, and provide space for emergency vehicles to move quickly [3]. Until today, Phnom Penh already has constructed seven flyovers, one flyover is under construction (i.e., Preah Monivong Flyover) and another flyover is on planning (i.e, known as the 2004 Flyover [4] or as Kong Sam Ol Flyover [2]). The 2004 Flyover is located at the intersection between the Russian Federation Blvd, Samdech Chaufea Veang Kong Sam Ol Blvd (Street 2004) and Street 2011. The 2004 Flyover was designed to have 516.2 m long, of which 233.9 m for main bridge along the Russian Federation Blvd, 15.8 m for width and 5 m - 5.5 m height [4]. This flyover has been planned to be built by local construction company (i.e., Overseas Cambodia Investment Corporation (OCIC)), with the total estimated project cost of $10 million and take 16 months to complete [2].

The 2004 Flyover construction will use around 70% of the current road space into construction and remain around 30% for traffic flow. Bottlenecks, slower speeds, and long trip times will be the problems during construction. This study will focus on minimizing traffic congestion during

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flyover construction using a micro traffic simulation (i.e., PTV VISSIM software). There are three main objectives in this study: (1) Understanding current traffic before construction, (2) Predicting traffic congestion during construction of flyover at the intersection 2004, and (3) Proposing alternative solutions to minimize traffic congestion during construction.

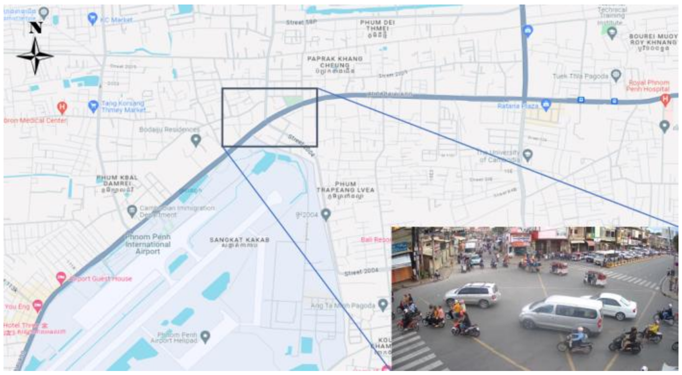

Fig. 1. The intersection 2004 currently (year 2024)

Fig. 2. The 2004 Flyover on planning [5]

1.2 Literature review

According to previous research, during flyover's construction at the Surabaya Intersection in Banda Aceh, Indonesia, analysis's conclusions showed that traffic loading has increases of up to 34% and 37% and Level of Service (LOS) declined from B to C [6]. Finding out how Rajagiriya flyover in Indonesia affected commuters and nearby communities during construction was the purpose of this study. Questionnaire and focus-group discussion is the primary data, and road development authority and department of survey (traffic data) is the secondary data. After analysis and comparison, the author suggests: giving a floating lance, regularly operating the bus priority lane, providing an extra lane for traffic during peak hours, especially in the morning; limiting or prohibiting U-turns around flyovers; joining the road network regularly; and introducing a one-way vehicle flow pattern [7]. The Antapani flyover construction make traffic congestion more serious. Research methodology is using deductive and inductive, deductive method is refer to PKJI 2014 and inductive method is used approaching model of drainage construction. Three alternative solutions had been proposed. The solution 1: increase road capacity, abutment works reduce traffic congestion reaching up 84% compared to existing maximum queue length, bridge wall works reduce traffic congestion reaching up 91% compare to maximum queue length existing. The solution 2: scheduling construction method, abutment works doesn't have any different queue length compare to existing condition, bridge wall works reduce traffic congestion reaching 55% compare to maximum queue length existing. The solution 3: the combining solution: abutment work the same as solution 1, bridge wall works reduce traffic congestion reaching up to 93% compare to maximum queue length existing [8].

Furthermore, the surrounding road network during the construction of urban road project will encounter a huge impact, traffic problems therefore emerged. This paper used the professional simulation software PTV VISSIM to analysis the impact of Qiwan road during the construction project. After collected data (traffic volume), simulation resulted with prediction that traffic load at Qiwen road will leap, level of service decrease B or C to E or F grade, queue length and traffic delay increase three to four time during the construction at Yangtze river road. The resulted of this paper is introduce one-way, closed turn left, curb parking prohibition, signal phase and phase sequence optimization [9]. Improving Urban Traffic Flow at Congested Signalized Intersections in Phnom Penh: Case Study of Neakvaon Intersection also use PTV VISSIM for running simulation, author proposed alternative solution base on possibility of redesigning geometry and changing the directional traffic flow at the intersection. Three alternative solution had considered: (1) direction from Techno to Kdan2 can turn left along Russian Blvd, (2) direction from Techno to Kdan2 and Kdan2 to Techno can turn left along Russian Blvd, (3) direction from Techno to Kdan2 can turn left along Russian Blvd and invert one-way on St.221, connecting to from Kampuchea Krom Blvd to Russian Blvd and change St.225 to one-way connecting from Russian Blvd to Kampuchea Krom Blvd. Author select best alternative solutions by compared queue length and LOS (level of service), in conclusion the third alternative solution is the best alternative solution [10]. Another study about improve traffic flow at Kdan Pir intersection, Phnom Penh, author chosen Autodesk infraworks for run traffic simulation. Six alternative options had been proposed and selected the best option by compared queue length, mean travel time and number of vehicle trip arrived, as the key indicator [11]. Traffic modelling has played an important role in all areas of transport infrastructure and it is the microscopic simulation program for modelling multimodal transport operations. For realistic and accurate in every detail before their implementation, PTV VISSIM can create the conditions for testing various operating scenarios [12].

In India, travelers were encouraged by the traffic police to take the detour route in order to avoid the traffic jams caused by the closing of the Sarita Vihar Flyover for renovations. Additionally, The traffic police also recommend that those heading to the railway or airport choose an alternate route to avoid delays [13]. Traffic advisory in India also recommended for used detouring route during Shilpa's flyover construction [14]. In Thailand, while Lam Sali flyover construction traffic police will open only two lances, one inbound and one outbound. Using detouring route were advised to driver for avoid the construction area [15]. Because of heavy traffic congestion at construction site of Preah Monivong Flyover, the Phnom Penh Capital Administration convene an emergency meeting to find a solution. As a result of meeting the Phnom Penh Capital Administration , including: (1) Keep traffic flowing by keep fence as small as possible, (2) Increase police force in peak hour, (3) Saler must stop using sidewalk for sale and buyer must stop using side of road for buy, (4) The Department of Public Works and Trasport shall study of ferrying from Koh Nora to Chroy Changvar and from Koh Nora to Koh Pich, (5) Use Google Maps for see traffic congestion and choose another road is there is an option [16]. Also announcement to use detouing route for inbound city and outbound city during construction of Preah Monivong Flyover [17]. Another Announcement from Phnom Penh municipality at Phsar Dey Huy flyover to prohibit all large trucks from turning left from all directions during construction [18].

In summary, many country using detouring route as a solution to minimize the traffic congestion during flyover construction include, Cambodia, Thailand and India. However, no study has demonstrated that taking a detouring route can reduces traffic congestion. Our study will use PTV VISSIM for traffic simulation, widening road and detouring route are going to be propose in alternative solution. The best alternative will be compared queue length and travel time as the key indicator.

2. METHODOLOGY

2.1 Site Observation

Before collecting data at the intersection, first of all, we went to the site to observe the surrounding environment, traffic flow, geometry, and driver behaviors. We were searching for the best location to install the camera, which should capture vehicles crossing the intersection clearly. After that, we observed traffic flow and queue length to recognize the most critical volume of vehicles crossing the intersection and the longer queue length. Then we were looking for the best road surrounding the site area for use as a detouring road. Signal timing was also noted during site observation.

2.2 Data Collection

2.2.1 Traffic Data and Queue Length

For data counting, we installed cameras at the corner of the intersection (Fig 3A) and along Street 60K (the detouring route). Recording was done on Wednesday, October 25th, 2023, during peak hours on 7:00 – 8:30 in the morning and 17:00 – 18:30 in the evening. After the recording was done, we counted the vehicles from the videos recorded by type, such as motorcycle, car, Bajaj, Remork, minibus, bus, light truck, and bicycle. We measured speed by using a speed gun and an app from the phone called Speed Gun, which cost \$1.99. We measured all vehicles cross the intersection, such as motorcycles, cars, Bajajs, remorks, mini-buses, light trucks, and bicycles. While the cameras were recorded, we also measured the queue length in four directions: street 2004, street 2011, and Russian Federation Boulevard inbound and outbound. We marked the side of the road every 20 m (Fig 3B) and recorded the queue length every 5 minutes, also recording the maximum queue length. The queue length that we measured is the distance from the stop line to the tail of the latest vehicle to stop.

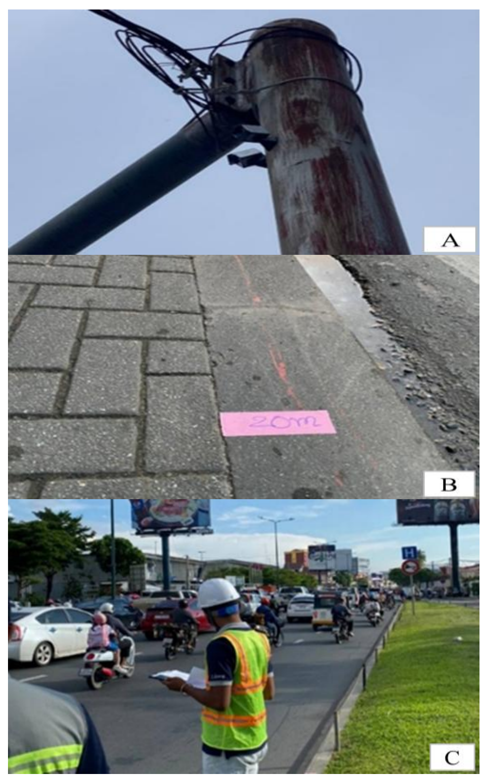

Fig. 3. Data collection activity

2.2.2 Geometry

We measured the geometry at the intersection, such as the road width of inbound and outbound along Russian Blvd, Street 2011, Street 2004, and surrounding roads. We also measured lane width on every road and sidewalk along Russian Blvd. We use ruler meter wheel to measure, as the wheel move the distance will measure.

2.3 Simulation

The simulation program that has been selected for our study is PTV VISSIM (version 11.0). And there are four important stages before running simulation and collecting result.

- Stage 1: checking data from survey such as: traffic data, speed, geometry and queue length.
- Stage 2: build the model, start by determining the vehicle type. Add vehicle 3D model to software such as: motorcycle, bajaj and remork, then adjust the speed of vehicle. Set vehicle composition with vehicle type, speed and relative type of vehicle from each direction. Set driving behaviors, use Wiedemann 74 which is suitable for urban traffic and merging areas [19]. Create link with number of lane and determine length of every width lane, and use link behaviors type we had adjust, then create connector from link to link, than set the conflict areas and Create signal control. Set the vehicle inputs and vehicle routes, input volume of vehicle with vehicle composition and fill the vehicle routes with ratio of vehicles go straight, turn left and turn right.
- Stage 3: calibration, it is the process which the various parameters of the simulation model are adjusted till the model accurately represents the field conditions. There are numerous calibration parameters that can be modified, like driving behaviors, desired speed distribution, acceleration or deceleration distribution. We adjusted the parameters till the queue length in simulation less than 10% different comparing to observe queue [20].
- Stage 4: analysis results, first of all we need to set queue counters near signal heads for measure queue length and set vehicle travel times. Before running simulation, open evaluation configuration, then tick delays and queue counters. Then run the Simulation model and the results will be obtained.

3. DATA

3.1 Study Area

Known as the Century intersection or the intersection 2004, it is a four-legged signalized intersection located at Khan Por Senchey, Phnom Penh, Cambodia. This intersection is crossing between the Russian Federation Blvd, Samdech Chaufea Veang Kong Sam Ol Blvd (Street 2004) and Street 2011. Russian Federation Blvd is connecting between middle of Phnom Penh city to Phnom Penh Internation Airport and continue to Kampot by national road number 3 and to Preah Sihanouk Ville by national road number 4. According to site observation, the high volume of vehicles crossing the intersection 2004 is in morning around 7:00am to 8:00am and evening around 5:00pm and 6:00pm. About road surrounding site, only road on north side can use as detouring route. we also observed signal timing at intersection, Cycle length at the intersection is 149s, inbound and outbound along Russian Blvd is 65s with turn left 20s green time and street 2011 is 22s green time and street 2004 is 34 green time, all direction yellow time is 4s.

3.2 Traffic Data

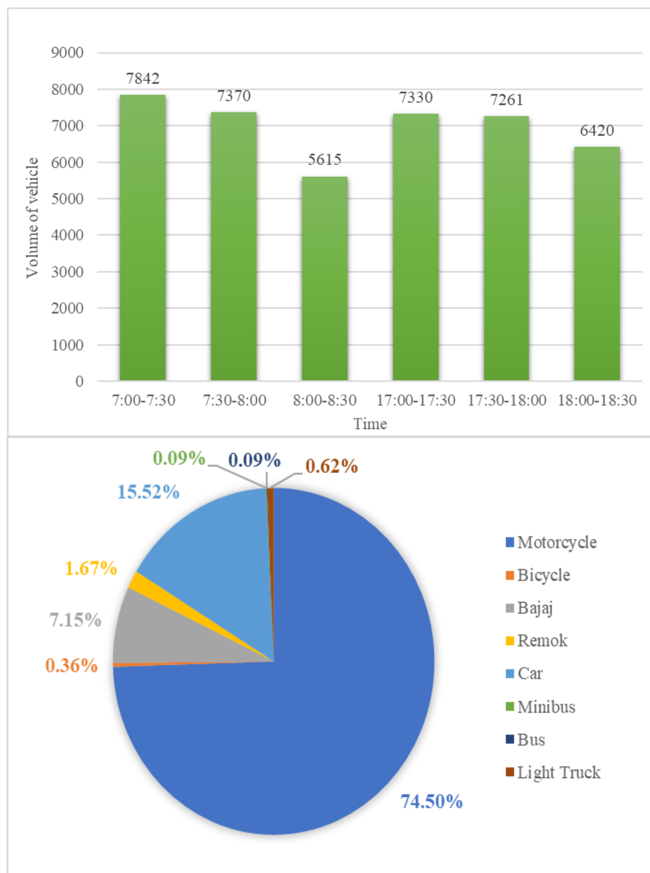

Fig. 4. Volume of vehicle and percentage of vehicle cross the intersection 2004

The traffic data was collected had shown in Fig 4 on above shows the total volume of vehicles that crossed the intersection during the counted period, the highest traffic volume was in the morning from 7:00 to 8:00 and in the evening from 17:00 to 18:00. The method of collecting data was counting from video records. And Fig 4 on below shows the percentage of all types of vehicles that cross the intersection, and we see that the motorcycle is the highest, followed by the car and the bajaj. The percentage of motorcycles was 74.50%, cars 15.52%, Bajaj 7.15%, Remork 1.67%, and light trucks 0.62%. bicycle 0.36%, bus and mini-bus 0.09%.

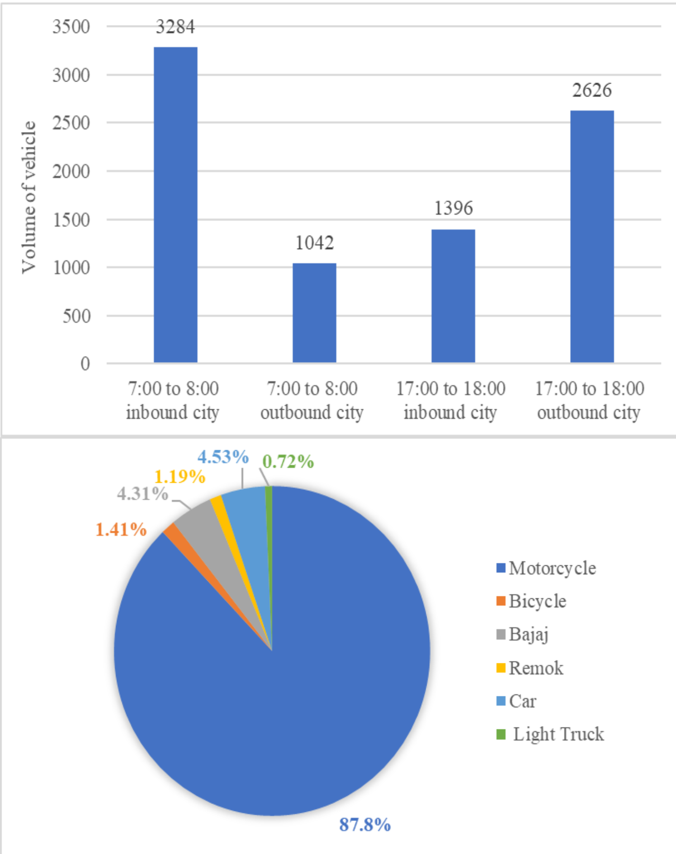

Fig. 5. Volume of vehicle Percentage of vehicle along street 60K (Detouring route)

The volume of vehicles along the detouring route also important for our study. Fig 5 shows the volume of vehicles along detouring route in morning 7:00 to 8:00 and in evening 17:00 to 18:00. Most vehicles driving along Street 60K are motorcycles, it is nearly 90% of all types of vehicles.

3.3 Speed

Speed gun and app from phone (Speed gun) were used to measure the speed of vehicles. The average speed is divided into two, in the morning (7:00 to 8:00) and evening (17:00 to 18:00). Four types of vehicles were shown in Fig 6, like motorcycles, bajajs, cars, minibuses, and buses. It shows that the average speed in the morning is slower than the evening, the average speed of a motorcycle decreases from 27.3 km/h to 18.8 km/h, the average speed of a Bajaj decreases from 17.1 km/h to 12 km/h, the average speed of a car decreases from 19.2 km/h to 14.8 km/h, and the average speed of a minibus and bus also decreases from 16.5 km/h to 12 km/h.

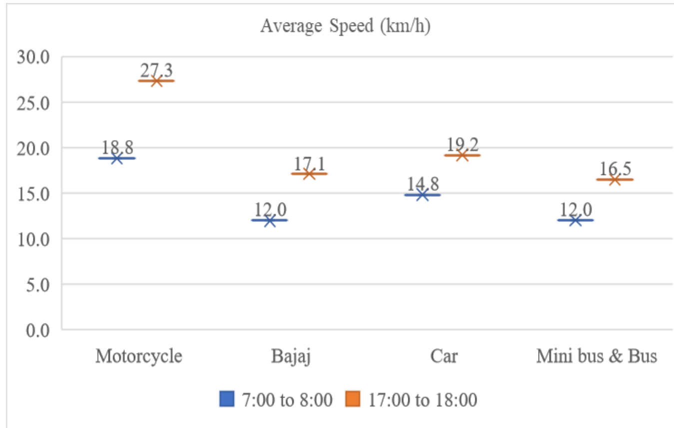

Fig. 6. Average speed at the intersection 2004

3.4 Queue Length

Fig 7 shows the maximum queue length from 7:00 to 8:00 in the morning and 17:00 to 18:00 in the evening. On Russian Blvd, the outbound city's morning queue length is 155 m shorter than the evening queue length of 654 m. Oppositely, the inbound city's morning queue length is 614 m longer than the evening queue length of 338 m. Streets 2004 and 2011 are similar between morning and evening.

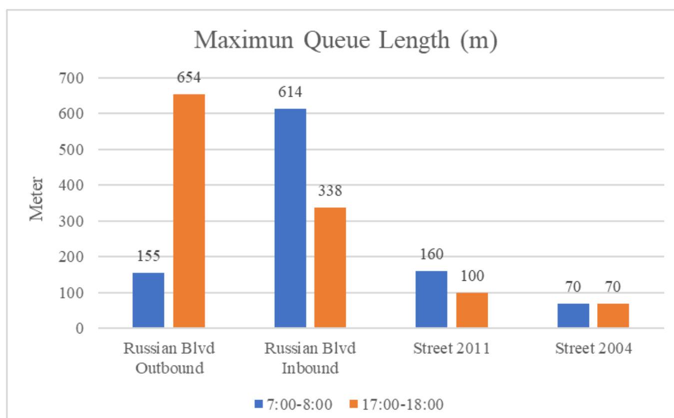

Fig. 7. Maximum queue length (meter)

3.5 Geometry

Fig 8 shows the road width at the intersection and surrounding road. On Russian Blvd east side, the road width is 21.3 m, with 6 lanes starting from 5 m on the north side and 2 lanes with 3.2 m, separated by a barrier with a width of 0.6 m, 2 more lanes with 3.3 m, and 1 more lane with 2.7 m on the south side. On Russian Blvd west side, the road width is 22.6 m and has 6 lanes, starting with 3 lanes on the north side with 3.6 m, separated by a barrier with a width of 0.6 m, 2 lanes with a width of 3.45 m, and 1 more lane of 4.3 m on the south side. We also measured the sidewalk, on Russian Blvd east side sidewalk width is 2.5 m on the north side and 4.5 m on the south side, on Russian Blvd west side sidewalk width is 2.5 m on the north side and 1.5 m on the south side. Street 2011 road width is 9.3 m, and Street 2004 road width is 14.8 m.

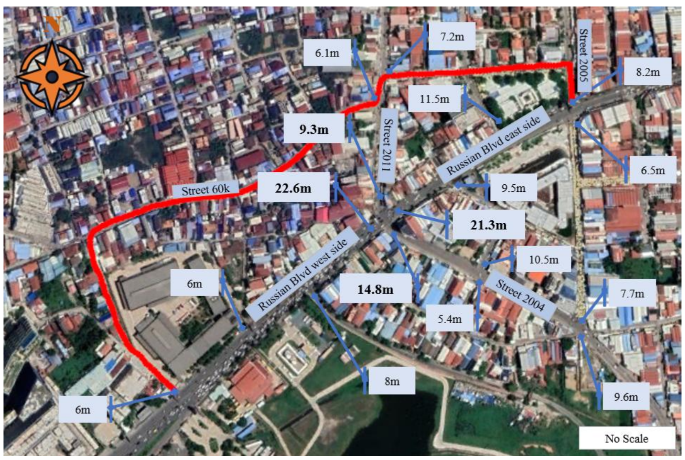

Fig. 8. Road width at the intersection 2004 and surrounding

4. ALTERNATIVE SOLUTIONS

Before proposed alternative solutions we need to comparing between existing observation, existing simulation and flyover construction. To model simulation correctly, the observed queue length and simulated queue length are not greater than 10% different [20]. The width of the flyover construction is 15.8 m, but in simulation we increased it to 17.8 m for some extra work, example: safety net around construction. We considered 4 alternative solutions below for comparison with the flyover construction condition, alternative 1 is converting sidewalks into driving lanes and alternatives 2, 3, and 4 had shown in Fig 9.

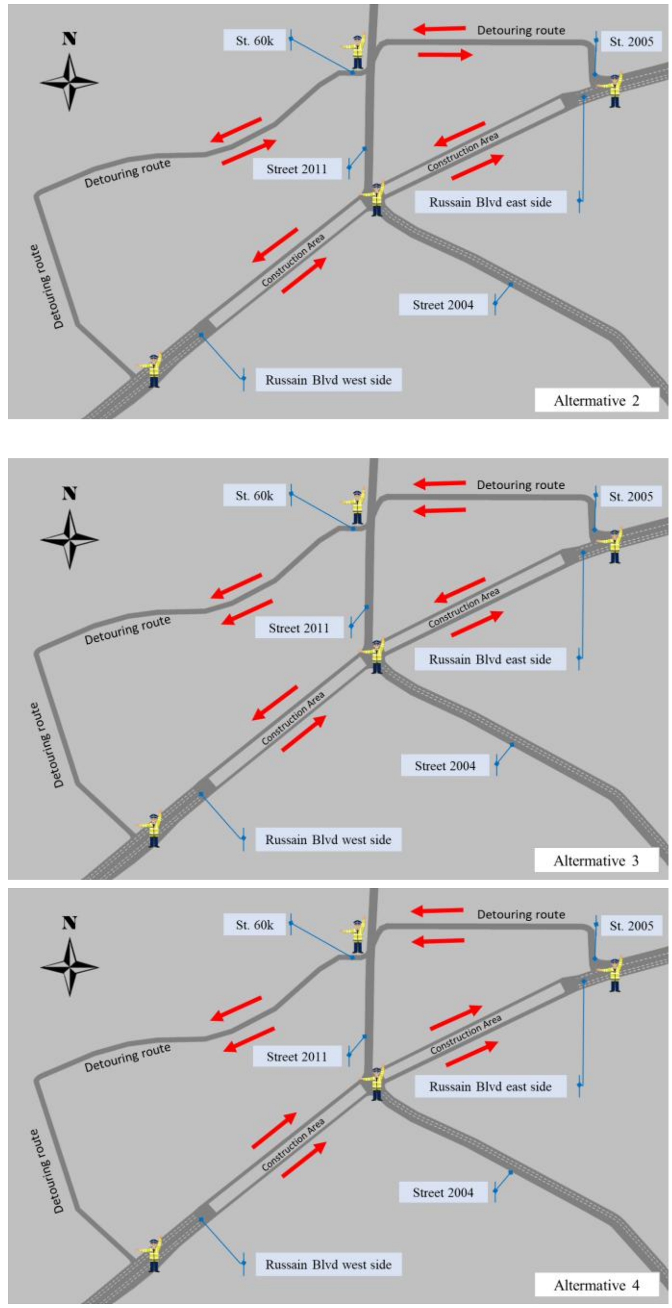

Fig. 9. Alternative solution 2, 3&4

4.1 Alternative Solution 1

The alternative solution 1 suggests widening the road width from sidewalk along Russian Blvd, we divide the sidewalk into a road for vehicles and keep one meter for pedestrians.

4.2 Alternative Solution 2

The alternative solution 2 suggests using the detouring route. When Russian Blvd congested, detouring allows you to find an alternate way to reach your destination, while Russian Blvd is still widening the same as alternative 1. This can involve taking different roads and paths surrounding construction. Detouring may take longer than the original route, but it can be necessary to avoid obstacles or reach your destination faster. The alternative solution is to use detouring route as a two-way direction and assume that 50% of the vehicle volume in the outbound city on Russian Blvd is using the detouring route, while Russian Blvd is still used as an inbound and outbound city. Detouring route on the north side of construction in the direction of the outbound city. Location of detouring: when we traveled outbound from the city on Russain Blvd, we turned right on Street 2005 and turned left behind the Pochentong Playground. We continued to Street 2011, then went to Street 60K and turned left to Russain Blvd. The detouring route distance was around 1000 m.

4.3 Alternative Solution 3

The alternative solution 3 is the same as the alternative solution 2, but for this solution, we suggest using the detouring route as a one-way traffic and one-direction outbound city. Vehicle outbound city is using the detouring route, and Russian Blvd. is still used as an inbound and outbound city.

4.4 Alternative Solution 4

The last alternative solution suggests using Russian Blvd as an inbound city and the Detouring Route as an outbound city. Vehicles used to use the detouring route to inbound city will use Russian Blvd instead and keep the detouring road as one way to outbound city, Russian Blvd still widening the same as alternative 1. In short, all vehicle directions inbound city use Russain Blvd, and direction outbound city use the detouring route. Then a vehicle from street 2004 in the outbound direction on Russian Blvd will use the detour route by crossing the intersection 2004 and turning left on street 60k.

5. RESULTS AND DISCUSSION

First of all we need to build simulation the same as real life by comparing queue length, the observed queue length and simulated queue length are not greater than 10% different [20].

Table 1. Different queue length (QL) between observed and simulated

		Russian Blvd Outbound QL (m)	Street 2011 QL (m)	Russian Blvd Inbound QL (m)	Street 2004 QL (m)	Total QL (m)
Morning	Observed(m)	155	160	614	70	999
	Simulated(m)	152.15	170.85	673.63	76.12	1072.75
	Different (%)	1.84%	6.78%	9.71%	8.74%	
Evening	Observed(m)	654	100	338	70	1162
	Simulated(m)	630.75	95.09	367.78	67.08	1160.7
	Different (%)	3.69%	5.16%	8.10%	4.35%	

Table 1. shows the difference between observed queue length and simulated queue length in morning and evening, we see that queue length between observed and simulated are acceptable. The queue length during flyover construction will increase three times by comparing queue length in total to simulated total queue length, total queue length during flyover construction is 3542.5 m in morning and 3210.93 m in evening, shown in Table 2.

In accordance with results in Table 2, it can seen that the best alternative solution in morning is alternative 2&4 and evening is alternative 4. By widening road in alternative 1 can reduce 11.1% in morning and 22.63% in evening comparing to flyover construction total queue length. Using detouring as two way traffic in alternative 2 can reduce around 30% it’s the best one, because traffic on detouring route not necessary to divert to use Russian Blvd. The alternative 3 is using detouring route as one way traffic can reduce 20% to 27%, direction inbound city on detouring route need to divert to use Russian Blvd, which make traffic around construction become poor. The alternative 4 is using Russian Blvd as inbound city and using detouring as outbound the city, it can reduce total queue length 35.71% in morning and 42.51% in evening. The alternative 4 can decrease conflict surrounding construction by using one way traffic on Russain Blvd and detouring route.

In Table 3 shows the vehicle travel time along Russian Blvd outbound city, inbound city and along the detouring route. It can seen that travel time along Russian Blvd inbound city is longer than outbound city during flyover construction both morning and evening, the volume and speed of vehicles were the reasons of that. All alternatives can decreased travel time, both inbound city and outbound city by comparing to flyover construction.

Table 2. Results of queue length (QL) of different alternative solution

		Russian Blvd Outbound QL (m)	Street 2011 QL (m)	Russian Blvd Inbound QL (m)	Street 2004 QL (m)	Total QL (m)	Reduction (%)
Morning	Flyover construction	1026.65	386.43	1858.76	270.66	3542.5	
	Alternative 1	924.63	369.9	1608.03	246.75	3149.31	-11.10%
	Alternative 2	143.33	138.6	1604.61	360.84	2247.38	**-36.56%**
	Alternative 3	138.78	142.21	1932.31	345.94	2559.24	-27.76%
	Alternative 4	622.99*	154.21	1131.99	368.12	2277.31	**-35.71%**
Evening	Flyover construction	1683.29	150.02	1068.08	309.54	3210.93	
	Alternative 1	1189.19	139.55	890.59	265.12	2484.45	-22.63%
	Alternative 2	717.02	127.31	906.35	272.97	2023.65	-36.98%
	Alternative 3	715.66	137.62	1430.49	280.25	2565.02	-20.12%
	Alternative 4	1003.29*	133.6	528.81	180.16	1845.84	**-42.51%**

(*) on detouring route

Table 3. Results of vehicle travel time (s) of different alternative solution

		Russian Blvd Outbound Vehicle travel time (s)	Russian Blvd Inbound Vehicle travel time (s)	Detouring route outbound Vehicle travel time (s)
Morning	Flyover construction	652.34	1091.18	-
	Alternative 1	534.37	783.96	-
	Alternative 2	258.97	730.52	342.65
	Alternative 3	273.6	721.11	268.67
	Alternative 4	-	615.59	478.19
Evening	Flyover construction	580.62	704.55	-
	Alternative 1	471.67	590.38	-
	Alternative 2	489.4	603.99	319.35
	Alternative 3	420.19	654.39	197.17
	Alternative 4	-	370.98	628.42

6. CONCLUSIONS AND FUTURE STUDY

Flyovers help to manage traffic by shortening travel times, reducing congestion, increasing pedestrian safety, and allowing emergency vehicles to pass quickly. Travelers may face considerable delays during the construction of these flyovers. The 2004 Flyover project will split around 70% of the present route for development, leaving approximately 30% for traffic flow. Bottlenecks, slower speeds, and longer travel times will be issues during construction.

Before proposed alternative solutions we have compared between existing observation, existing simulation and flyover construction. The accuracy between the existing observation and the existing simulation was acceptable, during flyover construction total queue had increased three times compared to existing in simulation. Four alternative solutions have been proposed. In the comparison of all alternative solutions, we can see that, in morning, the best alternative solution is alternative 2, which can reduce queue length by a total of 36.56%, and in the evening, the best alternative solution is alternative 4, which can reduce queue length by a total of 42.51%, shown in table 2. However, to make it easier for travelers and traffic police to control, we decided to use alternative 4 both in the morning and evening. In the morning, alternative 4 has comparable performance to alternative 2 as it can reduce queue length for 35.7% and it is easier for implementation. Travelers and traffic police won't be perplexed if we proceed the same route between morning and evening. The alternative 4 suggests using Russian Blvd as the inbound city and the detouring route as the outbound city.

In the recommendations of the future study, other congestion mitigations should considered in the future studies, including detouring route along street 60K crossing with street 2011 on the north side of the intersection 2004 and also consider on the steps of flyover construction effecting on the traffic flow in future study.

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