SOLUTIONS TO TRAFFIC CONTROL AND MANAGEMENT IN VIETNAM URBAN STREETS FOR BUS RAPID TRANSIT SYSTEM

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Abstract - The strategy for sustainable transportation development in Vietnam nowadays is focusing on public transport as the most important and long term solution. Bus Rapid Transit (BRT) has been designed and carried out in Hanoi. It will be carried out in Hochiminh city and Danang in the near future. There are issues to be considered. The basic one is how to maximize BRT's advantages to attract customers, regarding to providing transit services with high quality, punctuality and reliability. Characterized by its own exclusive lane, BRT has always prioritization at intersections as well as along routes; this creates difficulties in case of narrow streets and mixed traffic condition in Vietnam. What can be done to allocate BRT lane or to negotiate between BRT and other transport modes in the shared lane to achieve the whole system efficiency? Actually, BRT buses run non-stop between two BRT stations in order to reach their highest economic travel speeds, therefore adequate solutions at intersections and along routes are indispensable. This study presents design solutions for BRT lanes and prioritization in Vietnam urban streets. Case study of BRT-1 in Danang city is also conducted with the help of traffic microsimulation tools VISSIM.

Key words - bus rapid transit; sustainable transportation; traffic control and management; bus prioritization; mixed traffic condition.

1. Introduction

Most of the big cities in the world are facing with traffic and transportation problems; they are looking for a transport mean that provides economics efficiency, eco-friendly environment as well as positive social effects. Congestion has been for long time constrained economics development and endangered human living condition. Under this circumstance, BRT has been recognized among the most cost effective and high quality public transport service in urban areas, which help mitigating traffic congestion and achieving goals of sustainable development [1].

Although BRT has been implemented worldwide, it is still brand new in Vietnam with unique mixed traffic condition characterized by high percentage of motorcycles and narrow urban streets. The motorbikes acquire for 70-80 percent of modal choice, more than that of any city elsewhere, even Bangkok, Taipei or New Delhi [2]. This traffic condition has been challenging Vietnamese transport planners and engineers on the way of providing traffic control and management solutions on urban streets, in order to operate BRT system successfully. How to provide BRT prioritization on street and at intersection adequately? What are BRT advantages to attract customers? What solutions for BRT running non-stop between 02 stations without negative effects on shared lane traffic, ensuring pedestrian's safety and advoiding traffic congestion?

To answer these questions, it is obviously needed thorough researches on traffic control and management of mixed traffic flow, accompanying with the investigation and analysis on geometric condition and traffic condition along BRT routes. The collected data set then can be used as input into traffic simulation tools to propose adequate and effective traffic control and management solutions.

2. Methodology

In this study, we surveyed traffic flow in urban intersections and along planned BRT-1 route in Danang city (Figure 1). The theories of traffic light computation and intersection capacity computation are also explored to support the calculation process.

The findings have been used to simulate traffic control and management solutions in VISSIM microscopic simulation tools.

BRT routes run along the most crowded on main arterial streets of the city. Actually, BRT's stations are placed at high Point of Interest (POIs), which generate high travel demand, e.g universities, high schools, business district centers, transportation hubs. Therefore, the most feasible and suitable urban arterials are the primary and secondary ones including 6 lanes or greater.

In this study, we focus mainly on the traffic control and management on urban streets, especially along routes and at intersections.

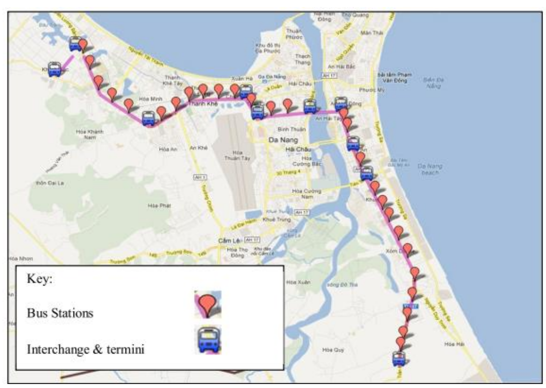

Figure 1. *BRT-1 and its stations [3]*

2.1. Study scope

2.1.1. The solutions on BRT routes

Basically the number of lanes plays an important role in allocation of dedicated BRT lane on streets, which can be considered on 6-lane streets or wider. The narrower streets are not feasible for exclusive BRT lane. In the world, BRT system could be classified into 03 priority levels based on street infrastructure, location of BRT's station, facilities, service, network configuration, ticket scheme and ITS system [4]. In our country, BRT was proposed at the second level, meaning BRT lane can be dedicated or shared, but BRT prioritization is compulsory.

2.1.2. The solution at intersections

At intersection, BRT stations are normally located nearby and solutions to BRT preemption are considered carefully. BRT has its own green phase at all intersections to run non-stop between two stations. There are two detector loops installed on road surface to identify BRT' entrance and leaving of the station in order to trigger the BRT green phase when BRT bus approaches the signalized intersection. This process is depicted as the following figure:

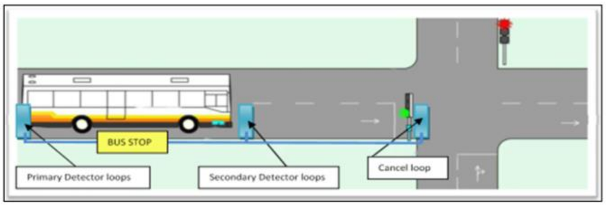

Figure 2. *Detectors for BRT prioritization [3]*

At intersections with BRT dedicated lane, traffic light provides preemption for both BRT back and forward directions. The best solution for BRT is its own phase isolated from other phases, but allows other vehicles' movements having without any conflict with BRT. Other vehicles' movements having conflict with BRT will be allocated in different phases or slipping phases (the green phase could be soon-closed, late-opening or soon-opening, late-closed) to serve the incoming BRT.

At intersections without BRT dedicated lane, to ensure BRT running efficiency, carriageway opening and approach rearranging are essential. In this case, it is necessary to consider the constraint of infrastructure, especially under- and on ground facilities along BRT routes, detector location and BRT stations.

2.1.3. Solutions for BRT stations

The allocation of BRT stations for passenger boarding and alighting depends on 2 situations of dedicated lane or shared lane. Specific alternatives could be:

- BRT station at the median, before or after the signalized intersections for passenger boarding and alighting in both directions. This option provides high comfort to passengers.

- BRT station at the median, before or after the signalized intersections, but serves only one running direction. This variation provides lower comfort to passengers.

- BRT station on the sidewalk, this option is considered only on narrow streets with shared lane between BRT and other vehicles.

The alternative a. and b. can be used in both cases: exclusive or shared lane, but there should be consideration on specific geometric condition and traffic control and management solution at the intersection. If necessary, a lane opening at the BRT station will help to increase BRT running efficiency.

The primary detector loop helps to indentify BRT entering and calculate stopping time at BRT station. This equipment will trigger the BRT prioritization at the intersection ahead.

The secondary detector loop will be activated when the bus leave BRT stop and recalculate stopping time of BRT bus, and the computed preemption signal will be recalculated appropriately.

The cancel loop detects the bus leaving out of stopping line and cancels the remaining preemption time.

All of these loops are installed on the BRT exclusive lane and do not influence on other vehicles.

2.2. Framework to design traffic light

2.2.1. Surveying of data

Parameters about geometric street condition: lane width, number of lane, median width, curb radius, sight distance, inclination, sidewalk width, etc.

Parameters about traffic condition: traffic flow according to time especially peak hour, average speeds of specific transport means in straight, left-turning, right-turning directions, waiting time and queue.

Parameters about traffic control and management: lane separation configuration, traffic signs, light cycle, number of phase, green, red and amber time.

2.2.2. Theory for calculation of traffic light

Calculation of cycle time and phase separation [5]

1. Sketching of intersection geometric configuration including traffic volumes (passenger car unit_PCU) [6];

2. Determining capacity parameter of approach $Z_{ci}=(N/S)_{ci}$;

3. Defining number of phase, considering separated phase for BRT;

4. Calculation of optimum light cycle T_0, checking of minimum light cycle T_{min}.

$$T_0 = \frac{1,5L+5}{1-\sum_{i=1}^{n}(\frac{N}{S})_{ci}} \qquad T_{\min} = \frac{L}{1-\sum_{i=1}^{n}(\frac{N}{S})_{ci}} \qquad (1)$$

Where: L is the sum of lost time at the beginning phase (s); N is the traffic volume in approach *i* (PCU/h); S is the saturation flow of approach *i* (PCU/h).

5. Calculation of maximum saturation flow, the ratio $(N/S)_{ci}$ and sum of all $(N/S)_{ci}$, the lost time t_L on each phase;

6. Caculation of effective green time for each phase t_c^{ch} and designed green time for each phase t_x

$$t_x^{ch1} = \frac{N_1}{N_1+N_2}T_x = \frac{N_1}{N_1+N_2}\left(T_{ck}-L\right) \qquad (2)$$

$$t_x^{ch2} = \frac{N_2}{N_1+N_2}T_x = \frac{N_2}{N_1+N_2}\left(T_{ck}-L\right) \qquad (3)$$

$$t_x^{ch} = t_x + t_v - t_L(s) \qquad (4)$$

7. Checking green phase to ensure enough time gaps for pedestrian crossing, $t_b = (B/V) +5(s)$, where B is the lane width and V=1.3m/s is pedestrian speed.

8. Presenting of traffic light and phases.

Phase-slipped or phase-shifted control [7]

In this phase formation, the green phase could be soon-closed, late-opened, or both late-opened and soon-closed. This option of traffic control utilizes green time, minimizing conflicts at intersection and avoiding separated phase for BRT or left-turning flow. However, inadequate operation can result in complicated traffic control, negative influences on drivers, resulted in ineffective and unreasonable traffic control. Therefore, it is recommended to consider the following propositions for the extent of phase-slipped and phase-shifted control via Z (level of service factor) and the difference of Z on various approaches.

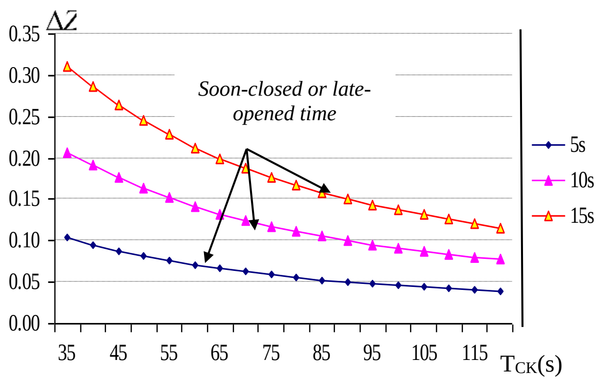

Figure 3. *Difference in Z factor in case of soon-closed or late-opened operation*

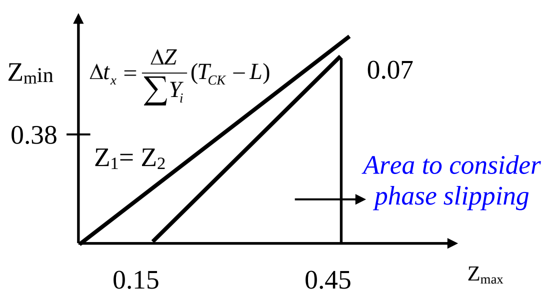

Figure 4. *Area to consider phase-slipped operation at signalized intersection where left-turning ratio less than 25%*

3. Case study of BRT-1 in Danang

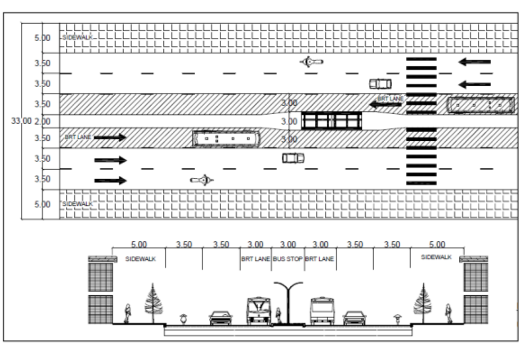

Figure 5. *Cross section design on Nguyen Luong Bang – Ton Duc Thang street (B<38m) [8]*

From the feasibility and preliminary study, the cross section of BRT-1 was designed based on street width. The BRT dedicated lane was allocated for street width B > 38m, otherwise shared lane would be implemented. All urban streets along BRT-1 route have been investigated thoroughly to propose suitable lane configuration and BRT station location. The following figures illustrate several findings.

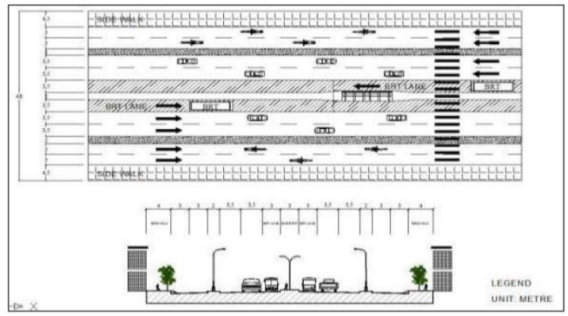

Figure 6. *Cross section design on Ngo Quyen – Ngu Hanh Son street (B>38m) [8]*

With the length of 24.9 km, BRT-1 connects 37 stations, 2 depots and runs through 62 intersections, including various types of traffic control and management [3]. The attention has been paid to 07 most important intersections with complicated geometrical configuration. The additional 17 intersections will be simulated in technical planning and integrated with above complicated ones to prove the efficiency of detail design.

Figure 7. *Simulation of mixed traffic flow in VISSIM with dedicated phase for left-turning vehicles*

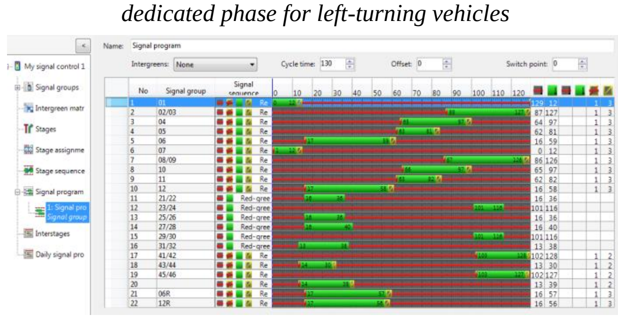

Figure 8. *Signal programs and signal groups*

We applied our theory of phase-slipped and phase-shifted calculation in the VISSIM simulation tool for traffic light design. Released in 1992, VISSIM is a microscopic, time step and behaviour based simulation model developed to model urban traffic and public transit operations. It is regarded today as a leader in the arena of micro-simulation software [9].

The results have shown the potential application of this calculation on finding suitable BRT phases to support its prioritization. However, the results are more accurate in the signalized intersections than in the complicated intersection including both signal and roundabout. It is due to our proposed theory is based mainly on the investigation and analysis of signalized intersection.

4. Conclusion

The study has been conducted to develop solutions for traffic control and management for urban streets with BRT operation. Along the route, it is reasonable to operate BRT with exclusive lane when street width is greater than 38m, and shared lane in another case. This solution facilitates BRT running as well as other vehicle movements. However, it is necessary to consider the u-turn locations of other vehicles in order not to affect on BRT operation.

The traffic control at signalized intersections has been focused more on special phase or phase-slipped and phase-shifted operation for BRT. These solutions ensure BRT preemption with the support of detector loops installed on pavement surface. The traffic simulation proved that the proposed calculation generated positive results in case of merely signalized intersections. More research in the future should be conducted to investigate the phase calculation at complicated intersection, controlled and managed by both signal and roundabout.

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