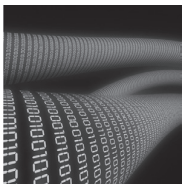

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Analysis of Bus Rapid Transit Problems in Cities with Dense Construction Area

Z. STOTSKO, Y. ROYKO, R. BURA, O. HRYTSUN
LVIV POLYTECHNIC NATIONAL UNIVERSITY, Stepana Bandery St., 12, 79013, Lviv, Ukraine
EMAIL: jurij.rojko@gmail.com

ABSTRACT
By the methods of field research, it is determined the primary factors of traffic flows on the sections of urban two-lane streets, where routes of tram and urban bus movement which have motion in general structure of traffic flow are laid. Using methods of documentary research and traffic simulation, there are received results of change of average operational speed of tram and urban bus movement during different periods of operation on the route; traffic flow delays connected with technological features of tram and urban bus routes functioning in zone of operation of tram and urban bus stops and controlled intersections. Using methods of traffic simulation, it is determined possible time losses and queue length in traffic flows in conditions of increase of traffic volume and change of its composition (increase of urban public transport rate).

KEYWORDS: speed of movement, traffic flow, traffic volume, traffic delay, urban public transport

1. Introduction

During improvement of existing and designing the new schemes of traffic management quite often the questions of justification the location of urban public transport (UPT) stops relatively intersections are appearing. The existing standards allow to locate stops either on approaches to intersections or after them depending from the UPT mode that carry the service of passenger flows on one or another routes. But, such determined engineering approach does not always meet interests of road users that is due to influence of many other factors, among which: geometric-planning parameters and configuration of intersection; traffic flow intensity and their redistribution in intersection zone; number of allowed directions of movement on approaches to intersection and after them; the way of pedestrian flows management within intersections and their intensity; presence of places of passenger flow generation and their location relative to the intersections; number and direction of UPT routes on intersections etc. Neglect of these factors and also their simultaneous imposition can cause additional time losses during crossing the intersections which are additionally differ between each other by configuration and the mode of movement control and, relatively, to worse the effectiveness of their work. Solving such problem in conditions of modern cities where the amount of transport and traffic intensity permanently increase, is current scientific-applied task which can have different decisions even within the same factors of traffic users, among which are intensity and its irregularity for traffic and pedestrian flows, traffic composition etc. Additionally, it is necessary to admit that UPT stops can be as equipped with parking pockets or without such pockets that also make changes in character of traffic flow movement, except those places where UPT moves in separated lanes. It is important to admit that in practice of designing it is not always possible to achieve the desired result even if for it was spent a significant amount of financial resources for redesigning the elements of road network on intersections and in zones of their action. Partly, this task can be realized using simulation methods that allows with sufficient level of results

accuracy to predict the effectiveness of implemented measures within existing and forecasted factors of road users.

2. Literature review

On the primary stage of the research lets analyze standard approaches to location the UPT stops relatively intersections of city roads and streets that are currently valid in Ukraine. It is stated [1] that stops of UPT that moves in general structure of traffic flow, as a rule, should be located after intersections on the distance not less than 5 m from pedestrian crosswalk and 20 m from intersection to loading refuges. Tram stops on separated lanes or in the middle of roadway should be located before intersection of roads and streets before pedestrian crosswalks on the distance not less than 5 m from intersection. Location of tram stops after intersections is allowed as exception in cases when after intersection big object of mass visiting is located (place of passenger flows generation) or capacity of street (road) lane after intersection is bigger than before it [1]. Having analyzed such standards, it is possible to say that equipment of stop is justified by the capacity of streets and intersections formed by them and also planning peculiarities from the view of laws of urban planning. But, guiding solely by laws of the norm, it is quite often not taken into account the specifics of transformation the pedestrian flow into passenger in within places of its significant generation, that leads to the necessity to equip the big amount of pedestrian crosswalks and to provide their appropriate regulation, and also that UPT passengers can make transfer between different routes and modes and for its realization it is necessary to perform additional movements in intersection zone. In conditions of controlled intersection, the crowding of pedestrians is happening that require provision to them separate phases that causes additional delay during traffic flow movement, in particular UPT [2]. Considering uncontrolled intersections, such additional delays can occur in case of necessity the realization of pedestrian crosswalks in their zones through all streets that create such intersections.

Let's consider the existing scientific approaches to the determination of movement delays on intersections and concentrate our attention on factors that cause them. All they are based on provisions that arrival of road users to intersection is a random process.

On controlled intersections, for determination of vehicle delay quite often such indicators are used: traffic light cycle duration; degree of saturation of movement direction; the duration of green signal to the traffic cycle duration ratio; traffic intensity on investigated direction; coefficient of variation of traffic flow intensity (mean square deviation to mathematical expectation the amount of vehicles that arrive to intersection during the cycle ratio); saturation flow [3-4].

On uncontrolled intersections of streets (roads) in one level time losses are determined with consideration of traffic intensity of the secondary street (road) in both directions in physical units, medium delay of one vehicle, coefficient of movement variation during the day, marginal interval that is necessary for vehicle from the secondary direction to ride on the main direction or to cross it [4].

Disadvantage of this method is that in both cases does not taken into account the impact of UPT stops, additional delay, predetermined by the need of intensive pedestrian flows in crossing in conditions of traffic light control, and also the fact that on uncontrolled intersections pedestrians cross the street not only on secondary directions but also on the main, where also, in this regard, appear delays in movement of vehicles. Besides, it is known that delays on all types (by regulation mode) of intersections can appear also because of road surface unevenness [3].

Considering time losses of pedestrians from crossing the uncontrolled pedestrian crosswalk, there, from the results of experimental research, is determined that the group of pedestrians accepts as acceptable for such crosswalk less interval between vehicles than separate pedestrian [5].

Considering UPT delays on controlled intersections, they can depend from such situations. Firstly, delay of traffic light signal is simple delay that appears because of big amount of vehicles that use the same lane ae UPT and connected with the capacity of intersection [6]. Secondly, delays can appear in connection with temporary crowding in lanes the buses, trolley-buses (or trams) that can have joint stops for boarding and alighting the passengers [7]. Priority traffic light control for UPT can have one of two forms – passive or active [8]. Passive traffic light control is development of such control systems, where the direction (street or road) that serve the route of UPT is always given more permissive signal in comparison with other conflicting directions. Such actions cause the increase of speed of the whole traffic flow that moves in given direction [9]. During active control, or control in real time regime, traffic light phase on the direction that serve UPT changes during the approach of such vehicles to the stop-line.

The aim of the study is determination of the change of the movement duration, average and maximum queue length depending from the change of intensity of traffic and pedestrian flows and the principle of UPT stops implementation in zones of city streets and roads intersections influence.

3. Materials and methods

In this study the results of simulation are reviewed that was carried out for determination the movement conditions and indicators of delay, vehicle queue length on uncontrolled intersection of Patona – Ryashivska Str. and controlled intersection of Horodotska – Korotka Str. and Kropyvnytskoho Sq. using specialized program software PTV VISSIM. These objects are chosen for the research because there stops are equipped due to standards. Simulation was to complete such stages:

- determination of traffic flow intensity and composition on all approaches to intersection;
- building of traffic lanes and constructive elements of intersection in PTV VISSIM using its copy and geographic informational data;
- determination of the duration of passage a zone of controlled intersection by one vehicle, maximum and average queue

length on approach through the Hohodotska St. (from city center) in the presence of UPT stop which is unequipped by parking pocket (existing model) and absence of the stop (model for simulation), when it is after intersection;
- determination of the duration of passage a zone of uncontrolled intersection in the main direction by one vehicle in two cases, when UPT stop is equipped in parking pocket (existing model) and without parking pocket (model for simulation) in the same simulation conditions as for controlled intersection;
- formation of results and their graphic interpretation.

Traffic flow intensity and composition, and also pedestrian flow intensity is determined from the results of field research using the method of operational tracking of traffic (determination of road users' indicators during short-term measurements up to one hour) in peak hours of working days of the week. Traffic flow intensity on the approach from Horodotska St. on controlled intersection of Horodotska – Korotka Str. and Kropyvnytskoho Sq. was 1252 auto/h under such traffic flow composition: automobiles – 60%; trucks – 8%; UPT (buses and trams) – 32%. Considered approach has 2 lanes in one direction. On the main straight and opposite direction of uncontrolled intersection of Patona – Ryashivska Str. measured traffic intensity was relatively 534 auto/h and 362 auto/h under such traffic flow composition: automobiles – 90%; trucks – 5%; UPT (buses and trolley-buses) – 5%.

After building the intersection model in specialized program software PTV VISSIM there was carried out simulation by duration of 1 hour aiming at determination the traffic flow characteristics for existing and project schemes.

4. Research results

Simulation was carried out taking into account sustainable growth of traffic intensity on the approach (20%) with unchangeable traffic flow composition with such assumptions. If vehicle rides on the intersection in the moment of turning on the yellow signal of traffic light, then it finishes the crossing of intersection. The aforementioned simplification leads to the fact that maximum number of the queue in the model reaches in the moment of turning on the permissive signal. In real conditions, at the time of starting the movement of the first vehicles from the queue some more vehicles arrive to its tail. In the moment of starting the movement of the last vehicle from the queue that was at the moment of turning on the permissive signal, its length on the approach to intersection is less than maximum but the extent (in vehicles or in meters) is bigger. That is why received results of maximum queue length can be used for the assessment of the effectiveness of control algorithm but not for assessment of the length of traffic lane, necessary for accumulation of the queue.

In the algorithm, it is not taken into account traffic flow composition, and also pedestrian movement through the intersection (let's consider that pedestrians have enough time for crossing the roadway during the permissive signal of the appropriate phase). Graphic interpretation of simulation results is given in Fig. 1.

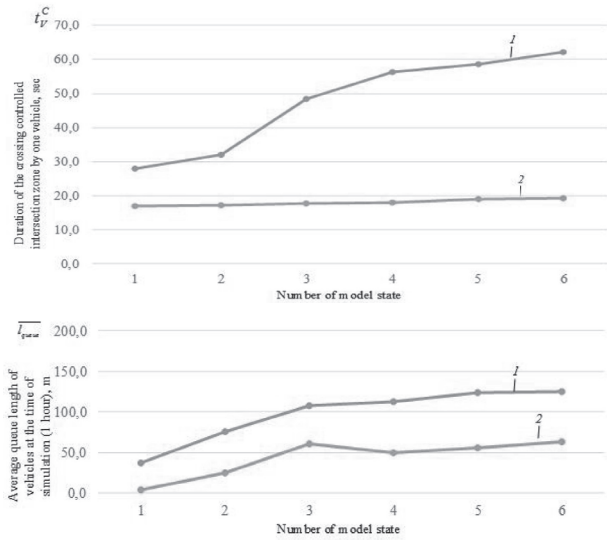

Fig. 1. Determination of the duration the crossing of controlled intersection zone by one vehicle (a) and the average queue length (b) on the approach from Horodotska St. (from the city center) providing the presence of UPT stop unequipped by parking pockets (1) and its absence (2) [own study]

Having analyzed Fig. 1a, it is possible to say that the change of the duration the crossing from the pointed approach the zone of controlled intersection by one vehicle with the presence of UPT stop unequipped by parking pocket changes with the increase of traffic intensity by 20% in an amount of 4% to 51%. Thereby, with the increase of the intensity in two times the duration of the crossing increases in 2,2 times. At the same time, when UPT stop is absent (moved after intersection) under the same parameters of traffic light control and the growth of intensity, the duration of the crossing changes from 2% to 5%, i.e. with the increase of traffic intensity in two times we receive the increase of crossing time in 1,14 times. Comparing among ourselves the simulation results of the duration of the crossing by one vehicle in conditions of presence and absence the UPT stop under the same value of intensity, we get the increase of the effectiveness from 1,66 times at the primary (measured) value of intensity to 3,22 times at its increase in two times. From the Fig. 1b, it is possible to say that similar trends are observed for the average queue length on the approach to controlled intersection.

In comparison with controlled intersections, where vehicle delay, apart from their dynamic characteristics, determines by the traffic light control regime, on uncontrolled intersections processes of randomness appear more often and are connected with the unevenness of vehicle arrival to the intersection, i.e. because of the random time intervals between them. Besides, such phenomenon of randomness is inherent to pedestrian flows which make the movement in intersection zone through uncontrolled pedestrian crosswalks. Graphical interpretation of simulation results for the main directions of uncontrolled intersections are given in Fig. 2

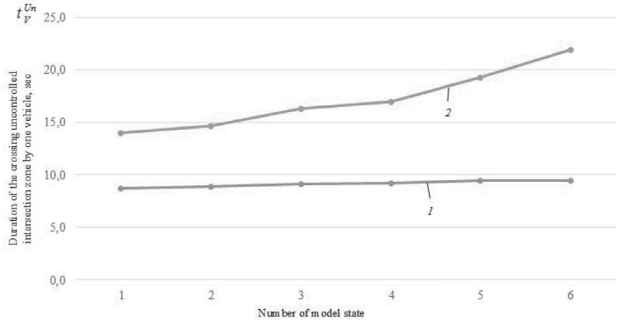

Fig. 2. Dependence of the duration the crossing of uncontrolled intersection zone by one vehicle by straight (1) and opposite (2) directions, where parking pockets for UPT stops are provided from the change of traffic intensity [own study]

Having analyzed Fig. 2, it is worth to admit that the duration the crossing of uncontrolled intersection zone by one vehicle is less than on controlled intersections which is due to the absence of delay connected with traffic light control regime. Besides, during increasing of the intensity such duration of the crossing between the steps of simulation does not exceeds 3%, and during the increase of summary intensity in two rimes (from 896 auto/h to 1972 auto/h) – from 8% to 56% that is less range of values in comparison to controlled intersections.

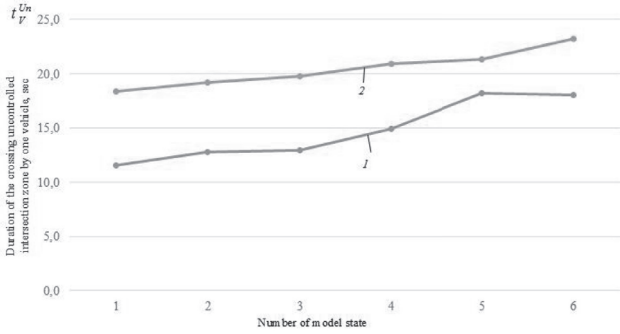

Fig. 3. Dependence of the duration the crossing of uncontrolled intersection zone by one vehicle by straight (1) and opposite (2) directions, where parking pockets for UPT stops are not provided from the change of traffic intensity [own study]

Similar trends are observed also at the change the same duration of the crossing, where parking pockets are not provided. There the difference in minimum and maximum values at the same change of the summary intensity on the approaches is 26% – 56%.

5. Conclusion

From the research results, it is possible to make such conclusions:

- the main factors are analyzed which have impact on the process of formation of delays in the movement of traffic and pedestrian flows in intersections control zones depending from the control mode and determined that they are: traffic intensity, traffic flow composition, and also the type of UPT equipment;
- it is determined that on controlled intersections the duration of the crossing in conditions of the absence of parking pockets on UPT stops and increase of traffic intensity on the approach from 1252 auto/h to 2354 auto/h increases in 2,2 times, and with the absence of such pocket in 1,14 times;
- it is determined that on uncontrolled intersections during the change of the summary intensity on the main direction the duration of the crossing is less than on controlled intersections, which is due to the absence of forced traffic light control and during simulation time (step-by-step increase of the summary intensity from 896 auto/h to 1972 auto/h) changes in range 8% – 56% providing that UPT stops are with parking pockets and 26% – 56% providing that UPT stops are without parking pockets.

Consequently, adherence to existing standards does not provide sufficient justification about the place and the mode of the UPT stop location, proceeding from the criterion of minimization the time of intersection zone crossing depending from the way of movement control on them and queues which appear on approaches to them.

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