7th INTERNATIONAL CONFERENCE
''TOWARDS A HUMANE CITY''
Environmentally Friendly Mobility
Novi Sad 6th and 7th December 2019

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EXCLUSIVE PEDESTRIAN PHASES AS A MEASURE TO IMPROVE PEDESTRIAN SAFETY ON SIGNALIZED INTERSECTIONS

Key Words

Pedestrians; Signal plan; Signalized intersections; Traffic safety

Abstract

Signal phases exclusively for pedestrians, i.e. exclusive pedestrian phase, demonstrate the idea of giving the priority to pedestrians at intersections located in area that attracts pedestrian flows, like central city zones. In this way pedestrian flows are served in safer way because the conflict between pedestrians and turning vehicles within the same phase are eliminated. However, other cities' experience indicates that although exclusive pedestrian phase are envisaged to be safer form for pedestrian flow serving, the effects of their implementation could be opposite. This paper describes conditions for introduction and the way of an exclusive pedestrian phase implementation within a signal plan. Based on the example of signalized intersection with signal plan containing exclusive pedestrian phase, the advantages and disadvantages of this solution were analysed from the perspective of pedestrians and other road users. Also, the locations in domestic conditions, which are convenient for implementation of this type of signal plan, were identified.

1. INTRODUCTION

Pedestrian safety is one of the main concerns of urban road safety having in mind that pedestrians are the most numerous group of vulnerable road users.

Traditionally, pedestrians use pedestrian crossings to cross the street safely but some complex urban traffic environment can make this action difficult. When it comes to signalized intersections, traditional signal plans imply that pedestrians are served simultaneously with left- and right-turning vehicles. That means that driver-pedestrian conflict still exists, although it is considered acceptable, so it is up to driver to give priority to pedestrians. At signalized intersections with intense pedestrian flows attracted by many facilities located in their neighbourhood, like central city zones, pedestrian trajectory around an intersection consists of three of four pedestrian crossings and sidewalks between them, which cause significant time delays and make pedestrians feel like second-in-queue road users. In order to enhance pedestrian level of service and safety, in some cities signal phases exclusively for pedestrians were implemented.

This papers deals with exclusive pedestrian phases and their potential to improve pedestrian safety on characteristic signalized intersections.

2. EXCLUSIVE PEDESTRIAN PHASE CONCEPT DESCRIPTION

Signal phases exclusively for pedestrians, i.e. exclusive pedestrian phase (EPP) or "Barnes Dance", demonstrate the idea of giving the priority to pedestrians at intersections located in area that attracts pedestrian flows. They imply that a signal plan consists of phases where one of them is reserved only for pedestrian and other ones for vehicles. During EPP pedestrians may cross the intersection transversely and diagonally. On the other hand, it is prohibited that vehicle enter the intersection during this phase, even for right-turning vehicles. In this way pedestrian flows are served in safer way because the conflict between pedestrians and turning vehicles within the same phase are eliminated and they need less time to cross all intersection legs at their travel route.

The idea of exclusive pedestrian phases originates from the first half of last century. First intersection where this idea has been implemented was located in New York. It was a pilot project. Since pedestrians were very satisfied with this solution, EPP were later implemented at more intersections. However, drivers were unsatisfied due to the greater time delays.

Today those phases are present in many countries, such as USA, Canada, Australia, New Zealand, Japan, the Netherlands and United Kingdom. They are a part of signal plans for busy intersections, like those located near bus station, rail station and attractive adjacent objects.

EPP implementation requires that some criteria must be satisfied. It is not enough just to have intense pedestrian flows – there is a need to provide enough space for pedestrian accumulation on sidewalks during signal phases for drivers.

There are two types of their implementation into signal plans:

- Regular implementation – when EPP is present in every cycle, at any time of day, and

- Irregular implementation – when EPP is present only sometimes or at certain time of day, in situations when a lot of pedestrian are expected at the intersection.

3. EFFECTS OF EXCLUSIVE PEDESTRIAN PHASE IMPLEMENTATION

Table 1 summarize advantages and disadvantages of EPP implementation from pedestrians' and drivers' point of view. Advantages and disadvantages are considered by comparing simultaneously serving of turning vehicles and pedestrian with exclusive pedestrian/driver phase. The huge advantage of this solution is the elimination of pedestrian-driver conflict. That means the minor risk of pedestrian accidents, faster left and right vehicle turnings and shorter pedestrian paths. Research from London indicates that EPPs can reduce the number of pedestrian casualties by 38%. However, the introduction of an additional, EPP implies longer signal cycle, which means greater time delays, i.e. waiting time for all road users. This triggers driver frustrations so rear-end collisions happen more often. Also, long waiting time causes more traffic offences.

Table 1. Advantages and disadvantages of EPP implementation

Road user group	Pedestrians	Drivers
Advantages	• Eliminated conflict points with drivers • Shorter trajectory over an intersection	• Eliminated conflict points with pedestrians • Faster driving of turning vehicles through the intersection
Disadvantages	• Greater waiting time	• Greater waiting time • More rear-end accidents

4. RESEARCH METHODOLOGY

The analysis was conduct in two stages. During the first stage it was investigating whether the exclusive pedestrian phase implementation is justified from vehicle and pedestrian time delay point of view. Based on the evidence from other countries, in the second phase a literature review was done with emphasis on road safety level on intersections having EPP implemented.

The first part of the analysis is conducted by running numerical simulation under following considerations:

- An isolated four-leg signalized intersection is considered (see Figure 1),
- Each intersection leg has one lane per direction,
- Tradition traffic signal plan consists of two phase, where main-road traffic flows with pedestrian flows across the side road are served in first phase and side-road traffic flows with pedestrian flows across main road are served in second phase,
- All lanes are 3.5 m wide and corner radii are 6 m,

- New traffic signal plan consists of three phase, where main-road traffic flows are served in first phase, side-road traffic flows are served in second phase and all pedestrian flows are served in third (exclusive pedestrian) phase,
- During EPP pedestrians are allowed to cross the intersection diagonally and horizontally,
- It is supposed that one half pedestrian flows need to cross only one street and second half needs to cross two streets,
- Traffic flows are homogenous, consisting solely of passenger cars,
- It is supposed that traffic flow distribution is the same at all approaches: 50% of vehicles go straight, 25% turn left and 25% turn right,
- It is supposed that pedestrian volume is the same on each pedestrian crossing,
- Two situations were considered: the ratio of main-road and side-road traffic volume was 3:2 and the ratio of main-road and side-road traffic volume was 4:1.

Vehicle time delay is calculated using Webster's formula [1] while for pedestrian delay it was used the model proposed by Marisamynathan and Vedagiri [2]:

$$D_{Avg} = D_{WT} + D_{CT} + D_{VIT} \quad [1]$$

where D_{WT} = average waiting time delay during non-green phases per pedestrian, D_{CT} = average crossing time delay during all phases per pedestrian and D_{VIT} = average-vehicular pedestrian interaction time delay during all phases per pedestrian.

Pedestrian level of service is determined according to categories proposed by Sahani, Devi and Bhuyan [3].

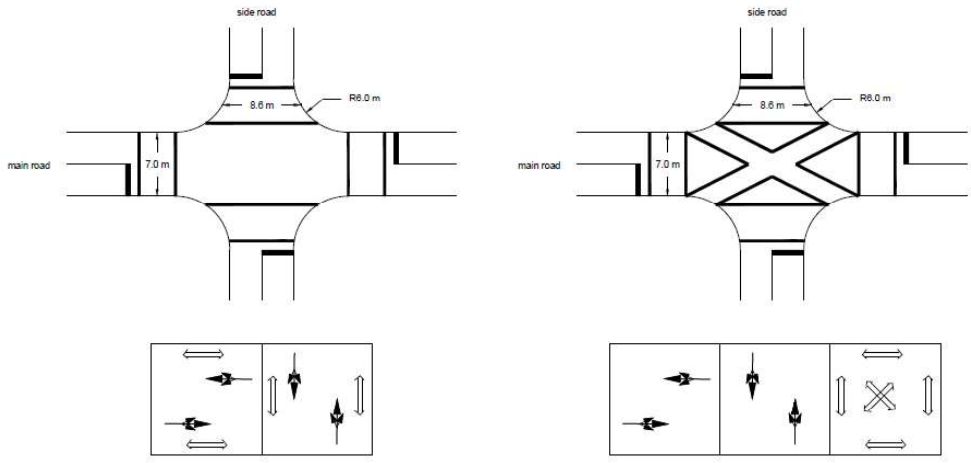

Figure 1. Intersection layout with different signal plan types: tradition signal plan (left) and EPP signal plan (right)

5. RESULTS

The data for the first analysis stage were obtained by numerical simulation. Main-road traffic volume, side-road traffic volume and pedestrian volume were varied while other factors kept constant. Table 2 summarize some results. The most important ones are following:

- Under above-mentioned conditions, vehicle time delay in the EPP signal plan is greater than delay in the traditional signal plan.
- Pedestrian time delay in the EPP signal plan is greater than their delay in the traditional signal plan because of the longer waiting time.
- From both vehicle and pedestrian time delay perspective, it is not justified to implement the EPP signal plan.
- There are ranges of vehicle and pedestrian volumes at which vehicle level of service in the EPP signal plan is one level below than in the traditional signal plan, so these cases could be considered reasonable for EPP implementation.

Hence, under simulated conditions, there is no such a combination of vehicular and pedestrian volume that makes the EPP implementation reasonable.

Table 2. Numerical simulation results

Total vehicle volume [veh/h]	Total pedestrian volume [pedestrians/h]		Traditional signal plan		EPP signal plan	
			Vehicle delay [s]	Pedestrian delay [s]	Vehicle delay [s]	Pedestrian delay [s]
350	A	2000	21	61	33	29
	B	760-1880	10-20	28-58	20-32	27-29
500	A	1720	20	49	33	33
	B	680-1680	10-20	24-49	21-32	30-33
800	A	1120	20	24	31	41
	B	480-1040	10-19	17-23	25-30	39-41
1000	A	800	23	22	32	49
	B	200-760	11-20	16-20	29-31	48-49

A – Maximal total pedestrian volume for which EPP is reasonable [pedestrians/h] (cycle ≤ 120 s).

B – Total pedestrian volume range at which vehicle level of service in the traditional signal plan is one level above than in the EPP signal plan.

The data for the second analysis stage couldn't be obtained from Serbia because there is no an intersection with implemented exclusive pedestrian phase (to the best of authors' knowledge). Consequently, it was analysed the evidence on EPP safety effects from worldwide.

According to pedestrian crash number and vehicle interaction severity prediction models for a sample of signalized intersections in Connecticut with either traditional signal plan or EPP signal plan [4], the probability of pedestrian conflicts decreases when pedestrians cross during EPP and increases when jaywalking or cross during

vehicle green phase while EPP is available. Also, compared with traditional signal plan intersections, those with EPP signal plan tend to have fewer pedestrian-vehicle crashes, but these crashes are more severe. This implies that EPP is only safer for pedestrians who wait for the green signal, not for violators.

6. DISCUSSION

Here obtained results indicate that EPP is not applicable for an intersection under considered conditions if the idea is to keep vehicle level of service. On the other hand, if the idea is to allow vehicle level of service to be one level below than in traditional signal plan, there are ranges of vehicle and pedestrian volume that satisfy this criterion. However, these results should be interpreted carefully because of numerous limitations. Here it was considered only an intersection with one lane per direction on each leg, with the same traffic flow distribution per allowed travel directions on each leg. The results may be different for different intersection geometry and different shares of turning vehicles. Also, it was supposed that one half of pedestrians have a need to cross the intersection diagonally, which is not always true. Pedestrian delay model was adopted and not calibrated according to local conditions. Also, when calculating minimal pedestrian green time it was supposed that 4 pedestrians start to cross the street simultaneously from one pedestrian crossing side (pedestrian crossing at considered intersection is 4 m wide), but this parameter was not check in real conditions. Those shortcomings are very likely to have a great impact on the results obtained here.

However, a simulation model for actuated controlled intersection, developed and calibrated based on field data from China, indicates that EPP is unsuitable for intersections with high vehicle volumes (>550 veh/h/approach), as well as when the pedestrian diagonal ratio and the vehicle turning ratio both reach 0.6 or more, EPP signal plan is recommended; otherwise, a traditional signal plan is recommended [5]. The importance of the share of pedestrian crossing the intersection diagonally in total pedestrian volume is also emphasised in Ma & Liu [6]: with the increase of diagonally-crossing pedestrian share, the performances of EPP signal plan are better than those of traditional signal plan. An economic model of safety and operational performance of these two signal plan types indicates that EPP is more suitable under high vehicle turning ratios and high pedestrian volumes [7]. There are also multi-approach methods for selection of an appropriate signal plan types. For example, Ishaque and Noland [8] have determined the suitability of various pedestrian phase types based on proportion of pedestrians to car users and the comparative value of time for pedestrians.

Although it was expected that an EPP signal plan will be pretty much safer than a traditional signal plan, the worldwide evidence indicate that the safety benefits are lesser than expected. It appears that an EPP should only be implemented at locations where it is more likely that pedestrians will obey traffic rules, where there are some conditions making greater risk for pedestrians and with significant vulnerable pedestrian share (children, old people and physically-impaired people)

is greater old and physically-impaired people. Safety paramount is a key criterion for implementing EPP [9], but the safety effects depend on pedestrian behaviour as it appears that safety benefits tends to be reduced because pedestrians act like they have a right to cross the street when parallel vehicular flows are served [10]. Contrary to the intuitive expectations, an EPP is recommended for intersections with low pedestrian volumes [4]. On the other hand, some researches indicate that EPP safety effects are very positive in small towns [11].

7. CONCLUSIONS

Although the results of this paper indicate that in many cases it is not justified to replace a traditional signal plan with an EPP signal plan, it doesn't mean that this idea should be rejected, especially because this research has a lot of limitations. Ultimately, if we consider pedestrians and drivers equally important road users, there is a room for setting the criteria in different way. Exclusive pedestrian phases are applicable in cities where pedestrians tend to comply with traffic rules, at locations with great number of pedestrians, especially vulnerable ones. In this case, they will create "a mass" during EPP making their safety improved by the idea on "safety in numbers".

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