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PEDESTRIAN CROSSING BEHAVIOUR AT UNSIGNALIZED CROSSINGS[1]

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Abstract

Pedestrian behaviour plays an important role in analyzing the operations of unsignalized intersections and isolated crossings, because a pedestrian creates a complex of interactions with vehicles at such locations. A crossing manoeuvre involves the pedestrian making a decision to accept a particular gap in the traffic flow. The "yes/no" nature of the decision gives gap acceptance a unique set of conditions that can be used in the analysis. The aim of this paper is to investigate pedestrians' traffic gap acceptance for street crossing in urban areas. The paper presents the most important studies that have been done in this area. Beside the basic concepts and methods of determining parameters such as accepted and the critical gaps, the paper shows the influence of certain factors on the length of the pedestrian delay, such as: pedestrians waiting time, the presence of illegally parked vehicles, built environment, the vehicles' characteristics (speed, size), pedestrians' characteristics (gender, age), etc.

Keywords-Pedestrian behaviour; unsignalized crossing; accepted gap; critical gap

INTRODUCTION

A pedestrian road crossing depends on a lot of factors which influence their decision and the way of road crossing (age and gender of pedestrians, drivers' behaviour, vehicles characteristics, road geometry, built street surroundings, etc.). Data base on factors which influence pedestrians' behaviour are formed on the basis of traffic video recordings, and often the

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experiments in controlled laboratory conditions are used. A special attention is directed to the span between the approaching vehicle and the pedestrian. A pedestrian road crossing includes his decision whether to accept the certain gap between the approaching vehicles in the traffic flow. For each gap between the approaching vehicle, the pedestrian has to make a decision ‘yes,or ‘no’, that is, whether the offered gap is to be accepted or refused. This decision gives the pedestrain’s accepted gapsa unique setoff conditions which can be used in statistical analysis and the analysis of pedestrian behaviour. The factors from the formed data bases represent the dependent or independent variables which are, by means of statistical tools, used for the evaluation of influences on pedestrian’s decision. In such way, certain models are modelled, and they are used for evaluating the probability of the accepted crossing gap. A logistic (logit) curve is most often used for the evaluation of accepted and refused gaps and it actually represents the probability of accepting gaps of certain lengths.

BASIC CONCEPTS OF PEDESTRIAN GAPS

A thorough review of pedestrian gap acceptance requires a familiarity with the various kinds of gaps that are encountered. There are gaps defined by the characteristics of the site (referred to as adequate gaps and critical gaps) and gaps dependent on the conditions present at the time a pedestrian attempts to cross (referred to as available, accepted, and rejected gaps) [1]. The available gap is the gap present for a pedestrian. If the pedestrian accepts the available gap (i.e., crosses the street within that gap), then it is an accepted gap; otherwise, it is a rejected gap. The adequate gap for a site is determined by dividing the crossing distance by the walking speed and adding an appropriate start-up time. However, while an approximate walking speed is used for such a calculation, the actual walking speed for each pedestrian will vary, largely depending on age and physical ability, along with the conditions present at the site.

The Highway Capacity Manual (HCM) defines the critical gap as “the time in seconds below which a pedestrian will not attempt to begin crossing the street. If the available gap is greater than the critical gap, it is assumed that the pedestrian will cross, but if the available gap is less than the critical gap, it is assumed that the pedestrian will not cross” [2]. The term “adequate gap” used in some studies is the same as the critical gap in the HCM.

There are several methods for determining the pedestrian accepted gaps. According to Yannis, accepted gaps are based on two time points: At the first point, the pedestrian is just ready to set foot on the street. In the second point, the head of the vehicle has just passed through the vertical virtual line indicating the pedestrian’s crossing path. Therefore, the traffic gap accepted was calculated as the difference in seconds between the two time points [3]. In a study conducted in the U.S. for gap acceptance analysis, the time each pedestrian arrived at the crossing and the time each vehicle entered the crossing were recorded. For vehicles that entered the crossing, their travel lane and stopping behaviour were recorded. The length of each gap was then calculated from the differences between the arrival times of two consecutive vehicles [1].

Using the data base of the accepted gaps for each location, the interval length and the pedestrian's attempt to cross the road are analysed. These analyses resulted in the graphs showing cumulative distribution of the accepted pedestrian gaps for road crossing. Figure 1 is the example of such a graph.

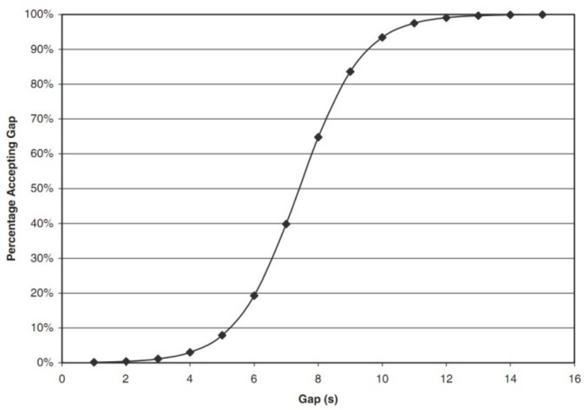

Fig.1. An example of cumulative distribution of accepted pedestrian gaps [1]

Values of the 85% of the accepted gaps in analyses are compared to critical pedestrian gap calculated for the certain speed in order to determine unsafe road crossings. Critical gap determination for road crossing which demands the speed value of pedestrian moving implies a strong connection between the speed of moving and the accepted gap. The value which has been chosen as average speed for a certain location determines the length of the critical gap.

LITERATURE REVIEW

Observing individual pedestrians' characteristics, such as the gender, it has been proved in research studies that women have higher values of time loss in relation to men, that is, they wait longer for the appropriate crossing interval [4,5]. In accordance with this, the research studies have shown that women spend 27% of time longer waiting at the pedestrian crossing [6], while the crossing speed is higher with men in relation to women [7,8].The waiting time of pedestrians for road crossing, as one of the parameters which appears in research studies, shows that with the increase of waiting time pedestrians become more impatient and accept shorter crossing gaps[9]. The same authors have concluded that the probability of accepting shorter time interval rises with the increase of the missed opportunities for road crossing.

The ability of different pedestrian groups to choose appropriate gaps depends on their ability to estimate the speed of the approaching vehicle and the time necessary for road crossing at the pedestrian crossing. This ability mostly depends on age and physical characteristics of pedestrians.

The experiment where the system of virtual reality was applied for simulation of the real traffic, implies that children aged 5-14 are those who perform most of the unsafe crossings, in relation to the older groups of the survey participants (older than 19) [10]. Also, the decision about road crossing is more often based on the distance than on the speed of the approaching vehicle. In another study [11] the authors have concluded that the participants mostly based their decisions on time interval (which included distance and speed), than just on vehicles' distance. The time for making the decision did not significantly influence the younger population replies. However, the older pedestrians made wrong decisions more often in relation to the length of the certain interval, if they were made to decide quickly. A similar research was carried out by a group of authors [12] who divided the participants into three age groups (aged 20-30, 60-70 and 70-80). The results showed that all age groups choose longer distances and shorter accepted gaps for the crossing at the vehicle's speed of 60 km/h compared to the speed of 40 km/h. This confirms the effect of the speed of the approaching vehicle on the accepted gaps as a risk factor which influences the decision about pedestrians' crossing for all age categories in the conditions of limited time for decision making. Choosing shorter gaps for crossing at speed increase, as well as choosing longer gaps for the older pedestrians has been proved in articles of many authors[13].

Observing the position of vehicles and pedestrians, the analysis of the participation of the pedestrians who accepted the gaps which lasted shorter than 2 s showed that these short gaps we usually chosen in case when pedestrians waited at the position which was closer to the trajectory of vehicles moving [14]. At the pedestrian crossings with the refuge island it was proved that pedestrians accept shorter time intervals between vehicles for road crossing when they have previously gone across the road part to the refuge island. Also, a part of the road from the refuge island to the opposite curb is crossed with shorter waiting time. This behaviour while road crossing is interpreted as pedestrians' adaptation to the traffic conditions and in that way reduces the total time necessary for the crossing [5,15].

The research carried out on the territory of Asia has shown that pedestrians who move in a group choose shorter gaps. Therefore, their behaviour in a group is more aggressive, and the procedure of road crossing is more risky. The authors explain this result with the fact that pedestrians found in a group might feel safer, therefore they behave more aggressively[16,17]. Taking into consideration the fact that in completely different traffic conditions, regulations, habits, as well as traffic culture, the results of the research studies carried out in Europe gave opposite results to those performed in Asia[3].

Influence factors from the data base which can be seen as independent variables serve for forming different mathematical models used for estimating the probability of accepting certain crossing gap length, as well as the probability of pedestrian road crossing as an independent event. One of few research studies of accepted pedestrian gaps carried out in Europe was done in Athens[3]. Based on the research results, a lognormal regression model was formed, and the results of the statistical analysis of elasticity showed that the distance between a vehicle and a pedestrian has the biggest influence on the accepted pedestrian gap. The following factor which has a big influence on the accepted gap is the presence of irregularly parked vehicles, because their presence near pedestrians make them become more cautious, therefore they choose longer gaps for road crossing. Also, vehicles' size influences the choice of gaps. When a vehicle of bigger dimensions approaches, pedestrians choose longer crossing gaps. The analysis of sensibility made for this model shows that the probability of road crossing decreases with the increase of pedestrian's waiting time.

Table 1. Connection between pedestrian level of service and the probability of accepting the interval of a certain length [18]

Level of service	**Average time loss per pedestrian**	**HCM 2000 risk evaluation**
A	< 5 s	Small probability of accepting the interval less than t_c
B	≥ 5 and ≤ 10 s	-
C	>10 and ≤ 20 s	Average probability of accepting the interval smaller than t_c
D	>20 and ≤ 30 s	-
E	> 30 and ≤ 45 s	Big probability of accepting the interval smaller than t_c
F	> 45 s	Very big probability of accepting the interval smaller than t_c

Apart from determining the influence of many factors on the pedestrian's decision when crossing a road and the choice of the interval of certain length, the aim of the analysis in this research area was firstly to determine whether the accepted models at the observed locations were, actually, less than the calculated critical gaps. Linking pedestrian level of service at unsignalized crossings and the probability of accepting the gaps of a certain length which was analysed in relation to the crossing critical gap, HCM 2000 has given recommendations shown in Table 1. Critical gap is the time in seconds below which a pedestrian will not attempt to begin crossing the street. For a single pedestrian, critical gap (t_c) can be computed using pedestrian speed, crosswalk length and pedestrian start-up time [18].

CONCLUSION

Much of the research was based on the examination of factors that influence the acceptance gap of a certain length that is chosen by a pedestrian to perform the manoeuvre of crossing the road. Pedestrian crossing decisions (to cross the road or not) may be associated with traffic conditions and with vehicle and pedestrian characteristics. The pedestrian must make a decision for each gap in traffic that occurs (accepts the gap or rejects it). This gives gap acceptance a unique set of conditions that can be used in analysis. The evaluation of actual accepted and rejected gaps provides the probability of accepting a gap of a certain length depending on many factors.

Most of the above mentioned research studies were carried out in Asia and the United States, where traffic conditions are significantly different from the region of Southeast Europe. As a consequence, the results of these research studies cannot be transferred and used in a national setting like the one of the Republic of Serbia, because our road and transport network has different characteristics and operational conditions. Therefore, it is necessary to do local researching this area: in that way the influences and specific qualities of the local environment and traffic flow characteristics would be valued, which was not the case until now. That would contribute to a more precise determination of LOS at pedestrian crossings.

REFERENCES

[1] Fitzpatrick, K. et al. „Improving Pedestrian Safety at UnsignalizedCrossings“,Transportation Research Board (TRB), Washington, DC, TCRP Report 112/NCHRP Report 562, 2006.

[2] Highway Capacity Manual, Transportation Research Board, National Research Council, Washington D.C., 2010.

[3] Yannis G. et al. „Pedestrian gap acceptance for mid-block street crossing“, 12th WCTR, Lisbon, Portugal, 2010.

[4] DiPietro, C. M., & King, L. E. (1970). Pedestrian gap-acceptance. Highway Research Record, No. 308, 80-91.

[5] Hamed, M. M. (2001). Analysis of pedestrians' behaviour at pedestrian crossings. Safety Science, 38(1), 63-82.

[6] Tiwari, G.et al. (2007). Survival Analysis: Pedestrian Risk Exposure at Signalized Intersections. Transportation Research Part F: Traffic Psychology and Behavior. 10(2), 77-89.

[7] Rastogi, R. et al. (2011). Parametric study of pedestrian speeds at midblock crossings. Journal of Urban Planning and Development, 137(4), 381-389.

[8] Tarawneh, M. S. (2001). Evaluation of pedestrian speed in Jordan with investigation of some contributing factors. Journal of Safety Research 32(2), 229–236.

[9] Lobjois, R. et al. (2013). The effects of age and traffic density on street-crossing behavior. Accident Analysis and Prevention, 53, 166–175.

[10] Simpson, G. et al. (2003). An investigation of road crossing in a virtual environment. Accident Analysis and Prevention (35), 787-796.

[11] Oxley, J.A.et al. (2005). Crossing Roads Safely: An Experimental Study of Age Differences in Gap Selection by Pedestrians. Accident Analysis and Prevention. Volume 37, 962-971.

[12] Lobjois, R., &Cavallo, V. (2007). Age-related differences in street crossing-desicions: The effects of vehicle speed and time constraints on gap selection in an estimation task. Accident Analysis Prevention 39 (5), 934-943.

[13] Petzoldt, T. (2014). On the relationship between pedestrian gap acceptance and time to arrival estimates. Accident Analysis and Prevention, 72, 127-133.

[14] Wilson, D. G., & Grayson, G. B. „Age-Related Differences in the Road Crossing Behaviour of Adult Pedestrians“,Transport Research Laboratory, TRRL Report LR 933, 1980

[15] Das, S.et al. (2005). Walk or wait? An empirical analysis of street crossing decisions. Journal of Applied Econometrics, 20(4), 529–548.
[16] Pawar, D. S., &Patil, G. R. (2015). Pedestrian temporal and spatial gap acceptance at mid-block streetcrossing in developing world, Journal of Safety Research 52, 39–46.
[17] Wang, T. et al. „Study of pedestrians' gap acceptance behavior when they jaywalk outside crossing facilities", 13th International IEEE Annual Conference on Intelligent Transportation Systems,Madeira Island, Portugal 2010, 1295-1300.
[18] Highway Capacity Manual, Transportation Research Board, National Research Council, Washington D.C., 2000.