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主　論　文　の　要　旨

論文題目

An Estimation Method of Exclusive Left-Turn Lane Capacity Considering the Bi-directional Flow of Crossing Pedestrians at Signalized Intersections

(信号交差点における二方向横断歩行者流を考慮した左折専用車線交通容量の推定手法)

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論　文　内　容　の　要　旨

Capacity is one of the most important indices for performance evaluation and signal timing design procedures of signalized intersections. Most of the time, traffic engineers are assigning concurrent signal timing design for crossing pedestrians and left turning vehicles (left hand traffic system) and facilitate the smooth traffic movement at signalized crosswalks by minimizing delay. Thus, pedestrian flow will be significant conflicting stream having major impact on the left turn lane capacity. The influence of crossing pedestrians on left turning vehicles is highly dependent on the individual or pedestrian platoon movement behaviour. Because, pedestrian crossing time can be highly influenced by variation of pedestrian platoon movement, traffic signal settings, crosswalk length and bi-directional interactions of pedestrians. The longest pedestrian-vehicle interaction time interval between crossing pedestrians and left turning vehicles is happening when the platoon of bi-directional waiting pedestrians crosses the crosswalk, at this time interval left turning vehicles are blocked by crossing pedestrians significantly. Consequently, the left turn lane capacity may considerably fluctuate depending on the composition of the bi-directional pedestrian demand. The duration of time that pedestrians occupy the shared space is highly dependent on the position of pedestrians with increasing elapsed time. In addition to the presence of crossing pedestrians the layout of the crosswalk has an impact on the left turning vehicles and pedestrian’s movement.

However, in existing methods, the crossing pedestrian impact is estimated through an adjustment factor by considering the number of pedestrians as a factor to investigate the influence of pedestrians on left turning vehicles. Meanwhile, those estimation procedures do not express the realistic pedestrian-vehicle and bi-directional pedestrian interaction situations, for instance, without considering the bi-directional pedestrian flow interaction, waiting pedestrian platoon effect and change in geometric layout of the crosswalk. Therefore, this study aims to propose an estimation method of exclusive left turn lane capacity by empirical observation of different signalized crosswalks that can appropriately reflect the Japanese situations considering the bi-directional crossing pedestrians and crosswalk layout factors, i.e. bi-directional pedestrian demand, signal timing, crosswalk setback distance, stop line set back distance and crosswalk length. The result of this study is expected to apply for planning and operational stage analysis of signalized crosswalks regarding the treatment of pedestrians and crosswalk location issues in future.

For the development of the capacity estimation procedure, the conceptual settings are outlined in **Chapter 3** when bi-directional crossing pedestrians and left turning vehicles use the signalized crosswalks under concurrent signal phasing situation. And then, under different bi-directional pedestrian demand conditions the left turning vehicles discharge flow situations are conjectured. In general, the green time can be divided into five time intervals based on the basic bi-directional pedestrian flow characteristics. The five intervals have six critical time thresholds which determine the boundary of the time intervals. Finally, by combining the conceptual bi-directional pedestrian flow condition and left turning vehicles discharge flow within the available green time intervals the hypothetical capacity estimation equation is proposed.

To generalize the components of the proposed capacity estimation procedure, first the bi-directional pedestrian characteristics at the signalized crosswalks are observed and then modeled in **Chapter 4**. Bi-directional crossing pedestrian position distribution along the crosswalk at higher and lower demand conditions are empirically observed at different signalized crosswalks. Furthermore, pedestrian presence probability is modeled by modifying existing time dependent model by considering crosswalk length, bi-directional pedestrian flow and signal timing settings. The model result implied that on longer crosswalks, pedestrian platoon tends to disperse. Besides, the model captured the platoon dispersion effect in the situation when the high demand of opposing pedestrian flow impedes on the subject direction pedestrian flow. Subsequently, by applying the pedestrian presence probability model the estimation procedure and the generalized model of waiting pedestrian's presence-time at the conflict-area of the crosswalk is defined. The pedestrian presence-time model can be applied to understand the influence of waiting pedestrians on left turning vehicles.

After the crossing pedestrian flow analysis, in **Chapter 5** the left turning vehicles discharge flow is observed. The observed discharge flow rate distribution at different signalized intersections showed that the position and slope of the distribution curve are different because of the variance in the number of arriving pedestrians per cycle and directional composition of arriving pedestrians. Subsequently, the discharge flow rate is modeled by selecting the significant factors i.e. influence of bi-directional arriving pedestrian presence and geometric layout conditions (crosswalk length, crosswalk and stop-line setback distances). The discharge flow rate model revealed that, when higher number of pedestrian's presence in the conflict-area the possibility of left turning vehicles to pass the conflict-area will be lower meanwhile the impact of far-side arriving pedestrian's presence is more significant than pedestrians entering from near-side direction. In addition, when the stop line is far from the intersection the arriving time of the left turning vehicle to the subject crosswalk will be long, due to that there will be delay to pass the conflict-area and unused green time may increase. On the other hand, when the subject crosswalk position is near to the intersection the left turning vehicles discharge flow rate show a decreasing trend. The reason is related with sight distance, left turning vehicles can easily notice the position and volume of crossing pedestrians at the onset of green and they will approach with lower turning speed, due to that the waiting time of turning vehicles before they pass the shared space will increase and consequently total number of turning vehicles within the available green time may decrease.

Chapter 6 outlined the validation and sensitivity analysis of the proposed method. The sensitivity of the proposed method is checked with different ranges of the five main components for the capacity estimation, i.e. signal timing settings, bi-directional pedestrian demand combinations, crosswalk length, crosswalk and stop-line setback distances. In addition, the proposed left turn lane capacity estimation method is compared with observed capacity at saturated cycles of signalized crosswalks and with selected existing left turn lane capacity estimation methods. The result reveled that; the proposed method can realistically capture the influence of crossing pedestrians and variation in crosswalk layout in the left turn lane capacity estimation procedures.

Application of the proposed method as an adjustment factors is also discussed in **Chapter 6**.A simplified equation is proposed to estimate the adjustment factors by considering the influence of bi-directional crossing pedestrians and variation in layout of the crosswalk at signalized crosswalks. The adjustment factors are useful for practitioners in the operational performance evaluation of signalized crosswalks and in the signal timing design procedures.