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Thoughts on the Avoidability Analysis of Collisions Between Vehicles and Pedestrians Crossing the Road

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ABSTRACT Collisions between vehicles and pedestrians crossing the road often result in severe injuries, highlighting the importance of accurate avoidability analyses in traffic accident reconstructions. Traditional assessments focus predominantly on the spatial relationship—comparing braking distance with the initial vehicle-pedestrian distance—while overlooking crucial temporal factors such as pedestrian walking speed. This brief study proposes a spatiotemporal approach that integrates both spatial and temporal variables to provide a more realistic evaluation of collision avoidability. Incorporating the pedestrian's crossing time and the vehicle's reaction and braking intervals enables a comprehensive analysis, potentially yielding more precise conclusions regarding accident responsibility.

KEY WORDS Vehicle-Pedestrian Collision; Collision Avoidability; Spatiotemporal Analysis; Traffic Accident Reconstruction; Road Safety

Collisions between vehicles and pedestrians occur frequently in road traffic accidents, often leading to severe injuries to pedestrians. In the analysis of vehicle-pedestrian collisions, conclusions drawn from avoidability assessments carry significant weight when determining responsibility for an accident.

Most existing avoidability analyses of collisions between a vehicle and a pedestrian crossing a roadway focus on whether, given the vehicle's speed at the time of the incident and the distance between the vehicle and the pedestrian (L), the vehicle could have braked to a stop before reaching the crossing point. In other words, if the vehicle's braking distance (s) exceeds the distance between the vehicle and the pedestrian (L), the collision is considered unavoidable (Scenario A). Conversely, if the vehicle' s braking distance (s) is less than L, the collision is deemed avoidable (Scenario B).

However, this approach predominantly accounts for only the spatial relationship between the vehicle and the pedestrian, with little consideration of temporal factors. In reality, the pedestrian's walking speed must also be taken into account. For instance, in Scenario A, if the temporal relationship shows that the pedestrian, walking at a sufficiently fast pace, has already crossed beyond the left or right side of the vehicle by the time the vehicle reaches the point of contact, then the collision could in fact have been avoided. This yields a more accurate conclusion. Compared with the earlier approach, an analysis that incorporates both spatial and temporal relationships is more reasonable.

The specific method is illustrated as follows:

$$\begin{cases} s_1 = L - (t_1 + t_2)v \\ (2v - at_3)t_3 = 2s_1 \\ a = k\mu g \\ t_v = t_1 + t_2 + t_3 \end{cases}$$

where:

· s_1 is the effective braking distance (m) before the vehicle reaches the point of contact with the pedestrian;

· L is the vehicle-pedestrian distance (m) within the driver's line of sight;

· v is the vehicle's initial speed (m/s);

· t_1 is the driver's reaction time (s);

· t_2 is the brake coordination time (s);

· t_3 is the effective braking time (s) from the point where the vehicle first sees the pedestrian to the contact point;

· a is the vehicle's deceleration (m/s²);

· μ is the friction coefficient between the vehicle and the

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road surface;

· k is the correction factor for the friction coefficient between the vehicle and the road surface;

· t_v is the total time (s) from sight distance to the point of contact.

Let the time interval in which the pedestrian crosses the left or right side of the vehicle be t_r.

Then:

If $\{t_v \cap t_r = \varnothing$, the collision can be avoided.

If $\{t_v \cap t_r \neq \varnothing$, the collision cannot be avoided.

Hence, in analyzing such traffic accidents, it is recommended to incorporate temporal considerations of both the vehicle and pedestrian, assessing avoidability from a comprehensive spatiotemporal perspective in order to derive more meaningful conclusions.

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POSTSCRIPT

(Chinese version) 车辆与横穿公路行人发生碰撞可规避性分析的思考

道路交通事故中人车碰撞事故频发并导致了严重的行人损伤。在人车碰撞交通事故分析中，可规避性分析的结论对事故的责任划分具有重要的参考意义。

对于车辆与横穿公路行人之间发生碰撞的可规避性分析，多数分析着重于研究在事发车速及人车间距（L）情况下车辆能否在行人横穿位置前制动并停驶，即车辆的制动距离（s）大于人车间距（L）则事故不可规避（A 情形）；反之，车辆的制动距离（s）小于人车间距（L）则可以规避（B 情形）。

这种分析方法只对人车的空间位置关系进行分析，而少见从时间位置关系上进行分析。实际情况中应结合考虑行人的步行速度，比如前述 A 情形，增加考虑时间位置关系，若行人步行较快且在车辆抵达人车接触点时已经横穿至车辆左/右侧车身之外，则应属于可规避的情形，从而得出更为真实的分析结论。与前述分析相比较而言，综合考虑时空位置关系的分析方法应更为合理。

具体方法如下所示：

$$\begin{cases} s_1 = L - (t_1 + t_2)v \\ (2v - at_3)t_3 = 2s_1 \\ a = k\mu g \\ t_v = t_1 + t_2 + t_3 \end{cases}$$

式中：

s_1——车辆行驶至人车接触点前有效制动距离（m）

L——视距情况下的人车间距（m）

v——车辆的初始行驶速度（m/s）

t_1——驾驶员反应时间（s）

t_2——制动协调时间（s）

t_3——车辆从视距位置行驶至人车接触点前有效制动时间（s）

a——车辆减速度（m/s^2）

μ——车辆与地面摩擦系数

k——车辆与地面摩擦系数的修正系数

t_3——车辆从视距位置行驶至人车接触点的总时间（s）

行人步行通过车辆左/右侧车身的时间范围表示为 t_r，则：

若$\{t_v \cap t_r = \varnothing$，则碰撞可以规避

若$\{t_v \cap t_r \neq \varnothing$，则碰撞无法规避

因此，在此类交通事故分析中，建议增加对人车时间位置关系的分析，从时空位置关系角度综合地对可规避性进行分析，从而得出更为有意义的分析结论。■