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An evidence based method to calculate pedestrian crossing speeds in vehicle collisions (PCSC)

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ABSTRACT

Pedestrian accident reconstruction is necessary to establish cause of death, i.e. establishing vehicle collision speed as well as circumstances leading to the pedestrian being impacted and determining culpability of those involved for subsequent court enquiry. Understanding the complexity of the pedestrian attitude during an accident investigation is necessary to ascertain the causes leading to the tragedy. A generic new method, named Pedestrian Crossing Speed Calculator (PCSC), based on vector algebra, is proposed to compute the pedestrian crossing speed at the moment of impact. PCSC uses vehicle damage and pedestrian anthropometric dimensions to establish a combination of head projection angles against the windscreen; this angle is then compared against the combined velocities angle created from the vehicle and the pedestrian crossing speed at the time of impact. This method has been verified using one accident fatality case in which the exact vehicle and pedestrian crossing speeds were known from Police forensic video analysis. PCSC was then applied on two other accident scenarios and correctly corroborated with the witness statements regarding the pedestrians crossing behaviours. The implications of PCSC could be significant once fully validated against further future accident data, as this method is reversible, allowing the computation of vehicle impact velocity from pedestrian crossing speed as well as verifying witness accounts.

1. Introduction

Pedestrian collisions are tragic events, which can lead to death. When death occurs, the Police Force is responsible for investigating the causes leading to the accident. These causes can be various and complex and rely on physical evidence at the scene of the accident, as well as witness statements, driver interviews, CCTV evidence and on-board vehicle systems (ECU, RCM, GPS, AV, Telcoms, etc...). The vehicle speed, should no other suitable video evidence be available, is calculated using various pedestrian throw distance disciplines, perhaps the most widely used in the UK is that of Searle (Searle (1993)). Conveniently, Searle's equations relate well to real life pedestrian throw distances from Happer (Happer et al., 2000), as illustrated in Fig. 1. Searle's equation impact speed range (V_{min} and V_{max}) bear some use in UK court proceedings.

Searle's equations are useful, however they are limited as they depend on witness evidence on the ground, i.e. debris from the vehicle as well as the resting pedestrian location. Should any of this information not be available, then the vehicle impact speed range cannot be calculated. This is also true when the pedestrian contacts against street furniture during the post-impact bouncing and sliding phases (Fig. 2), as the final pedestrian resting location is not what it should have been had there been no contact. Searle uses a universal road friction parameter of 0.7 (Searle, 1993) to calibrate his theory displayed in Fig. 1, meaning that there may be measurement discrepancies should in real life the road be icy (road friction near 0.1). Consequently, the Searle vehicle velocity calculation depends on events taking place after the collision, which in some cases may influence or void the use of this method. Nevertheless, the Searle method is also in agreement with the latest computer science tools, like the THUMS full Finite Element Model, using various pedestrian stance (Standing facing the car – SF; Standing sideways (left side impact) – SS; Walking (left side impact, right food forward) – WLR; Waking (right side impact, right foot forward) - WRR and Running (left side impact, left foot forward) – RLL) (Bastien et al., 2017) illustrated in Fig. 1, as well as using multi-body computer models (Leglatin et al., 2006). These computer models are expensive, complex to setup and take sometimes days to compute on High Performance Computing (HPC) clusters, making them to date, a useful tool but still only accessible to specialist computer scientists.

The Searle equations relate to the pedestrian projection in a plane

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Nomenclature

A	Visible impact point on the bonnet leading edge
B	Head impact strike on the windscreen
C	Planar projection of point B to the bonnet leading edge
D	Pedestrian head centre of gravity
H	Planar horizontal distance between vehicle dent and windscreen damage
W	Planar car-line distance between vehicle dent and windscreen damage
β	Angle (BCE) measuringthe angle between the actual pedestrian head centre of gravity to from the location of strike to its location on the windscreen along the vehicle travelling direction
λ	Isthetheoretical angle between the pedestrian velocity and the vehicle velocity
Γ	Head offset to the bumper impact location. It compensates offset by half a pedestrian stride length
Δ	Combined offset including the head strike on the windscreen ad gait head offset
α	Pedestrian crossing angle relative to the vehicle direction

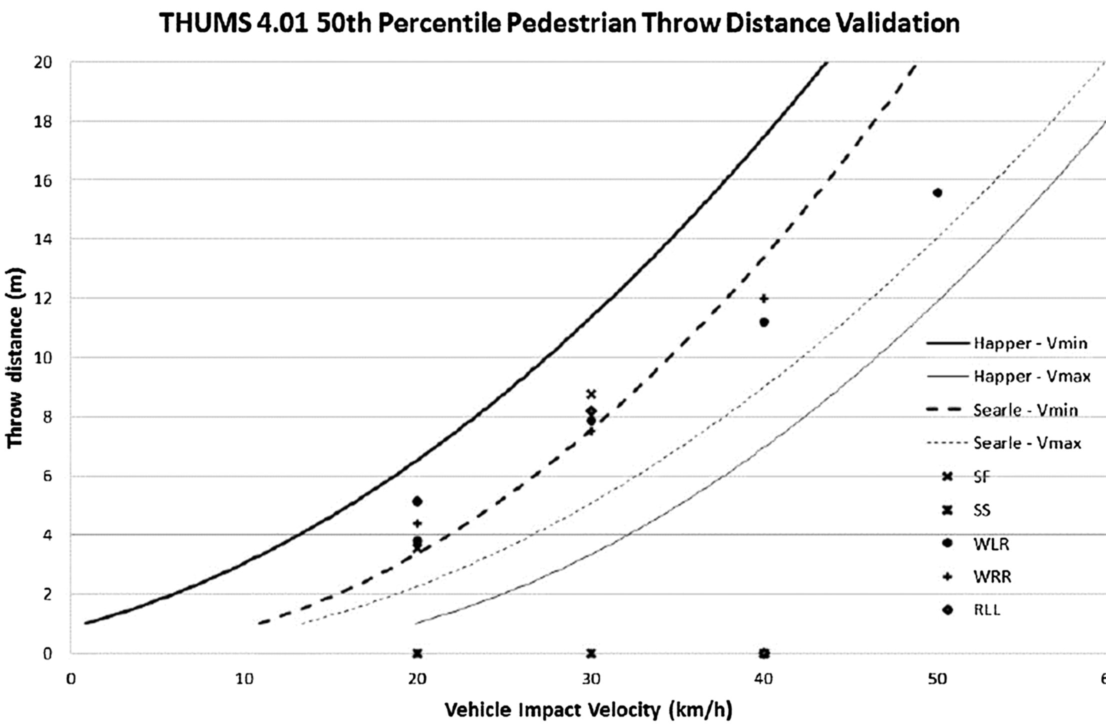

Fig. 1. Comparison of pedestrian throw distance between Searle, Happer and THUMS (Real life data) (Bastien et al., 2017).

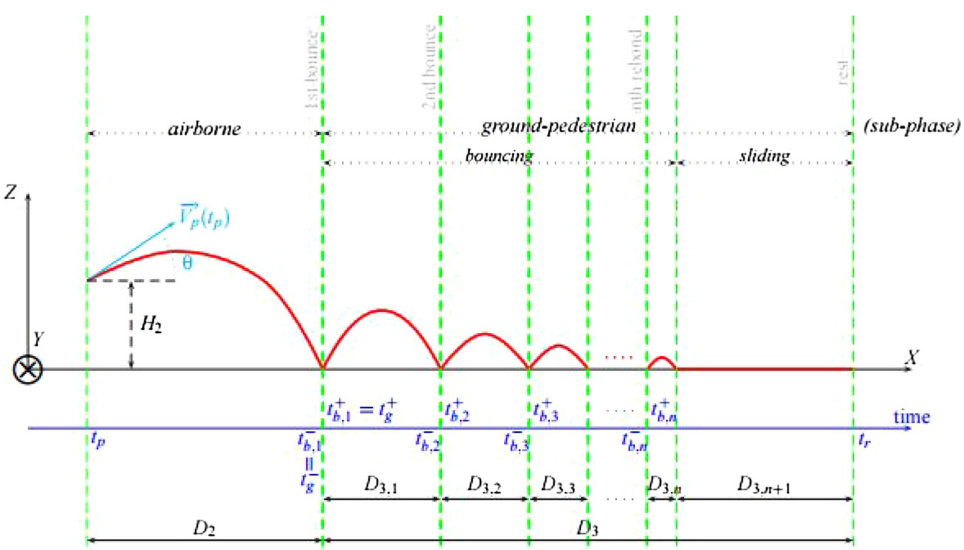

Fig. 2. Theoretical kinematics computed from Searle's equations (Searle, 1993).