Insights into In-Crash Kinematics of Delivery Cyclists: the Influence of Backpacks on Vehicle Collision Outcomes

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I. INTRODUCTION

Bicycles have become a common sustainable means of transportation for delivery couriers. Delivery workers are incentivised by extra commissions and tips for fast deliveries, which could lead to reckless behaviour on the road and increase the risk of potential traffic accidents [1].

Cyclist passive protection has been the subject of numerous studies over the years. However, in the case of delivery couriers, an additional factor could be considered: delivery couriers often have large backpacks for storage of delivered wares. The influence of this additional equipment on the kinematics of a cyclist during the impact phase has not yet been sufficiently studied. The aim of this research is to study the differences between standard cyclists and delivery cyclists through a series of multibody simulations of vehicle-to-cyclist impacts.

II. METHODS

Traffic accident reconstruction software CYBID V-SIM 7.0. was used in this study. The software is equipped with a library of vehicle geometries, vehicle dynamics models and an embedded Multibody solver with a humanoidal multibody model and a multibody bicycle model. The baseline bicycle model and the 50th percentile male cyclist model were validated against a post-mortem human subject (PMHS) full-scale crash test (v = 42 km/h) [2]. The model yielded qualitatively similar response in terms of full-body kinematics (Fig. 1), and thus default contact characteristics of the vehicle, bicycle and humanoidal models were deemed satisfactory. Additional validation in terms of cyclist throw distance, while not reported in the current study, was also carried out. The humanoidal model displayed good response for a velocity range up to 60 km/h.

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Fig. 1. Comparison between the baseline model and the PHMS study – the time after impact in [ms].

In the study, a series of bicycle-to-family-car impacts were modelled. Four simulation variables were considered: cyclist model (standard/delivery); collision velocity (20–50 km/h, intervals of 10 km/h); impact angles (0–345°, in intervals of 15°); bicycle lateral offset from vehicle's centreline (-0.6–0.6, in intervals of 0.2 m). An example of an impact configuration is presented in Fig. 1. No velocity was assigned to the cyclist. In total, 1,344 simulations were conducted, with 43 excluded from the final analysis due to lack of head-to-vehicle contact. The process of running the simulations and collecting output (e.g. head impact time measurements, head-to-vehicle contact detection) was automatised with Python scripts using the simulation program's scripting interface.

The delivery cyclist model was created by rigidly attaching a 4 kg backpack cuboid to the chest segment of the model (Fig. 2). Preliminary experiments indicated that the compression of the backpack under a static 80 kg load (i.e. equivalent to a mass of a 50th percentile cyclist) is 50% (~20 cm); the backpack model's contact characteristics were calibrated to obtain a similar static response.

III. INITIAL FINDINGS

Three qualities were analysed: head impact time (here defined as the time between the first contact with the bicycle and head-to-vehicle impact) (Fig. 4), head impact velocity (Fig. 5), and head impact location (Fig. 6). As rear impacts could potentially differ the most between the two cyclist models, the subset of rear collisions (i.e. impact angles between -45° and 45°) was studied in more detail.

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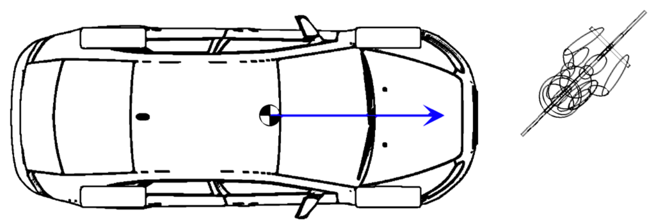

Fig. 2. Sample impact configuration: 45° impact angle, +0.4 offset.

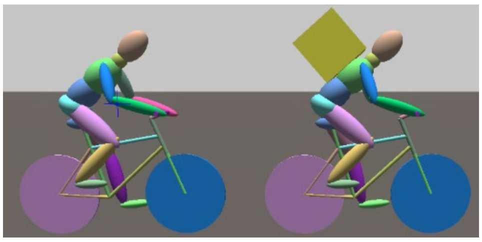

Fig. 3. Standard and delivery cyclist models.

For the 20 km/h and 30 km/h impact, a significant difference ($p<0.05$, t-test/Mann-Whitney test) in head impact time and resultant head impact velocity was found between standard cyclist and delivery cyclist models. In terms of the y-coordinate of head impact location (a measure of wrap-around distance), no significant differences were found. Head impact time (HIT) for the 30 km/h rear-impact configuration was, on average, higher for the delivery cyclist (μ = 258, SD=24.0) than for the standard cyclist (μ = 246, SD=22.7). This can be compared with the min./max. values from the TB024 pedestrian model certification protocol, v = 30 km/h, lateral pedestrian impact (107.6 and 108.5 s, respectively) [3].

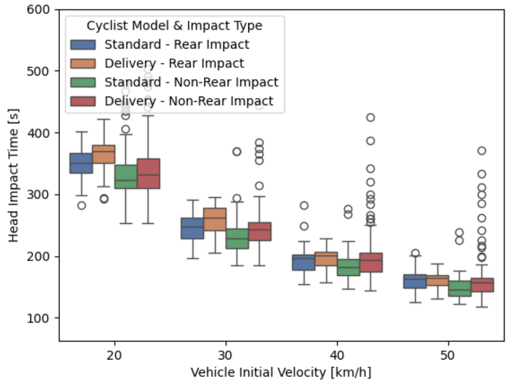

Fig. 4. Summary of head impact time results.

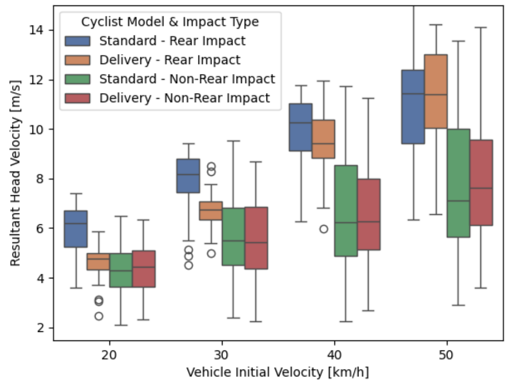

Fig. 5. Summary of head impact velocity results.

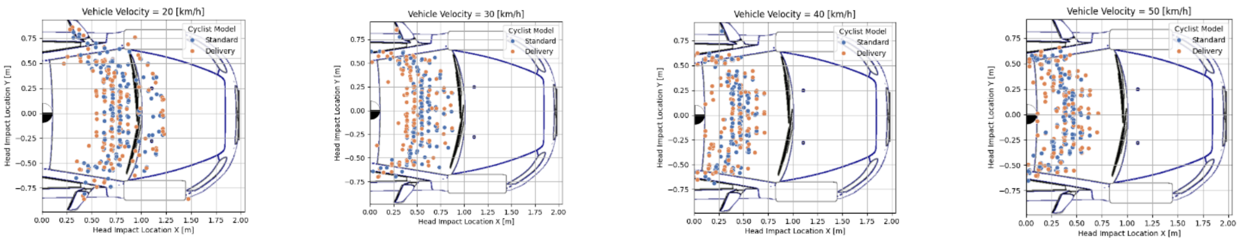

Fig. 6. Head impact locations for different impact velocities (rear and non-rear impacts).

IV. DISCUSSION

Multibody models are generally limited in their injury prediction capabilities, and this study could be extended with a FE analysis of cyclist injury. No helmet model was used as its usage was considered irrelevant to the determination of head-to-vehicle impact initial conditions. It is recognised that the inclusion of cyclist impact velocity or reaction pattern could potentially influence the results. While there have been studies into general helmet usage frequency [4], it would be beneficial to investigate the subject specifically among delivery workers. The study provides additional insight into conditions in which cyclists are impacted, especially in terms of head impact areas on the vehicle.

V. REFERENCES

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[2] Serre, T., *et al.*, *Int J Crashworthiness*, 2007.
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