The Effect of Physical Environment Factors on Child Pedestrian Severity Collisions in Peninsular Malaysia

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Abstract. This study is aimed at investigating the association between child-pedestrian severity levels of collisions and physical environmental variables. The outcome of this study could be applied to road safety intervention for improving engineering modifications related to children pedestrians. The retrospective analysis was carried out using 9-year data from Royal Malaysian Police records from the years 2009 to 2018. Multinomial logit modeling (MNL) was applied. The results demonstrated that the injury severity of the collisions is related to road surface material, traffic system, posted speed limit, lighting conditions, location, type of area and time of collisions. Notably, the findings revealed the importance of more in-depth studies on physical environmental features that relate to child- pedestrians' severity level of collisions. This is essential for improvements to physical environmental designs by policymakers. Thus, policymakers and stakeholders can utilize the findings to further improve the physical environment through structure and design.

1 Introduction

In Malaysia, road traffic injuries (RTI) are the leading cause of death for children aged 0 to 14 years from 2016 to 2021 except for 2018 [1]. The situation in Malaysia is currently in line with Zegeer & Bushell [2] which was highlighted that the death rate from traffic injuries is comparable to death from infectious diseases. Road traffic injuries (RTI) are the critical issue need to be investigated with many risk factors. One of the factors that plays an important role in road traffic collisions is the physical environment elements and it was highlighted by past researcher that the child pedestrian injury risk is a partially function of this element [3]. This

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is due to the fact that the road environment is design, construct and for consideration of adults which placed the children at the greater risk.

According to the World Health Organization (WHO) [4], child-pedestrians of all ages are at risk of being involved in a road traffic collision. WHO also highlighted that 38% of children under 19 years old are injured or killed as pedestrians on the roads each year [5]. In Malaysia, the statistics of child- pedestrian fatalities in Malaysia are particularly worrying due to a high rate of fatal road collisions [6]. The authors highlighted that 12% of children aged 1 to 18 years old were involved in fatal road collisions from 2007 to 2009. This figure is higher than that of high-income countries, which only have 5% to 10% of fatalities [7]. A study by Darus et al. [8] found a total of 2,243 child-pedestrian (aged 0–18 years) casualties were reported between 2009 and 2012, accounting for about 27.9% of the total number of pedestrian casualties. As a result, this scenario implies that child-pedestrians are among the most susceptible road users to traffic injury.

As stated by the World Health Organization (WHO) [7], a distinguishing aspect of the physical environment, particularly the road environment, is the unique contributing variables associated with children. By and large, the road environment is constructed by adults for the benefit of adults. As a result, this scenario has increased the danger of harm for children.

Physical environment elements can be defined as the physical surrounding elements which may be contributed to the occurrence of potentially injury. In a Haddon Matrix model established by Willam Haddon Jr, physical environment is one of the attributes in preventing injury [9]. Some research has been reported on the effect of the physical environment to the child pedestrian injury risk [10-12] The results showed that some of the physical environment factors has significant effect on child pedestrian injury risk. Hence, this paper mainly aims to identify the effects of physical and traffic environment features on the different levels of severity collisions involving child pedestrian aged between 0 to 17 years in Peninsular Malaysia.

Thus, the primary objective of this research is to ascertain the impact of physical and traffic environment characteristics on the severity of accidents involving child-pedestrians aged 18 years or younger in Malaysia. The models are built specifically utilizing multinomial logistic analysis (MNL), which include critical information about the physical environment. The models produced may be used to inform intervention and environmental change efforts aimed at reducing injury severity.

2 Methodology

2.1 Data Source and Data Preparation

The data were acquired from Royal Malaysian Police (RMP) by the Malaysian Institute of Road Safety Research (MIROS). The subset of the data contains information on child pedestrian-vehicle collisions that occurred from January 2009 to June 2018. A total number of 2232 child pedestrian-vehicle collisions were analyzed after 5% had to be excluded due to the missing variables. Child pedestrian in the present study refer to children in the age-range of 0-17 years old. For the purpose of this study, 21 parameters related to physical environmental elements was analyzed. The estimation of MNL model and relative risk ratio (RRR) are using Statistical Package for the Social Sciences (SPSS) version 23.

2.2 Classification of Injury Collisions by Definition

The present study applies the definitions below as shows in Table 1.

Table 1. Term use defined by Royal Malaysian Police

Term	Definition
Pedestrian	Any person who is not/on a vehicle but occupying a portion of road; includes road construction workers, a person pushing a breakdown vehicle, etc.
Fatal injury collision	A road accident in which one or more person were killed within 30 days from the date event.
Serious injury collision	A road accident in which at least a person sustained serious injury but none killed.
Slightly/minor	A road accident in which one or more person were injured but

2.3 Model Formulation

In this study, the theory of planned behaviour's original framework was extended. Initially comprising attitude, subjective norms and perceived behavioural control, two innovative constructs were added: environmental concern and service quality. This was to assist in predicting the mode-changing behaviour of users of private vehicles with regard to utilising the travel alternative of mass rapid transit. The theory of planned behaviour framework was extended in this way so that the theory's predictive capability could be enhanced, as proposed by [28].
In this study, multinomial logit model is used to estimate the severity of collisions. The dependent variable is the severity of collisions recorded at 4 levels: fatal, serious, slight and damage. The MNL is used to increase flexibility in modeling estimation. Thus, the effect of a variable on the likelihood of an injury or fatality can be showed [13, 14].

The probability of the child pedestrian collision nth with severity level i, is given by:

$$Pni = P\,(Uni \geq Uni'),\ \forall i' \in I,\ i' \neq I \qquad (1)$$

Where I denotes a set of possible mutually exclusive severity levels of collisions. The Uni can be expressed as:

$$Uni = \beta ixn + \varepsilon ni \qquad (2)$$

Where β denotes a vector of coefficients, while xn denotes a vector of explanatory variables and εni denotes an unobservable random error. εni is assumed to have generalized extreme value distribution. From the assumption, the MNL can be expressed by:

$$P_{ni} = \frac{e^{\beta iXn}}{\Sigma \forall I' \in I\ \ e^{\beta iXn}} \qquad (3)$$

Where βi is a vector of coefficient can be estimated for severity level i using standard maximum likelihood methods. As the explanatory variables do not vary across injuries, the I-1 log-odd ratios of the model become:

$$ln = \frac{P_{ni}}{P_{ni}} = \beta_i x_n - \beta_I x_n = (\beta_i - \beta_I) x_n, i = 1 \ldots\ldots, I = 1 \qquad (4)$$

Only the difference in coefficient is identifiable, therefore the coefficient is identifiable up to an additive constant. The coefficients of one outcome (the base case) are set to zero to resolve the interdeterminancy [15]. The slightly injury collisions as a base case or reference following the work of Tay et al. [16].

As the MNL is a nonlinear model, the estimated coefficients of the explanatory variables (independent variables) do not represent of their effect on dependent variables [14, 17]. So, the relative risk ratio (RRR) is computed relative to the base category to show the effect of a significant risk factors. From equation (4), the relative probability of an injury accident (i=2) to the base case (i=1) is

$$\frac{PrPr\ (i=2)}{Pr\ (i=1)} = e^{x\beta(^2)} \tag{5}$$

Relative risk ratio (RRR) for binary variables is written as

$$RRR = e^{\beta_i^2} \tag{6}$$

Generally, the RRR refers to the increase if RRR more than 1 (RRR>1) or decrease if RRR less than 1 (RRR<1) in risk of a specific severity level of collisions compared to the base case [14, 17]. The Statistical Package for Social Sciences (SPSS) version 23 is used to estimate the MNL and RRR.

3 Results and Discussion

Table 2 depicted the estimation results of the multinomial logit model. The multicollinearity test was performed to assess the presence of correlation among the parameters. No multicollinearity was found. Generally, the results showed a large chi-square value 249.114 and a very small p-value <0.0001 indicated that the model fits well. The parameters at the significant level α=0.1, α= 0.05 and α=0.01 were retained [14, 17]. This means that the impacts of these parameters are significant. The estimated coefficients and relative risk ratios (RRR) were used to interpret the effects of significant parameters. The magnitudes and the signs of the estimated parameters are discussed. The parameter with positive sign indicates the increasing risk of an injury collision severity.

Among 21 parameters, seven parameters are significantly associated with child pedestrian collisions severity. The significant parameters comprised of road surface material, traffic system, posted speed limit, lighting conditions, location, type of area and time of collisions. As for road surface material, fatal injury collisions are 11.9 times more likely to occur on earth road surfaces (RRR=11.996, p=0.000) and 9.9 times on concrete surfaces (RRR=9.926, p=0.002). Also, it was found that damage or non-injury collisions are nearly 160 times more likely to occur when the collisions took place on brick road surfaces (RRR=160, p=0.005). In relation to the traffic system, roads with dual- carriageway (RRR=5.623, p<0.001) are at a higher risk fatality. This result may have contributed by the characteristic of the traffic system such as the number of lanes, presence of median and type of flow which can influence the severity of injury collisions [12, 18]. This finding is consistent with research conducted in Hong Kong [19], Brazil [20] and Riyadh [21], which discovered that two-way and dual/multiple lane roads were associated with a higher risk of serious accidents.

In terms of posted speed limit, the results show that collision at locations with posted speed limit 70 km/hr, 80 km/h and 90 km/h tend to be fatal. Fatal injury collisions are 2.4

times (RRR=2.435, p=0.001) more likely more likely to occur on road with speed limit 70km/h, 3.3 times (RRR=3.314, p=0.000) on roads with 80km/h and 3.7 times (RRR=3.704, p=0.000) on roads with 90km/h. Also, the results show that dark roads without street lights, dawn and dark roads street lights are related to fatal injury collisions. Dark roads increase the risk of being fatal and seriously injured. Fatal injury collisions were found to be three times more likely to occur in darkness without street light (RRR=3.294, p=0.000) and with street light (RRR=3.447, p=0.000). This may have related to the poor visibility of children and vehicles during darkness [17, 18]. According to the findings of previous research conducted in the United States, Australia, South Korea and Ghana, the risk of death or serious injury for pedestrians is higher at night (dark lighting) than during the day [16, 22-24].

The land use is a significant parameter classified as "others" areas. This area tends to be fatal compared to shopping (RRR=0.318, p=0.010) and school area (RRR=0.611 p=0.046). Subsequently, results show that the presence of built-up area decreased the risk of being seriously (RRR=0.751, p=0.059) injured. Moreover, damage collisions are more likely to occur in city area (RRR=1589, p=0029) and urban area (RRR=60.4 p=0.013). Poor road traffic management, pedestrian behaviour, inadequate road infrastructure and pedestrian facilities may be an important factor that contribute to the risk of an injury [17, 25]. With respect to the time of collision, the collision occurring from 1000 to 1559 were significantly related to fatal injury compared to 1600 to 1859 (RRR= 0.675 p=0.023). and 1900 to 2459 (RRR=0.528 p=0.014).

From a traffic engineering perspective, road characteristics, road designs, and traffic operations play an important role in providing safe walking conditions for vulnerable road users [26]. Fundamentally, child-pedestrians should be provided with good and protective facilities based on their abilities [27] and skills. For example, there should be special attention given to locations with complex road geometrics and traffic systems, such as cross intersections, and multilane roads with bidirectional flows, as all these locations tend to be more severe. The reduction in child-pedestrian collisions is associated with lighting conditions and road surface conditions. It should be noted that child- pedestrian collisions may be attributed to drivers' negligence and irresponsible behavior.

Importantly, dark areas should be installed with adequate street lighting to increase visibility. Furthermore, road safety educational programs and campaigns should also be targeted at drivers to increase their awareness of pedestrians' and cyclists' activities [28]. Moreover, modifications to the physical environment should be combined with effective training techniques involving children, especially in school zones, to reduce the selection of poor routes [29]. Notably, future research should examine the human factors concerning children's behavior and development in order to better understand child-pedestrians' abilities and limitations in designing pedestrian facilities.

Table 2. MNL Model of child pedestrian collisions in Peninsular Malaysia

Slight injury collision (Base)	**Fatal injury collision**				**Serious injury collision**				**Damage/ non injury only**			
Parameters	**B**	**S.E**	**Sig**	**RRR**	**B**	**S.E**	**Sig**	**RRR**	**B**	**S.E**	**Sig**	**RRR**
Intercept	-2.003	0.198			-0.909	0.140			-12.084	3.872	0.002	
Road surface material												
Bitumen (Reference)												
Crusher run	0.508	0.390	0.192	1.662	-1.119	0.546	0.041***	0.327	-10.218	2876	0.997	$3.6x10^{-5}$
Brick	0.159	0.224	0.476	1.173	0.282	0.170	0.096**	1.326	5.081	1.823	0.005***	160.95
Earth	2.485	0.614	0.000***	11.996	1.395	0.638	0.029***	4.036	-10.370	7241	0.999	$3.1x10^{-5}$
Concrete	2.295	0.729	0.002***	9.926	1.387	0.739	0.060**	4.004	-7.168	6267	0.999	0.01
Traffic system												
2-way (reference)												
One-way	0.303	0.205	0.139	1.354	-0.012	0.174	0.947	0.988	0.823	1.707	0.630	2.278
Dual carriageway	1.732	0.407	0.000***	5.653	0.498	0.438	0.256	1.645	-15.859	2127	0.994	$1.3x10^{-7}$
3-lane	0.580	0.482	0.229	1.786	0.110	0.453	0.809	1.116	-9.755	3021	0.997	$5.8x10^{-5}$
Speed limit												
50 km/h (reference)												
Others	0.179	0.184	0.332	1.196	-0.056	0.125	0.655	0.946	0.399	1.960	0.839	1.491
70 km/h	0.890	0.204	0.000***	2.435	0.121	0.157	0.441	1.129	-13.686	848.0	0.987	$1.1x10^{-6}$
80 km/h	1.190	0.323	0.000***	3.314	0.589	0.265	0.026**	1.802	-11.601	2610.	0.996	$9.1x10^{-6}$
90 km/j	1.309	0.278	0.000***	3.704	0.575	0.234	0.014**	1.776	2.752	2.308	0.233	15.675
110 km/h	-0.163	1.122	0.884	0.849	-1.004	1.081	0.353	0.366	-12.757	0.000	-	$2.8x10^{-6}$
Lighting condition												

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Day (reference)												
Dark without street light	1.192	0.337	0.000***	3.294	0.555	0.278	0.046**	1.743	-18.520	1913	0.992	$9.1x10^{-9}$
Dawn/dusk	0.693	0.278	0.013**	2.000	0.197	0.228	0.386	1.218	-14.169	1139	0.990	$7.0x10^{-7}$
Dark with street light	1.237	0.257	0.000***	3.447	0.226	0.228	0.322	1.253	-4.700	2.871	0.102	0.009
Location												
Rural (reference)												
City	-0.343	0.371	0.355	0.710	-0.222	0.310	0.474	0.801	7.371	3.369	0.029**	1589
Urban	0.301	0.206	0.144	1.351	-0.044	0.170	0.794	0.957	4.102	2.289	0.073*	60.432
Built up	-0.063	0.195	0.745	0.938	-0.286	0.152	0.059*	0.751	3.263	2.307	0.157	26.133
Type of area												
Others (reference)												
Residential	0.226	0.165	0.173	1.253	0.039	0.130	0.765	1.040	-17.352	603.2	0.997	$2.9x10^{-8}$
Office	-0.399	0.393	0.311	0.671	-0.030	0.297	0.919	0.970	-15.329	1977	0.994	$2.2x10^{-7}$
Shopping	-1.147	0.447	0.010***	0.318	-0.169	0.269	0.530	0.844	-16.029	1803	0.993	$1.1x10^{-7}$
Industrial/construction	0.746	0.468	0.111	2.109	-1.400	0.760	0.065*	0.246	-9.784	2997	0.997	$5.6x10^{-5}$
Bridge	0.081	0.851	0.924	1.085	0.488	0.622	0.432	1.629	-14.054	9075	0.999	$7.8x10^{-7}$
School	-0.493	0.248	0.046**	0.611	0.116	0.156	0.456	1.123	3.055	2.222	0.169	21.212
Time of collision												
1000 to 1559 (reference)												
0700 to 0959	0.208	0.253	0.410	1.231	0.054	0.211	0.797	1.056	-13.412	1745	0.994	$1.5x10^{-6}$
0000 to 0659	-0.046	0.314	0.882	0.955	0.034	0.273	0.900	1.035	-10.517	1626	0.995	$2.7x10^{-5}$
1600 to 1859	-0.392	0.172	0.023***	0.675	0.162	0.123	0.190	1.176	-13.075	680.4	0.985	$2.1x10^{-5}$
1900 to 2459	-0.640	0.26	0.014***	0.528	0.115	0.202	0.568	1.122	5.963	2.741	0.030*	388.67
Sample size (n)	**2232**											
Log-LI (zero)	**4071.562**											
Log-LI (Final)	**3822.448**											

P value	**0.000**
Chi square	**249.114**

Note: Symbols *, ** and *** denote statistically significant at the 90%, 95% and 99% confidence interval. Slight injury collision used as base case.

4 Conclusion and Limitations

The current study identified several risk factors associated with the increasing severity of vehicle collisions involving child-pedestrians. The explanatory variables associated with increased probability of fatal injury collisions include: road surface material, traffic system, posted speed limit, lighting conditions, location, type of area and time of collisions. It is recommended that pedestrian facilities structure for child pedestrian should be designed to suits the abilities and skills of the children [30, 31]. The study's conclusions have a number of significant applications for researchers and policymakers. The first step in creating age-based child pedestrian accident prevention policies is being able to comprehend the different elements that affect the severity of injuries and accidents involving children. Furthermore, this study's specific physical environmental factors can be applied to the design of physical environments for children's training virtual simulations. The results of the study can also be applied to the enhancement of places according to the children's ages. The following are some recommendations for future research on child pedestrian road safety, specifically studying the degree of injury and accident among child pedestrians and the behaviour of vehicle drivers. Based on the literature review, this factor has received little attention, particularly in Malaysia. In addition, considering the spatial aspect and combining it with accident data. It is also proposed to conduct in- depth research into children's cognitive limitations and behaviour, as well as to relate these findings to road safety issues.

Nevertheless, the database does not include spatial features such as the dimensions of pedestrian pathways, the layout and usage of the area between the road and the sidewalk. It is recommended that the analysis of physical environment characteristics in combination with spatial analysis with different analytical approach should be further investigated.

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References

1 Department of Statistic. (n.d.). Statistics on causes of death: MALAYSIA 2017-2021. DEPARTMENT OF STATISTICS, MALAYSIA. Retrieved September 29, 2023, from www.dosm.gov.my

2 Zegeer, C.V., Bushell, M.: 'Pedestrian crash trends and potential countermeasures from around the world' *Accid. Anal. Prev.*, 2012, **44**, (1), pp. 3–11.

3 Barton, B.K., Morrongiello, B.A.: 'Examining the Impact of Traffic Environment and Executive Functioning on Children's Pedestrian Behaviors' *Dev. Psychol.*, 2011, **47**, (1), pp. 182–191.

4 Peden, M.: 'World report on road traffic injury prevention' *Public Health*, 2004, **120**, (3), pp. 280.

5 Toroyan, T.: '*Global status report on road safety*.' World Health Orgainisation, 2015, p. 318,

6 Mohamed, N., Wong, S.V., Hashim, H.H., Othman, I.: 'An overview of road traffic injuries among

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children in Malaysia and its implication on road traffic injury prevention strategy (MRR 03/2011 Research report)' *Malaysian Institute of Road Safety Research*, 2011.

7 Sminkey, L.: 'World report on child injury prevention' *Inj. Prev.*, 2008, **14**, (1), pp. 69.

8 Darus, N.S., Borhan, M.N., Ishak, S.Z., Ismail, R., Mohd. Razali, S.F.: 'Pattern of child pedestrian collisions and injuries in Malaysia' *J. Teknol.*, 2018, **80**, (4), pp. 1–8.

9 Haddon, W.: '*Advances in the Epidemiology of Injuries as a Basis for Public Policy*' LANDMARKS IN AMERICAN EPIDEMIOLOGY, 1990.

10 Darus, N.S., Borhan, M.N., Ishak, S.Z., Ismail, R., Mohd. Razali, S.F., Yunin, N.A.M., Hamidun, R.: 'The effect of physical environment risk factors on vehicle collisions severity involving child-pedestrians in Malaysia' *SAGE Open*, 2022, **12**, (1), pp. 1–15.

11 Kupferberg, N., David, B., Rice, R.G.: 'The role of the physical environment in child pedestrian accidents' *J. Adv. Transp*., 1994, **28**, (2), pp. 171–187.

12 Winn, D.G., Agran, P.F., Castillo, D.N.: 'Pedestrian injuries to children younger than 5 years of age' *Pediatrics*, 1991, **88**, (4), pp. 776–789.

13 Abdul Manan, M.M., Várhelyi, A., Çelik, A.K., Hashim, H.H.: 'Road characteristics and environment factors associated with motorcycle fatal crashes in Malaysia' *IATSS Res*., 2018, **42**, (4), pp. 207– 220.

14 Çelik, A.K., Oktay, E.: 'A multinomial logit analysis of risk factors influencing road traffic injury severities in the Erzurum and Kars Provinces of Turkey' *Accid. Anal. Prev.*, 2014, **72**, pp. 66–77.

15 Carson, J., Mannering, F.: 'The effect of ice warning signs on ice-accident frequencies and severities' *Accid. Anal. Prev.*, **33**, pp. 99–109.

16 Tay, R., Choi, J., Kattan, L., Khan, A.: 'A multinomial logit model of pedestrian-vehicle crash severity' *Int. J. Sustain. Transp*., 2011, **5**, (4), pp. 233–249.

17 Rifaat, S.M., Tay, R., De Barros, A.: 'Effect of street pattern on the severity of crashes involving vulnerable road users' *Accid. Anal. Prev.*, 2011, **43**, (1), pp. 276–283.

18 Amoh-Gyimah, R., Aidoo, E.N., Akaateba, M.A., Appiah, S.K.: 'The effect of natural and built environmental characteristics on pedestrian-vehicle crash severity in Ghana' *Int. J. Inj. Control Saf. Promot.*, 2017, **24**, (4), pp. 459–468.

19 Wong, S.C., Sze, N.N., Li, Y.C.: 'Contributory factors to traffic crashes at signalized intersections in Hong Kong' *Acc. Anal. Prev.*, 2007, **39**, pp. 1107–1113.

20 Boschi-Pinto, C., da R. Curvello, H.G., Fonseca, S.C., Kale, P.L., Kawa, H., Guimarães, J.C.C.: 'What do children aged 5 to 14 years die from in the state of Rio de Janeiro, Brazil? Trend analysis of the period 2000-2019' *Ciência & Saúde Coletiva*, 2023, **28**, (2), pp. 473–485.

21 Al-Ghamdi, A.S.: 'Pedestrian-vehicle crashes and analytical techniques for stratified contingency tables' *Acc. Anal. Prev.*, 2002, **34**, (2), pp. 205–214.

22 Koopmans, J.M., Friedman, L., Kwon, S., Sheehan, K.: 'Urban crash-related child pedestrian injury incidence and characteristics associated with injury severity' *Acc. Anal. Prev.*, 2015, **77**, pp. 127–136.

23 Adanu, E.K., Dzinyela, R., Agyemang, W.: 'A comprehensive study of child pedestrian crash outcomes in Ghana' Acc. Anal. Prev.,2023, **189**, pp. 107146.

24 Nasri, M., Aghabayk, K., Esmaili, A., Shiwakoti, N.: 'Using ordered and unordered logistic regressions to investigate risk factors associated with pedestrian crash injury severity in Victoria Australia' *J. Safety Res.*, 2022, **81**, pp. 78–90.

25 Sun, M., Xiaoduan, S.: 'Pedestrian crash analysis urban and rural areas Louisiana' *J. High. Transp. Res. Dev.*, 2020, **14**, (1), pp. 102–110.

26 Oxley, J., O'Hern, S., Burtt, D., Rossiter, B.: 'Falling while walking: A hidden contributor to pedestrian injury' *Acc. Anal. Prev*., 2018, **114**, pp. 77–82.

27 Assailly, J.P.: 'Characterization and prevention of child pedestrian accidents: An overview' *J. Appl. Dev. Psychol.*, 1997, **18**, (2), pp. 257–262.

28 Desapriya, E., Sones, M., Ramanzin, T., Weinstein, S., Scime, G., Pike, I.: 'Injury prevention in child death review: Child pedestrian fatalities' *Inj. Prev.*, 2011, **17**, pp. 4–9.

29 Schwebel, D.C., Davis, A.L., O'Neal, E.E.: 'Child pedestrian injury: A review of behavioral risks and preventive strategies' *Am. J. Lifestyle Med.*, 2012, **6**, pp. 292–302.

30 Schieber, R.A., Thompson, N.J.: 'Developmental risk factors for childhood pedestrian injuries' *Inj. Prev.*, 1996, **2**, pp. 228–236.

31 Vinje, M.P., 'Children as pedestrians: Abilities and limitations' *Acc. Anal. Prev.*, 1981, **13**, (3), pp. 225– 240.