International Journal of Injury Control and Safety Promotion

ISSN: (Print) (Online) Journal homepage: www.tandfonline.com/journals/nics20

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To cite this article: Thomas Kolawole Ojo, Anthony Baffour Appiah, Abena Obiri-Yeboah, Atinuke Olusola Adebanji, Peter Donkor & Charles Mock (2022) Structural equation modeling of pedestrian behavior at footbridges in Ghana, International Journal of Injury Control and Safety Promotion, 29:4, 489-499, DOI: 10.1080/17457300.2022.2081984

To link to this article: https://doi.org/10.1080/17457300.2022.2081984

Published online: 04 Jul 2022.

INTERNATIONAL JOURNAL OF INJURY CONTROL AND SAFETY PROMOTION
2022, VOL. 29, NO. 4, 489–499
https://doi.org/10.1080/17457300.2022.2081984

Structural equation modeling of pedestrian behavior at footbridges in Ghana

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ABSTRACT

This study was undertaken to fill the information gap by exploring pedestrian behavior at footbridges in the Greater Accra and Kumasi Metropolitan areas of Ghana. Further, the study modelled the behavior of 69,840 pedestrians at the footbridges using Structural Equation Modeling (SEM). Pedestrians were observed as users and non-users of seven selected footbridges in the morning (7:00 am–9:00 am), afternoon (11:00 am–1:00 pm), and evening (3:00 pm–5:00 pm) periods for seven consecutive days (Monday to Sunday). Selected footbridges were characterized by traffic generators as schools, shopping malls, bus stops, office complexes, and restaurants in different matrices. The results showed that 30.7% of the observed pedestrians did not use the footbridges, males and young pedestrians were more likely not to use the footbridges as opposed to females and the elderly with more than half of observed pedestrians carrying luggage or load. Footbridge users were more likely to talk and hold phones than non-users and the elderly were more likely to run and ride compared to young pedestrians. Officials of the National Road Safety Authority should carry out effective public education on pedestrian safety targeting males and young pedestrians to encourage the use of pedestrian footbridges.

ARTICLE HISTORY
Received 6 December 2021
Revised 5 May 2022
Accepted 21 May 2022

KEYWORDS
Pedestrian safety; footbridges; pedestrian behavior; Ghana; SEM

1. Introduction

Pedestrians the world over account for some 35% of road traffic deaths (RTDs) and another 50% from Sub-Saharan Africa (World Health Organisation, 2018). According to World Health Organisation (2018) pedestrians, as vulnerable road users constitute the majority in national and global road traffic statistics. The UK, a country with one of the safest road networks in the world recorded 448 pedestrian deaths, 10% more than in 2016 (Macllroy et al., 2019). Understanding pedestrian behavior is a prerequisite to any successful global or national road safety campaign. This is because, planning pedestrian environments entails certain assumptions on how pedestrians will respond to characteristics of the surroundings as they formulate their walking itineraries (Zacharias, 2001).

Many studies have been conducted on understanding pedestrian behavior in different situations (Macllroy et al., 2019). These studies adopted varying methods including virtual reality laboratory studies (e.g. Tapiro et al., 2016, 2018), travel diary and location data (e.g. Quistberg et al., 2017), road traffic collision data (e.g. Obeng-Atuah et al., 2017), vehicle-based video recordings (e.g. Jha et al., 2017), and, most commonly, static video recording observations (e.g. Brosseau et al., 2013; Zhuang et al., 2018;) and direct observations (Ojo et al., 2019).

Some of these methods have come under criticism such as the lack of generalization beyond where the data was collected (Macllroy et al., 2019). However, the use of direct observations offers the opportunity to observe the phenomenon in a natural terrain. There are many examples of the use of direct observations in studies on pedestrian behavior in low and middle-income countries (LMICs) like Ghana, Nigeria, and Iran. Other examples can be seen in high-income countries (HICs) like Australia.

Recent contributions include Sisiopiku and Akin (2003), Stefanova et al. (2015) who made direct observations of pedestrian unsafe crossing at urban Australian level crossings; Olawole and Olayiwola (2018) observed pedestrian behavior before reaching the curb, at the curb and during street crossing in Southwestern Nigeria; Hamann et al. (2017) made direct observations of pedestrian risky behaviors during crossing in Romania; Ojo et al. (2019) observed pedestrian risky behavior at zebra crossings in Ghana; Yankson et al. (2020) made direct observations of road use behavior of urban primary school children in Ghana; and Adjakloe et al. (2020) directly observed gendered perspective

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on road crossing behavior of University of Cape Coast students.

All these studies have shed light on pedestrian behavior using pedestrian facilities. However, there is a dearth of research on direct observations of pedestrian behavior at footbridges in both LMICs and HICs. Therefore, this study fills this gap by exploring pedestrian behavior at footbridges in the Greater Accra and Kumasi Metropolitan areas, Ghana using direct observations. Further, the study seeks to model pedestrian behavior (such as footbridge use/non-use, accompanied, talking and riding, holding a phone) at footbridges using Structural Equation Modeling (SEM). This model will enable the use of several criteria especially the t-value (structural path coefficients) to assess the goodness of fit. Pedestrians were observed as users and non-users at seven selected footbridges from 7:00 am–9:00 am, 11:00 am–1:00 pm, and 3:00 pm–5:00 pm, for seven continuous days (Monday to Sunday). This study will specifically provide information on the rate of use of footbridges in the study area and determine the relationship between the socio-demographic characteristics of pedestrians (gender, age and usage status) and pedestrian behavior (including holding a phone, talking, accompanied and wearing an ear piece) using an SEM.

This study will provide information on how to improve pedestrian safety at footbridges to officials of the National Road Safety Authority (NRSA), Motor Transport and Traffic Department (MTTD) of the Ghana Police Service (GPS) and Ghana Highway Authority (GHA). Further, the findings will also add to the literature on pedestrian safety at footbridges in LMIC like Ghana, Nigeria, and India.

1.1. Pedestrian safety

Pedestrian safety is a major road safety concern in both HICs (such as the UK and US) and LMICs (including Ghana, Nigeria, and South Africa) (Koekemoer et al., 2017; Peltzer, 2011). In Africa, pedestrians are the most frequently injured road users (Peltzer, 2011). In almost all countries, they account for the largest share of road traffic fatalities between 40–45%; only Botswana (29%) and Zimbabwe (31%) have lower cases (Obeng-Atuah et al., 2017). Pedestrian injuries are a leading cause of death among African children with the young ones in LMICs being majorly at risk (Koekemoer et al., 2017).

Pedestrian crashes are prevailing because of various factors such as inadequate road infrastructure, lack of maintenance, exposure to traffic due to over-reliance on walking as the principal means of transport and the lack of supervision (Koekemoer et al., 2017). The occurrence of pedestrian injuries takes place at certain times of the day with most of the fatalities on weekdays (Mabunda et al., 2008; Hobday et al., 2010). There is a concentration of pedestrian deaths in urban areas, but evidence exists that some of these fatalities occur on highways traversing settlements (Damsere-Derry et al., 2019).

Pedestrians form a mixture of people with certain socio-demographic characteristics (such as age, sex, travel behavior). Globally, young child pedestrians are largely at risk of hospitalization due to collision (e.g. head injuries) in a pedestrian-bicycle collision especially due to impact with the ground (Chong et al., 2010). Boys are more at risk than girls for serious pedestrian crashes.

In LMICs, gender-based role factors significantly affect the length of time pedestrians spend on roads. Therefore, there are more girls and women pedestrians. These pedestrians largely carry loads and are significantly at a higher risk of pedestrian crashes than the men. However, the lack of research on gendered pedestrian crashes in LMICs leaves many questions unanswered (Porter, 2002, 2008).

Male pedestrians of all age groups are overly represented in pedestrian crashes with two-thirds of children killed at a fatality rate of 57% higher than their female cohorts (Stoker et al., 2015).

1.2. Pedestrian facilities

Pedestrian facilities including pedestrian crossing or zebra crossing, sidewalk or pedestrian walkway, footbridges or pedestrian bridges are constructed to reduce pedestrian-vehicular interactions (Ojo et al., 2019; Zegeer, 2002). These facilities are supposed to be accessible to all pedestrians including those with disabilities.

In planning pedestrian facilities, the urban designers and civil engineers have to adopt a consolidated approach about the flow characteristics and relationship between basic flow parameters over different types of pedestrian facilities (Banerjee et al., 2020). Even though designing pedestrian facilities requires a well-thought-out venture, the architecture of roads and pedestrian facilities in LMICs usually do not meet the standard. Thus, the planning and building of pedestrian facilities in LMICs should consider population dynamics, social orientation of the populace, the trend of pedestrian facility usage, and the economic activities of that city.

1.3. Pedestrian behavior at pedestrian facilities

Pedestrian road crossing behavior is diverse (Hasan et al., 2020; Hasan & Napiah, 2018; Ojo et al., 2019; Yankson et al., 2020). Pedestrian behavior such as speed, crossing road outside pedestrian footbridge, waiting for delay and clustering have been studied via observations and measured with a video camera at an un-signalized midblock crosswalk (Shi et al., 2007). In LMICs, women pedestrians walk more and often carry loads of household goods that include children, water, and wood (Porter, 2002, 2008).

Pedestrian crossing outside pedestrian footbridge is informed by several factors including the pedestrian, vehicular and roadway characteristics which influence the pedestrian road crossing behaviour (Hasan et al., 2020; Hasan & Napiah, 2018). In the conceptual framework (Figure 1), age, monthly income, being in a hurry, vehicle volume, and waiting time have a direct influence on jaywalking. Crossing distance, education, number of companions, and pedestrian volume, waiting time, number of conflicting

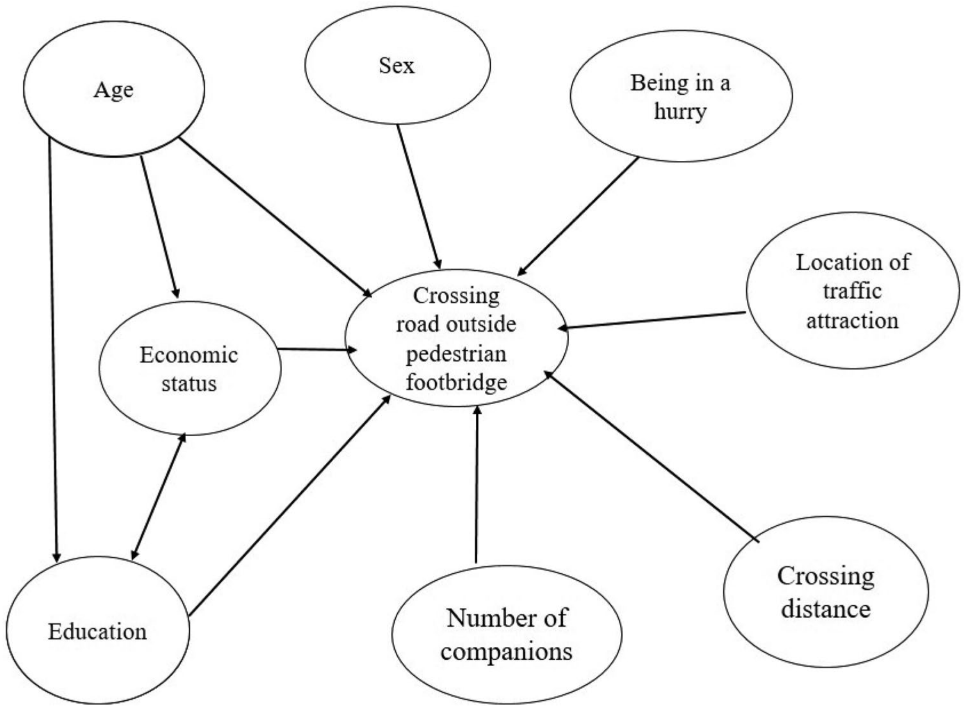

Figure 1. Framework of crossing road outside of a pedestrian footbridge.

traffic lanes, conflicting vehicular traffic volume, usage frequency, comfortability, street characteristics and personal characteristics of the pedestrian influencing behavior (Hasan et al., 2020; Hasan & Napiah, 2018; Noora et al., 2016; Wu et al., 2014).

Pedestrians tend to walk alone or in groups and may engage in the use of mobile phone, talking to other crossing pedestrians, run or ride using or not using a pedestrian facility such a zebra crossing and footbridges (Truong et al., 2019). Pedestrians walking in groups compensate for the associated risk of jaywalking and avoiding digital and social distractions including making phone calls, and listening to music (Truong et al., 2019).

2. Methods and data

2.1. Study area

Ghana is an LMIC located in West Africa with a population of 31million. Ghana is rapidly urbanizing with its administrative, commercial and entertainment centres moving outside Accra. Other very important cities are Cape Coast, Kumasi, Tamale and Sekondi-Takoradi. Accra has the highest number of footbridges (16) with Kumasi and Cape Coast having one apiece. The footbridges in Accra and Kumasi are used by all categories of pedestrians unlike that of Cape Coast which connects the two campuses of Aggrey Memorial A.M.E and is mainly used by students at the school.

Accra is the administrative capital of the Accra Metropolitan Assembly which is one of the 10 districts that make up the Greater Accra Metropolitan Area (GAMA) (see Figure 2). The estimated population of GAMA is 4.3 million and this is expected to double in 20 years.

Six out of 16 footbridges comprising Accra Mall, Kaneshie (the one very close to the markets), Mallam, Lapaz, Kwashieman, Madina were selected because of the observed heavy pedestrian volume in Accra. The only footbridge in Kumasi (Tech Junction) was also surveyed (see Figures 2 and 3). These footbridges are characterized by traffic generators such as schools, shopping malls, bus stops, office complexes, and restaurants. Owing to the prevailing economic, educational, and social activities in these locations, pedestrians have the choice to either use the footbridge to cross the road or jaywalk (except Kaneshie with a long and tall barricade). The characteristics of the footbridges and roads are in Table 1.

Kumasi city has now become the nucleus of an emerging metropolitan region (often referred to as Greater Kumasi Metropolitan Area or GKMA) that comprises the old city and six adjoining districts—Ejisu-Juabeng, Bosomtwe, Kwabre East, Afigya Kwabre, Atwima Nwabiagya, and Atwima Kwanwoma (see Figure 3). The GKMA covers an area of approximately 2,746km^2 and had a combined population of 2,564,120 in 2010, 79% of which reside in the Kumasi metropolis.

2.2. Research design

The study adopted a descriptive-exploratory research design.

2.3. Pilot study

A pilot study conducted between 31st May and 1st June 2021 at Shiashie footbridge, Accra helped in refining the instrument such as the addition of ‘riding’ to the

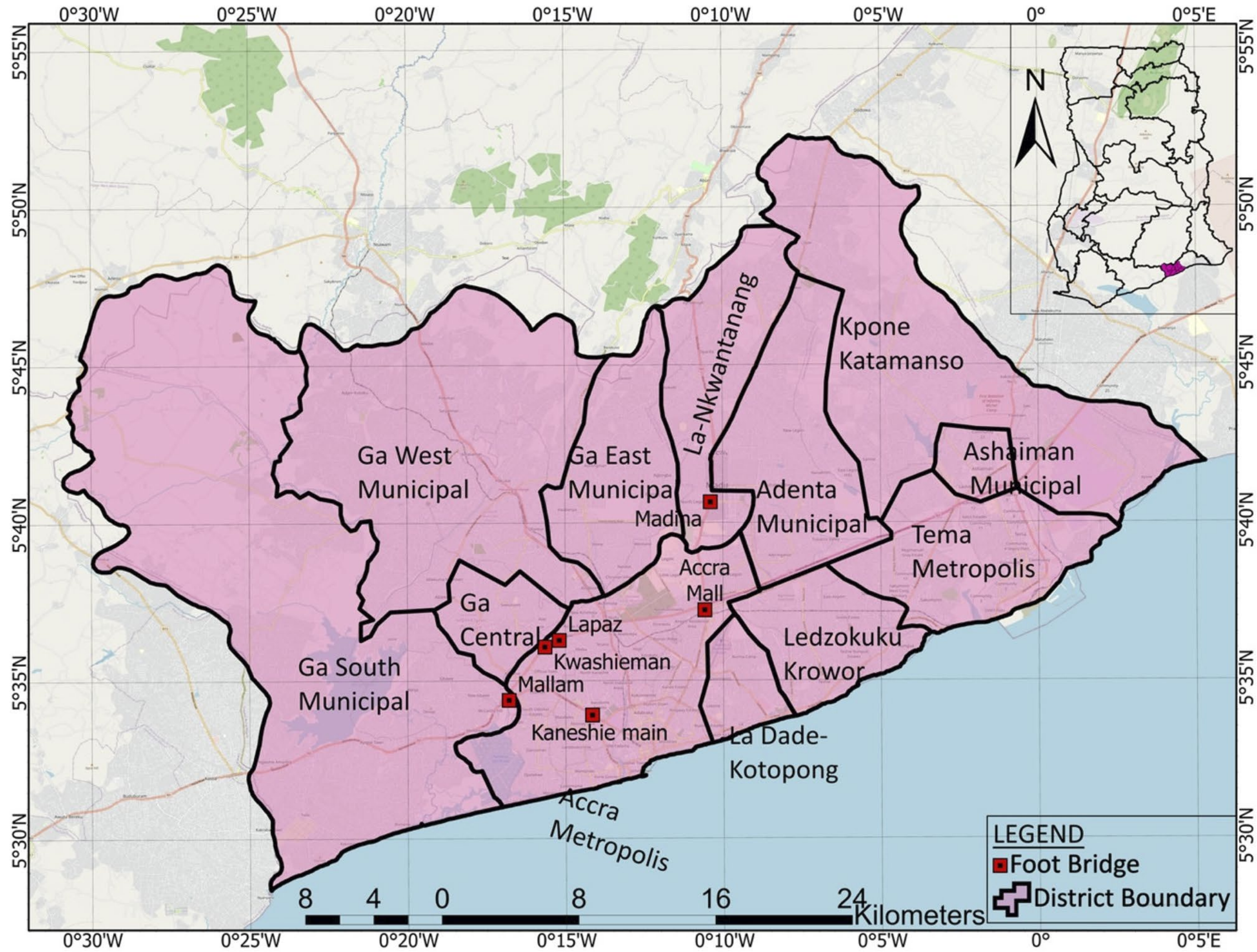

Figure 2. Map showing the location of six footbridges in GAMA. Source: GIS Unit, Department of Geography and Regional Planning, UCC.

instrument. The initial instrument also contained 'alone' and 'accompanied'.

2.4. Research instrument

The observational checklists for both users and non-users comprised gender, age, accompanied, school children in uniform, talking, holding a phone/making a call, wearing an earpiece, carrying a luggage/load, running, and riding a bicycle or motorcycle.

2.5. Ethical issues

Ethical clearance was obtained from the Committee on Human Research Publication and Ethics Kwame Nkrumah University of Science and Technology (KNUST) (CHRPE/AP/174/21). Data were gathered through unobtrusive observations of pedestrians. There were no interactions between the research assistants and the pedestrians.

2.6. Target population

The target population comprises all users and non-users of the selected footbridges during the observation period.

2.7. Sampling technique

Census was done for all users and non-users of the selected footbridges. This indicates that all users and non-users were candidates to be observed.

2.8. Data collection

Thirteen research assistants were recruited for the data collection. Two research assistants made observations at each of the footbridges except for Kaneshie. The nature of the Kaneshie footbridge prevents jaywalkers. A research assistant stationed on the footbridge observed users and the other observed non-users within 100 m radius of the footbridge during three time periods (7:00 am–9:00 am, 11:00 am–1:00 pm and 3:00 pm–5:00 pm daily) from Monday 7th–Sunday 13th June 2021 (Ojo et al., 2019). To minimize fatigue, the research assistants changed roles after each observation session (7:00 am–9:00 am, 11:00 am–1:00 pm and 3:00 pm–5:00 pm).

2.9. Data analysis

The data from the observational checklists were processed using SPSS V 21. The preliminary results of the data were

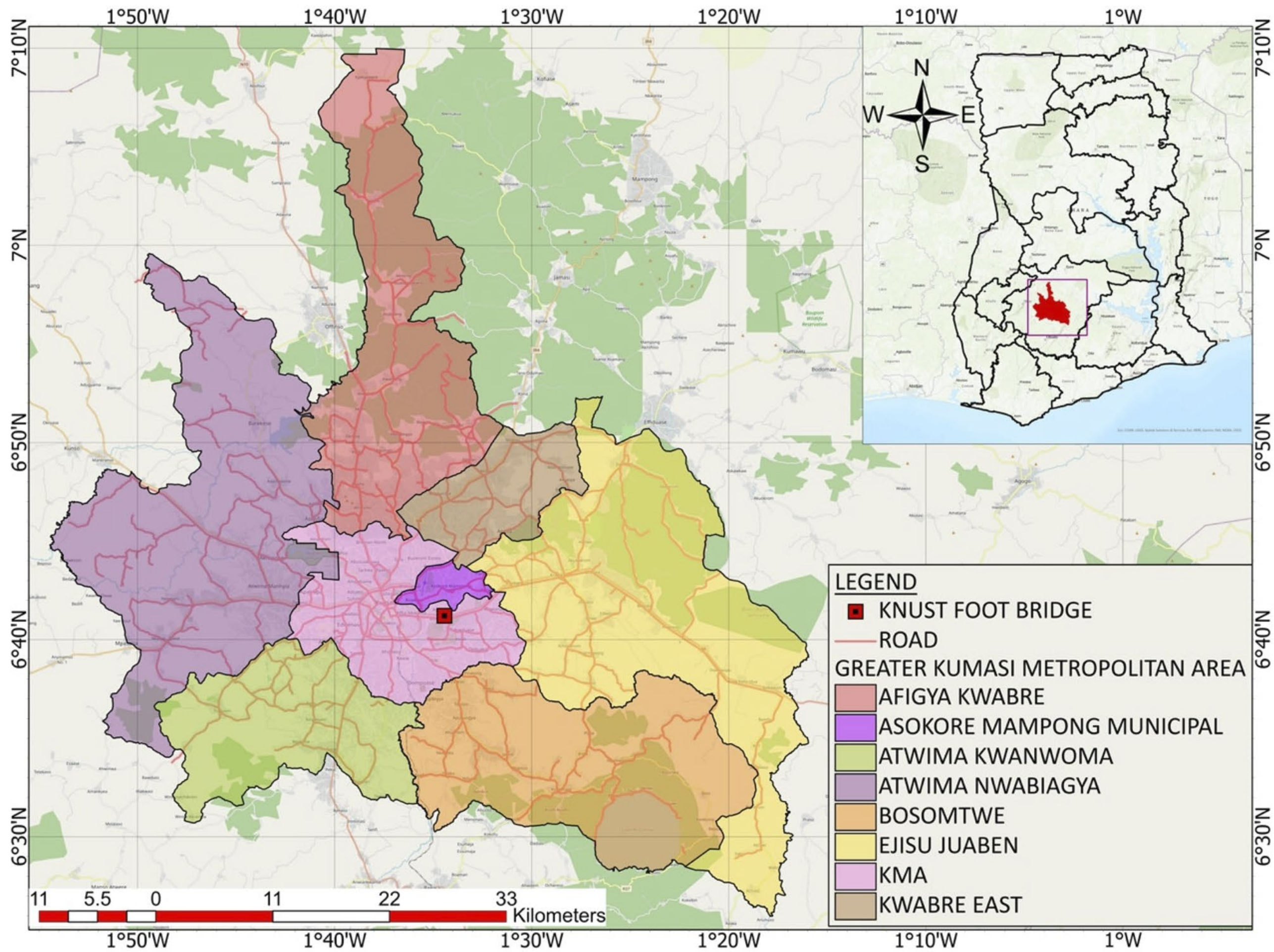

Figure 3. Map showing the location of KNUST footbridge in GKMA. Source: GIS Unit, Department of Geography and Regional Planning, UCC.

presented using frequencies and percentages. The relationship between the independent and dependent variables were established using structural equation modelling (SEM) (Adedia et al., 2020, 2021). Independent variables included being accompanied, talking, holding a phone, or making phone calls, wearing an earpiece, carrying a load, running, and riding at highways and were for both users and non-users of footbridges. The model fit indices used in assessing the SEM models in this study include the root mean square error of approximation (RMSEA), standardized root mean residual (SRMR), root mean residual (RMR), comparative fit index (CFI), goodness of fit index (GFI), adjusted goodness of fit index (AGFI) and Tucker-Lewis Index (TLI). The RMSEA, SRMR and RMR are referred to as badness of fit indices, because the smaller they are the better the model fit. However, other fit indices must assume values greater or equal to 0.95 for a good model fit, with an acceptable model with values of 0.90 or more (Adedia et al., 2020).

An SEM consists of two components: an SEM that specifies the structural relations between latent variables and a measurement model that defines the relationships between latent variables and observed variables (Sheykhfard et al., 2021). An SEM has a structural part as shown in Eq. (1):

$$\eta = (\mathrm{I} - -\beta)^{--1}\,\mathrm{r}\xi + (\mathrm{I} - \beta)^{--1}\zeta = (\mathrm{I} - -\beta)^{--1}(\mathrm{r}\xi + \zeta). \quad (1)$$

The manifest variables are to measure the exogenous (ξ) and endogenous (η) theoretical variables in Eq. (1) shown in models 2 and 3 respectively:

$$\mathrm{X} = \Lambda_x \xi + \delta, \quad (2)$$

$$\mathrm{Y} == \Lambda_y \eta + \varepsilon, \quad (3)$$

where η represents the endogenous latent variables, ξ represents the exogenous latent variables, β represents the coefficients of η variables, ζ represents the random disturbances or errors associated with the structural model. r is the matrix of the coefficients of exogenous latent variables, ε and δ are the random errors associated with the measurement models for determining, respectively, endogenous, and exogenous latent variables, and X and Y are the independent and dependent manifest variables (Bollen, 1989).

The omnibus test is conducted using the absolute fit indices employed in an SEM to test whether $\Sigma = \Sigma(\theta)$ or not, where Σ is the covariance matrix for the estimated population using sample covariance matrix S (Kelloway, 1995). The GFI determines the amount of variance and covariance in the sample variance matrix that is predicted by the $\Sigma(\theta)$ (Hooper et al., 2008), which is affected by sample size. The GFI is represented in equation:

$$\mathrm{GFI} = 1 - \frac{tr[(\Sigma^{-1} S - I)^2]}{tr[(\Sigma^{-1} S)^2]} \tag{4}$$

which usually falls between 0 and 1 but becomes desirable if it is at least 0.95 (Hooper et al., 2008). The AGFI adjusts the GFI for model complexity with degrees of freedom (Hooper et al., 2008) As in GFI, the AGFI falls between 0–1 and it is also sensitive to the sample size (Hooper et al., 2008). AGFI is calculated using Eq. (5):

$$\mathrm{AGFI} = 1 - \left[\frac{k(k+1)}{2df}\right](1 - - \mathrm{AGFI}). \tag{5}$$

The RMR is the square root of the average residual between the elements of sample covariance and predicted covariance matrix as shown in Eq. (6) (Hooper et al., 2008).

$$\mathrm{RMR} = \sqrt{\sum_{i=1}^{k}\sum_{j=1}^{i}\frac{(sij - \sigma ij)^2}{k(k+1)}}, \tag{6}$$

where $k = \mathrm{n} + \mathrm{m}$, which it the total number of exogenous and endogenous variables. Generally, RMR assumes values from 0 to 1 ($0 \leq \mathrm{RMR} \leq 1$), but $\mathrm{RMR} \leq 0.05$ is more preferred. When there are differences in the scales of measurement for the observed variables, it makes it difficult to interpret, and hence, standardized root mean square residual (SRMR) was developed for easier and meaningful interpretation (Hooper et al., 2008). The SRMR is computed using Eq. (7):

$$\mathrm{SRMR} = \sqrt{2\sum_{i=1}^{k}\sum_{j=1}^{i}\frac{(sij - \sigma ij)/(sij\ sjj)]^2}{k(k+1)}}, \tag{7}$$

where s_{ij} and σ_{ij} are the elements of the covariance matrix of the sample data and implied covariance matrix, respectively. The SRMR takes values from 0 to 1, and the lower the value of SRMR, the better. The RMSEA is one of the fit indices used to assess the fitness of the model data and are classified as badness-of-fit indices (Steiger, 2000). The RMSEA is calculated using equation:

$$\mathrm{RMSEA} = \sqrt{\sqrt{\frac{X^2 - df}{df\,(N-1)}}} \tag{8}$$

Several studies consider a model as close fit if RMSEA < 0.05, an average fit if $0.05 \leq \mathrm{RMSEA} \leq 0.08$, neither good nor bad fit if $0.08 < \mathrm{RMSEA} \leq 0.1$, and poor fit if RMSEA > 0.1 (Hooper et al., 2008).

The CFI is used when comparing hypothesized and baseline models using Eq. (9) (Bentler, 1990):

$$\mathrm{CFI} = 1 - \frac{\max[(X_h^2 - df_h), 0]}{\max[(X_b^2 - df_b), (X_h^2 - df_h), 0\}}, \tag{9}$$

where X_b^2 and X_h^2 are the chi-square test statistics of the baseline and the hypothesized models, respectively, with corresponding degrees of freedom df_b and df_h. The CFI value is between 0 and 1, which is less affected by sample size and has an acceptable value of greater than or equal to 0.95 (Bentler, 1990).

The TLI otherwise known as non-normed fit index was developed against or to reduce the effect of sample size (Bollen, 1989; Tucker & Lewis, 1973). It is sometimes expected that the report values may not be within 0–1. The equation represents TLI:

$$\mathrm{TLI} = \frac{(F_b / df_b) - (F_h / df_h)}{(F_b / df_h) - [1/(N-1)]} = \frac{(X^2 / df_b) - (X^2 / df_h)}{(X^2 / df_b) - 1} \tag{10}$$

3. Result

3.1. Cross tabulation of pedestrian characteristics and their behavior

In all, 69,840 pedestrians were observed with 30.7% being jaywalkers. Majority of the observed were males (52.2%) and aged 26–50 years (46.4%) (see Table 1). Further, more than half (54.4%) were observed to be carrying luggage or load with the majority being females (52.1%), aged 26–50 years (47.9%), and users (72.3%). It is revealed that most of the males (53.0%, 75.0%), and those aged 26–50 years (60.6%, 55.3%) were running and riding respectively. Non-users and users of the footbridges were largely associated with running (88.0%) and riding (63.6%) (see Table 1).

3.2. Modelling pedestrian behavior at footbridges

The model was checked for the goodness of fit by reporting good fit indices, root mean square error of approximation (RMSEA), standardized root mean residual (SRMR), root mean residual (RMR), Comparative Fit Index (CFI), Goodness of Fit Index (GFI), Adjusted Goodness of Fit Index (AGFI) and Tucker-Lewis Index (TLI) values of 0.003, 0.001, 0.000, 1.000, 1.000, 1.000 and 0.999, respectively (Table 2). The values indicated a correctly fit model.

As shown in Figure 3, users of footbridges are more likely (p-value < 0.001) to be talking. Meanwhile the males (p-value < 0.045) as well as the elderly (p-value < 0.001) are less likely to be talking. Males (p-value < 0.001) and users of footbridges (p-value < 0.001) are more likely to hold phones than the females and non-users of footbridges. Males (p-value < 0.001), users of footbridges (p-value < 0.001) and young people (p-value < 0.001) are more likely to hold phones than the females, non-users of footbridges and the elderly. Females (p-value < 0.001), users of footbridges (p-value < 0.001) and elderly (p-value < 0.001) are

Table 1. Cross-tabulation of demographics and pedestrian behavior.

Demographics			Pedestrian behavior						
			Accompanied	Talking	Holding a phone/ calling	Wearing an earpiece	Carrying a load	Running	Riding
		F (%)	F (%)	F (%)	F (%)	F (%)	F (%)	F (%)	F (%)
		69,840 (100)	11,827 (16.9)	12,803 (18.3)	14,755 (21.1)	11,282 (16.2)	38,689 (54.4)	10,811 (15.5)	868 (1.2)
Gender	Male	36,434 (52.2)	5675 (48.0)	6507 (50.8)	8143 (55.2)	6206 (55.0)	18,543 (47.9)	5733 (53.0)	651 (75.0)
	Female	33,406 (47.8)	6152 (52.0)	6296 (49.7)	6612 (44.8)	5076 (45.0)	20,146 (52.1)	5078 (46.7)	217 (25.0)
Age group	<18	9122 (13.1)	3114 (26.3)	3020 (23.6)	1683 (11.4)	1606 (14.2)	4953 (12.8)	698 (6.4)	73 (8.4)
	18–25	23,429 (33.5)	4092 (34.6)	4552 (35.6)	5904 (40.0)	4789 (42.4)	12,215 (31.6)	2548 (23.6)	273 (31.5)
	26–50	32,417 (46.4)	3914 (33.1)	4522 (35.3)	6267 (42.5)	4237 (37.6)	18,551 (47.9)	6548 (60.6)	480 (55.3)
	<50	4872 (7.0)	707 (6.0)	709 (5.5)	901 (6.1)	650 (5.8)	2970 (7.7)	1019 (9.4)	42 (4.8)
Status	User	48,385 (69.3)	9979 (84.4)	10,684 (83.4)	11,855 (80.3)	9162 (81.2)	27,991 (72.3)	1297 (12.0)	552 (63.6)
	Non-user	21,455 (30.7)	1848 (15.6)	2119 (16.6)	2900 (19.7)	2120 (18.8)	10,698 (27.7)	9514 (88.0)	316 (36.4)

*F = Frequency.

more likely to carry luggage than the males, non-users of footbridges and young people. Also, males are less likely to be running (p-value < 0.001) and are accompanied (p-value < 0.001) than the females, whilst the males are more likely to be riding (p-value < 0.001). The elderly are more likely to be running (p-value < 0.001) and riding (p-value < 0.001) than the young ones, however, the elderly are less likely to be accompanied (p-value < 0.001). Users of footbridges are less likely to be running (p-value < 0.001), riding (p-value < 0.035) than the non-users, however, the users are more likely to be accompanied (p-value < 0.001).

Among all the exogenous variables for running, the status of pedestrians has the strongest negative relationship with the standardized coefficient of −0.52. It was followed by age, which has positive effects with a standardized coefficient of 0.05, before gender. Moreover, the status of participants has the highest effects on wearing earphone (0.11), holding a phone (0.13) and talking (0.13) than the other exogenous variables. This implies that being a user is linked to the above-mentioned characters. Gender strongly affects riding (0.05) and carrying luggage (−0.09), as men were more likely to ride, women were more likely to carry luggage. There is a strong correlation between talking and being accompanied (0.34).

Table 2. Fit indices.

RMSEA	SRMR	RMR	CFI	GFI	AGFI	TLI
0.003	0.001	0.000	1.000	1.000	1.000	0.999

4. Discussion

The study explored pedestrian behavior at footbridges using an SEM. An SEM is a multivariate statistical analysis technique that is used to analyze the structural relationship between measured variables and latent (exogenous) constructs (Abbas et al., 2020). Modelled variables studied included being accompanied, talking, holding a phone, or making phone calls, wearing an earpiece, carrying a load, running, and riding at highways. Several criteria were used to assess the goodness of fit of the structural model, the most basic of which was t-values (Structural path coefficients). This criterion is defined for measuring the relationship between the factors in the model (Adedia et al., 2020, 2021). The results showed that the variables in the SE model were statistically significant at p-value <0.05 on the likelihood of pedestrian behaviour. This is because when utilizing an SEM, the current analysis accounted for this high correlation between the latent variables that accurately modelled the pedestrian behaviour at footbridges. The model correctly fitted by reporting good fit indices, root mean square error of approximation, standardized root mean residual, root mean residual, Comparative Fit Index, Goodness of Fit Index, Adjusted Goodness of Fit Index and Tucker-Lewis Index.

Using an un-obstructive data collection technique provided an unbiased assessment of pedestrian behavior at footbridges in Ghana. There is a dearth of research on direct observations of pedestrian behavior at footbridges in LMICs including Ghana. In this study, a total of 69,840 pedestrians were observed in a week to examine their

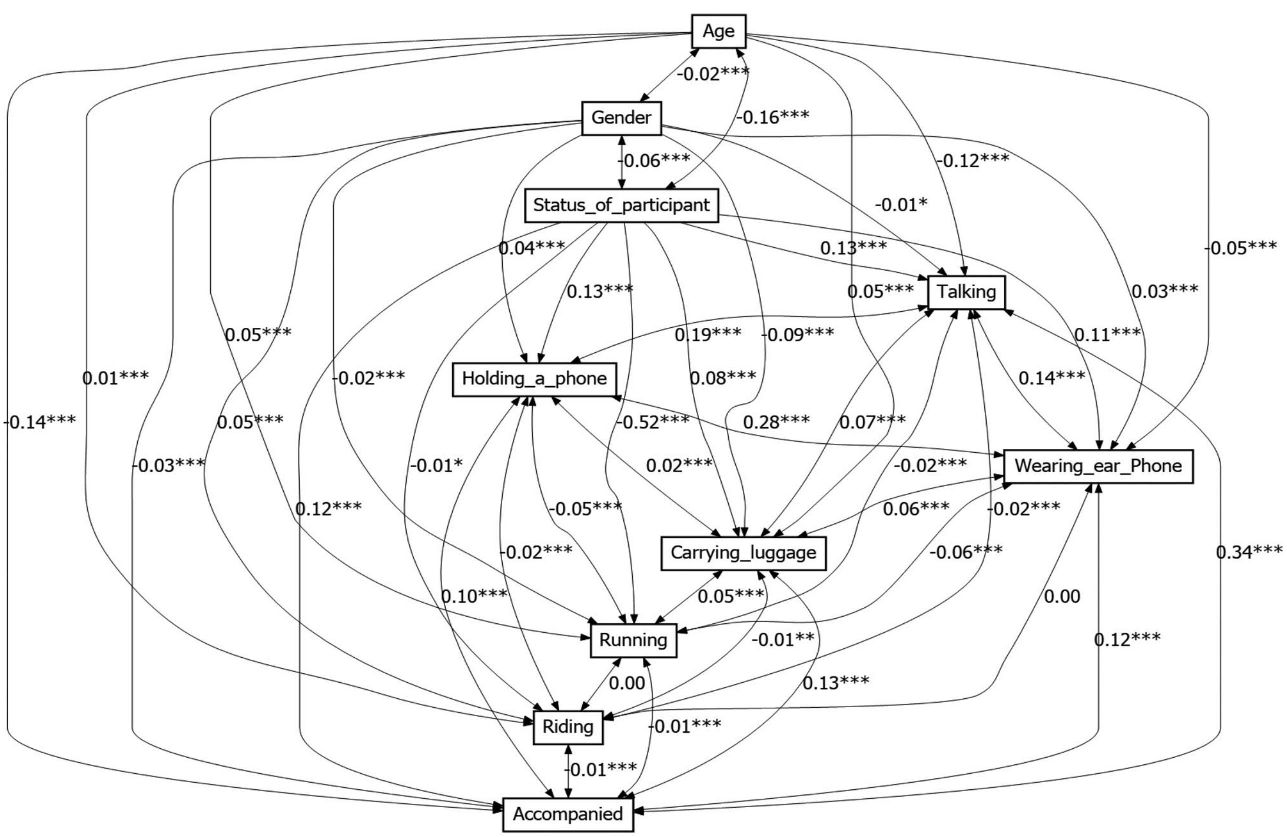

Figure 4. SEM model. Standardized coefficients close to ±1, signifies strong relationships or effects.Source: From the study.

behavior at seven selected footbridges on Ghanaian highways. Considering the number of pedestrians using these highways within the 6 hours (7:00 am–9:00 am, 11:00 am–1:00 pm, and 3:00 pm–5:00 pm) of a day and within a radius of 100–150 m from a pedestrian footbridge, explains how busy those areas are. This could be attributed to the number of residents and business facilities on either side of the highways in the Capital City of Ghana, Greater Accra, and Ashanti Regional Capital, Greater Kumasi.

Pedestrians in these areas who have businesses or access any social facility across the highway are likely to use or not use the pedestrian footbridges several times a day (Noora et al. 2016). As revealed in the study, less than a third of the observed pedestrians did not use the footbridges. This rate of non-usage puts these pedestrians at a higher risk considering the nature of the highway with high vehicular speed. The use of footbridges in Ghana was found to be better than what was observed in Turkey but lower than that of China (Demiroz et al., 2015; Wu et al., 2014). It should be noted that footbridge usage may differ among countries and cities which may be attributed to the level of road traffic enforcement (Truong et al., 2019). This incidence accounts for the pedestrian injury severity on these highways with footbridges (Damsere-Derry et al., 2019; Noora et al., 2016). What may compound the pedestrian injury severity is the behavior being exhibited in crossing the highway illegally.

Pedestrians form a varied mix of people with different socio-demographic characteristics (age, gender, and footbridge user status) which inform their road crossing behaviors. Males and young pedestrians were more likely not to use the footbridges as opposed to females and the elderly. This could be because males and young adults like to engage in risky behaviors and are the most active groups in the population (Ojo et al., 2019). Similar studies in Ghana also highlighted that pedestrians who do not use the footbridges were mostly young adults and dominantly males (Noora et al., 2016).

The observed pedestrian behavior were 'being accompanied', 'talking', 'holding a phone', or 'making a phone call', 'wearing an earpiece', 'carrying a load', 'running', and 'riding' a motorcycle or bicycle while crossing the highway either on a footbridge or using an unapproved route. The exhibition of certain behavior such as making a call, listening to music, and talking to other pedestrians while jaywalking alone increases the risk of pedestrian crashes (Truong et al., 2019). The analysis showed that more than half of the observed pedestrians were carrying a piece of luggage or load with the majority being females. Notably, female pedestrians abound in LMICs such as Ghana and Nigeria and mostly carry loads that may include water, children, and household utensils (Porter, 2002, 2008). This category of pedestrians is less likely to run whether using the bridge or not because of the encumbrance of the load.

The findings also revealed that males and young people were more likely to hold phones than females and the elderly. Further, users of footbridges were more likely to be talking and holding phones than the non-users of footbridges. The non-users don't want to be distracted and as such may not want to engage in risky behavior that can put them at a higher risk in addition to the risk associated with jaywalking. On the other hand, the elderly were more likely to be running and riding compared to the young pedestrians. This indicates that the elderly and females have better risk perceptions while avoiding the potential threat of pedestrian crashes. This could explain why males and young adults are the most affected in terms of pedestrian crashes (Sheykhfard et al., 2021). The findings on males and young adults' risk-taking behavior are consistent with previous studies (Debnath et al., 2021).

5. Conclusion and practical implication

This paper examined the pedestrian behavior at footbridges in Ghana using an SEM. It was evident that almost a third of the pedestrians did not use the footbridges. All latent variables in the SEM model were statistically significant with pedestrian behaviour. Males and young adults were less likely to use footbridges. Pedestrian behaviors identified in this study were being accompanied, talking, holding a phone, or making phone calls, wearing an earpiece, carrying a load, running, and riding. Age, gender, and footbridge user status were significantly associated with pedestrian behaviors.

We recommend effective public education by the officials of NRSA on pedestrian safety targeting males and the young population to encourage the use of pedestrian footbridges. Officials of the Motor Transport Traffic Department (MTTD) of the Ghana Police Service should deploy uniformed men to footbridges to prevent people from using unapproved routes. For further studies, the pedestrian safety perception, reasons for risk-taking and choice of road crossing route on highways must be investigated. The officials of the Ghana Highway Authority should consider fencing the median separating the highways with footbridges to enhance usage.

6. Limitations to the study and further studies

This study sought to analyse pedestrian behavior at footbridges in Ghana, however, seven footbridges (six in GAMA and one in GKMA) were selected for being the popular bridges and the only one available in Accra and Kumasi respectively. Although the findings of this study can be applied to other footbridges especially the ones in Accra, a further study can be conducted to consider the less popular footbridges in Accra. This further research can help understand pedestrian behavior holistically at footbridges in Ghana. Further, the current study used an observational survey to understand the phenomenon. It could be better if some of the observed pedestrians were intercepted to ascertain the reasons for the exhibited behavior. It is, therefore, recommended that future studies can address this.

The current study addressed the phenomenon by looking at all forms of pedestrians. It could have looked at the different categories of pedestrians such as school children, aged pedestrians and persons living with a disability. This could have addressed the peculiarities of these people in the design and use of footbridges in Ghana. Despite the foregoing limitations, the current study has laid a foundation for further research to improve pedestrian safety at footbridges in Ghana and other LMICs.

The study could have adopted the use of two research assistants observing users and non-users respectively. This approach would give the opportunity to assess the inter-reliability of the data being collected. However, this study has offered the platform for further studies using this alternative to improve the data collected.

It is possible that the research assistants made more or less observations. Under-observing results from the inability of the research assistants to observe all users or non-users of footbridges. Over-observing occurs when the research assistants make more observations than expected. This under-observing or over-observing could have been averted with the use of two research assistants observing the same phenomenon leading to the use of inter-reliability test.

The use of drones or CCTVs is an alternative to the use of observational survey explored in the current. Future studies could adopt either of this approach.

Authors' contributions

Thomas Kolawole Ojo—conceptualization and writing of the original draft. **Anthony Baffour Appiah**—Project administration and resources and investigation. **Abena Obiri-Yeboah**—Writing-review and editing. **Atinuke Olusola Adebanji**—formal analysis and data curation. **Peter Donkor**—Supervision and project administration. **Charles Mock**—Writing review and editing and visualization.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

This study was funded in part by grant D43-TW007267 from the US National Institutes of Health. The content of this study is solely the authors' responsibility and does not necessarily represent the official views of the National Institutes of Health.

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References

Abbas, M. H. N., Jiang, Y., Miao Miao, M., & Naqvi, M. H. (2020). The effect of social influence, trust, and entertainment value on social media use. *Evidence from Pakistan, Cogent Business & Management*, *7*, 1. https://doi.org/10.1080/23311975.2020.1723825

Adedia, D., Adebanji, A. O., & Appiah, S. K. (2020). Comparative analysis of some structural equation model estimation methods with application to coronary heart disease risk. *Journal of Probability and Statistics*, *2020*, 1–15. https://doi.org/10.1155/2020/4181426

Adedia, D., Adebanji, A. O., & Appiah, S. K. (2021). Calculating non-centrality parameter for power analysis under structural equation modelling: An alternative. *Pakistan Journal of Statistics and Operation Research*, *17*(1), 273–289. https://doi.org/10.18187/pjsor.v17i1.3148

Adjakloe, Y. D., Boateng, E. N., Agyapong, F., Aboagye Osei, S., Koranteng, C., Baidoo, A. N., & Amoako-Sakyi, R. O. (2020). Gendered perspective on road crossing behaviors: A study of university of cape coast students. *Current Research Journal of Social Sciences and Humanities*, *3*, 109.

Banerjee, A., & Maurya, A. K. (2020). A study on understanding the factors influencing pedestrian inclination towards using pedestrian bridges. In *Recent advances in traffic engineering* (pp. 661–677). Springer.

Bentler, P. M. (1990). Comparative fit indexes in structural models. *Psychological Bulletin*, *107*(2), 238–246. https://doi.org/10.1037/0033-2909.107.2.238

Bollen, K. A. (1989). *Structural equations with latent variables.* New York: John Wiley and Sons, Inc. https://doi.org/10.1002/9781118619179

Brosseau, M., Zangenehpour, S., Saunier, N., & Miranda-Moreno, L. (2013). The impact of waiting time and other factors on dangerous pedestrian crossings and violations at signalized intersections: a case study in montreal. *Transportation Research Part F, 21*, 159–172.

Chong, S., Poulos, R., Olivier, J., Watson, W. L., & Grzebieta, R. (2010). Relative injury severity among vulnerable non-motorised road users: Comparative analysis of injury arising from bicycle-motor vehicle and bicycle-pedestrian collisions. *Accident; Analysis and Prevention*, *42*(1), 290–296. https://doi.org/10.1016/j.aap.2009.08.006

Damsere-Derry, J., Ebel, B. E., Mock, C. N., Afukaar, F., Donkor, P., & Ojo, T. K. (2019). Evaluation of the effectiveness of traffic calming measures on vehicle speeds and pedestrian injury severity in Ghana. *Traffic Injury Prevention*, *20*(3), 336–342.

Debnath, M., Hasanat-E-Rabbi, S., Hamim, O. F., Hoque, M. S., McIlroy, R. C., Plant, K. L., & Stanton, N. A. (2021). An investigation of urban pedestrian behaviour in Bangladesh using the Perceptual Cycle Model. *Safety Science*, *138*, 105214. https://doi.org/10.1016/j.ssci.2021.105214

Demiroz, Y. I., Onelcin, P., & Alver, Y. A. L. Ç. I. N. (2015). Illegal road crossing behavior of pedestrians at overpass locations: Factors affecting gap acceptance, crossing times and overpass use. *Accident; Analysis and Prevention*, *80*, 220–228. https://doi.org/10.1016/j.aap.2015.04.018

Hamann, C., Dulf, D., Baragan-Andrada, E., Price, M., & Peek-Asa, C. (2017). Contributors to pedestrian distraction and risky behaviours during road crossings in Romania. *Injury Prevention*, *23*(6), 370–376. https://doi.org/10.1136/injuryprev-2016-042219

Hasan, R., & Napiah, M. (2018). The perception of Malaysian pedestrians toward the use of footbridges. *Traffic Injury Prevention*, *19*(3), 292–297. https://doi.org/10.1080/15389588.2017.1373768

Hasan, R., Oviedo-Trespalacios, O., & Napiah, M. (2020). An intercept study of footbridge users and non-users in Malaysia. *Transportation Research Part F: Traffic Psychology and Behaviour*, *73*, 66–79. https://doi.org/10.1016/j.trf.2020.05.011

Hobday, M. B., & Knight, S. (2010). Motor vehicle collisions involving adult pedestrians in eThekwini in 2007. *International Journal of Injury Control and Safety Promotion*, *17*(1), 61–68. https://doi.org/10.1080/17457300903524870

Hooper, D., Coughlan, J., & Mullen, M. (2008). *Evaluating model fit: A synthesis of the structural equation modelling literature* [Paper presentation]. In 7th European Conference on Research Methodology for Business and Management Studies, September, pp. 195–200.

Jha, A., Tiwari, G., Mohan, D., Mukherjee, S., & Banerjee, S. (2017). Analysis of pedestrian movement on Delhi roads by using naturalistic observation techniques. *Transportation Research Record: Journal of the Transportation Research Board*, *2634*(1), 95–100. https://doi.org/10.3141/2634-14

Kelloway, E. K. (1995). Structural equation modelling in perspective. *Journal of Organizational Behavior*, *16*(3), 215–224. https://doi.org/10.1002/job.4030160304

Koekemoer, K., Van Gesselleen, M., Van Niekerk, A., Govender, R., & Van As, A. B. (2017). Child pedestrian safety knowledge, behaviour and road injury in Cape Town, South Africa. *Accident; Analysis and Prevention*, *99*(Pt A), 202–209. https://doi.org/10.1016/j.aap.2016.11.020

Mabunda, M. M., Swart, L. A., & Seedat, M. (2008). Magnitude and categories of pedestrian fatalities in South Africa. *Accident; Analysis and Prevention*, *40*(2), 586–593.

McIlroy, P. A., King, R. S., Garrouste-Orgeas, M., Tabah, A., & Ramanan, M. (2019). The effect of ICU diaries on psychological outcomes and quality of life of survivors of critical illness and their relatives: a systematic review and meta-analysis. P MID: 30431494. https://doi.org/10.1097/CCM.0000000000003547

Michelle Hobday, M., & Knight, S. (2010). Motor vehicle collisions involving child pedestrians in eThekwini in 2007. *14*(1), 67–81. https://doi.org/10.1177/1367493509347059.

Noora, C. L., Afari, E. A., Nuoh, R. D., Adjei, E. Y., Anthony, G. K., Abdulai, M., Sackey, O. S., Ernest Kenu, E., & Nyarko, K. M. (2016). Pedestrian adherence to road traffic regulations on the N1 highway in Accra, Ghana. *Pan African Medical Journal 25*(Suppl 1), 11. https://doi.org/10.11604/pamj.supp.2016.25.1.6184

Obeng-Atuah, D., Poku-Boansi, M., & Cobbinah, P. B. (2017). Pedestrian crossing in urban Ghana: Safety implications. *Journal of Transport & Health*, *5*, 55–69. https://doi.org/10.1016/j.jth.2016.06.007

Ojo, T., Adetona, C. O., Agyemang, W., & Afukaar, F. K. (2019). Pedestrian risky behavior and safety at zebra crossings in a Ghanaian metropolitan area. *Traffic Injury Prevention*, *20*(2), 216–219. https://doi.org/10.1080/15389588.2018.1555372

Olawole, M. O., & Olayiwola, A. M. (2018). Pedestrians' crossing behaviour in south-western Nigeria. *Human Geographies*, *12*(2), 209–223.

Peltzer, K. (2011). Road use behavior in sub-Saharan Africa. In *Handbook of traffic psychology* (pp. 503–518). Academic Press.

Porter, G. (2002). Living in a walking world: Rural mobility and social equity issues in sub Saharan Africa. *World Development*, *30*(2), 285–300. https://doi.org/10.1016/S0305-750X(01)00106-1

Porter, G. (2008). Transport planning in sub-Saharan Africa II: Putting gender into mobility and transport planning in Africa. *Progress in Development Studies*, *8*(3), 281–289. https://doi.org/10.1177/146499340800800306

Quistberg, D. A., Howard, E. J., Hurvitz, P. M., Moudon, A. V., Ebel, B. E., Rivara, F. P., & Saelens, B. E. (2017). The relationship between objectively measured walking and risk of Pedestrian-Motor Vehicle Collision. *American Journal of Epidemiology*, *185*(9), 810–821. https://doi.org/10.1093/aje/kwx020

Sheykhfard, A., Haghighi, F., Nordfjaern, T., & Soltaninejad, M. (2021). Structural equation modelling of potential risk factors for pedestrian accidents in rural and urban roads. *International Journal of Injury Control and Safety Promotion*, *28*(1), 46–57. https://doi.org/10.1080/17457300.2020.1835991

Shi, J., Chen, Y., Ren, F., & Rong, J. (2007). Research on pedestrian behavior and traffic characteristics at unsignalized midblock crosswalk: Case study in Beijing. *Transportation Research Record 2038*. 23–33. https://doi.org/10.3141/2038-04.

Sisiopiku, V. P., & Akin, D. (2003). Pedestrian behaviors at and perceptions towards various pedestrian facilities: An examination based on observation and survey data. *Transportation Research Part F: Traffic Psychology and Behaviour*, *6*(4), 249–274. https://doi.org/10.1016/j.trf.2003.06.001

Stefanova, T., Burkhardt, J. M., Wullems, C., Freeman, J., Rakotonirainy, A., & Delhomme, P. (2015). Direct observations of pedestrian unsafe crossing at urban Australian level crossings. *Urban Rail Transit*, *1*(2), 112–130. https://doi.org/10.1007/s40864-015-0022-9

Steiger, J. H. (2000). Point estimation, hypothesis testing, and interval estimation using the RMSEA: Some comments and a reply to Hayduk and Glaser. *Structural Equation Modeling: A Multidisciplinary Journal*, *7*(2), 149–162. https://doi.org/10.1207/S15328007SEM0702_1

Stoker, P., Garfinkel-Castro, A., Khayesi, M., Odero, W., Mwangi, M. N., Peden, M., & Ewing, R. (2015). Pedestrian safety and the built environment: A review of the risk factors. *Journal of Planning Literature*, *30*(4), 377–392. https://doi.org/10.1177/0885412215595438

Tapiro, H., Oron-Gilad, T., & Parmet, Y. (2016). Cell phone conversations and child pedestrian's crossing behavior; a simulator study. *Safety Science*, *89*, 36–44. https://doi.org/10.1016/j.ssci.2016.05.013

Tapiro, H., Oron-Gilad, T., & Parmet, Y. (2018). The effect of environmental distractions on child pedestrian's crossing behavior. *Safety Science*, *106*, 219–229. https://doi.org/10.1016/j.ssci.2018.03.024

Truong, L. T., Nguyen, H. T. T., Nguyen, H. D., & Vu, H. V. (2019). Pedestrian overpass use and its relationships with digital and social distractions, and overpass characteristics. *Accident Analysis & Prevention*, *131*, 234–238. https://doi.org/10.1016/j.aap.2019.07.004

Tucker, L. R., & Lewis, C. (1973). A reliability coefficient for maximum likelihood factor analysis. *Psychometrika*, *38*(1), 1–10. https://doi.org/10.1007/BF02291170

World Health Organisation. (2018). *Global road safety report*.

Wu, Y., Lu, J., Chen, H., & Wu, L. (2014). Identification of contributing factors to pedestrian overpass selection. *Journal of Traffic and Transportation Engineering (English Edition)*, *1*(6), 415–423. https://doi.org/10.1016/S2095-7564(15)30291-9

Yankson, I. K., Nsiah-Achampong, N. K., & Yeboah-Sarpong, A. (2020). Road use behaviour of urban primary school children in Ghana: Case study of Ablekuma South Education Circuit of Metropolitan Accra. *Ghana Journal of Science*, *61*(1), 88–95. https://doi.org/10.4314/gjs.v61i1.7

Zacharias, J. (2001). Pedestrian behavior pedestrian behavior and perception in urban walking environments. *Journal of Planning Literature*. https://doi.org/10.1177/08854120122093249.

Zegeer, C. V. (2002). *Pedestrian facilities users guide: Providing safety and mobility*. Diane Publishing.

Zhuang, X., Wu, C., & Ma, S. (2018). Cross or wait? Pedestrian decision making during clearance phase at signalized intersections. *Accident; Analysis and Prevention*, *111*, 115–124. https://doi.org/10.1016/j.aap.2017.08.019