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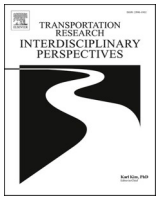

Evaluation of speed characteristics and gap acceptance behavior of pedestrians of Asian Countries: A review

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ABSTRACT

Daily pedestrian travels involve navigating various locations, putting them at risk because they are vulnerable worldwide to road users. Road traffic accidents claim the lives of many pedestrians every year. Any roadway and traffic management design must consider the speed at which pedestrians cross or walk. To improve current operating policies and to provide logical safety assessments, it is essential to comprehend the characteristics of pedestrian speed. While crossing several vehicular lanes, pedestrians must look for vehicle gaps in each route according to the direction of traffic. However, existing studies often overlook the diversity in pedestrian behaviors. This paper seeks to summarize the pedestrian crossing speeds, delays, and gap acceptance behavior in Asian nations based on several investigations. Several notable pieces of information were also formulated through tabulation. By averaging the pedestrian speed of some Asian countries, it was found that pedestrians move at 1.23 m/s, and Indonesian pedestrians move slower than other countries' pedestrians. Gap acceptance behavior depends on age, gender, group/individual, education status, day/night, vehicle type, traffic flow, waiting location etc. Such factors are also the influencing factors for pedestrian speed too. The study's conclusions will help mitigate traffic safety issues by creating an effective intersection control system. Practitioners and policymakers can use the study results to develop effective management strategies to lessen collisions between pedestrians and vehicles in uncontrolled locations in urban areas.

Introduction

Nearly everyone walks at least a little throughout the day, and walking is often recognized as the most effective and efficient transportation for short distances. African, Asian, and Latin American cities had average walking shares of 57, 37, and 22 %, respectively (Montgomery, 2006). Being the most vulnerable road users, pedestrians are renowned for having a wide range of freedom when selecting a particular walking style, significantly setting them apart from motorized users. Unlike moving vehicles, pedestrians continually interact with one another and their environment, which constantly modifies their gait and direction (Banerjee et al., 2018). Especially in emerging nations, pedestrian traffic accidents have grown to be a significant safety concern. Approximately 1.35 million people die in road accidents yearly, with pedestrians accounting for 22 % of all fatalities (World Health Organization, 2018). Roadway traffic studies have always focused on motor vehicles. Pedestrian convenience, comfort, and safety are frequently overlooked when planning roads. The intricacy of simulating pedestrian behavior is one of the leading causes (Sankaran and Perumal, 2014). During travel, crosswalks and sidewalks are both included in pedestrian walks (Table 1).

In contrast to crosswalks, pedestrians have more freedom to move and navigate on sidewalks. Signboards, signals, or speed limits do not restrict unprotected mid-block crosswalks. Therefore, a pedestrian's ability to move about depends primarily on the conduct of vehicles and the ability to identify adequate gaps in vehicular traffic. Because they are inherently unsafe, mid-block crosswalk placements pose a severe risk to motorists and pedestrians. Throughout the journey, pedestrians must cross the street at an intersection or a specified crosswalk point (Kadali et al., 2015).

Pedestrians use crosswalks with a risk-taking attitude. The risk is higher when a crossing is unsupervised and situated in the midst of a block. Due to a lack of adequate infrastructure, developing nations experience this type of pedestrian exposure on high-speed highways

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Table 1
Summary of the previous research on pedestrian speed in Asian countries.

Author	Country	Variable/Input	Methodology	Output/Findings
(Banerjee et al., 2018)	India	Space; Free-flow speed; Jam density; Speed, Flow; and Density	Diagram/histogram; Linear function	Pedestrian speeds across sidewalk facilities in different countries ranged from 52 m/min to 98 m/min, with a mean speed of 79 m/min; the basic relationships for sidewalk facilities assumed that the range of open flow speeds would be 65 to 85 m/min and that jam density would range from 3.5 to 5.3 ped/m; The male pedestrians moved at a 4–9 m/min faster rate than the female pedestrians; Older pedestrians moved at a pace that was 15 to 20 m per minute slower than younger ones.
(Ye et al., 2012)	China	Gender; Age; Luggage-carrying	Video observation (1000 Walking samples); One-Sample Kolmogorov–Smirnov Nonparametric Test; The multifactor ANOVA models; Independent-samples T-test	Males walk up to 5–7 % faster than females do; Older people walk 18 to 24 percent slower than middle-aged people, who move at a 6–8 % slower pace; The average walking pace is only 2 % to 3 % slower when modest luggage is compared to no luggage; For medium luggage, large luggage, and trolley cases, the rates of reduction in walking speed were 5–8 %, 10–14 %, and 3–8 %, respectively.
(Zafri et al., 2019)	Bangladesh	Pedestrian characteristics; Intersection control type; Crossing type; Crossing behavior; Traffic condition on pedestrian crossing speed; Waiting time	Videography survey (560 crossing-related data of pedestrians); Descriptive and Statistical analysis; Multiple linear regression model	The pace of a pedestrian crossing is 1.15 m/s; waiting periods and speed are connected to the type of junction control, a person's gender, age, the type of crossing, how many people are in a group crossing, and how well they follow control directions; Pedestrian generally do not wait more than 20–30 s as a pedestrian.
(Guo et al., 2017)	China	Walking speed; Step length; Step frequency	Automated video analysis; Gait Analysis	In comparison to women, men often walk faster, have a greater walk ratio, and take longer steps; Compared to walkers in groups, single pedestrians are observed to move at a faster speed and with more steps per second; The presence of bikes at crosswalks considerably reduces the speed, frequency, and length of pedestrian steps, increasing gait variability.
(Iryo-Asano et al., 2015)	Japan	Crosswalk distance; The speed at the onset of the PFG; Movement direction; The presence of turning vehicles	Binomial Logit Model; Cumulative Gamma distribution; Monte Carlo Simulation Structure	Significantly more pedestrians will stop at longer crosswalks; The speeds of pedestrians in the first and second sections of crosswalks change noticeably.
(Haghighi et al., 2021)	Iran	Pedestrians' Positive pedestrian behaviors; Adhering to traffic rules; Pedestrians' distraction; Pedestrians'aggressive behaviors traffic violations;	Regression; Chi-square; ANOVA tests; Independent *t*-test	The five characteristics of Iranian pedestrian traffic behaviors show gender inequalities.
(Sarsam, 2002)	Iraq	Gender; Age; Clothing tradition	Video Recording; Descriptive Analysis; Histogram; Chi-square	Male pedestrians walk far faster than female pedestrians; The fastest group of pedestrians are those between the ages of 18–50; The slowest pedestrians were found to be those over 50; Male pedestrians in Kurdish attire move more quickly than those wearing trousers from the West; Compared to other nations; Erbil pedestrians move at a slower average free-flowing speed.
(Rastogi et al., 2011)	India	Gender; Age; Group size; Activity; Landuse; Movements in groups; Carrying baggage	Descriptive analysis; Hypothesis testing using F-test	On sidewalks, pedestrians go at a faster average speed than the general population; Pedestrians walk at 74.57 m per minute and 62.44 m per minute for exercise and leisure, respectively; Travelling speeds of pedestrians vary substantially when traveling alone or with others; People move more slowly when carrying bags; Cell phone users on foot are slower; pedestrian speeds are 28 % faster in shopping districts (60.21 m/s) and 16 % slower in educational zones (85.27 m/s), respectively.

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Table 1 (*continued*)

Author	Country	Variable/Input	Methodology	Output/Findings
(Jahandideh et al., 2019)	Iran	Personal traits (such as gender, age, kind of clothing, speed of pedestrians, etc.); Environmental factors (such as other pedestrians who are disobeying the law, kerb parking, waiting times, etc.); Traffic conditions, including approaching vehicle speeds and time to collision, etc.)	Binary Logit model	Pedestrians chose an average time to the collision of 6.6 s at signalized junctions and 5.8 s at unsignalized intersections; Every kind of factor significantly affects risk-taking behavior.
(Alhajyaseen, 2015)	Saudi Arabia, Japan	Crosswalk length; Signal timing; Turning vehicles	Video recorded image analysis; Macroscopic pedestrian speed analysis	Pedestrian entry and travel speeds quickly increase as the pedestrian green interval persists; Longer crosswalks have longer travel times for pedestrians; Lower travel speeds arise when pedestrians are forced to slow down or even stop when automobiles are vying with them for the right of way under conditions when there is a considerable demand for turning traffic.
(Yosritzal et al., 2020)	Indonesia	Age; Gender; Walking distance	Data collected through evacuation drills; Cross-tabulation	The evacuation's average walking speed was 1.69 m/s, with differences according to age, gender, and distance.
(Sankaran and Perumal, 2014)	India	Gender; Age; Crossing type; Group size; Crosswalk utilization; Compliance; Crossing speed;	ANOVA test; *t*-test; Pearson's correlation coefficient test; Logistic Regression Models;	A crossing speed of 0.95 m per second and 1.12 m per second, respectively, has been found for elderly and adult pedestrians; Male pedestrians cross the road more quickly than female pedestrians; The size of the group and the gender of the pedestrians were important variables influencing their compliance behavior; The type of approaching vehicle and the proper separation between the vehicle and the pedestrian were discovered to be contributing factors.
(Kadali and Vedagiri, 2020)	India	Pedestrian behavior (rolling, changing lanes, etc.); Pedestrian speed; Pedestrian characteristics (gender and age); Vehicle characteristics (vehicle type and speed); Pedestrian crossing speed change patterns; and Traffic Characteristics	Video graphic survey; Binary Logistic regression Model	As the vehicle gap size increases, the pedestrians crossing speed the street decreases; Younger pedestrians are more likely to demonstrate patterns of changing crossing speed; As vehicle speed and the type of heavy vehicle increase, so do the pedestrians crossing speed the street
(Hoe Goh et al., 2012)	Malaysia	Crosswalk type; Age; Gender; Lighting; Race	Chi-square test	Age, gender, and the type of crosswalk substantially impact pedestrian speed; Neither the daytime nor nighttime lighting nor the pedestrians' race affects their speed; Children cross the street the fastest, while old persons cross the street the slowest. Male pedestrians cross the road far more swiftly than female pedestrians.
(Koushki, 1988)	Saudi Arabia	Purpose; Time; Distance; Speed	Origin-destination survey; Statistical analysis	Varying nationalities and sexes of pedestrians were observed to walk at significantly varying speeds and distances.
(Solmazer et al., 2020)	Estonia, Greece, Kosovo, Russia, Turkey	Age; Gender; Behavior	Large-scale survey; Pedestrian behavior scale; Descriptive statistics; Hierarchical regression analysis; Short-Schwartz's Value Scale;	The influence of values on pedestrian actions may depend on the context or country.
(Shaaban, 2019)	Qatar	Gender; Age; Clothing Tradition; Carrying bags; Use of mobile phone; Waiting; Flow against; Flow with	Histogram; Cumulative speed distribution; Descriptive Analysis; Anova test	68.1 % of pedestrians crossed the street during the Walk interval at an average speed of 1.32 m per second. During the Walk interval, differences in average crossing speeds by gender, age group, type of clothing, carrying luggage, using a mobile phone, group, waiting, flow against, and flow with were statistically significant. The average speed of individuals and groups of pedestrians differed significantly.
(Minhas et al., 2017)	Pakistan	Gender; Age; Land use; Level of development; Level of income; Traffic signal	Video recording; Chi-square	Compared to teenagers and middle-aged walkers, children and older pedestrians demonstrated considerably different behavior; At locations near more established commercial sectors and affluent residential communities, pedestrian behavior was safer; When

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more frequently (Hasan et al., 2020; Oviedo-Trespalacios and Scott-Parker, 2017; Tiwari, 2020). It is crucial to comprehend the decision-making processes involved in using such crosswalks to guarantee pedestrian security (Table 2).

Road-crossing strategy is one of the most crucial pedestrian activities (Zhang et al., 2019a). According to research (Brewer et al., 2006; Zhang et al., 2018), there are three different pedestrian crossing techniques: rolling gaps, single-stage crossings, and two-stage crossings. No matter how long the road is, pedestrians always use a single-motion, single-stage crossing technique. They do not stop in the middle of the road on the median or walk through the small gap between cars. Instead, with a two-stage crossing, people move through the first section of the crossing

Table 1 (*continued*)

Author	Country	Variable/Input	Methodology	Output/Findings
				traffic signals were present at junctions, driver behavior was safer; Driver conduct varied by experience level and gender.
(Go et al., 2017)	Philippines	Pedestrian flow; Space; Speed; Volume-capacity	Statistical Analysis	For walkability, all places have a "low" rating, and 83 % of them have "very poor" LOS; The LOS ranges from D to F on 62 % of crosswalks and 93 % of sidewalks; Lack of amenities like illumination, traffic lights, pavement markings, and ramps is a common problem at intersections; The facilities were not intended to handle the "high" pedestrian volume.
(Jiang et al., 2011)	China, Singapore	Lane number; Intersection type; Culture; Lane type;	Hierarchical regression analysis; T-test; Student Newman-Keuls (SNK) test	Road design, lane number, intersection type, and culture were important factors in illegal pedestrian crossings.; Singapore's violation rate was lower than Beijing's; Illegal crossing of elderly, pregnant, or handicapped pedestrians was more visible in Singapore than in Beijing; The infractions had to do with how pedestrians understood what safety meant
(Ahmed et al., 2021)	Malaysia	Intersection type; lane number; Culture; Pregnant; Handicapped pedestrian	Questionnaires-video technique; PCLOS technique based on a point system	There was a significant impact of lane type, lane number, intersection type, and culture on illegal pedestrian crossing. A zebra crossing was considered the most important indicator at pedestrian crossings, whereas drainage near crosswalks was considered the least useful.
(Issa, 2018)	Saudi Arabia	Gender; Age; Driving experience; Educational level; Using crosswalks; Using footbridges	Chi-square test; Contingency tables	Female pedestrians are more likely than male pedestrians to use crossing facilities, with illiterate pedestrians typically unwilling to use crosswalks or footbridges in their crossing.
(Onelcin and Alver, 2017)	Turkey	Crosswalk geometry; Gender; Age; Group size; Items carrying; Signal cycle; Land use; Traffic volume;	Video recording; Delay models; Anova test; Descriptive analysis	The average crossing speed is found to be 1.31 m/s, whereas the 15th percentile crossing speed is 1.07 m/s; The speed restriction and the position of speed limit relationship significantly impacted the safety margin.
(Sarsam and Abdulameer, 2015)	Iraq	Speed; Density; Space; Volume for pedestrian flow; The level of service	Manual survey; Histogram; Descriptive analysis; Logistic regression	The density of the pedestrian flow shows that pedestrian walking speed, particularly in the minor flow, comes to a standstill, and queues build up when the pedestrian concentration is high in both streams and the sidewalk widths are narrow; The crossing speed of 0.83 m/s; the pedestrian tends to take the shortest course; 24 % of the pedestrian were unaware of the danger of lengthy exposure to traffic movement; Land use strategies have a significant effect on the level of services.
(Afandizadeh et al., 2022)	Tehran	Gender, Speed	Video Recording; Regression Analysis; Social force model.	The presented model considers the effects of specific behavior variables derived from Iranian culture and local laws. The speed of male and female pedestrians is significantly different from each other.
(Qazimirsaeed et al., 2022)	Iran	Gender, Age, Household income, Car ownership, Household expenses, Social, Spatial, Accessibility, Safety dimensions	Questionnaire survey, Partial least squares – structuralequation modeling (PLS-SEM) analysis	To implement the walkability policies, 46 % participants to pay additional taxes. The most significant elements are safety, social, spatial, and accessibility, which all positively impact willingness to pay (WTP).

Table 2
Summary of the previous research on the gap acceptance behavior of pedestrian.

Author	Country	Variable/Input	Methodology	Output/Findings
(Zafri et al., 2020)	Bangladesh	Median width; Vehicle flow; Age group; Crossing group; Size; Crosswalk Intersection control type; Available gap	Binary logistic regression model	They showed less rolling gap crossing on highways with bigger medians; when a large gap was present on the road, they showed less rolling gap crossing than when a smaller gap was present; more people expressed rolling gap crossing in uncontrolled junctions than in managed intersections; When compared to younger walkers, older pedestrians demonstrated less rolling gap crossing; those who obeyed the crosswalk while crossing the road demonstrated less rolling gap crossing than those who did not.
(Zhang et al., 2019)	China	Pedestrian crossing behavior; Pedestrian and vehicle conflicts distribution on several vehicle lanes	Three ordered probit (OP) models for pedestrian-vehicle conflicts analysis; PVCA	Conflicts with moving automobiles significantly increased when people crossed in rolling gaps or did so in groups.
(Zhang et al., 2018)	China	Gender; Age; Waiting time; Traffic volume	Logistic regression model	According to the results, the model's accuracy may reach 88.6 % when used to characterize 31 pedestrian crossing behaviors.
(Kadali et al., 2015)	India	Pedestrian (gender and age); Vehicular; Traffic; Pedestrian behavioral characteristics	MLR; ANN	The model's results revealed that, in mixed traffic situations, the ANN model outperformed the MLR model in terms of prediction and the capacity to take into account the impact of a wider range of variables on pedestrian gap acceptance behavior; The extent of the space that pedestrians accept is significantly influenced by how they roll when walking.
(Pawar and Patil, 2015)	India	Available gaps; Pedestrians' decision; Traffic volume	Binary logit analysis; Six utility models	The 50th percentile temporal and spatial gaps were 4.1 to 4.8 s and 67 to 79 m, respectively, and the 85th percentile temporal and spatial gaps were 5 to 5.8 s and 82 to 95 m, respectively. These gap values were lower than those found in studies conducted in 29 developed countries.
(Vasudevan et al., 2020)	India	Pedestrian street crossing behavior and the respective headways (both accepted and rejected); Pedestrian demographic characteristics (gender, age) ; Pedestrian group composition; Waiting time; Crossing time	Binary logit analysis	Pedestrian risk behavior shifts in response to peer pedestrian conduct.
(Paul and Rajbonshi, 2014)	India	Combination of land uses; Width of the Road; Direction of traffic; Traffic volume and intensity ofpedestrian (age, gender) movement	Video recording; F-test	Pedestrians prefer rolling gaps over others on unsignalized roads; Younger individuals were more likely to choose a safe crossing point with little time to spare; women and people walking with baggage need more time to cross the street; The 85th percentile permissible gaps should be bigger than the crucial spacing for safe road crossing.
(Kadali and Vedagiri, 2013a)	India	Vehicular gap size; Movement of pedestrians from the curb or median;Rolling gap (pedestrian rolling over available small gaps) ; Type of gap; Pedestrian speed change condition; Pedestrian waiting time	MLR	When starting from the median of a six-lane divided road, walkers are likelier to choose close gaps than when starting from the curb, and they are more likely to exhibit behaviors like rolling gaps and speed change conditions.
(Chandra et al., 2014)	India	Carriageway width (number of lanes); Directional movements; Traffic volume; Pedestrians' characteristics of the gaps accepted by the pedestrians' as well as on the critical gaps	Descriptive Analysis; Parametric Analysis	The allowed gap was found to change depending on the number of lanes on the road to be crossed, and it was also found to decrease with the speed of opposing cars and pedestrian crossings.
(Arman et al., 2019)	Iran	Caution behavior	Behavioral Hybrid mixed logit model	The size of the current gap, exemplary behavior, and waiting time significantly impact whether a pedestrian accepts or rejects a gap.
(Arman et al., 2015)	Iran	Caution behavior	Binary mixed logit model	The longer the wait, the more belligerent the pedestrians get, resulting in their acceptance of narrower distances.
(Chu et al., 2017)	Japan	TTC; Relative distance; Relative speed; Density; Geometry factors (acceleration lane length and chevron marking length)	MNL, NL, LCS	Future research must thoroughly validate the conclusion that the LCS model outperforms conventional models by accounting for the latent decision set.
(Hell et al., 2021)	Japan	Velocity; Accelerations; Gap acceptance; Compliance rate at signalized crossings; Initiation of red-light crossings; Fine for red-light violations; Fatality rates; Traffic orientation; Number of intersections	Qualitative Analysis	A summary of recent research findings on pedestrian speeds, compliance, risk perception, and acceptability in both ethnic groups.
(Alhajyaseen et al., 2013)	Japan	Vehicle speed	Probalistic lag/gap acceptance models	Drivers generally accept lower lags/gaps between the two groups when compared to far-side pedestrians.

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Table 2 (*continued*)

Author	Country	Variable/Input	Methodology	Output/Findings
(Alajnaf et al., 2016)	Malaysia	Traffic characteristics such as traffic size, traffic speed, etc.; Pedestrian individual characteristics such as gender, in addition to individual behavior such as waiting, frequency of attempt	A lognormal regression model; Binary logistic model by SPSS (22)	The Pedestrian Gap Acceptance BL model performs admirably, predicting pedestrians' acceptance of gaps with 86.4 % accuracy.
(Mohamad Nor et al., 2017)	Malaysia	Gap size; Vehicle speed; Time waiting; Traffic volume; Pedestrian speed; Pedestrian Volume; Gender; Type of vehicle; Pedestrian platoon; Gap acceptance	Multiple regression; Binary logit regression method	The road environment has a significant impact on the permitted pedestrian gap in addition to vehicular traffic conditions; The vehicle speed and gap size of the approaching vehicle has a substantial effect on pedestrian crossing decisions because pedestrians prefer not to cross when the vehicle speed is high, and the gap size is small
(Shaaban and Hamad, 2018)	Qatar	Gap; Vehicle type	Group gap acceptance	The essential gap was calculated because most cars accept the crack in groups
(Shaaban and Hamad, 2020)	Qatar	Gap; Vehicle type	Raff's method	The critical gap values for one-, two-, and three-lane roundabouts were 2.24 s, 2.55 s, and 2.40 s, respectively.
(Koh and Wong, 2014)	Singapore	Available gap; Stage of crossing, Gender	Logistic regression	Pedestrians exposed to Type 2 gaps (without the last passing vehicle) are the most likely to accept the gap; pedestrians exposed to longer available gaps are likelier to do so.
(Wickramasinghe et al., 2021)	Sri-lanka	Gender; Age; Crossing point; Waiting time, whether a pedestrian is standing at the curb or median; Crossing speed	Multiple linear regression model	In different traffic conditions, females accept a larger gap (12.3 s) than males (9.46 s) when using crosswalks on divided two-lane motorways.
(Alver et al., 2021)	Turkey	Gender; Group size; whether they carried items or not, and their accepted/rejected gaps	Image processing methods; YOLOv3; YOLACT models, Raff's method	Gap acceptability was impacted by the size of the approaching vehicle and the presence of a physical barrier.
(Alver and Onelcin, 2018)	Turkey	Gender; Age; Vehicle position; Items carrying; Group size	Raff's method; Binary logit model; ANOVA	Gender, age, vehicle location, the weight of the objects being carried, and group size all interacted significantly with the safety margin.
(Onelcin and Alver, 2015)	Turkey	Gender; Age; Vehicle speed; Group size and items carrying on safety margin; Crossing time; Distance gap	ANOVA test	Rather than considering the amount of time before crossing, pedestrians decide based on distance.

in a single motion until they reach the median, where they wait for a moment before moving to the other side. The distinction between single-stage and two-stage is relatively slight. By altering their speed and direction of travel, pedestrians using the rolling gap technique keep looking for suitable gaps in the continuous flow of vehicles. To cross the street, they roll over the little vehicle gaps.

Most researchers assumed that pedestrians made choices based on now gaps, which were estimated in the context of the entire road's cross-section. They ignored other vehicles and just considered the closest one (Chandra et al., 2014; Cherry et al., 2012; Kadali and Vedagiri, 2013). Most people do not cross the street after all lanes have been completely cleared. Instead, they employ the rolling gap-crossing approach, particularly on busy roads (Brewer et al., 2006; Kadali and Vedagiri, 2013). They may start crossing the road once they have discovered a suitable opening in the nearest lane, assuming that the lanes will be clear when they cross. Pedestrians may continue to cross the lane after their initial lane crossing after it has been clear. Otherwise, after accepting a successful gap, they can stop in the middle of the road and search for another suitable gap in the next lane (Arman et al., 2015). In developing nations, pedestrians may encounter various intricate and dynamic gaps. They frequently monitor the openings in each lane before selecting the ideal opening to cross the street (Kadali and Vedagiri, 2013). They might accept a tiny gap during the rolling gap crossing, increasing the chance of a collision between a pedestrian and a vehicle (Raghuram Kadali and Perumal, 2012). The most dangerous crossing methods include rolling gap, two-stage, and single-stage (Brewer et al., 2006; Zhang et al., 2019b). Injuries to pedestrians when using the rolling gap crossing are a significant risk. Therefore, it is advised against using the dangerous rolling gap crossing technique by pedestrians (Koh and Wong, 2014).

Meta analysis were conducted to summarize the work on pedestrian gap acceptance probabilities (Theofilatos et al., 2021). The decision to cross an accessible gap and choose an appropriate vehicle gap size are two crucial elements of the gap acceptance mechanism (Kadali et al., 2015). According to earlier research, factors like pedestrian age and gender, crossing behavior (such as path modification or pedestrian speed), and traffic and vehicular features (such as vehicle speed) all affect these decisions. The number of vehicle lanes on mid-block crosswalks has also been proven in several studies to have a variety of effects on pedestrian crossing safety (Kadali et al., 2015; Kadali and Vedagiri, 2013).

An important feature of pedestrian behavior is speed flow. Prior studies have shown that a variety of human and environmental factors, such as gender, age, disability, and the ability to carry luggage, as well as walkway characteristics, such as slope and pavement width, and travel purposes, such as commuting, shopping, and recreation, have an impact on pedestrian crossing speeds (Aultman-Hall et al., 2009; Buchmueller and Weidmann, 2007; Fujiyama and Tyler, 2010; National Research Council, 2000). Additionally, elements affecting the walking environment have an impact on this relationship. The aim of the excursion is one of the inherently influencing elements of walking speed. Interviews are the only way to learn the aim of the trip. However, it can be achieved inadvertently through land-use decisions made near the pedestrian facility. If a walker engages in any activity while walking or travels in a group, this might also affect their walking speed. Additional functions that affect walking pace include the pedestrian's traits, such as age and gender. Combining all these elements may significantly alter the pedestrian's speed and flow (Rastogi et al., 2011).

Despite the substantial body of literature on pedestrian behavior and safety, significant gaps remain in understanding the nuanced speed characteristics and gap acceptance behavior of pedestrians, particularly in Asian countries. Most research has been conducted in Western contexts, leaving a gap in region-specific insights due to cultural, social, and infrastructural differences. Additionally, while previous studies often provide average pedestrian speeds, they lack detailed analyses of how factors such as age, gender, group size, and environmental conditions affect these speeds in diverse Asian settings. Existing literature on gap acceptance behavior mainly focuses on Western traffic conditions, which differ significantly from the more chaotic and less regulated

traffic environments in many Asian countries. Furthermore, socioeconomic status, education levels, and cultural norms, which significantly influence pedestrian behavior, are often underrepresented. Environmental factors like day/night conditions, weather, and urban versus rural settings also impact pedestrian behavior, but comprehensive data and analysis on their effects are scarce. Most studies tend to focus narrowly on either traffic engineering or behavioral aspects without integrating these perspectives to provide practical solutions. This research aims to address these gaps by providing a comparative analysis across various Asian countries, offering a more detailed and context-specific understanding of pedestrian behavior.

The available data was compiled in this study to give a summary of the measures that were possible. Two important behaviors of pedestrians, speed characteristics and gap acceptance behavior, have gained importance in this study. This study selected papers from Asian countries and investigated systematically to find out the holistic scenario of research done and conclude the future scope. The findings are cross-checked, and a review conclusion is illustrated.

The rest of the paper is organized as shown below. The procedure for choosing papers from a huge collection of previously published studies is described in Section 2. The various research looked at are categorized under the "Taxonomy of the Reviewed Systems" section for a fuller understanding. The many publications that examined pedestrians' speed characteristics and gap acceptance behavior are described and summarized in the section on "Literature on Developed Systems." The "Open discussion and future challenges" is shown in Section 5. The "Future scope and relevant implications" is shown in Section 6. The article concludes with "Conclusions.".

Review methodology

Online databases such as Scopus, Web of Science, Dimensions.ai, etc., were searched and studied to identify relevant studies. A wider range of literature, including books and conference proceedings relating to speed analysis and gap acceptance behavior of pedestrians, was also searched using Google Scholar. In this study, we solely considered peer-reviewed literature. English-language articles were taken into consideration. It was used the following terms to search a broad range of literature: "pedestrian" AND "speed" OR "gap acceptance" OR "walking speed", OR "crossing time" OR "vehicle gap" OR "walking behavior" OR "clearance time" OR "rolling gap" OR "pedestrian mobility" etc. It was searched with names of different countries in Asia to find relevant articles for easy evaluation.

Using a PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flow chart, the number of records included or excluded at each stage was shown (see Fig. 1). Here, 218 papers were taken into account initially. By following the identification, screening, eligibility and included stages, 49 articles were included for appraisal with the reading of the abstract and full text subsequently. The full process of the PRISMA method for selecting articles is depicted clearly in the following Fig. 1.

According to the PRISMA method, 218 papers are identified first, where 25 of them are duplicated and found from different sources. During the screening phase, 115 papers are excluded. Another 35 papers are excluded in the eligibility phase as these are considered ineligible after assessing the full text. Finally, 49 studies are selected for further exploration.

The following criteria of study selection was established in this study.

1. Studies examining the effect of human characteristics such as age, gender, educational status, group/individual etc on pedestrian speed and gap acceptance behavior were considered. Additionally, studies including the effect of environmental factors were also taken into account.
2. Studies were limited to Asian countries.

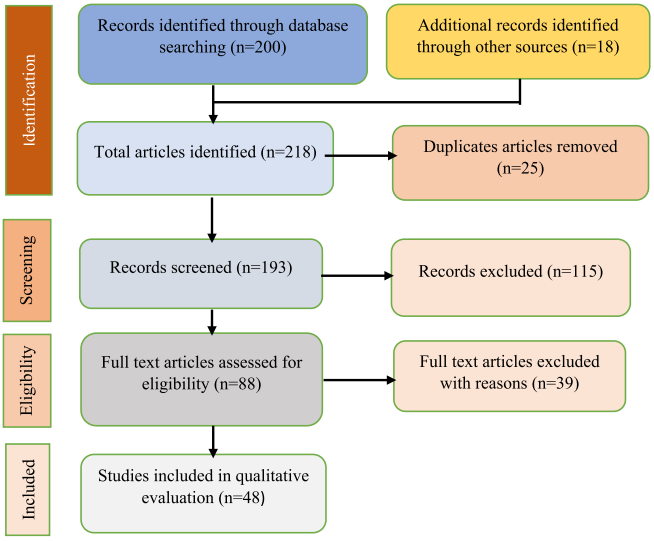

Fig. 1. Flow chart of PRISMA method for selection of papers.

3. It was focused on articles which were published in the last two decades (after 2000) in the Transportation Engineering field and the high-quality studies from view point of highly cited articles were prioritized.
4. Journal articles were chosen over conference papers.
5. In this study, it was solely considered peer-reviewed literature. English-language articles were taken into consideration.

Taxonomy of the reviewed systems

Fig. 2 describes the taxonomy of different papers used in this study.

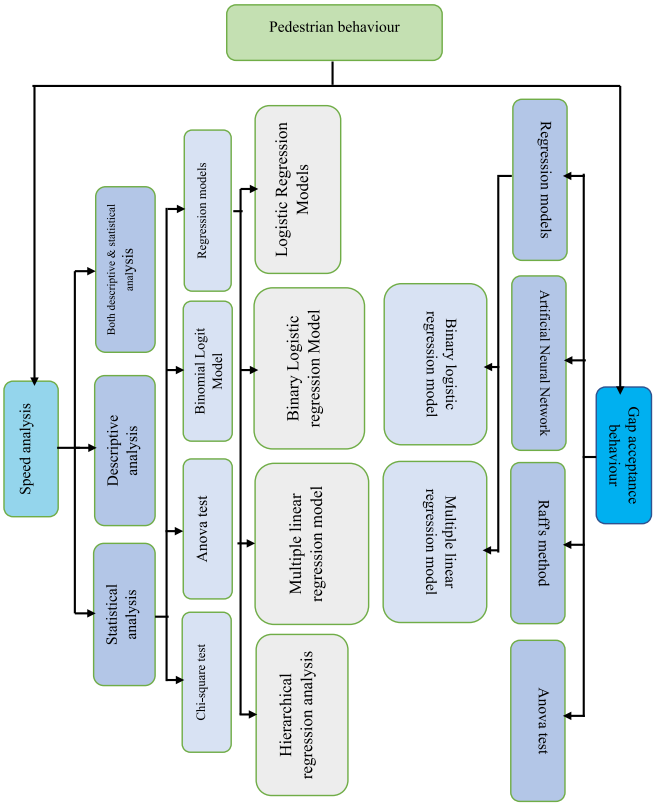

Fig. 2. Taxonomy of previous study of pedestrian speed and gap acceptance behavior.

Among the 48 studies, 25 papers investigated Speed analysis. Others looked into gap acceptance behavior. Data are mostly collected through video recording and image analysis. The studies investigating speed analysis have mostly conducted three kinds of analysis: descriptive analysis, statistical analysis, and both descriptive & statistical analysis. The chi-square test, ANOVA test, Binomial Logit model, and Regression models are mostly used as statistical tools. The studies used the Binomial Logit model of different types, such as the Hierarchical regression model, multiple linear models, Binary logistic regression model, and logistic regression models.

A regression model is also used in studies concentrating on gap acceptance behavior. Binary and Multiple linear regression models are used here. Artificial Neural Networks, Raff's method, and the ANOVA test are the other models used besides regression models to explore gap acceptance behavior.

Literature on developed systems

Pedestrian speed analysis

Literature groups

According to their areas of inquiry, the literature on pedestrian speed analysis can be split into many divisions. According to research concentration, the literature can be put into two broad categories such as studies exploring the pedestrian flow/speed analysis (Banerjee et al., 2018; Guo et al., 2017; Sarsam, 2002) and studies exploring the factors which have an impact on pedestrian flow/speeds (Ye et al., 2012; Zafri et al., 2020). Most studies are conducted after 2010, indicating that this research gap has been prominent recently.

Variable

Each study figures out the distinct output of pedestrian behavior according to different variables to an extent. The most explored variables are Age, Gender, Item carrying, Education and Group size. Other than that, Traffic Infrastructure (Zafri et al., 2020), presence of vehicles (Iryo-Asano et al., 2015), pedestrians behavior (Guo et al., 2017; Haghighi et al., 2021), Land use (Minhas et al., 2017), Clothing tradition (Sarsam and Abdulameer, 2015; Shaaban, 2019), culture (Hoe Goh et al., 2012; Jiang et al., 2011) are taken into consideration in different studies. Zahra et al. (2017) considered a wide range of variables such as Individual traits (such as gender, age, type of clothing, walking pace, etc.), environmental factors (such as other disobedient pedestrians, curb parking, waiting times, etc.), and traffic conditions (such as approaching vehicle speed, collision time, etc.) (Jahandideh et al., 2019).

Methodology

In most studies, the researcher used video-recorded image analysis for primary data collection (Ahmed et al., 2021; Minhas et al., 2017; Onelcin and Alver, 2017). Statistical tools are utilized to illustrate the result. Most of the studies are conducted through Logit model (Jahandideh et al., 2019; Kadali and Vedagiri, 2020), Regression analysis(Jiang et al., 2011; Sarsam and Abdulameer, 2015; Solmazer et al., 2020), Histogram (Sarsam and Abdulameer, 2015; Shaaban, 2019), ANOVA test (Shaaban, 2019), T-test (Jiang et al., 2011; Ye et al., 2012), Chi-square (Issa, 2018; Minhas et al., 2017) and cross-tabulation (Yosritzal et al., 2020). Other than that, delay models (Onelcin and Alver, 2017), contingency tables (Issa, 2018), Newman-Keuls test (Jiang et al., 2011), Gait analysis (Guo et al., 2017), and descriptive analysis (Onelcin and Alver, 2017; Shaaban, 2019) are used in different studies.

General statistics

The speed range for pedestrian crossings is 0.95 to 1.69 m per second (Sankaran and Perumal, 2014; Shaaban, 2019; Yosritzal et al., 2020; Zafri et al., 2019). Usually, they do not pause for more than 20 to 30 s. For the walking interval, there were statistically significant differences in average speeds by gender, age group, type of clothing, carrying luggage, group, waiting, flow against, and flow with (Shaaban, 2019).

Physical pedestrians properties

Age. Numerous sources were discovered that amply demonstrate how age affects walking speed. The quickest group of pedestrians are those aged 18 –50 (Sarsam and Abdulameer, 2015). According to Ye et al. (2012), Elderly pedestrians move at an 18–24 % slower pace than younger ones, whereas middle-aged pedestrians move at a 6–8 % slower pace. Older pedestrians walked 15–20 m per minute more slowly than younger ones. Adult and elderly pedestrians cross the street at speeds of 0.95 and 1.12 m per second, respectively (Sankaran and Perumal, 2014). The slowest pedestrians were those above 50 (Sarsam and Abdulameer, 2015).

Gender. There are disparities between the genders in all aspects of how pedestrians behave (Haghighi et al., 2021). Males often walk more quickly, with longer steps, and a higher walk ratio than females (Guo et al., 2017). The average walking pace of male pedestrians was 4–9 m per minute faster than female pedestrians (Banerjee et al., 2018). On the contrary, Males are less likely than females to use crossing facilities (Issa, 2018).

Luggage. Pedestrians carrying baggage walk slower (Rastogi et al., 2011). Small luggage merely slows down the mean walking speed by 2 % to 3 % compared to no luggage. Medium luggage, big luggage, and trolley cases all had a 5–8 %, 10–14 %, and 3–8 % drop in walking speed, respectively (Ye et al., 2012).

Cultural influence/race/land use. Male pedestrians dressed in Kurdish style are faster than those dressed in Western style (trousers) (Sarsam and Abdulameer, 2015). Race and lighting—daytime and nighttime—do not affect how fast the pedestrians move. Land use choices significantly influence the level of services and pedestrian speed (Sarsam and Abdulameer, 2015). There were locations where pedestrian conduct was safer in more established commercial areas and wealthy residential neighborhoods (Minhas et al., 2017). Pedestrian speed is 28 % faster in educational areas (85.27 m/min) and 16 % slower in shopping areas (60.21 m/min) (Rastogi et al., 2011).

Country. The influence of values on pedestrian actions may depend on the context or country (Solmazer et al., 2020). Different nationalities of pedestrians showed significant differences in walking distances and pace (Parviz, 1988). For instance, Erbil pedestrians move more slowly than those in other countries when walking (Sarsam, 2002).

Traffic conditions. Traffic conditions are an important factor for pedestrian safety and behavior. 24 % of pedestrians were unaware of the danger of lengthy exposure to traffic movement (Sarsam and Abdulameer, 2015). According to Sankaran and Perumal (2014), the kind of oncoming vehicle and the ideal separation between the pedestrian and the moving object were deciding considerations. The speed at which people cross the roadway slows as the vehicle gap widens. On the other hand, when vehicle speed and heavy vehicle type increase, so does the speed of pedestrians cross the street (Kadali and Vedagiri, 2020).

Additionally, at extended crosswalks, pedestrians exhibit faster walking rates. Additionally, significantly increased pedestrian stop probabilities are produced by longer crosswalks. The speed of pedestrians in the first and second parts of crosswalks varies considerably (Iryo-Asano et al., 2015).

Environmental influences

Group size/rush-hour/daytime/trip purpose. When traveling alone or with others, pedestrians' walking speeds change noticeably. Compared to groups in groups, single pedestrians are shown to move faster and

take more steps per second (Guo et al., 2017). Drivers and pedestrians can compete for the right of way in situations with significant turning traffic demand, slowing or even stopping pedestrians and lowering travel speeds (Alhajyaseen, 2015). The speed of the pedestrians is not affected by race or day/night lighting (Hoe Goh et al., 2012). For leisure and exercise, pedestrians walk at speeds of 62.44 m/s and 74.57 m/s, respectively (Rastogi et al., 2011).

Gap acceptance analysis

Literature groups

Previous studies examined how people cross the street and the elements that affect their choice. Various types of roads and intersections, such as controlled-uncontrolled, signalized-unsignalized, midblock-roundabouts, and multi-lanes, are considered for the study area.

Variable

The demographic characteristics of pedestrians (Gender and Age) are considered in every study. Other pedestrian characteristics such as caution behavior, pedestrian speed, movements of pedestrians from the curb or median, directional movements and group composition are explored in different studies. The other analyzed variables are environmental phenomena such as waiting time, crossing time, fatality rate and traffic phenomenon such as traffic volume, intersection type, control type, land use, LOS of road, and vehicle speed.

Methodology

The data was collected and processed using a lot of video capture and image analysis. To get the final output, a logit model and regression analysis are primarily conducted (Pawar and Patil, 2015; Vasudevan et al., 2020; Zafri et al., 2020; Zhang et al., 2018). Other than that, few studies conducted three ordered probit model (Zhang et al., 2019b), six utility models (Pawar and Patil, 2015), MLR (Kadali et al., 2015), gap acceptance models (Alhajyaseen et al., 2013), Raff's method (Alver et al., 2021; Alver and Onelcin, 2018; Shaaban and Hamad, 2020), and ANOVA test (Alver and Onelcin, 2018; Onelcin and Alver, 2015).

Analysis

The investigations identified pedestrians' propensity to cross roads and the factors contributing to it. At uncontrolled crossroads, pedestrians showed more rolling gap crossing than managed intersections (Paul and Rajbonshi, 2014; Zafri et al., 2020). They demonstrated that highways with broader medians or open gaps had fewer rolling gap crossings. Old pedestrians are more skeptical about following rolling gap crossing than young pedestrians (Zafri et al., 2020). Additionally, it was discovered that young people used minimum time to cross the gap in the street safely and quickly (Paul and Rajbonshi, 2014). Pedestrian risk behavior changes with the conduct of peer pedestrians (Vasudevan et al., 2020). Pedestrian rolling behavior significantly influences the permissible gap size for pedestrians (Kadali et al., 2015). The accepted pedestrian gap is influenced considerably by characteristics in the road environment, including walking speed, waiting time, gender, jaywalking, vehicle speed, vehicle type, the current gap, and the width of the roadway, according to multiple regression and logit models (Arman et al., 2019; Mohamad Nor et al., 2017). It was also discovered to vary with the number of road lanes to be crossed(Chandra et al., 2014). Pedestrians decide to cross based on distance rather than the remaining time (Onelcin and Alver, 2015). The critical gap values for one-, two-, and three-lane roundabouts were 2.24 s, 2.55 s, and 2.40 s, respectively (Shaaban and Hamad, 2020). In different traffic situations, females accept a more significant gap (12.3 s) than males (9.46 s) when using crosswalks on divided two-lane motorways (Wickramasinghe et al., 2021). Females and pedestrians carrying bags need additional time to cross the street (Paul and Rajbonshi, 2014). It was determined that antagonistic behavior among pedestrians increases with waiting time; hence smaller gaps should be accepted (Arman et al., 2015). For a six-lane split road crossing, most pedestrians choose near gaps from the median and far gaps from the curb (Kadali and Vedagiri, 2013). The accepted gap was discovered to be decreasing with pedestrian crossing speed and conflicting traffic (Chandra et al., 2014). To analyze gap acceptance behavior, some researcher adopts the safety margin concept (Avinash et al., 2020) which is defined as "the difference between the time a pedestrian crossed the conflict point and the time the next vehicle arrived at the same conflict point" (Chu and Baltes, 2001). Avinash et al. (2020) claimed that the pedestrian behavioral characteristics significantly affect the safety margin value. Group size, direction of approaching vehicle, and vehicle size all affect the safety margin (Raoniar et al., 2020).

Review conclusions

In recent years, researchers have been focusing on pedestrian behavior analysis. Speed analysis and gap acceptance behavior are two of the primary concern. Studies from different countries, cultures, and circumstances provide different results, which further lead to an elaborate illustration of these topics. In most papers reviewed in this study, video recording and image processing are used for primary data collection. The methodology of these studies can be categorized through the models/tools used. Regression models, Logit models, ANOVA tests, Chi-square tests, Histogram etc., are mostly used to carry out the result. In the pedestrian speed analysis-based studies, pedestrian crossing speed differs in different countries shown in Fig. 3.

For instance, the average crossing speed in Iraq is 0.83 m/s while 1.69 m/s in Indonesia. The pedestrian speeds in other countries are somewhere between these two speeds. The reasons for differences in pedestrian speed by country are different pedestrian facilities in walkway such as footpath effective width, obstruction, capacity and flow rate etc. On road rather than the footpath, pedestrian speed may vary for different roadway facilities in different countries. Further, the significant reasons are pedestrian different physiological, psychological and environmental elements in different countries. On the other hand, the pedestrian crossing gap also varies with countries, and it is more distinct. A few studies show a pedestrian accepted gap to cross from the viewpoint of time in a road, including Qatar, India, and Sri Lanka is 2.55 s, 4.45 s, and 9.46 s, respectively depicted in Fig. 4. In Bangladesh, pedestrians want to take not more than 20–30 sec to cross the road.

Most of the studies focused on influencing factors to accept the gap to cross the road, such as waiting location, group/individual pedestrian, gender, education status, age, roadway width, vehicle flow, vehicle types on the road etc. However, the factors affecting pedestrian speed and accepted gap are the same. Individual characteristics, demography, traffic environment, land use, etc., are the deciding factors behind the different pedestrian's behavior.

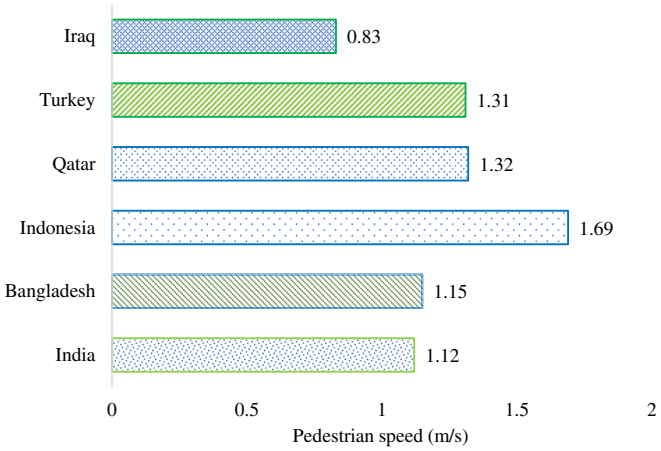

Fig. 3. Pedestrian speed of some countries.

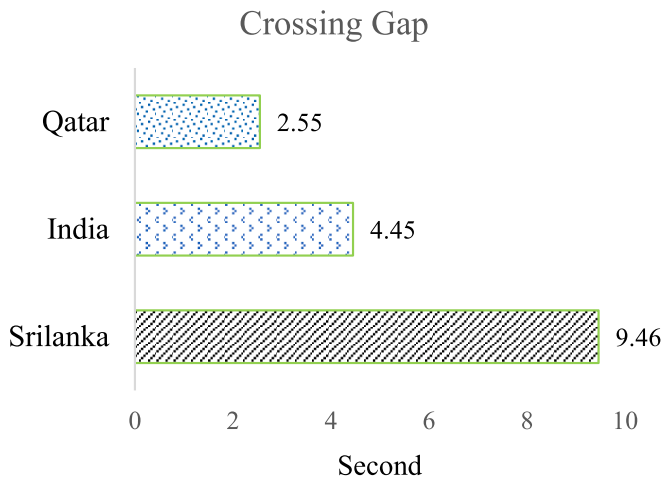

Fig. 4. Gap acceptance behavior from view point of time.

It can be said that the safety margin for pedestrian depends on group size, vehicular gap size, direction of approaching vehicle, vehicle size, pedestrian speed, rolling gap, age and pedestrian behavioral characteristics etc.

Open discussion and limitations

Pedestrians are the greatest number of users in the roadway and the most vulnerable users. So, it is vital to ensure pedestrians' safety by facilitating the movement environment on the route. In Asian countries, it looks that pedestrian-vehicle accidents are common scenario and causes spot death. This study demonstrated the pedestrian speed analysis of some Asian countries and showed the influencing factor on pedestrian speed in the roadway. Some elements are common such as age, gender, group/individual, vehicle type, vehicle flow, sideway friction etc. On the other side, this study explored the gap acceptance behavior of pedestrian in the road of Asian countries and the influencing factor that increases the waiting time to cross the street also find out such as signalized/unsignalized intersection type, marking crosswalk or not, waiting for location, traffic density, gender, age etc. A few numbers of papers were selected for the study. They tabulated important information on pedestrian speed and gap acceptance behavior to get these countries' holistic scenarios, which will help the next researcher determine the scope. They show an interest in spending time on this side. More studies are needed in this respective matter; the countries are Bangladesh, Maldives, Myanmar, Singapore, Jordan, Iraq, Lebanon, Syria, Vietnam etc., because only a few studies have found relevant topics. The study's findings will help to ease traffic safety issues by building an effective intersection control system. It also helps to take improvement measures in the roadway to ensure pedestrian safety. As the place of an uncontrolled intersection and midblock looked like a risky area, each of the Asian country's researchers would get importance to evaluate these places, which will assist the government in taking potential mitigating measures to overcome accidents. To increase the smoothness of pedestrian movement in the roadway, it is necessary to hide side friction from the road.

Limitations of this study include the reliance on data from previous investigations, which may not be uniformly collected across all Asian countries. Additionally, the review may not capture real-time changes and trends in pedestrian behavior due to rapid urbanization and infrastructure development. Further empirical research is needed to validate the findings and to explore pedestrian behaviors in more diverse and specific contexts, such as during different weather conditions or in varied socio-economic environments.

Future scope and relevant implications

The future aim of this study should be aiming to gather thorough and high-quality data from a wider range of Asian nations, including those that aren't currently covered, such Thailand, Vietnam, Myanmar, South and North Korea, Nepal, Syria, Afghanistan, the United Arab Emirates, and so on. These collected data will contribute to a more comprehensive and representative image of pedestrian behavior throughout the continent of Asia, which can be applied to other continents as well. Standards for data gathering techniques should be developed as it is required to guarantee dependability and comparability amongst the investigations. Researchers should create, plan, and implement standard procedures for gathering data on pedestrian speed and gap acceptance using both manual and automated methods as needed for some regions. To improve the data's dependability, further study should establish a correlation between the manual and automated data collection methods. Future research should examine a broader range of demographic variables, such as socioeconomic position, physical aptitude, and health. Research on the impact of different pedestrian infrastructure, as well as the availability and quality of sidewalks, should be investigated as these studies will offer important insights into these environments. In order to predict future trends, it is important to analyze how pedestrian behavior has changed over time with respect to the effects of daily changes in urban landscapes, traffic patterns, and legislative changes. In order to increase pedestrian safety, the researcher should also look at how different traffic laws, regulations, and fining affect how people behave. This should be done through a comprehensive analysis of various policies and legal penalties. Future studies in these areas will be able to offer a far more focused and thorough understanding of the behavior of pedestrians in Asian nations, which will be helpful for managing traffic, urban planning, and the building of pedestrian-friendly roadways.

To increase their applicability, the main conclusions of this study should be linked to concrete policy recommendations. Studies on pedestrian behavior, speed characteristics, and gap acceptance can be used to guide the development of specific interventions, such as enhanced pedestrian infrastructure including crosswalks with designated lanes, traffic calming measures, and pedestrian crossings. Some customized volunteering educational and practical campaign can monitor and manage fatal pedestrian behaviors, thereby encouraging safer crossing procedures. The result of these study can help to prepare a strategy which should be used by policymakers, urban planners, and traffic engineers to create pedestrian-friendly interventions that take into account local conditions, such as cultural norms and environmental factors. By putting these tactics into practice, pedestrian safety, traffic flow, and urban livability can all be significantly improved.

Conclusions

This study set out to assess pedestrians' speed preferences and gap-acceptance tendencies in Asian nations. Along with significant conclusions, data sources and methodological summaries of pertinent research are also presented. These details could help academics at the expert level create and analyze future transportation planning and policy. There have been studies on pedestrian behavior in the literature, but they typically only looked at the speed at which pedestrians cross the street or how they perceive gaps in the road. It was shown that the parameters affecting the pedestrian crossing speed were group size, age, items carried, gender, and the interaction between age and group size. In every instance, there was a notable distinction in the average speed of individuals and groups of pedestrians. Additionally, it was discovered that men walked more quickly than women. Also, Adults moved more rapidly than senior citizens, whereas young people did the same. Gap acceptance behavior was strongly correlated with the gap size, the speed of the vehicles, the length of the wait, and whether the gap was in the lane closest to the pedestrians. The gap's size, type, crossing stage, and speed influence the gap acceptance. It is recommended that crosswalks

be provided at all locations where people cross the roadway and that both motorists and pedestrians be instructed on how to use them. Campaigns aimed at educating the public and promoting safe crossing techniques should be used to increase pedestrian safety by discouraging dangerous behavior. The study's findings will help policymakers make the required measures to lessen issues linked to pedestrian safety and, as a result, create a more walkable and pedestrian-safe city.

CRediT authorship contribution statement

Samsuddin Ahmed: Methodology, Investigation, Formal analysis, Conceptualization. **Shahadat Hossain:** Writing – review & editing, Writing – original draft, Formal analysis. **Md. Ebrahim Shaik:** Writing – review & editing, Supervision. **Ahmed Shakik:** Writing – review & editing, Writing – original draft.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

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