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INFLUENCE OF PEDESTRIAN ATTRIBUTES ON WALKING SPEED AT BOTTLENECK OF BUS TERMINAL WALKWAY

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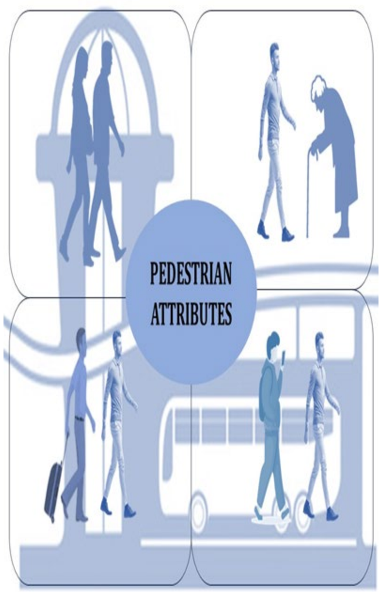
Graphical abstract



Abstract

Walking speed, a fundamental aspect of transportation, varies across individuals and is influenced by factors such as age, gender, and environmental conditions. This study focuses on pedestrian behavior, particularly walking speed, at bottlenecks in Larkin Sentral bus terminal in Johor Bahru, Malaysia. The country's lower average walking speed compared to other Asian nations underscores the need for efficient urban transportation planning. The objectives are to determine pedestrian walking speeds and explore the relationship between pedestrian attributes and walking speed. Data was collected using video recording at selected walkways during peak and non-peak hours. The analysis, conducted using Minitab software, reveals a mean walking speed of 0.80 m/s, influenced by factors such as age, gender, carrying bags, using phones, attire, and time. Correlation analysis indicates that time and phone usage significantly affect walking speed. This study contributes valuable insights for enhancing urban planning, emphasizing the impact of technology and time on pedestrian experiences at bus terminals. The implications for urban transportation planning are substantial, advocating for custom interventions in pedestrian-friendly designs at bus terminals. The study challenges assumptions, highlighting the need for nuanced understanding and further research to comprehend the complex dynamics shaping pedestrian behavior.

Keywords: Pedestrian attributes; walking speed; bottleneck; bus terminal; pedestrian behavior

Abstrak

Kelajuan berjalan, aspek asas pengangkutan, berbeza mengikut individu dan dipengaruhi oleh faktor seperti umur, jantina dan keadaan persekitaran. Kajian ini memberi tumpuan kepada tingkah laku pejalan kaki, terutamanya kelajuan berjalan, di kesesakan di terminal bas Larkin Sentral di Johor Bahru, Malaysia. Purata kelajuan berjalan negara yang lebih rendah berbanding negara-negara Asia yang lain menekankan keperluan untuk perancangan pengangkutan bandar yang cekap. Objektifnya adalah untuk menentukan kelajuan berjalan pejalan kaki dan meneroka hubungan antara sifat pejalan kaki dan kelajuan berjalan. Data dikumpul menggunakan rakaman video di laluan pejalan kaki terpilih pada waktu puncak dan bukan waktu puncak. Analisis yang dijalankan menggunakan perisian Minitab, mendedahkan purata kelajuan berjalan 0.80 m/s, dipengaruhi oleh faktor-faktor seperti umur, jantina, membawa beg, menggunakan telefon, pakaian dan masa. Analisis korelasi menunjukkan bahawa masa dan penggunaan telefon mempengaruhi kelajuan berjalan dengan ketara. Kajian ini menyumbangkan pandangan berharga untuk mempertingkatkan perancangan bandar, menekankan kesan teknologi dan masa ke atas pengalaman pejalan kaki di terminal bas. Implikasi untuk perancangan pengangkutan bandar adalah besar, menyokong campur tangan tersuai dalam reka bentuk mesra pejalan kaki di terminal bas. Kajian ini mencabar andaian, menonjolkan keperluan untuk pemahaman bernuansa dan penyelidikan lanjut untuk memahami dinamik kompleks yang membentuk tingkah laku pejalan kaki.

Kata Kunci: sifat pejalan kaki, kelajuan berjalan, kesesakan, terminal bas, tingkah laku pejalan kaki.

1.0 INTRODUCTION

Pedestrian flow dynamics are of paramount importance in urban settings as they significantly influence the safety, reliability and efficiency of transportation systems. It is critical to understand the fators that impact pedestrian mobility, specifically in congested regions like bus terminal walkways, in order to develop infrastructure that facilitates uninterrupted traffic flow and improves the overall pedestrian experience.(Giacomini et al., 2017). This paper investigates the influence of various pedestrian attributes on walking speed at bottleneck of a busy bus terminal walkway. Bus terminals serve as major hubs for public transportation, accommodating a large volume of pedestrian traffic throughout the day. Within these terminals, walkways often experience congestion and bottlenecks, especially during peak hours, leading to inefficiencies in pedestrian movement (Ma et al., 2021).

Numerous factors contribute to pedestrian behavior and walking speed, including individual attributes such as age, gender, physical capabilities, and personal preferences, as well as environmental factors such as crowd density, spatial constraints, and signage placement (Figueroa-Medina et al., 2023; Kim et al., 2020; Matsuura & Yano, 2023; Pinna & Murrau, 2018). It is imperative to understand the correlation between pedestrian attributes and walking speed at bottleneck points in bus terminal walkways, in order to optimize pedestrian flow and enhance the overall efficiency of the terminal. Transportation planners could use output from these types of studies to target interventions to improve safety, reduce congestion, and make pedestrian environments more user-friendly for all demographic groups (Khudhair & Alsadik, 2021; Zhuang & Wu, 2011).

Several studies have examined the spatial variation of pedestrian walking speed in diverse contexts, providing insights into the variables impacting variations in speed. Studies have indicated that the pace at which pedestrians walk within transportation terminals varies. Studies by Hassouna (2020) and Pinna and Murrau (2018) observed faster walking speeds on walkways with straight, unobstructed sections as opposed to those with sharp turns or obstacles. Additionally, Bargegol et al. (2022) discovered that there appears to be a correlation between pedestrian density and walking speed along walkways, with a tendency for pedestrian speed to decrease in areas with high pedestrian density.

Terminal layout, amenities offered, and crowd density impact on how quickly pedestrians walk at transportation terminals. Fugger Jr et al. (2001) carried out a study at a major train station and discovered that people walked faster through open concourse areas than through ticketing and waiting areas. Similarly, Dias et al. (2013) observed variations in walking speeds between concourse areas and terminal platforms, with slower walking speeds in the vicinity of amenities and ticket counters. At bottleneck locations in transportation terminals, pedestrian walking speeds are often slower due to space constraints and increased traffic (Adrian et al., 2020; Cao et al., 2022; Dai et al., 2013).

The demographic attributes of age, gender, and socioeconomic status have a notable impact on the variability of pedestrian walking speeds in various settings. Studies consistently demonstrate that older adults walk slower than younger adults, which is indicative of age-related decreases in mobility and gait speed (Iryo-Asano & Alhajyaseen, 2017; Papadimitriou et al., 2016; Pinna & Murrau, 2018). Gender differences in walking speed are also observed, with males generally walking faster than females in both urban and suburban environments (Mustafa et al., 2014; Sukhadia et al., 2016). Additionally, socioeconomic factors may influence walking speed, as individuals from lower socioeconomic backgrounds may face environmental barriers that impact their mobility (Ekawati & Eves, 2020). Physical capabilities and health status also contribute to differences in walking speed across various locations. Mobility impairments, disabilities, and chronic health conditions can affect gait patterns and walking speed, leading to variations in pedestrian movement (Guío-Burgos et al., 2023; Zhou et al., 2014). For instance, pedestrians using mobility aids such as wheelchairs or walkers may navigate at a slower pace compared to those without mobility limitations. Moreover, temporary factors such as fatigue, injury, or illness can also impact walking speed, highlighting the dynamic nature of pedestrian behavior in different environments (Rosenbloom et al., 2011).

Personal preferences and behavioral factors significantly influence pedestrian walking speed in diverse locations (Rosenbloom et al., 2011). The environmental context and situational factors within different locations also play a crucial role in shaping pedestrian walking speed. Crowd density, spatial layout, signage visibility, and amenities can impact pedestrian movement dynamics and walking speed variation (Franěk, 2013).

The rest of this paper is organized as follows. Section 2 outlines the methodology employed in this study, including data collection methods, data analysis techniques, and experimental design. Section 3 presents the findings of the research. Finally, Section 4 discusses the implications of these findings and identifies avenues for future research.

2.0 METHODS AND METHODOLOGY

This study was conducted at the largest and main public transport terminal in Johor Bahru; The Larkin Sentral bus terminal (Figure 1). It serves as a major transportation hub connecting various destinations within Malaysia and to neighboring countries like Singapore. The terminal's strategic location, combined with its extensive network of bus routes and services, contributes to its high passenger volume. The busy walkway that was selected for data collection was carefully chosen to capture the range of walking speeds of pedestrians. It was specifically chosen to act as a bottleneck walkway because it is located between a convenience store and the ticketing counter.

The word "bottleneck" suggests that there is probably a lot of pedestrian traffic in this area, which makes it a suitable place for data collection. Research data were collected during peak and non-peak hours. The peak and non-peak periods were chosen by analyzing the frequency of bus departures every day and every hour. From the analysis, the periods between 9.00 a.m. to 11 a.m., and 7.00 p.m. to 9.00 p.m. were chosen as peak and non-peak hours respectively.

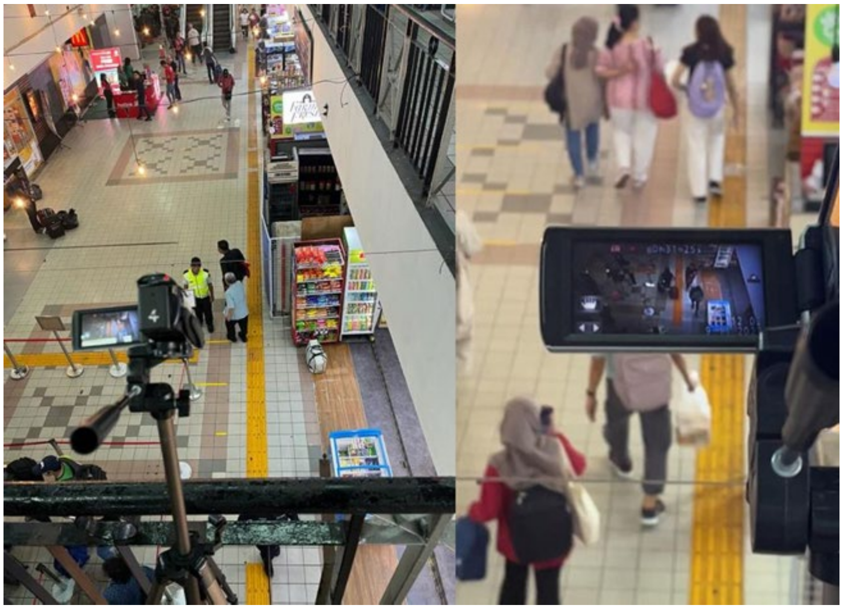


Figure 1 Study location.

Footage of pedestrians walking across the selected bottleneck area was analyzed to extract relevant pedestrian attributes. Pedestrian attributes considered in this study are age, gender, carrying bag and attire. Of these attributes, only age is non-binary. Pedestrians were categorized into three age groups, with each age group assigned a number when recording data from the footage as shown in Table 1. Walking speed was calculated manually using time taken by each data point in the footage (pedestrian) to traverse two fixed points along the walkway.

Table 1. Definitions of attributes used in the study.

Attribute	Definitions
Age	Child (0), Adult (1), Old (2)
Hindering attire	No (0), Yes (1)
Phone use	No (0), Yes (1)
Carrying bag	No (0), Yes (1)

2.1 Sample Size

Determining an appropriate sample size is a crucial aspect of research design and statistical analysis. The size of the sample directly impacts the precision and reliability of study findings. The process of calculating the sample size involves considering various factors such as the desired level of confidence, the margin of error, and the variability within the population. Results from data collection revealed a dataset of 22,828 data points. A broad range of observations regarding the variables under study are contained in this sizable dataset. Using Eqn. 1, a sample size of 378 was obtained for data analysis.

$$Sample\ size = \frac{S}{1 + [\frac{(S-1)}{Population\ size}]} \qquad \text{Eqn. 1}$$

where $S = \frac{[Z^2 P(1-P)]}{e^2}$ with Z = 1.96 for 96% confidence level, a margin of error (e) of 0.05 and population standard deviation (P) of 0.5.

3.0 RESULTS AND DISCUSSION

3.1 Average Walking Speed at Larkin Sentral Terminal

Pedestrian walking speed at terminals refers to the speed at which individuals walk in terminal environments. The effectiveness, comfort, and overall experience of passengers in these transportation facilities can be greatly improved by analyzing pedestrian walking speed at terminals. Figure 2 shows the scatterplot of pedestrians' walking speed at the bus transit terminal bottleneck walkway in comparison with previous research on pedestrian walking speed at terminal.

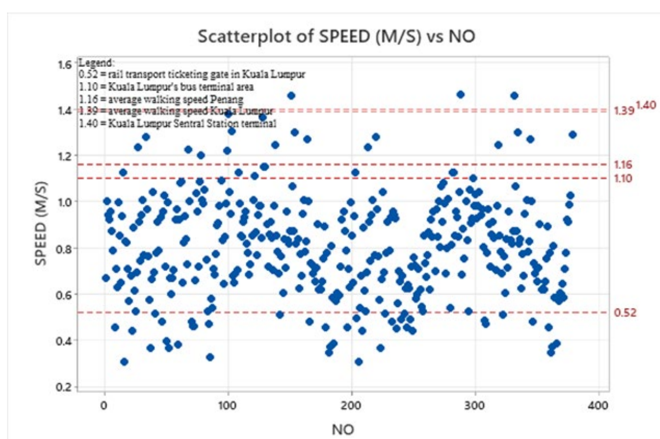


Figure 2 Comparison of average walking speed at study location with past research.

Figure 2 reveals that majority of pedestrians at the study walk at speeds higher than the average walking speed measured at the rail station ticketing gate in Kuala Lumpur, which was 0.52 m/s. Also, there was a noticeable difference in the walking speeds observed in this study with those recorded at other well-known transportation centers. More specifically, pedestrian speeds at the study area were significantly slower than the recorded averages in Kuala Lumpur's bus terminal area (1.10 m/s) and Kuala Lumpur Sentral Station terminal (1.40 m/s). The apparent contradiction that this study's careful analysis revealed places pedestrian walking speeds at Larkin Sentral within a particular range. This suggests a complex relationship between pedestrian walking speed and the surrounding environment, which contradicts the conclusions established by past studies.

3.2 Descriptive Statistics of Pedestrian Attributes

Table 2 shows the descriptive statistics of the attributes investigated in this study. The average pedestrian walking speed at the study location was found to be 0.80 m/s. The mean age of pedestrians in the sample is 1.11 (Table 2), indicating a predominance of adults. While adults generally exhibit faster walking speeds compared to children or older individuals, the inclusion of a wider age range encompassing older adults could contribute to a lower overall average walking speed. 65% of the pedestrians are male. Males typically exhibit slightly faster walking speeds compared to females. However, the overall distribution of genders in the sample may not fully account for the lower average walking speed observed.

Table 2. Descriptive Statistics of pedestrian attributes.

Variable	Mean	St. Dev.	Min.	Median	Max.
Speed (m/s)	0.80	0.22	0.31	0.79	1.46
Age	1.11	0.50	0.00	1.00	2.00
Gender	0.35	0.48	0.00	0.00	1.00
Carrying bag	0.44	0.50	0.00	0.00	1.00
Using phone	0.13	0.33	0.00	0.00	1.00
Attire	0.06	0.24	0.00	0.00	1.00

Analysis shows that 44% of the pedestrians in the sample were carrying bags. Carrying a bag can potentially affect walking speed by adding weight and altering posture, leading to slightly slower speeds. The prevalence of individuals carrying bags in the sample could contribute to the lower average walking speed observed. About 13% of the pedestrians were using phone while passing through the study location. Similarly, only 6% of pedestrians were wearing attire that seems to hinder movement. Although distractions such as using phone can lead to slower walking speeds, the low percentage of pedestrians using phones could not significantly result in the lower average walking speed at the study location.

3.3 Correlation Analysis of Pedestrian Attributes with Walking Speed

The foundational technique for determining the strength and direction of a linear relationship between two variables is correlation analysis. In this study, the Pearson correlation coefficient is used to establish the correlation between the attributes under investigation, with a view to evaluating the strength of their relationship with pedestrian walking speed.

3.3.1 Correlation between Walking Speed and Period of Transportation Demand

According to Mustafa et al. (2015), pedestrians walking speed during peak hours are lower than non-peak hours. However, this is contrary to the findings in this study, where pedestrian walking speeds were found to be slightly higher during peak hours. Walking speeds during peak hours are averagely 0.2% higher than those during non-peak hours (Figure 3). Various variables can be linked to the occurrence of increased mean walking speed in the pedestrian research during non-peak hours compared to peak hours. One important contributing element is the less crowded walkway during non-peak hour, which allow people to move faster and more freely along it. One possible explanation for this could be the lack of time pressure during non-peak hour, when people are not as rushed for time to make it to transit.
Furthermore, there may be a difference in the demographics of pedestrians during non-peak hours, with less people hurrying and more people taking leisurely strolls. Moreover, the purpose of travel during non-peak hours may vary, with individuals engaged in activities that are not time-sensitive, contributing to a more diverse and potentially higher average speed. The observed variation highlights the complex relationship between multiple factors affecting pedestrian behavior in distinct temporal settings.

3.3.2 Correlation between Walking Speed and Pedestrian Attributes

Expanding on the previous analysis of pedestrian walking speed, a significant relationship between walking speed and phone use was identified. This study provides insight on how using a phone affects walking speed and finds that using a phone while walking has an important effect on speed. The focus of individuals is split between the screen and their surroundings when they use electronics while out for walks. This split attention when using a phone clearly influences changes in walking speed, demonstrating the complex relationship between technology use and pedestrian movement.

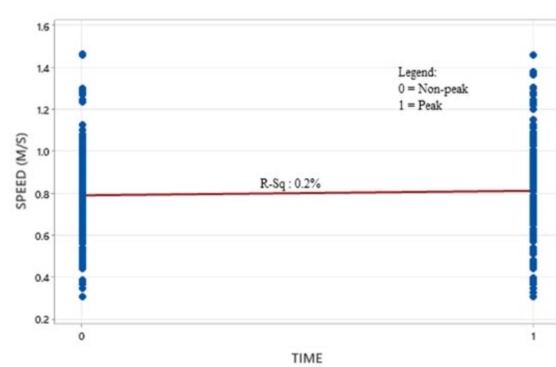


Figure 3 Variation of walking speeds with period of transportation demand.

The numbers 0 and 1 in Figure 4 represent the absence and presence of phone use while walking, respectively. It is crucial for pedestrians to be aware of their gadget usage while walking in order to ensure pedestrian safety and maintain the ideal walking speed. Citing Li et al. (2022), a notable decrease in average walking speed, 11% for males and 12% for females, was observed in those not using devices compared to the typical pedestrian. Based on this observation, it is proposed that when pedestrians use electronic devices while walking, there is a significant difference in their average walking speed. This theory highlights the possible effects of gadget use on pedestrian mobility by indicating that such use may result in noticeable differences in walking speeds, an element that is essential for both safety concerns and the effectiveness of pedestrian movement.

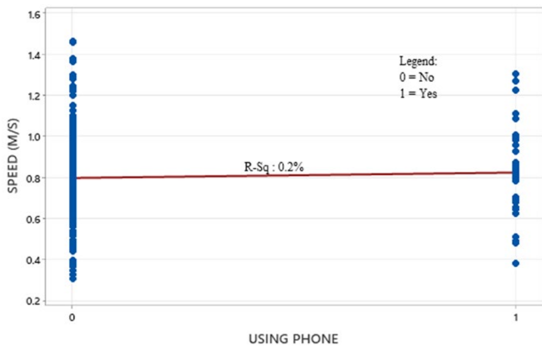


Figure 4 Variation of walking speed with pedestrians using phone.

From Table 2, pedestrians who use their phones while walking have a higher mean walking speed than those who do not. There are multiple possible explanations for this. People who use their phones while walking may be a little faster since they are more concentrated on getting where they are going quickly.

4.0 CONCLUSIONS AND FUTURE RESEARCH

4.1 Conclusions

This research examined the complexities surrounding pedestrian walking speeds at the bus transit terminal's bottleneck walkway, paying particular attention to the correlation between different pedestrian attributes and speeds. A valuable understanding of pedestrian movement dynamics, especially in congested and cramped spaces, was gained from the study conducted at Larkin Sentral bus terminal in Johor Bahru, Johor. A mean pedestrian walking speed of 0.80 m/s was discovered by the investigation, and correlation analysis highlighted significant relationships between walking speed and the pedestrian attributes investigated. The relationship between walking speed and phone usage was especially interesting because it suggests that walking faster is a result of temptations from using a gadget.

The results of the study have important implication for urban transportation planning, highlighting the significance of customized interventions for pedestrian friendly designs. Key recommendations on improving ease of pedestrian flow and eliminating bottleneck at the study area include staggered arrivals and departure times, peak time management strategies such as providing temporary barriers or additional walkways during peak times and, provision of designated entry and exit points to eliminate cross-pedestrian traffic.

4.2 Future Research

Future research could explore the influence of psychological factors, such as perceptions of crowding, feelings of urgency or impatience, individual personality traits, and emotional states on pedestrians' navigational choices around bottleneck areas. Environmental condition plays a significant role in pedestrian movement. Studying factors such as lighting, temperature, noise levels, and visual distractions can help identify how these elements impact walking speeds and overall pedestrian flow around bottleneck areas. Also, future research could explore pedestrian dynamics in multi-modal bottleneck areas. Exploring how interactions between pedestrians and other modes of transportation (e.g., buses, bicycles, scooters) influence walking speeds and overall pedestrian flow at bottleneck areas can inform the design of integrated transportation systems.

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Conflicts of Interest

The author(s) declare(s) that there is no conflict of interest regarding the publication of this paper

References

[1] Adrian, J., Boltes, M., Sieben, A., & Seyfried, A. 2020. *Influence of Corridor Width and Motivation on Pedestrians in Front of Bottlenecks.* Paper presented at the Springer Proceedings in Physics. DOI:10.1007/978-3-030-55973-1_1

[2] Bargegol, I., Najafi Moghaddam Gilani, V., Hosseinian, S. M., & Habibzadeh, M. 2022. Pedestrians Crossing and Walking Speeds Analysis in Urban Areas under the Influence of Rain and Personality Characteristics. *Mathematical Problems in Engineering, 2022*. DOI:10.1155/2022/7768160

[3] Cao, S., Xi, X., Ni, J., & Yao, M. 2022. Simulation of pedestrian flow at bottleneck of stairs considering group behavior. *China Safety Science Journal, 32*(2), 28-33. DOI:10.16265/j.cnki.issn1003-3033.2022.02.005

[4] Dai, J., Li, X., & Liu, L. 2013. Simulation of pedestrian counter flow through bottlenecks by using an agent-based model. *Physica A: Statistical Mechanics and its Applications, 392*(9): 2202-2211. DOI:10.1016/j.physa.2013.01.012

[5] Dias, C., Sarvi, M., Shiwakoti, N., & Ejtemai, O. 2013. *Experimental study on pedestrian walking characteristics through angled corridors.* Paper presented at the Australasian Transport Research Forum, ATRF 2013 - Proceedings.

[6] Ekawati, F. F., & Eves, F. F. 2020. Effects of climbing choice, demographic, and climate on walking behavior. *Kesmas, 15*(2): 59-64. DOI:10.21109/KESMAS.V15I2.2909

[7] Figueroa-Medina, A. M., Valdés-Díaz, D., Colucci-Ríos, B., Cardona-Rodríguez, N., & Chamorro-Parejo, A. 2023. Analysis of walking speeds and success rates on mid-block crossings using virtual reality simulation. *Accident Analysis and Prevention, 183*. DOI:10.1016/j.aap.2023.106987

[8] Franěk, M. 2013. Environmental factors influencing pedestrian walking speed. *Perceptual and motor skills, 116*(3): 992-1019.

[9] Fugger Jr, T. F., Randles, B. C., Wobrock, J. L., Stein, A. C., & Whiting, W. C. 2001. *Pedestrian behavior at signal-controlled crosswalks.* Paper presented at the SAE Technical Papers. DOI:10.4271/2001-01-0896

[10] Giacomini, C., Longo, G., & Zornada, M. (2017). *Pedestrian infrastructure: Design optimization and performance.* Paper presented at the GSTF Conference Proceeding.

[11] Guío-Burgos, F. A., Combariza-Pinzón, M. J., & Cerquera-Escobar, F. Á. 2023. Pedestrian gaps and walking speed at uncontrolled midblock crosswalks. *Revista Facultad de Ingenieria.* 107: 26-38. DOI:10.17533/udea.redin.20220371

[12] Hassouna, F. M. A. 2020. Evaluation of pedestrian walking speed change patterns at crosswalks in Palestine. *Open Transportation Journal, 14*: 44-49. DOI:10.2174/1874447802014010044

[13] Iryo-Asano, M., & Alhajyaseen, W. 2017. *Consideration of a Pedestrian Speed Change Model in the Pedestrian-Vehicle Safety Assessment of Signalized Crosswalks.* Paper presented at the Transportation Research Procedia. DOI:10.1016/j.trpro.2017.03.080

[14] Khudhair, H. A., & Alsadik, S. M. 2021. Modeling the pedestrians walking behaviour at a commercial center in Baghdad City. *Journal of Engineering Science and Technology, 16*(4): 3104-3118.

[15] Kim, S. H., Kim, J. W., Chung, H. C., Choi, G. J., & Choi, M. Y. 2020. Behavioral dynamics of pedestrians crossing between two moving vehicles. *Applied Sciences (Switzerland), 10*(3): DOI:10.3390/app10030859

[16] Li, M., Zhou, Z., Zhou, X., Zhang, P., Cheng, H., Jiang, J., Yang, L. 2022. How bottleneck width and restricted walking height affect pedestrian motion: Experimental analysis. *Physica A: Statistical Mechanics and its Applications, 605*. DOI:10.1016/j.physa.2022.127967

[17] Ma, Z. Y., Zhang, J. X., Philbin, S. P., Li, H., Yang, J., Feng, Y. L., Skitmore, M. 2021. Dynamic Quality Monitoring System to Assess the Quality of Asphalt Concrete Pavement. *Buildings, 11*(12) DOI:10.3390/buildings11120577

[18] Matsuura, T., & Yano, N. (2023). Behaviors of pedestrians on streets with roadside strips. *Transportation Research Interdisciplinary Perspectives, 19*. DOI:10.1016/j.trip.2023.100799

[19] Mustafa, M., Baser, N., & Ashaari, Y. 2014. *Evaluating pedestrian crossing speed distribution: A case study of Shah Alam.* Paper presented at the IET Conference Publications.

[20] Mustafa, M., Noor, M., & Mohamad, A. I. 2015. *Understanding pedestrian movement at rail transit station ticketing gate.* Paper presented at the Conference of Eastern Asia society for transportation studies.

[21] Papadimitriou, E., Yannis, G., & Golias, J. 2016. Analysis of Pedestrian road crossing behaviour in urban areas *Civil and Environmental Engineering: Concepts, Methodologies, Tools, and Applications*. 3: 1140-1155.

[22] Pinna, F., & Murrau, R. 2018. Age factor and pedestrian speed on sidewalks. *Sustainability (Switzerland), 10*(11) DOI:10.3390/su10114084

[23] Rosenbloom, T., Beigel, A., & Eldror, E. 2011. Attitudes, behavioral intentions, and risk perceptions of fatigued pedestrians. *Social Behavior and Personality: an international journal, 39*(9): 1263-1270.

[24] Sukhadia, H., Dave, S. M., Shah, J., & Rathva, D. 2016. *The Effect of Events on Pedestrian Behavior and its Comparison with Normal Walking Behavior in CBD Area in Indian Context.* Paper presented at the Transportation Research Procedia. DOI:10.1016/j.trpro.2016.11.120

[25] Zhou, J. B., Chen, H., Yan, B., & Zhu, H. J. 2014. Pedestrian traffic characteristics analysis in the metro transfer hub. *Wuhan Ligong Daxue Xuebao/Journal of Wuhan University of Technology, 36*(4): 92-99. DOI:10.3963/j.issn.1671-4431.2014.04.017

[26] Zhuang, X., & Wu, C. 2011. Modeling of pedestrian crossing behavior at unmarked roadway in China. Paper presented at the ICTIS 2011: Multimodal Approach to Sustained Transportation System Development - Information, Technology, Implementation - *Proceedings of the 1st Int. Conf. on Transportation Information and Safety*. DOI:10.1061/41177(415)223