International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-15 Issue-4, March 2026

Operational Performance of Pedestrian at the Crosswalk

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Abstract: ***The study of pedestrian operational performance at crosswalks is essential for enhancing pedestrian safety, streamlining traffic, and boosting overall urban mobility. Five points were selected in Hyderabad where the road intersection has a signal and a pedestrian crosswalk. The pedestrian crosswalk footage was recorded between 8 a.m. and 10 a.m. and between 4 p.m. and 6 p.m. The data was extracted from the same footage and used to determine the number of different vehicles and pedestrians using the crosswalk. The key parameters chosen for study are the number of pedestrians, their gender, walking speed, and the time they wait at the crossing. It is noted that the number of persons walking and their walking speeds varied in that selected time period. The purpose of the study is to determine how improvements, such as modifying traffic light timings or improving pedestrian-friendly crossings, affect the safety and comfort of walking for people. This study will help improve roadways and crossings, making them safer and more pleasant for pedestrians. This implies that roads and crossings must be planned to facilitate safe walking. Therefore, policymakers and urban planners can create safer, more accessible urban settings by designing more effective, pedestrian-friendly infrastructure informed by an understanding of pedestrian behaviour, crossing patterns, and interactions with automobiles.***

Keywords: Crosswalk, Walking Speed, Delay Time, Pedestrian Volume, Traffic Volume, Pedestrian Flow Rate.

Nomenclature:
LOS: Level of Service

I. INTRODUCTION

Pedestrians use crosswalks to cross the road at signalled crossings. Pedestrians should be aware of traffic signals and walk in designated areas. Lack of adherence to traffic regulations at pedestrian crossings, particularly by drivers, creates a paradigm in which pedestrians may become bold and force approaching vehicles in the traffic stream to brake to gain priority at the crossing [5]. It is safe to cross the road when the signal is green and displays a walking person symbol. Red indicates to stop and wait for the pedestrian at the signal crossing. This may involve adjusting signal timing or enhancing crosswalk design. Pedestrian crosswalks are essential for the safe and effective passage of both vehicular traffic and pedestrians on city streets.

Manuscript received on 13 January 2026 | First Revised Manuscript received on 25 January 2026 | Second Revised Manuscript received on 09 March 2026 | Manuscript Accepted on 15 March 2026 | Manuscript published on 30 March 2026.
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Optimising traffic flow, improving safety, and establishing pedestrian-friendly environments all depend on understanding how pedestrians use crosswalks. This introduction addresses knowledge gaps, examines key factors affecting pedestrian behaviour at crosswalks, and emphasises operational issues to inform traffic management and urban design plans. The authors examined how people behave at crosswalks of signalled intersections in different parts of Hyderabad City. There are still certain doubts about their effects compared to traditional traffic lights, i.e., the extent to which they actually improve pedestrian behaviour and enhance pedestrian safety [6]. Improving the quality of the crossing pavement, the sidewalk, and the curb ramp, especially at pedestrian crossings, might help reduce this fear and encourage the oldest pedestrians to favour these crossing sites [2]. This research aids our understanding of how individuals move and respond to traffic lights, thereby reducing the risk of accidents.

A. Pedestrian Flow Studies

Pedestrian delay depends on the arrival pattern, crossing speed, and noncompliance rate. The delay in pedestrian arrivals during the effective green time is constant and depends on pedestrian crossing speed [9]. Among those who develop and manage public areas, transit networks, and structures, urban planners, architects, and engineers must have a thorough understanding of pedestrian flow characteristics. Pedestrian arrival rates were not uniform throughout cycles; pedestrians arriving during green phases might also receive delays [18]. The movement of people on foot in a designated area, such as sidewalks, streets, plazas, and transit stations, is referred to as pedestrian flow. The characteristics of pedestrian flow include elements that affect how people move through an area, such as walking speed, crowd density, preferred directions, interactions with infrastructure, and environmental factors. By researching these characters, planners may make informed choices to improve traffic control, encourage sustainable transportation, and make public spaces more accessible and usable.

B. Factors Affecting the Road Crossing Behaviour of Pedestrians

The characteristics of pedestrian flow at signalised crosswalks differ from those on walkways or sidewalks. Several factors might contribute to these differences, such as the generally short length of crosswalks, traffic signal operations, and the impacts of motorised traffic [15]. The complex interplay among elements shaped by personal qualities, the environment, and infrastructure design determines how pedestrians behave when crossing roads. Based on historical traffic data, the paper shows that the primary factor driving pedestrian traffic conflicts is pedestrian

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violations of traffic laws, followed by inadequate crossing facilities [16]. Designing efficient urban environments, increasing traffic flow, and improving pedestrian safety all depend on an understanding of the factors influencing road-crossing behaviour. The introduction establishes the context for analysing the complex nature of pedestrian road-crossing behaviour and the wide range of factors that influence it. Urban planners and transportation engineers may construct pedestrian-friendly neighbourhoods, reduce pedestrian-vehicle conflicts, and encourage safer and more effective pedestrian movement by learning more about these aspects.

II. OBJECTIVES OF THE STUDY

Based on the research gaps identified, the following specific objectives are proposed as

A. Evaluate pedestrian crossing times and waiting periods at crosswalks to understand the operational efficiency and identify potential bottlenecks in pedestrian flow.
B. Assess the impact of infrastructure design, signal timing, and signage on pedestrian behaviour to enhance the safety and effectiveness of crosswalks.
C. Investigate the influence of technological interventions, such as smart crosswalk systems, on improving operational performance and optimizing the overall integration of pedestrians into the urban traffic network.
D. To assess the efficiency and safety of pedestrian movements at signalised intersections.

III. LITERATURE REVIEW

The prior research conducted under both homogeneous and heterogeneous traffic conditions has been examined, and a summary is provided below. Previous research conducted under these conditions is reviewed on pedestrian crossing behaviour and service level.

R. Nagraj et al. (2013) developed a pedestrian delay model for signalised intersection crosswalks in Mumbai, India, considering factors such as turning traffic, through traffic, pedestrian count, and pedestrian delay. A new model was created because there was no model for Indian scenarios that accounted for nonuniform arrival rates and signal noncompliance behaviour. The study aimed to accurately estimate pedestrian LOS, which is crucial for assessing pedestrian facilities, and proposed a method for estimating pedestrian LOS at signalised crosswalks under mixed-traffic conditions. The model was applied at the Sakinaka intersection, showing the direct impacts of all parameters on LOS and improving service-quality predictions [1].

Flávio Cunto et al. (2008) study presents a method for calibrating and validating a microscopic traffic simulation model to evaluate safety at signalized intersections. The VISSIM simulation platform was calibrated using vehicle trajectory data from the FHWA NGSIM dataset. Safety was measured using indicators such as the Crash Potential Index, number of vehicles in conflict, and conflict duration. A calibration process involving statistical screening, factorial analysis, and genetic algorithms was used to determine optimal model inputs [4].

Qiangqiang Guo et al. (2019) study reviews urban traffic signal control systems using Connected and Automated Vehicles to improve traffic efficiency and safety. It explains how CAV data and mobile sensing can provide accurate, real-time information on traffic flow, queue lengths, travel times, and vehicle trajectories. The study categorises CAV-based traffic control into methods such as driver guidance, adaptive signal control, platoon-based control, planning-based control, and signal-vehicle-coupled control. Results show that integrating CAV technology can reduce congestion, improve mobility, enhance fuel efficiency, and increase traffic safety at intersections [19].

Eom, M et al. (2020) study reviews the Intersection Traffic Signal Control Problem, focusing on optimising traffic signal timings to improve traffic flow and reduce congestion. It explains important signal concepts such as cycle length, phase sequence, and green signal duration. The study summarises various solution approaches, including optimisation models, simulations, genetic algorithms, and reinforcement learning. It also discusses factors affecting signal control, such as traffic demand, network type, and road user categories [20].

Sankaran Marisamynathan et al. (2015) present a new approach to estimating pedestrian delay at signalised intersections by accounting for pedestrian crossing behaviour and vehicular interactions under mixed-traffic conditions. Data collection, methodology, pedestrian crossing behaviours, and the development of delay models are detailed. The study aims to develop accurate pedestrian delay estimation models by analysing pedestrian behaviours and interactions at crosswalks. Two sets of data were collected at four signalised intersections to develop delay models that incorporate pedestrian compliance and noncompliance with traffic signals, as well as pedestrian-vehicular interactions. The models were validated using field data and compared with existing models [21].

M. Kruszyna et al. (2003) Mackiewicz document provides a detailed report on observations and measurements conducted at pedestrian crosswalks in Wroclaw, Poland, in 2003. It includes information on the methodology used, characteristics of the crosswalks, pedestrian flow rates, and the estimation of average pedestrian delay at crosswalks. The study analysed the accuracy of existing models. It proposed three new models to estimate pedestrian delays at signalised crosswalks, highlighting the importance of considering pedestrians' entry process during the red phase for more accurate estimates. The new models showed higher accuracy than existing models, especially for locations with specific conditions, such as midblock entries. Sensitivity analysis of delay values with respect to the parameters used in the models was also conducted, emphasising the significance of the red ratio parameter [22].

Miho Iryo-Asano et al.'s (2017) study analyses pedestrian speed-change events at signalised crosswalks, considering factors such as signal timing, crosswalk geometry, and interactions with vehicular traffic. Data processing involves manually tracking pedestrians using a Traffic Analyser to extract positional and timing information. The study concludes that crosswalk length, pedestrian signal indication, and turning traffic significantly affect speed change events [23].

M K Singh et al. (2022) study analyses driver behaviour at signalised intersections under heterogeneous traffic

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conditions in India. GPS and video data from around 900 drivers were used to examine acceleration and deceleration patterns near intersections. The research identified the Intersection Zone of Influence, where drivers begin to reduce speed after seeing a red signal. Results show that cars begin slowing at about 160 m, three-wheelers at 124 m, and buses at about 98 m from the intersection [7]. The probabilities of a driver braking or weaving, and of a pedestrian continuing to cross in response to an encounter are identified for a variety of pedestrian, environmental, and traffic conditions [14].

M. Essa et al. (2018) study develops traffic conflict–based Safety Performance Functions to evaluate the safety of signalised intersections at the signal cycle level using video data from six intersections in Canada. Vehicle trajectories were extracted to quantify traffic volume, queue length, shock-wave characteristics, and platoon ratio. Rear-end conflicts were identified using Time-to-Collision and analysed using Generalized Linear Models. Results show that higher traffic volume, longer queues, larger shock waves, and lower platoon ratios increase the occurrence of conflicts [8].

Shahana, A et al. (2024) study develops conflict-based Safety Performance Functions to predict rear-end and side-swipe conflicts at signalized intersections under disordered traffic conditions in India. Vehicle trajectory data from 9,586 vehicles at four intersections were analysed using a modified Time-to-Collision method. Results show that higher traffic volume, higher vehicle speeds, and more right-turning vehicles increase the incidence of rear-end collisions. Side-swipe conflicts increase with the number of lane-changing manoeuvres and right-turning traffic [10].

S.C. Wong et al.'s (2007) study examines the factors influencing crash occurrence at 262 signalised intersections in Hong Kong using statistical count data models. Two models were developed: a Negative Binomial regression model for slight-injury crashes and a Poisson regression model for fatal or serious-injury crashes. The results show that factors such as traffic volume, road curvature, the presence of tram stops, and the road environment significantly increase the likelihood of slight-injury crashes. For severe crashes, key factors include tram stops, a higher proportion of commercial vehicles, more pedestrian crossing streams, narrower lanes, and road curvature. The study concludes that improved intersection design, better pedestrian facilities, and efficient traffic management can reduce crash risk and improve safety at signalized intersections [11].

Tiwari et al. (2007) study analyses pedestrian crossing behaviour at signalized intersections in Delhi using survival analysis to measure the risk of pedestrians crossing during unsafe signal phases. Data were collected through video observations at seven intersections, focusing on pedestrians' waiting time before crossing. The results show that pedestrians become impatient as waiting time increases and often cross during unsafe conditions, increasing crash risk. Female pedestrians were found to wait longer than males before crossing, indicating more cautious behaviour. The study concludes that reducing pedestrian waiting time and improving intersection design can significantly enhance pedestrian safety [12].

Qing et al.'s (2016) study examines pedestrian and bicycle crash frequency at the macro level using Traffic Analysis Zones in Florida. It compares single-state models with dual-state models to address crash data with many zero counts. The research also incorporates spatial spill-over effects by considering the influence of neighbouring zones on crash occurrences. The findings indicate that factors such as traffic exposure, population density, employment, sidewalks, intersections, and commuter patterns significantly influence crash frequency [13].

Their sudden stops due to signal changes or emergent situations with unexpectedly high deceleration rates may contribute to rear-end accidents. Therefore, significant patterns associated with accident risk for the vehicle/driver have been identified [17]. The lack of existing methods for calculating pedestrian delay at multistage crossings means that signal-timing plans with multistage crossings are sometimes developed that inadvertently lead to very long pedestrian delays because of the poor progression they offer from one stage to the next [3].

The literature studies collectively focused on estimating pedestrian delay and understanding pedestrian behaviour at signalised crosswalks, particularly in mixed-traffic conditions. They explore factors influencing pedestrian movement, including turning traffic, signal timing, crosswalk geometry, pedestrian compliance with signals, and vehicular interactions. The research highlights the need for accurate models to estimate pedestrian delay and Level of Service (LOS), with some studies introducing new models designed for specific conditions, such as midblock entries or non-uniform pedestrian flows. Through field data collection, analysis of pedestrian arrival times at the crossing, and sensitivity testing of delay parameters. These studies aim to develop more precise models to enhance pedestrian safety and service quality at signal intersections.

IV. METHODOLOGY

Data collection and analysis are done in an organized manner as part of the process for evaluating how well pedestrians function at crosswalks. We seek to assess elements including safety, effectiveness, accessibility, and pedestrian behaviour using a mix of observational studies, traffic counts, and questionnaires. The effectiveness of crosswalk infrastructure and traffic management techniques, and the influence of environmental factors on pedestrian experience, will all be examined in this study using both qualitative and quantitative methodologies.

A. Site Selection

The author selected five signalised road crossings in Hyderabad City. Simple data were extracted using a manual count and on-site physical measurements. The data was then saved and assessed using a variety of criteria in Microsoft Excel.

Sites such as Nacharam X Road, Ramanthapur intersection, DMHS Bus station, Sri Nagar colony, and Panjagutta X Road are chosen in proximity to Hyderabad. These roads have two-lane channelised intersections with a minimum to maximum pedestrian traffic rate.

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B. Methods

i. Video Recording Method

Mobile cameras were used at the signalized junctions of Nacharam X Road and Ramanthapur. At the same time, CCTV footage from the Traffic Police Department was accessed at the other three crossroads (DMHS bus stand, Sri Nagar colony, Panjagutta X Road). The videos are taken at the chosen intersections for one day during peak hours, when traffic is at its busiest and vehicles rush. The recording was done at regular intervals for four hours, from 8:00 a.m. to 10:00 a.m. and from 4:00 p.m. to 6:00 p.m., and the process was repeated for all five junctions for one day.

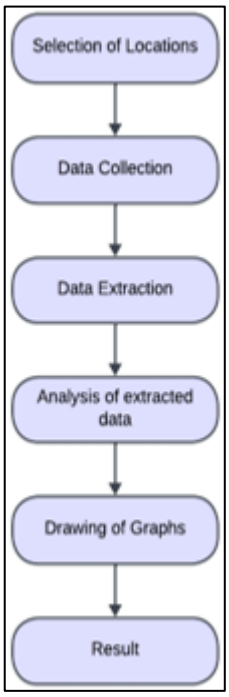
These gathered videos are stored on disks for future use to ensure clean study results.

ii. Manual Calculation

The data was collected by watching the videos and manually counting the information, since the maximum values for the parameters were not available. The following elements are influenced by the HCM manual https://sjnavarro.wordpress.com/wp-content/uploads/2008/08/highway_capacital_manual.pdf, which was used as a reference to establish the pedestrians' level of service: Average space, speed, capacity, flow rate, and delay.

Pedestrians were classified according to gender, age, and whether they were carrying luggage. Specifically, the age groups considered were individuals below 18 years, between 18 and 40 years, and those above 40 years. Additionally, pedestrians carrying luggage were identified and classified separately.

C. Flow Chart



[Fig.1: Flow Chart of Methodology]

V. DATA COLLECTION

Data was collected from the playback videos; to determine the peak volume and peak hour, a classified volume count was conducted every hour for four hours over the course of one day, during the peak hours of 8:00 am to 10:00 am and 4:00 pm to 6:00 pm. Peak hour volume is used to identify saturated green intervals. Illegal pedestrian crossings during the vehicle-green phase are manually tallied. where the red and green signal timing phases, pedestrian crossing times and speeds, and environmental and physiological parameters are computed.

A. Date & Time

Dates and times of the work are:
8th February 2024,
10th February 2024,
13th February 2024.
The work carried out is from 8:00 am to 10:00 am and from 4:00 pm to 6:00 pm.

B. Locations

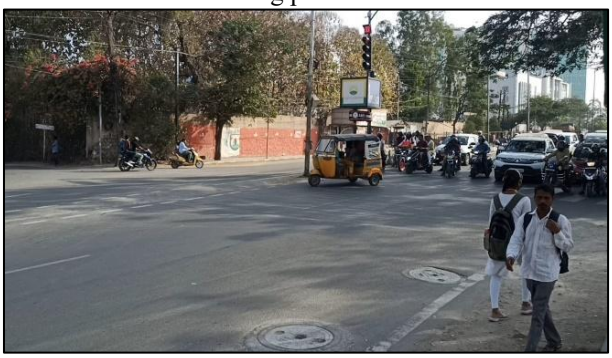
The collected data locations are:
Nacharam x road
Ramanthapur intersection
DMHS bus stand
Sri Nagar Colony
Panjagutta x road

C. Photographs of Each Location



[Fig.2: Data Collected at Nacharam x Road on 8th February 2024]

Figure 2 shows the intersection of Nacharam X Road. It shows the layout of pedestrian crossings, traffic signals, and surrounding infrastructure. This image depicts pedestrian flow at the crosswalk during peak hours.



[Fig.3: Data Collected at Ramanthapur Intersection on 13th February 2024]

Figure 3 shows the intersection of Ramanthapur intersection. It shows the layout of pedestrian crossings, traffic signals, and surrounding infrastructure. This image depicts pedestrian flow at the crosswalk during peak hours.

Retrieval Number: 100.1/ijitee.C122215030226
DOI: 10.35940/ijitee.C1222.15040326
Journal Website: www.ijitee.org

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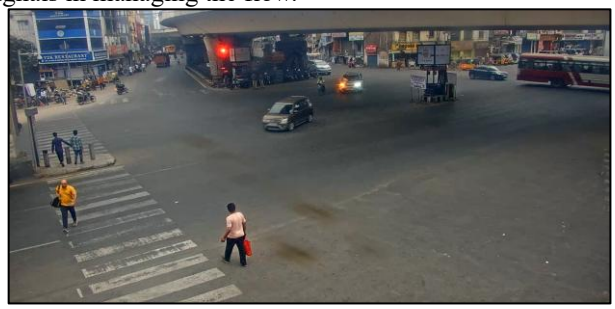
[Fig.4: Data Collected at DMHS Bus Stand on 10th February 2024]

Figure 4 shows the intersection of the DMHS Bus Stand. It shows the layout of pedestrian crossings, traffic signals, and surrounding infrastructure. This image depicts pedestrian flow at the crosswalk during peak hours. It highlights the volume of foot traffic and the effectiveness of pedestrian signals in managing the flow.



[Fig.6: Data Collected at Panjagutta x road on 10th February 2024]

Figure 6 shows the intersection of Panjagutta X Road. It shows the layout of pedestrian crossings, traffic signals, and surrounding infrastructure. This image depicts pedestrian flow at the crosswalk during peak hours. It highlights the volume of foot traffic and the effectiveness of pedestrian signals in managing the flow.



[Fig.5: Data Collected at Sri Nagar Colony on 10th February 2024]

Figure 5 shows the intersection of Sri Nagar colony. It shows the layout of pedestrian crossings, traffic signals, and surrounding infrastructure. This image depicts pedestrian flow at the crosswalk during peak hours. It highlights the volume of foot traffic and the effectiveness of pedestrian signals in managing the flow.

VI. FORMULAS FOR FINDING FACTORS

A. Calculation of Delay Time:

The delay experienced by pedestrians at signalised intersections was computed using the formula:

$$\boldsymbol{Dp} = \frac{(C-G)^{+4}}{2C} \quad \ldots \quad (1)$$

Where C represents the cycle length, and G denotes the effective green time.

B. Calculation of Capacity:

The capacity of the pedestrian flow is estimated utilising the formula:

$$\textbf{Capacity} = 1500 \times e^{-((1.75y+4.24)Qp)/3600} \quad \ldots \quad (2)$$

Here, Y signifies the average driver's age, and Qp represents the pedestrian flow rate.

C. Calculation of Average Space:

The average space occupied by pedestrians per square meter was calculated as:

$$\textbf{Pedestrian Space} = \frac{\text{Volume}}{\text{Area of Crosswalk}} \quad \ldots \quad (3)$$

The author took the HCM manual as a reference for the formulae.
https://sjnavarro.wordpress.com/wp-content/uploads/2008/08/highway_capacital_manual.pdf

D. Parameters Considered:

Pedestrian Behaviour:
Pedestrian Volume, Gender, Age, Group size, Carrying, Luggage, Walking Speed

E. Traffic Parameters:

Total PCU
Total Traffic volume (Veh)
Violators (Veh)

F. Geometric Parameters:

Cycle length (Sec)
Red time (Sec)
Clearance time (Sec)
Total Lanes
Width of Crosswalk (m)
Length of Crosswalk (m)

G. Determined Parameters:

Area of Crosswalk (m^2)
Crossing Frequency (Sec^-1)
Delay time (Sec)
Space = Volume/Area of Crosswalk (P/m^2)
Pedestrian Flow Rate (P/min/m)
Capacity (Veh/hr)
Average Space (P/m^2)
Average Speed (m/s)
Average pedestrian Flow Rate (P/min/m)

The listed factors are taken into account when determining task outcomes, with each parameter observed and recorded separately for cars and pedestrians to produce the final results. However, because there was a lot of traffic moving in both directions in each instance, the data accuracy for the total number of vehicles is low. As a result, an approximate number of vehicles is provided, and 90-95% accuracy in traffic parameters is anticipated.

VII. RESULTS AND ANALYSIS

A. Data Collected Results

Data was collected at 5 selected intersections in Hyderabad; video was recorded for 4 hours across 4

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intervals, including different parameters calculated using basic speed formulae.

Table I: Data Collected on 8th February 2024 (Nacharam x Road)

Parameters		8:00-9:00	9:00-10:00	4:00-5:00	5:00-6:00
Pedestrian Volume		121	114	120	113
Gender	Male	63	62	81	63
	Female	58	52	39	50
Age	Below 18 years	13	11	21	12
	18 to 40 years	103	100	87	96
	Above 40 years	5	3	12	5
Group size		4	4	5	5
Carrying Luggage		32	32	37	26
Total Traffic volume (Veh)		7472	7688	7557	7395
Violators (Veh)		117	73	80	98
Crossing Frequency (Sec^-1)		0.684			
Walking Speed (m/s)		1.5	1.5	1.35	1.5
Delay time (Sec)		17.5			
Cycle length (Sec)		90			
Red time (Sec)		30			
Clearance time (Sec)		5			
Total Lanes		2			
Width of Crosswalk (m)		3.2			
Length of Crosswalk (m)		18			
Area of Crosswalk (m^2)		57.6			
Space = Volume/Area of Crosswalk (P/m^2)		2.1	1.97	2.08	1.96
Pedestrian Flow Rate (P/min/m)		6.45	6.08	6.4	6.02
Capacity (Veh/hr)		1305.63			
Average Space (P/m^2)		2.02			
Average Speed (m/s)		1.46			
Average pedestrian Flow Rate (P/min/m)		6.23			

The above table describes the data extraction at Nacharam X Road on 8th February 2024. The total number of pedestrians is 468. It includes various parameters such as pedestrian demographic character, signal data, traffic and geometry factors. Here, female pedestrians are fewer compared to male pedestrians. At the same time, pedestrian compliance behaviour is moderate. Length of crosswalk is 18m.

Table II: Data Collected on 13th February 2024 (Ramanthapur Intersection)

Parameters		8:00-9:00	9:00-10:00	4:00-5:00	5:00-6:00
Pedestrian Volume		99	118	122	109
Gender	Male	57	66	79	60
	Female	42	52	43	49
Age	Below 18 years	3	13	18	8
	18 to 40 years	89	99	91	91
	Above 40 years	7	6	13	10
Group size		4	4	8	9
Carrying Luggage		30	31	33	24
Total Traffic volume (Veh)		7431	7521	7134	7265
Violators (Veh)		86	79	83	93
Crossing Frequency (Sec^-1)		0.641			
Walking Speed (m/s)		1.45	1.6	1.5	1.71
Delay time (Sec)		23.47			
Cycle length (Sec)		155			
Red time (Sec)		60			
Clearance time (Sec)		5			
Total Lanes		2			
Width of Crosswalk (m)		3.2			
Length of Crosswalk (m)		18			
Area of Crosswalk (m^2)		57.6			
Space = Volume/Area of Crosswalk (P/m^2)		1.71	2.04	2.11	1.89
Pedestrian Flow Rate (P/min/m)		5.28	6.29	6.5	5.81
Capacity (Veh/hr)		1313.22			
Average Space (P/m^2)		1.93			
Average Speed (m/s)		1.56			
Average pedestrian Flow Rate (P/min/m)		5.97			

The table above outlines the data extraction at the Ramanthapur intersection on 13th February 2024. The total number of pedestrians is 448. Cycle length is 155 secs. For the 18-40 age group, pedestrian volume is higher. Delay time is 23.47 secs. Average crossing speed is 1.56 m/secs.

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Table III: Data Collected on 10th February 2024 (DMHS Bus Stand)

Parameters		8:00-9:00	9:00-10:00	4:00-5:00	5:00-6:00
Pedestrian Volume		173	154	162	121
Gender	Male	95	79	108	84
	Female	78	75	54	37
Age	Below 18 years	16	22	31	24
	18 to 40 years	132	118	110	85
	Above 40 years	25	14	21	12
Group size		4	4	5	7
Carrying Luggage		24	37	34	44
Total Traffic volume (Veh)		1530	1620	1611	1593
Violators (Veh)		41	27	32	14
Crossing Frequency (Sec^-1)		0.653			
Walking Speed (m/s)		1.64	1.56	1.45	1.5
Delay time (Sec)		14.84			
Cycle length (Sec)		165			
Red time (Sec)		65			
Clearance time (Sec)		5			
Total Lanes		2			
Width of Crosswalk (m)		3.2			
Length of Crosswalk (m)		24			
Area of Crosswalk (m^2)		76.8			
Space = Volume/Area of Crosswalk (P/m^2)		2.25	2	2.1	1.57
Pedestrian Flow Rate (P/min/m)		9.22	8.21	8.64	6.45
Capacity (Veh/hr)		1251.53			
Average Space (P/m^2)		1.98			
Average Speed (m/s)		1.53			
Average pedestrian Flow Rate (P/min/m)		8.13			

The table above outlines the data extraction at the DMHS Bus Stand on 10th February 2024. The total number of pedestrians is 610. Cycle length is 165 secs. For the 18-40 age group, pedestrian volume is higher. Delay time is 14.84 secs. Average crossing speed is 1.53 m/secs. The length of the crosswalk is 24m, and the width is 3.2m.

Table IV: Data Collected on 10th February 2024 (Sri Nagar Colony)

Parameters		8:00-9:00	9:00-10:00	4:00-5:00	5:00-6:00
Pedestrian Volume		148	164	124	135
Gender	Male	87	94	79	71
	Female	61	70	45	64
Age	Below 18 years	20	27	15	19
	18 to 40 years	123	123	90	103
	Above 40 years	5	14	19	13
Group size		6	4	7	5
Carrying Luggage		28	34	29	31
Total Traffic volume (Veh)		1856	2154	2215	1948
Violators (Veh)		49	37	28	42
Crossing Frequency (Sec^-1)		0.645			
Walking Speed (m/s)		1.5	1.67	1.72	1.34
Delay time (Sec)		24.39			
Cycle length (Sec)		185			
Red time (Sec)		70			
Clearance time (Sec)		5			
Total Lanes		2			
Width of Crosswalk (m)		3.2			
Length of Crosswalk (m)		20			
Area of Crosswalk (m^2)		64			
Space = Volume/Area of Crosswalk (P/m^2)		2.31	2.56	1.93	2.1
Pedestrian Flow Rate (P/min/m)		7.89	8.73	6.61	7.2
Capacity (Veh/hr)		1266.39			
Average Space (P/m^2)		2.22			
Average Speed (m/s)		1.55			
Average pedestrian Flow Rate (P/min/m)		7.6			

The table above outlines the data extraction at Sri Nagar colony on 10th February 2024. The total number of pedestrians is 571. Cycle length is 185 secs. For the 18-40 age group, pedestrian volume is higher. Delay time is 24.39 secs. Average crossing speed is 1.55 m/secs. The length of the crosswalk is 20m, and the width is 3.2m.

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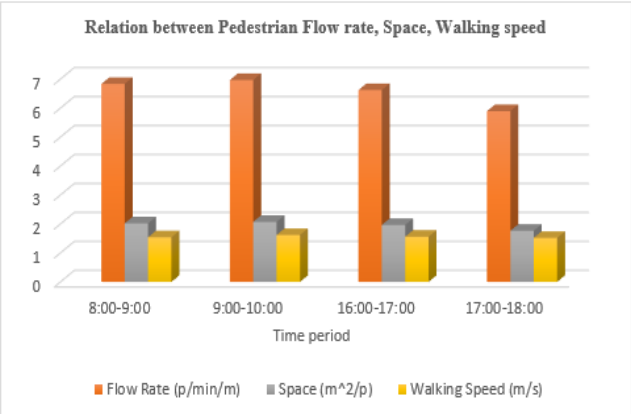
Table V: Data Collected on 10th February 2024 (Panjagutta x Road)

Parameters		8:00-9:00	9:00-10:00	4:00-5:00	5:00-6:00
Pedestrian Volume		100	104	93	75
Gender	Male	48	61	51	44
	Female	52	43	42	31
Age	Below 18 years	12	22	14	11
	18 to 40 years	70	72	70	60
	Above 40 years	18	10	9	7
Group size		5	6	4	4
Carrying Luggage		24	31	18	27
Total Traffic volume (Veh)		3508	3183	2987	3 251
Violators (Veh)		55	41	81	35
Crossing Frequency (Sec^-1)		0.595			
Walking Speed (m/s)		1.64	1.75	1.78	1.55
Delay time (Sec)		19.28			
Cycle length (Sec)		210			
Red time (Sec)		85			
Clearance time (Sec)		5			
Total Lanes		2			
Width of Crosswalk (m)		3.2			
Length of Crosswalk (m)		18			
Area of Crosswalk (m^2)		57.6			
Space = Volume/Area of Crosswalk (P/m^2)		1.73	1.8	1.61	1.3
Pedestrian Flow Rate (P/min/m)		5.33	5.54	4.96	4
Capacity (Veh/hr)		1343.4			
Average Space (P/m^2)		1.61			
Average Speed (m/s)		1.68			
Average pedestrian Flow Rate (P/min/m)		4.95			

The table above outlines the data extraction at Panjagutta X Road on 10th February 2024. The total number of pedestrians is 372. Cycle length is 210 secs. For the 18-40 age group, pedestrian volume is higher. Delay time is 19.28 secs. Average crossing speed is 1.68 m/secs. The length of the crosswalk is 18m, and the width is 3.2m.

B. Graphs



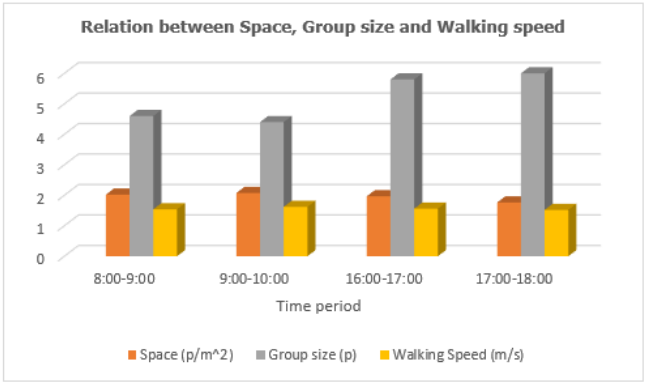
Graph 1: The Graphs Between Flow Rate, Space, and Walking Speed

In evaluating pedestrian behaviour at crosswalks, Graph 1 illustrates the relationship between flow rate and space across all five locations.

i. According to the graph, a high space correlates to a high pedestrian flow rate over all five locations.

ii. According to the graph, the flow rate is highest in all five locations between 9:00 a.m. and 10:00 a.m.

iii. When the size of the space rises, the pedestrian volume also increases; similarly, when the space decreases, the pedestrian volume similarly reduces.



Graph 2: The Graphs Between Space, Group Size and Walking Speed of the Pedestrian

In evaluating how efficiently pedestrians behave at crosswalks, Graph 2 illustrates the relationship between space and group size across all five locations.

i. According to the graph, the group size is largest in all five locations between 5:00 p.m. and 6:00 p.m.

ii. There is relatively minimal variation in the space; it is generally uniform throughout.

iii. The size of the pedestrian group drops when the space increases, and the group size increases when the space decreases.

VIII. CONCLUSION

The analysis of pedestrian behaviour at crosswalks in Hyderabad reveals significant perceptions into pedestrian and vehicle interaction, as well as the progressive patterns of pedestrian traffic at intersections. The study highlights that pedestrian volume, walking speeds, and wait times vary across intersections and times of day, affecting both pedestrian safety and vehicular traffic efficiency. The findings suggest that enhancing crosswalk infrastructure and

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optimising signal timings can positively influence pedestrian safety and comfort, reducing congestion and minimising conflict points between pedestrians and vehicles. By implementing these improvements, urban planners and policymakers can create safer, more accessible, and pedestrian-friendly environments. Ultimately, the study underscores the importance of designing crosswalks that account for pedestrian behaviour and needs, thereby contributing to more inclusive and effective urban mobility solutions.

A. Key Findings

i. Using factors like pedestrian volume, gender distribution, age groups, walking speed, wait time, etc., the study examined how people behaved at five signalised junctions in Hyderabad.

ii. Average pedestrian crossing durations for various signal phases were determined, indicating possible delays or bottlenecks. observed different degrees of adherence to pedestrian signals, with adherence being influenced by variables such as pedestrian volumes, visibility, and signal timing.

iii. Evaluated how well safety features like pedestrian islands, crosswalk markers, and signals work to improve safety and lessen conflict.

B. Implications

i. Proposed suggestions for enhancing pedestrian operating performance include modifying signal timings, upgrading infrastructure, and conducting campaigns to educate people on pedestrian safety.

ii. Improving traffic flow, pedestrian safety, and intersection efficiency all depend on an understanding of pedestrian behaviour and operational performance.

iii. Minimising pedestrian-vehicle confrontations, improving intersection performance overall, and streamlining traffic operations are all possible outcomes of putting recommendations into practice.

C. Future Scope

Modern technology, urban planning, and human-centred design must all be integrated to improve pedestrian performance at signalised intersections. Real-time data on pedestrian behaviour can be gathered by Internet of Things devices and advanced sensors to improve resource allocation and signal timings. AI systems can anticipate pedestrian movements and dynamically adjust signals to prioritise safety and efficiency. Using smartwatches or smartphones, virtual reality can deliver real-time crossing information and directions. Smooth multimodal transportation is supported by integrating pedestrian systems with urban mobility choices. Rain gardens and sustainable materials are examples of green infrastructure that improve comfort and aesthetic appeal. Safety can be increased by using communication protocols between signal systems and automated vehicles. Coordinated rules with politicians yield consistent, pedestrian-friendly urban layouts. Statistical analysis of pedestrian data, such as mean wait times, standard deviations in pedestrian flow, and maximum and minimum foot-traffic levels, can further refine signal timings and resource allocation, ensuring a more adaptive and efficient system. The effectiveness and safety of pedestrian crossings can be significantly improved by thorough behavioural research and educational initiatives.

IX. DISCUSSION

The paper emphasises the need for data-driven solutions to improve safety and efficiency by highlighting key insights into pedestrian behaviour at signalised junctions in Hyderabad. Significant differences were observed in pedestrian volume, walking speeds, and signal adherence between places and times, indicating the need for intersection-specific tactics. Reducing pedestrian-vehicular conflict can be achieved by improving crosswalk infrastructure, such as by installing pedestrian platforms and accessible markings. By adjusting signal timings to match pedestrian flow patterns, delays and congestion can be reduced and signal compliance increased. Real-time monitoring and adaptive signal regulation can be further improved by cutting-edge technologies such as artificial intelligence algorithms and Internet of Things sensors. Accessibility is guaranteed for all pedestrians, including those with disabilities, through inclusive design features such as textured pavements and audible signalling. Smooth, sustainable transportation is promoted by integrating pedestrian systems with urban mobility options. In addition to enhancing aesthetics, green infrastructure supports environmental sustainability. Working with policymakers could ensure uniform, pedestrian-friendly city plans. In the end, this study emphasises the importance of prioritising pedestrian behaviour and developing safer, more inclusive, and more effective urban mobility systems.

DECLARATION STATEMENT

Some of the references cited are outdated, noted explicitly as [1], [2], [4], [5], [6], [11], [12], [14], [15], [16], [17], [18] and [22], However, these works remain significant for the current study, as they are pioneering in their fields.

As the article's author, I must verify the accuracy of the following information after aggregating input from all authors.

- **Conflicts of Interest/ Competing Interests:** Based on my understanding, this article has no conflicts of interest.
- **Funding Support:** This article has not been funded by any organisations or agencies. This independence ensures that the research is conducted objectively and free from external influence.
- **Ethical Approval and Consent to Participate:** The content of this article does not necessitate ethical approval or consent to participate with supporting documentation.
- **Data Access Statement and Material Availability:** The adequate resources of this article are publicly accessible.
- **Author's Contributions:** The authorship of this article is contributed equally to all participating individuals.

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