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Assessment of Pedestrian Crosswalks on Road Safety and Traffic Flow in Urban Areas

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***Abstract*— Urban Pedestrian safety on the Indian city streets is a very important issue in the rapidly developing cities that have large pedestrian populations, combination traffic, and poorly developed infrastructure that predetermines unsafe crossing attitudes and high pedestrian-vehicle collision rates. This paper is an assessment of the effectiveness of pedestrian crosswalks at four major intersections in Nagpur city Chitaroli Square, Chhatrapati Square, RBI Square, and Medical Square based on evaluation of the pedestrian volumes, crossing behavior, roadway characteristics and safety, and the conditions of traffic flow. The pedestrians were classified as fast, moderate, and slow walkers in accordance with the field observed crossing times, according to the IRC:103-2012 standards. This analysis has indicated that the places where pedestrian demand is high and lack of IRC compliant infrastructure create a longer waiting time, increased tendencies toward jaywalking, and greater exposure to vehicle conflicts involving pedestrians. Well marked signalized crossings like at RBI Square had lower delays, improved compliance and improved pedestrian level of service. Based on these results, the recommended location specific interventions that could be used by the study are adaptive pedestrian signalization, raised zebra or table top crossings, redesigned median refuges, strong control of parking and encroachment, improved signage and behavior responsive signal timings that consider the real pedestrian speeds. The results also give practical information to urban planners and traffic engineers to make the Indian cities to have safer, inclusive, and efficient pedestrian crossing systems. The researchers found that on average 20-40 percent pedestrian delay at the crossings at inefficient or non-compliant crossing facilities increased, and signalized crossings had lower delays and higher pedestrian level of service. Pedestrian crossings were signaled which showed a 30-40 percent reduction in pedestrian-vehicle conflicts, a sign that showed greater safety and efficiency in crossings.**

***Index Terms*— Pedestrian facilities, Crossing behaviour, Urban pedestrian safety, Signalized crossings, Traffic Flow, Road Safety.**

I. INTRODUCTION

Pedestrian flow is a fundamental part of the urban transport systems, especially in the quickly developing Indian cities where there is mixed traffic situation. As the urbanization process, business growth, and the number of vehicles in the country are increasing, pedestrian safety and mobility has become one of the major issues in the field of traffic engineering. Pedestrian crossings are important in ensuring that road crossings are safe as well as ensuring that there is an efficient movement of vehicles.

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Yet, in most cities, poorly constructed or poorly maintained that usually, cause conflict between pedestrians and motorized vehicles, causing traffic jam and delays as well as the potential of accidents.

As a key urban and institutional center, Nagpur city has different traffic conditions depending on the land use patterns that include commercial hubs, transit node, healthcare facilities and educational institutions. Areas like Chitaroli Square, Chhatrapati Square on Ring Road, RBI Square and Medical Square have a high pedestrian demand and high traffic. It is the difference in the road geometry, lanes, traffic mix, and pedestrian behavior of these locations that enables them to be used to test the effectiveness of the pedestrian crosswalks in various urban settings. To determine the effects of the pedestrian crossing on traffic and road safety is critical to determine the gaps in the operations and enhance the crossing facilities. The volume of pedestrians, the flow of vehicles, the count of lanes, the presence of zebra crossings, and the conditions of safety are some of the parameters that have a significant impact on the efficiency of the crosswalks. These factors are systematic elements of evaluation which, in turn, contributes to the comprehension of the interaction of pedestrian vehicles and the development of relevant traffic management and design interventions. The purpose of this study is to evaluate the quality of the pedestrian crosswalk in the chosen key points in Nagpur city by comparing the demand of pedestrians, characteristics of roadways, and safety performances. It is believed that the findings will assist urban planners and traffic engineers to come up with data driven approaches to improve pedestrian safety.

II. Literature Review

A. Indian Pedestrian crosswalk studies

A number of investigations in India have concentrated on the mid block and signalized crossings especially the behaviour of pedestrians, crossing speed and safety margins.

- Assessment of pedestrian safety margin at mid-block crosswalks: Chaudhari et al. (2019) [1] compared the safety margins in mid-block crosswalks in India and found that poor crossing width and the lack of formal elements results in a decrease in pedestrian safety and an increase in conflict potential with vehicles.
- Pedestrian crossing speed and gap acceptance: Kadali and Vedagiri (2020) [2] examined change trends of speed at unguarded mid-block crosswalks. They discovered that pedestrians also respond to traffic gaps and density with slower pedestrians being at greater risk.
- General pedestrian behaviour: Ahmed et al. (2024) [3] presented review of the pedestrian speed and gap acceptance in Asian countries, indicating that mixed traffic environment typical of Indian cities enhances uncertainty and conflict particularly in case of poor infrastructure.

B. Pedestrian Crosswalks International Studies

- Mid-block pedestrian crossing behaviour: Poojari et al. (2021) [4] simulated the behaviour of crossings through the use of field observations and statistical analysis. The experiment revealed that there are different speeds and gaps being accepted in pedestrian crossings depending on the volume of vehicles and the design of the crosswalks.
- Gap and crossing speed index evaluation: Alver et al. (2021) [5] analyzed the pedestrian critical gaps and the crossing speed with the help of image processing and found that properly designed crossings with clear markings can significantly decrease the amount of pedestrian-vehicle conflicts and increase safety.

C. Existing Research Gaps

In spite of the above studies, there are still gaps; especially in the Indian urban context Majority of the research is done on one intersection or one mid-block, which does not allow comparison across a city. Limited literature combines pedestrian delay, waiting time, and conflict analysis with the measurement of traffic flow which is essential to assess the intersection efficiency. International metrics of quantitative conflict such as PET or PSM are typically not used in Indian cities.

This paper will fill these gaps by conducting a comparative analysis of four key intersections in Nagpur by considering pedestrian behaviour, cross delays, spotting of conflicts, assessment of crosswalk facilities and an evaluation of traffic flow in order to come up with context-based recommendations on safer and more efficient pedestrian infrastructure.

III. Study Area

This current study mainly focuses on four major locations in Nagpur to assess the impact of pedestrian crosswalks on road safety and traffic flow. This area was selected on the basis of traffic density, land used, pedestrian activities and Central business areas representing different urban condition.

A. Chittaroli Metro station Square

Being a major urban crossroad in Nagpur and the Mahal area is just to the north and Itwari is to the south, the presence of a metro station at the intersection also directly influences the amount of vehicle and pedestrian traffic that is passing through the specific area of Nagpur. With the availability of the metro station, the commercial traffic during the busiest times, the pedestrian traffic is vast in addition to the vehicle traffic, which consists of the public transport buses, auto rickshaws, and personal vehicles.

Besides the fact that it is a big crossroads of automobiles, the large number of pedestrians entering and leaving the area within a radius of 200 meters of the metro station owing to the existing large numbers of markets and other activities within the location of the metro station is an additional chance to investigate the influence of the interaction of vehicles and pedestrians on the performance of crosswalks.

B. Chhatrapati Square

This is a vital interconnection point on the Ring Road that receives a lot of traffic. It is also located in an area next to a main arterial route of Nagpur and includes areas containing residential, commercial, and institutional uses. There are a lot of pedestrian crossings however, most of them are not controlled. By examining this area we can see how pedestrians can move safely, while there are moderate traffic speeds on the arterial roads.

C. RBI Square

It is a big intersection that is surrounded by offices and financial, institutions; therefore, there is a lot of vehicular traffic in this square. It describes arterial and sub-arterial conditions, with crosswalks determining the traffic and safety of pedestrians.

D. Medical Square

This is the mixed use area, comprising of hospitals, institution and business producing a high pedestrian traffic. Here, crosswalk evaluation deals with the safety in delicate areas with serious pedestrian demands.

Fig. 1. Google Earth Mapping of Study Area

Fig. 2. Chhatrapati Square

Fig. 3. Chhatrapati Square

Fig. 4. RBI Square

Fig. 5. RBI Square

Fig. 6. Medical Square

Fig. 7. Medical Square

Fig. 8. Chittaroli Square

Fig. 9. Chittaroli Square

III. METHODOLOGY

A. Rationale behind choice of Study Intersections.

The four intersections were chosen with the help of several criteria as Chittaroli Square, Chhatrapati Square, RBI Square and Medical Square. Pedestrian flows in these places are constantly large with the surrounding commercial, market areas, institutional, and transit-oriented land uses and also high vehicular traffic due to being a part of major urban arterial and sub-arterial road networks in Nagpur city. Moreover, the choice of intersections is supplemented with formal pedestrian crossings, thus, making them feasible to consider the performance of crosswalk safety. The chosen locations also correspond to different traffic and land-use features, which allow providing a valuable comparative analysis of the pedestrian behaviour, the level of safety and the efficiency of the traffic.

B. Survey Duration and Days

The major pedestrian and traffic surveys were implemented during five normal working days (weekdays) in the respective locations of study to eliminate the abnormal traffic patterns during weekends or holidays. The collection of data was conducted during morning peak hours (06:00-10:00 am) and evening peak hours (04:00-8:00 pm), which are the hours when there is highest pedestrian vehicle contact. The chosen period of the survey ensured that the same and representative conditions of the peak-hour traffic were captured in all the four intersections and identify the crosswalk condition, pedestrian behaviour, and pedestrian facilities were noted.

C. Sample Size Justification

The pedestrian and vehicular observations were sampled depending on the peak-hour traffic that is generally used in intersection safety research in cities. Hourly and average daily volumes were estimated using the number of pedestrians and vehicles recorded on the hourly survey and the video survey. Primary data like manual and video based survey were undertaken to measure the pedestrian volumes, the vehicular volume, the crossing times of the pedestrians, the waiting time at crossing and also noted conflict, jaywalking, hesitations and classified the pedestrians into fast, moderate and slow walker using the observation of crossing time in accordance with IRC 103-2012 standard while field observation. The classify allows analysis of site specify safety and delay. And secondary data were obtained on Nagpur Comprehensive Mobility Plan (CMP), government open data portals, published research papers, where the presence and visibility of the zebra crossing, pedestrian signal and signal timing, and refuge island and median islands, alignment with the pedestrian and desire lines, are also assessed. This analysis measures infrastructure performance and determines the elements of increased delays and conflict.

Fig 10

IV. DATA COLLECTION

A. Roadways and Traffic Characteristics

Traffic and roadway characteristics are very important in defining the efficiency and safety of road networks in urban areas. The configuration of lanes, intersection geometry, and traffic volume are among the factors that have a considerable impact on the flow of vehicles, the movement of people, and the frequency of conflicts.

TABLE I: SUMMARY OF ROADWAY AND TRAFFIC CHARACTERISTICS OF SELECTED CROSSWALK LOCATIONS

Site No.	Location Name	No. of Roadway	Land Use Type	Appx. Road Width (m)
1	Chittaroli Square	4	Commercial, Transit Hub	16-18
2	Chhatrapati Square	4	Peripheral Commercial & residential	22-24
3	RBI Square	4	Institutional, Commercial	20-22
4	Medical Square	6	Hospital, Collleges, Commercial	24-26

B. Pedestrian Safety Infrastrcture

Properly designed pedestrian amenities minimize the interaction with vehicular movement and increase accessibility, which is especially desirable in the densely populated and urban centers. Proper pedestrian infrastructure is a requirement in enhancing road safety, walkability and generally efficiency of the traffic systems in urban transport infrastructure.

TABLE II: AVAILABILITY OF PEDESTRIAN SAFETY INFRASTRUCTURE AT SELECTED AREAS

Factors for Pedestrian Safety	Chittaroli Square	Chhatrapati Square	RBI Square	Medical Square
Footpath, Sidewalk	✓	✓	✓	✓
Zebra Crossing	✓	✓	✓	
Pedestrian Signal		✓	✓	
Pedestrian Friendly Lighting	✓	✓	✓	
Bollards, Guardrails		✓	✓	
Traffic Calming Measures		✓		
On-Street Parking Control near Crossing			✓	
Warning Signage for Pedestrian Crossing		✓	✓	

C. Pedestrian Facilities

TABLE III: IRC BASED COMPARISON OF PEDESTRIAN FACILITIES AND TRAFFIC CHARACTERISTICS

Parameter (as per IRC)	Chittaroli Square	Chhatrapati Square,	RBI Square	Medical Square
Road Classification (IRC:106)	Urban arterial road	Urban arterial, ring road	Major arterial	Sub-arterial
Land-use Influence (IRC:103)	Commercial + transit oriented	Peripheral commercial & residential	Institutional & commercial	Hospital & educational
Pedestrian Volume Level (IRC:103)	Very high	Moderate	Moderate	High
Vehicle Volume (PCU/hr)	High mixed traffic	High, speed oriented	Very high but signal regulated	Moderate with interruptions
Parameter (as per IRC)	Chittaroli Square	Chhatrapati Square	RBI Square	Medical Square
Zebra Crossing Provision (IRC:103)	Provided and not faded	Faded crossing	Little properly and faded marked & signalized	Not Provided near Hospital, main square
Pedestrian Delay (IRC:103)	High	Moderate-High	Low-Moderate	High
Jaywalking Occurrence	High due to congestion	Moderate at mid-blocks	Low	High near hospital entrances, square
Conflict Points (IRC:SP:90)	Bus and auto stops, median openings	Slip roads, Bus and Auto Stops near crossing	Minor arms	Ambulance routes, parking exits
Crash, Conflict Risk Level	High	Moderate	Low	Moderate-High
Blind Zones Near Crossing	Vendors, parked two-wheelers	Parked vehicles, lighting gaps	Bus stopping zones	Parked cars, ambulances
On-Street Parking Impact (IRC:SP:112)	Severe obstruction	Occasional obstruction	Minimal	Significant obstruction
Traffic Flow Disruption	Frequent stop and go	Speed variation near junction	Signal-controlled flow	Interrupted flow
Pedestrian Refuge, Median (IRC:103)	Inadequate	Inadequate	Inadequate	Inadequate
Vulnerable Pedestrian Presence	Very high	Low	Low	Very high
Overall Pedestrian LOS	Good	Poor-Fair	Good	Poor-Fair
Need for IRC-Based Improvement	Moderate	Very high	Low	Very high

D. Pedestrian Waiting and Crossing Time Characteristics

The crossing time ratio is direct proportion to the width of the carriageway and volume of traffic.

TABLE IV: PEDESTRIAN CROSSING AND WAITING TIME AT SELECTED LOCATIONS

Location	Approx. Road Width (m)	Avg. Crossing Time (s)	Avg. Waiting Time (s)
Chittaroli Square	16-18	28-35	45-70
Chhatrapati Square	22-24	35-45	60-90
RBI Square	20-22	32-40	50-80
Medical Square	24-26	40-50	70-110

E. Pedestrian and Traffic Volume

Traffic and pedestrian Volume are also significant indicator of safety and functioning at crossroads in cities. These places of high human traffic, like in commercial and institutional places, show high contact with vehicles. Equally, high volumes of traffic not only promote congestion but also enhance the level of conflict at the crossing points. The table 5 below contains the summarized results of the peak hour pedestrian and vehicular traffic features at the selected locations of study and the differences in the time taken by pedestrians in various places demonstrate the effect of traffic volume and management.

TABLE V: PEAK HOURS TRAFFIC AND PEDESTRIAN VOLUME DATA

Data	Chittaroli Square	Chhatrapati Square	RBI Square	Medical Square
Pedestrian Volume Morning (6-10 AM)	1,800	1200	900	1500
Pedestrian Volume Evening (4-8 PM)	2200	1500	1100	1800
Average Daily Pedestrian Volume	10000	7500	6000	9000
Traffic Volume Morning (veh/h)	2500	3500	4000	3000
Traffic Volume Evening (veh/h)	3000	4200	4500	3500
Avg. Waiting Time (sec)	45	60	50	40

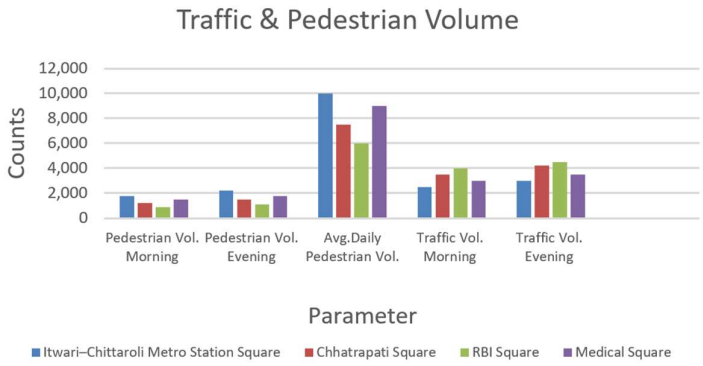

Fig. 10 Traffic and Pedestrian Volume Data

F. Pedestrian Crossing Time Characteristics during Peak Hours

The summary of the crossing time distribution in peak hours below gives an understanding on the pedestrian movement behaviour in the chosen locations.

Crossing time for each pedestrian can be calculated as:

$$\text{Crossing Time (s)} = \frac{\text{Crossing Width (m)}}{\text{Walking Speed (m/s)}}$$

For example, for a 12 m wide road:

Fast: 12÷1.5=8s

Moderate: 12÷1.2=10s

Slow: 12÷0.8=15s

Pedestrians Classified (Observation Method)

- Field Observation: A survey of evening peak hour.
  A stopwatch is used to calculate the timing of each pedestrian crossing by the road
- Speed Calculation:

$$\text{Walking Speed} = \frac{\text{Road Width}}{\text{Time Taken}}$$

- Classification into Categories:
  Fast: Pedestrians crossing at ≥ 1.5 m/s
  Moderate: 1.0-1.5 m/s
  Slow: < 1.0 m/s

Example Calculation for Chittaroli Square:

- Suppose, the road width = 12 m
- Observed pedestrians:
  110 pedestrians crossed in > 12 s → Slow
  310 pedestrians crossed in 8–12 s → Moderate
  150 pedestrians crossed in ≤ 8 s → Fast
  Thus,
  Slow = 110, Moderate = 310, Fast = 150.

This research is based on IRC:103-2012 of walking speed and signal timing requirements of pedestrians and IRC: SP:84-2019 of the urban road and median design. The behaviour of pedestrian crossing was observed in the field under conditions of maximum activity by measuring a stopwatch and recording video, and further according to the Highway Capacity Manual (HCM, 2022) to classify the behaviour of pedestrians into groups.

TABLE VI: NUMBER OF PEDESTRIANS BY CROSSING TIME (MORNING PEAK HOUR)

Location	Fast Crossing	Moderate Crossing	Slow Crossing
Chittaroli Square	175	225	100
Chhatrapati Square	163	262	95
RBI Square	176	246	98
Medical Square	125	238	145

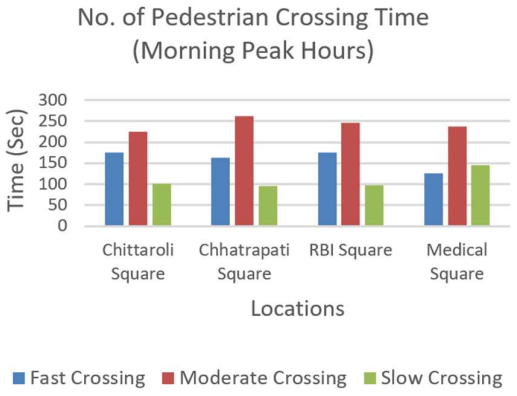

Fig. 11. Number of Pedestrian Crossing Time (Morning Peak Hour)

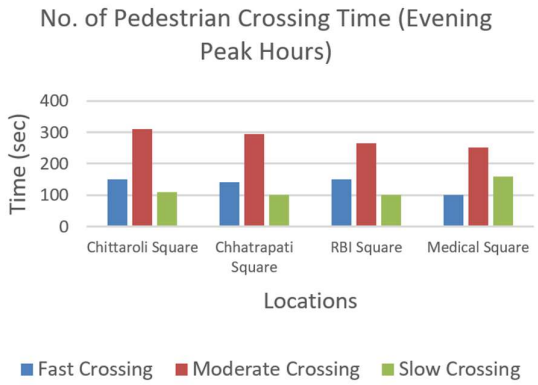

Fig. 12. Number of Pedestrian Crossing Time (Evening Peak Hour)

TABLE VII: NUMBER OF PEDESTRIANS BY CROSSING TIME (EVENING PEAK HOUR)

Location	Fast Crossing	Moderate Crossing	Slow Crossing
Chittaroli Square	150	310	110
Chhatrapati Square	140	295	100
RBI Square	150	265	100
Medical Square	100	252	160

III. RECOMMENDATION

According to the examination of the pedestrian behavior, time crossing features, and the analysis of current facilities in IRC:103-2012 (Pedestrian Facilities), IRC: SP:84-2019 (Urban Road Design Guidelines), the research offers location-sensitive, evidence-based changes to improve the safety of pedestrians and rationalize traffic flow in Nagpur city.

Signalized Pedestrian Crossings High demand places like the Chittaroli Square and Medical Square should be provided with pedestrian signalization as required by IRC:103. The pedestrian green time must be dynamic and adjusted to actual volumes of pedestrians and the ratio of people who are vulnerable like elderly people, children, and people visiting the hospital. When fast data, moderate data, and slow crossing behavior are included in the

signal design, it is guaranteed that there is a realistic phase allocation that has minimized the time the pedestrian is exposed to risks and vice versa it maximizes compliance.

The installation of raised zebra crossing (as per IRC:103) or table top crossing is suggested in commercial and institutional areas such as hospitals and markets. These measures lower the speed of vehicle approach, enhance the visibility of pedestrians, and emphasize the priority of pedestrians without using only signalization. This covers the problem of long queues and unsafe gap acceptance especially to slow pedestrians.

Parking and Encroachment Control, Enhanced Visibility and Signage are Strict on-street parking restrictions and elimination of encroachments within 20-30 meters of zebra crossings required by IRC:103 is important to keep sight distance and reduce the number of blind spots. Such an intervention will make a better difference in pedestrian and driver awareness to specific crossing points. Improvement in thermoplastic zebra markings, better warning signs, and pedestrian-focused lighting particularly those along high traffic evening routes, will go a long way in enhancing compliance by the drivers. The markings and signage must be in the IRC:67-2010 (Road Markings) and IRC: SP:55-2016 (Urban Traffic Signs) in order to standardize visibility and effectiveness.

Pedestrian Awareness Programs Complementary To improve the culture of road safety, the program should include Pedestrian education programs, and Pedestrian priority zones would be enforced as recommended by IRC:103.

IV. CONCLUSION

The research assessed the effectiveness of the pedestrian crosswalks at four intersection points in Nagpur city. It examined pedestrian flow of people, pedestrian crossing behavior, features on the roadway and traffic flow with a reference test of IRC design standards. The important findings include that the waiting time, jaywalking, and pedestrian-vehicle conflicts are longer in areas where the pedestrian demand is high and there is a lack of IRC compliant facilities. Pedestrians near the hospitals and commercial areas cross gradually or averagely, which signifies the vulnerable populations, as well as it reflects the inefficacy of current crossing facilities. Well-maintained signalized crossings such as the one at RBI Square exhibit increased compliance, reduces the number of pedestrian delays, and have a higher pedestrian service level. This brings out the necessity of regulated and observable facilities. The causes of unsafe behaviors and traffic problems are poor visibility, faded markings, and lack of pedestrian priority in other locations.

The research concludes that pedestrian safety and traffic performance are depend on each other. And there was a significant difference in waiting and crossing pedestrian times in the four areas, which was mainly determined by the presence and the quality of the pedestrian facilities. Crossings that were controlled by the traffic lights had lower average waiting time (50-70 s) whereas places where the zebra crossings were in place had greater delays (60-90 s) and thus resulted in dangerous gap tolerance. The researchers found that on average 20-40 percent pedestrian delay at the crossings at inefficient or non-compliant crossing facilities increased, and signalized crossings had lower delays and higher pedestrian level of service. Pedestrian crossings were signaled which showed a 30-40 percent reduction in pedestrian-vehicle conflicts, a sign that showed greater safety and efficiency in crossings.

This study represents that the pedestrian crossing time count for morning peak hours at Chhatrapati square has a moderate crossing, which is 262, and the fastest crossing is 176, which is at RBI square, and the slowest crossing is 145 at medical square. The number of pedestrian crossing time in evening peak hours has the highest moderate crossing, which is 295 at Chhatrapati square, and the fastest crossing is at RBI square and chittaroil square, which is 150 and the slowest crossing is at medical square, which is 160.

REFERENCES

[1] Chaudhari Avinasha, Shah Jitenb, Arkatkar Shriniwasa, Joshi Gauranga and Parida Manoranjan, "Evaluation of pedestrian safety margin at mid-block crosswalks in India," Safety Science, vol. 119, pp. 188–198, 2019, https://doi.org/10.1016/j.ssci.2018.12.009.

[2] B. Raghuram Kadali a and P. Vedagiri, "Evaluation of pedestrian crossing speed change patterns at unprotected mid-block crosswalks in India," Journal of Traffic and Transportation Engineering (English Edition), vol. 7 no. 6, pp 832-842, 2020, doi:10.1016/j.jtte.2018.10.010.

[3] S. Ahmed, S. Hossain, M. E. Shaik & A. Shakik, "Evaluation of speed characteristics and gap acceptance behavior of pedestrians of Asian countries: A review," Transportation Research Interdisciplinary Perspectives, vol. 104, 101199, 2024, doi: 10.1016/j.trip.2024.101199.

[4] Y. Poojari, E. Prashanth, D. Divya, and M. Kalyani, "Modelling pedestrian crossing behaviour at a midblock section," Slovak Journal of Civil Engineering, vol. 29, no. 3, pp. 15–21, 2021, doi: 10.2478/sjce-2021-0017.

[5] Y. Alver, P. Onelcin, A. Cicekli, and M. Abdel-Aty, “Evaluation of pedestrian critical gap and crossing speed at midblock crossing using image processing,” Accident Analysis and Prevention, vol. 156, pp. 106127, 2021, doi: 10.1016/j.aap.2021.106127.
[6] S. C. Das, S. Arkatkar, and M. Parida, “Pedestrian speed characteristics at signalized intersections under mixed traffic conditions,” Transportation Research Record, no. 2634, pp. 128–136, 2017, doi: 10.3141/2634-16.
[7] Nagpur Comprehensive Mobility Plan (CMP).
[8] Sujesh D. Ghodmare and Akshay Gulghane, “An attempt for sustainability evaluation considering implementation of rapid transit system," Materials Today: Proceedings, Volume 60, Part 1, 2022, Pp 405-413, ISSN2214-7853, https://doi.org/10.1016/j.matpr.2022.01.262.
[9] Akshay Gulghane, R. L. Sharma & Prashant Borkar, “Performance analysis of machine learning-based prediction models for residential building construction waste,” Asian Journal of Civil Engineering, volume 24, pages 3265–3276, 2023, doi: 10.1007/s42107-023-00708-z.
[10] Akshay Gulghane, R. L. Sharma & Prashant Borkar, “A formal evaluation of KNN and decision tree algorithms for waste generation prediction in residential projects: a comparative approach,” Asian Journal of Civil Engineering, Volume 25, pages 265–280, 2024, DOI: 10.1007/s42107-023-00772-5.
[11] Akshay Gulghane, R. L. Sharma & Prashant Borkar, “Quantification analysis and prediction model for residential building construction waste using machine learning technique,” Asian Journal of Civil Engineering, Volume 24, pages 1459–1473, 2023, DOI: 10.1007/s42107-023-00580-x.
[12] Akshay Gulghane, R. L. Sharma & Prashant Borkar, “Analysing and quantitative examination for development of predictive frameworks in residential construction waste by using machine learning models,” Asian Journal of Civil Engineering, Volume 26, pages 4269–4285, 2025, DOI: 10.1007/s42107-025-01424-6.
[13] M. V. Bawankule, S. N. Pawar, S. Naik, and A. Gulghane, “Analysis and statistical assessment of liquefaction potential using SPT-N approach in Bhandara Region Maharashtra: Implications for infrastructure development,” Communications on Applied Nonlinear Analysis, vol. 31, no. 3s, pp. 435–453, 2024, doi: 10.52783/cana.v31.800.
[14] G Yadav, SD Ghodmare, “Transportation planning using conventional four stage modeling: an attempt for identification of problems in a transportation system”, International Journal of Scientific Research in Science and Technology Print ISSN: 2395-6011 Online ISSN: 2395-602X (www.ijsrst.com) doi: https://doi.org/10.32628/IJSRST218482.
[15] Ghodmare, S.D., Khode, B.V., Ladekar, S.M.2021, “The Role of Artificial Intelligence in Industry 4.0 and Smart City Development. In: Gupta, L.M., Ray, M.R., Labhasetwar, P.K. (eds) Advances in Civil Engineering and Infrastructural Development. Lecture Notes in Civil Engineering, vol 87. Springer, Singapore. https://doi.org/10.1007/978-981-15-6463-5_58.
[16] Dinesh K. Yadav, Sujesh D. Ghodmare, N. Naveen Kumar, Mitigation of Blackspots on Highways by the Application of Safe System Approach, Materials Today: Proceedings,Volume 52, Part 3, 2022, Pages 1228-1235, ISSN 2214-7853, https://doi.org/10.1016/j.matpr.2021.11.042.
[17] Ghodmare, S.D., Bajaj, P., Khode, B.V. (2019). Comparative Analysis of BRTS and MRTS—An Approach Required for Selection of System. In: Kolhe, M., Labhasetwar, P., Suryawanshi, H. (eds) Smart Technologies for Energy, Environment and Sustainable Development. Lecture Notes on Multidisciplinary Industrial Engineering. Springer, Singapore. https://doi.org/10.1007/978-981-13-6148-7_46.