PEDESTRIAN LEVEL OF SERVICE AT UNSIGNALISED INTERSECTION

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ABSTRACT

The research investigates Pedestrian Level of Service (PLOS) at unsignalized intersections in urban Indian contexts, focusing on pedestrian safety, comfort, and efficiency. In India, heterogeneous traffic conditions, characterized by various types of vehicles and a significant pedestrian presence, necessitate effective pedestrian facilities to mitigate conflicts and accidents. This study highlights the need for improved pedestrian infrastructure amidst growing urban populations and increased foot traffic. The research adopts a multi-faceted methodology, including reconnaissance surveys, land use activity surveys, pedestrian volume counts, and visual walking surveys, to evaluate pedestrian flow characteristics such as density, speed, and flow rate. Key performance indicators for PLOS were identified and measured, such as pedestrian delay, perceived vehicle conflicts, and perceived exposure. The findings indicate that insufficient pedestrian amenities and poorly designed intersections lead to increased pedestrian delays and heightened safety risks. The study's insights are based on data gathered from multiple intersections in Mysuru, utilizing video analysis and on-site observations. The results underscore the critical need for incorporating pedestrian considerations into traffic planning and intersection design to enhance overall urban mobility and safety. The research concludes by proposing specific design recommendations and interventions to improve pedestrian infrastructure at unsignalized intersections, thereby ensuring safer and more efficient pedestrian movement in urban settings.

Keywords: *Unsignalized Intersections, Pedestrian Level of Service (PLOS), Pedestrian Safety, Urban Traffic Planning, Pedestrian Flow Characteristics, Intersection Design*

1. INTRODUCTION

Pedestrian safety and convenience at intersections are critical aspects of urban transportation planning, particularly in densely populated countries like India, where mixed traffic conditions are common. This study examines pedestrian level of service (PLOS) at unsignalized intersections, using the case study of the Sathagalli junction. Pedestrian Level of Service is a qualitative measure that reflects the pedestrian experience regarding safety, comfort, and convenience when interacting with vehicular traffic at crosswalks.

In India, the nature of traffic is predominantly heterogeneous, consisting of a variety of vehicles sharing the same road space with pedestrians. This mixed traffic condition poses significant challenges for pedestrians, who often have to navigate through vehicular streams without designated walkways or crossing aids. Consequently, pedestrian facilities are frequently overlooked in transportation planning, leading to unsafe and inconvenient conditions for walkers.

The study aims to quantify pedestrian characteristics and their impact on PLOS at the Sathagalli junction. By employing videographic methods and statistical analysis, pedestrian flow characteristics such as speed, density, and

flow rate are measured and analyzed. The findings are then compared against the Indian Roads Congress (IRC) guidelines to assess the level of service provided to pedestrians.

This research underscores the necessity of integrating pedestrian factors into comprehensive urban transportation planning strategies. Improved pedestrian facilities not only enhance safety and convenience but also encourage walking as a sustainable mode of transport, contributing to healthier and more livable urban environments. The study's results are intended to inform policymakers and urban planners on the necessary improvements required to elevate pedestrian infrastructure to acceptable standards, ensuring safe and efficient pedestrian movement at unsignalized intersections.

1.1 Problem Statement

In India, the heterogeneous nature of traffic and the lack of structured pedestrian facilities significantly affect pedestrian safety and convenience, especially at unsignalized intersections. Despite the growing importance of sustainable and pedestrian-friendly transportation planning, pedestrians are often neglected in road design and traffic management practices. This neglect leads to increased conflicts between pedestrians and vehicles, resulting in a higher risk of accidents and fatalities among pedestrians.

Uncontrolled intersections present a unique challenge due to the intricate dynamics between pedestrian movement and diverse vehicular maneuvers. The lack of controlled vehicle movements and inadequate pedestrian facilities exacerbate these conflicts, causing delays and reducing safety and comfort for pedestrians. Furthermore, the rapid urbanization and increasing population density in Indian cities amplify the need for effective pedestrian infrastructure to ensure safe and efficient pedestrian movement.

The study aims to address these issues by evaluating the Pedestrian Level of Service (PLOS) at unsignalized intersections. It focuses on identifying critical factors influencing pedestrian safety, comfort, and convenience, and proposes measures to enhance pedestrian facilities. To comprehensively assess pedestrian needs at unsignalized intersections, this study utilizes pedestrian flow characteristics, crossing delays, and perceptions of vehicle interactions. The resulting knowledge will inform the development of optimized pedestrian infrastructure design recommendations.

1.2 Objectives

- Ensure safe and efficient pedestrian movement at unsignalized intersections.
- Reduce the rate of accidents involving pedestrians.
- Create a pedestrian-friendly environment.
- Minimize delays experienced by pedestrians.
- Provide adequate crossing opportunities for pedestrians.
- Enhance the visibility of pedestrians to drivers.

2. LITERATURE REVIEW

The study of pedestrian level of service (PLOS) at unsignalized intersections has gained significant attention in recent years, focusing on various aspects such as safety, comfort, and efficiency. Drawing on prior research, this review synthesizes knowledge on evaluating Pedestrian Level of Service (PLOS).

Pedestrian Flow Characteristics

Polus et al. (1983) conducted a seminal study on pedestrian flow characteristics on sidewalks in Haifa, Israel. They used a recording device and a digital clock to gather data, revealing that men's walking speeds were generally higher than women's and that walking speeds inversely correlated with pedestrian density. This study proposed service level definitions based on these observations, which are fundamental for designing pedestrian facilities.

Pedestrian Level of Service Models

Marisamynathan et al. (2019) developed a PLOS model considering pedestrian safety, comfort, and efficiency at signalized intersections in Mumbai, India. They employed video graphic surveys and questionnaires, identifying

significant factors through Pearson correlation analysis. The study utilized fuzzy linear regression analysis to create a statistically adjusted PLOS model, which categorized service levels from A to F based on perceived pedestrian experience scores. The model was validated with field data, providing a reliable framework for assessing pedestrian service levels.

Factors Affecting PLOS at Unsignalized Crosswalks

Kadali et al. (2015) examined pedestrian perceptions of LOS at unsignalized mid-block crosswalks with various land uses such as shopping and residential areas. They used an ordered probit model to identify critical factors, including perceived safety, crossing difficulty, and the number of vehicles. The findings highlighted the importance of land-use planning in enhancing pedestrian access facilities.

Lee et al. (2005) proposed a new set of LOS guidelines for signalized crosswalks in Hong Kong, taking into account bidirectional pedestrian flow impacts. They defined specific congestion limits for each service level based on area occupancy, pedestrian flow, and walking speed, demonstrating the applicability of these guidelines in densely populated Asian urban areas.

Pedestrian Delay and Safety

Nagaraj et al. (2013) developed a PLOS model for signalized intersection crosswalks in Mumbai, India, focusing on pedestrian delays. They utilized a modified Webster delay model suitable for Indian conditions, considering non-uniform pedestrian arrival rates. The study emphasized the importance of accurately measuring delays to assess LOS, using regression analysis to identify key influencing factors.

Pedestrian Behaviour at Intersections

Muraleetharan et al. (2005) identified factors influencing pedestrian behavior at intersections in Sapporo, Japan. Using regression analysis, they created a PLOS model that considered various intersection characteristics and pedestrian perspectives. The model provided reliable insights into pedestrian service levels based on observed data.

Intersection Design and Pedestrian Behavior

Asaithambi et al. (2016) investigated pedestrian crossing behavior at signalized intersections, analyzing factors such as intersection layout, waiting time, and pedestrian speed. Their study found that the installation of signals influenced pedestrians' choice to cross in one step and provided space to wait during red signals.

Summary

The reviewed studies highlight the multifaceted nature of PLOS evaluation, emphasizing the importance of pedestrian safety, comfort, and efficiency. These studies employ various methodologies, from regression analysis to fuzzy logic, to develop models that can assess and improve pedestrian facilities at both signalized and unsignalized intersections. The findings underscore the necessity of considering local conditions and pedestrian behaviors in developing effective PLOS models.

3. METHODOLOGY

This section outlines the methodology adopted for evaluating the Pedestrian Level of Service (PLOS) at unsignalized intersections. The methodology involves a series of systematic steps designed to collect, analyse, and interpret data relevant to pedestrian movements and interactions at selected intersections.

3.1 Site Selection

The study focuses on the Sathagalli Junction in Mysuru, an unsignalized intersection. Locations were chosen based on the type and nature of activities in each land use category, ensuring a representative sample of pedestrian environments.

3.2 Data Collection

The data collection phase includes several surveys to gather comprehensive information on pedestrian behaviour and intersection characteristics:

1. **Reconnaissance Survey**: Initial survey to familiarize with the site and identify key features and issues.
2. **Land Use Activity Survey**: Identifying the types of activities at each location to understand the context of pedestrian movements.
3. **Pedestrian Volume Count Survey**: Measuring the number of pedestrians using the intersection throughout the day to determine peak usage times.
4. **Pedestrian Characteristics Survey**: Collecting data on pedestrian flow speed, density, and other relevant characteristics.
5. **Visual Walking Survey**: Observing and recording the physical conditions and features of the crosswalks.

3.3 Data Analysis

The collected data is analysed to understand the variations in pedestrian level of service and to identify peak hour pedestrian volumes. Key pedestrian flow characteristics such as space, speed, density, and flow rate are determined and used to assess the current level of service.

1. **Pedestrian Speed**: Calculated by selecting a random pedestrian entering the grid, noting the entry and exit times, and dividing the grid length by the walking time.
2. **Pedestrian Space and Density**: Determined by counting the number of pedestrians within a designated area and dividing this number by the area of the pedestrian grid.
3. **Pedestrian Flow Rate**: Measured by counting the number of pedestrians passing a point per unit time, usually expressed in pedestrians per minute per meter (p/min/m).

3.4 Performance Measures

Pedestrian flow characteristics are crucial for determining the Pedestrian Level of Service (PLOS). These characteristics include:

1. **Pedestrian Speed**: The average walking speed of pedestrians.
2. **Pedestrian Density**: The number of pedestrians per unit area within the crosswalk.
3. **Pedestrian Flow Rate**: The rate at which pedestrians pass a point in the crosswalk.

3.5 Comparison and Evaluation

The adequacy of effective crosswalks is evaluated at three different intersections in Mysuru. A comparison of pedestrian flow characteristics across these intersections is conducted to identify patterns and differences in service levels.

Quantitative Method

The quantitative method involves the following steps:

1. **Data Extraction**: Video recording of pedestrian movements during peak hours to extract necessary parameters.
2. **Calculations**: Using the collected data to calculate pedestrian speed, density, and flow rate.

Pedestrian Flow Characteristics

Pedestrian flow characteristics are analysed using relationships similar to vehicular traffic flow. These include:

1. **Speed-Density Relationship**: Describes how pedestrian speed varies with density.
2. **Flow-Density Relationship**: Expressed as $Qped=Sped\times Dped$, where $Qped$ is the pedestrian flow rate, $Sped$ is the pedestrian speed, and $Dped$ is the pedestrian density.

Summary

The methodology provides a detailed framework for assessing the pedestrian level of service at unsignalized intersections. By systematically collecting and analysing data on pedestrian behaviour and intersection characteristics, the study aims to improve the safety, comfort, and efficiency of pedestrian movements in urban areas.

4. STUDY AREA AND DATA COLLECTION

4.1 Study Area

The study area selected for this research comprises three different locations within Mysuru, focusing particularly on the Sathagalli Circle. The chosen sites represent various land use categories to capture diverse pedestrian activities

and behaviors. The Sathagalli Circle, an unsignalized intersection, was chosen specifically due to its high pedestrian traffic and the presence of commercial blocks and shopping complexes. The crosswalk studied at this location is 10 meters in length and 4 meters in width.

Fig. 4.1: Unsignalized intersection at Sathagalli

4.2 Data Collection

Data collection involved several systematic surveys to gather comprehensive information about pedestrian behaviors and traffic conditions. The data collection process was divided into several steps:

Reconnaissance Survey: An initial survey to familiarize with the study sites and understand the general layout and conditions.

Land Use Activity Survey: Identified the types of activities at each location, providing context for pedestrian movement patterns.

Pedestrian Volume Count Survey: Conducted throughout the day to capture the volume of pedestrians using the crosswalks at different times.

Pedestrian Characteristics Survey: Collected detailed data on pedestrian flow, speed, density, and flow rate.

Visual Walking Survey: Examined the physical features of the crosswalks, such as width, presence of road markings, and surrounding road furniture.

The primary data collection method was videography. A digital video camera recorded pedestrian movements at the study sites in 15-minute segments. The recordings were made during peak hours, specifically from 8:00 AM to 10:00 AM, capturing the busiest times of pedestrian activity. This method allowed for detailed observations of pedestrian behaviors, interactions with road furniture, and interactions among pedestrians.

The video data was subsequently analyzed using MS Excel, with data entries made at one-minute intervals. The extracted data included various parameters such as time, gender, age, platoon movements, mobile usage, and baggage carrying. Additionally, pedestrian flow characteristics such as waiting time, entry and exit times, crossing

time, and crossing speed were recorded. These measurements provided insights into pedestrian speed, density, and space, which are critical for calculating the pedestrian flow rate.

Overall, the collected data helped in understanding the pedestrian level of service (PLOS) at the unsignalized intersections, providing a quantitative basis for evaluating pedestrian safety and comfort.

5. DATA EXTRACTION

In this section, we outline the procedures and results of the data extraction process conducted for assessing the Pedestrian Level of Service (PLOS) at an unsignalized intersection, specifically at the Sathagalli Circle.

5.1. Data Collection Methodology

Data for this study was collected through a videographic survey conducted at the Sathagalli Circle intersection. The survey was carried out over a period of two hours, from 8:00 AM to 10:00 AM. The survey focused on a crosswalk stretch of 10 meters in length and 4 meters in width. The surrounding area comprises commercial blocks and shopping complexes, which contribute to the pedestrian traffic.

The collected data encompasses various pedestrian behaviors and flow characteristics, such as:

- Time
- Gender
- Age
- Platoons
- Movement
- Mobile usage
- Carrying baggage
- Waiting time (entry and exit times while crossing)
- Crossing time
- Crossing speed
- Density
- Pedestrian space

The data from the videographic survey was extracted using Microsoft Excel, with entries made at one-minute intervals to capture the detailed pedestrian flow characteristics.

5.2. Pedestrian Flow Characteristics

To determine the PLOS, several pedestrian flow characteristics were measured, including speed, density, pedestrian space, flow, and flow rate. The following table summarizes the extracted pedestrian flow characteristics for different time intervals:

speed	density	pedestrian space	flow	flow rate
0.09	0.55	1.82	248	23.62
0.09	0.66	1.52	297	28.29
0.03	0.44	2.27	198	18.86

1.88	0.55	1.82	248	23.62
0.67	0.88	1.14	396	37.71
0.05	0.46	2.17	207	19.71
0.08	0.48	2.08	216	20.57
0.27	0.59	1.69	267	25.43
0.08	0.6	1.67	270	25.71

TABLE 5.2: Pedestrian flow characteristics for Sathagalli

From the data, it is evident that pedestrian density varies significantly at different times. The average pedestrian space was calculated to be 1.8 m² per pedestrian, and the flow rate was found to be 0.75 pedestrians per meter per minute.

5.3. Pedestrian Level of Service (PLOS)

Using the extracted data, the PLOS was determined by considering factors such as pedestrian speed, density, space, and flow rate. The Green Shield macroscopic method was employed to derive critical parameters such as free flow speed (Vf) and jam density (Kj), which were then compared with IRC guidelines.

The summarized results indicate that the pedestrian space at the Sathagalli Junction is 1.58 m² per pedestrian, and the flow rate is 0.75 pedestrians per meter per minute. According to IRC guidelines, these values correspond to a common degree of service level D for pedestrian facilities. For road crossing, the average waiting time was found to be 6 seconds, placing the level of service for road crossing at B.

5.4. Data Analysis

The analysis of pedestrian speed and density, along with the flow characteristics, provides a comprehensive understanding of pedestrian behavior at the intersection. The graphical representation of the relationship between speed and density, as well as density and flow, further aids in visualizing the pedestrian dynamics at the intersection.

These findings contribute to the assessment and improvement of pedestrian facilities, ensuring better safety, comfort, and convenience for pedestrians at unsignalized intersections like Sathagalli Circle.

The data extraction and subsequent analysis have provided valuable insights into pedestrian flow characteristics and their impact on the PLOS at unsignalized intersections. This study highlights the importance of detailed data collection and analysis in urban planning and traffic management to enhance pedestrian infrastructure and safety.

5.5. Data Analysis

Sathagalli Junction for the pinnacle hour is summed up in the table. The qualities were contrasted and the IRC 103-2012 rules. From the above table, Walker space is 1.58 m2/ped and flowrate id 0.75 p/m/min, where in IRC rules for walker space (>1.3-1.9) m2/ped and for flowrate (<21-27) p/m/min, so Common degree of administration for person on foot offices is D and for street crossing, the typical holding up time is 6. Numerous persons on foot boundaries determined by above segments - 523 seconds, according to IRC rules it ought to between (>3AND<13) thus common degree of administration for street crossing is 8.

6. SIMULATION MODEL USING VISSIM SOFTWARE

Theoretical Background of the PTV VISSIM Software

PTV VISSIM is a microscopic traffic and transport planning tool widely used for modeling and simulation. According to PTV Group (2020), it is a versatile software applied in various areas including:

1. Traffic Flow Simulation: Assists in decision-making for creating sustainable transport systems.

2. Advanced Traffic Management Systems: Helps reduce negative impacts of transport systems.

3.Multimodal Systems: Facilitates the study of all transport modes, including pedestrian interactions.

4. Autonomous Vehicles and New Mobility: Models and simulates impacts of autonomous driving.

5. Virtual Reality Traffic Simulation: Creates detailed microscopic traffic simulations.

PTV VISSIM is globally recognized and used by the public sector, consulting firms, and universities for its ability to accurately test various operational scenarios before implementation.

Application in This Study

In this research, the PTV VISSIM software was used to simulate and analyze the pedestrian level of service (PLOS) at an unsignalized intersection. The steps involved in developing the simulation model are outlined below:

1. Data Collection and Input:

- Reconnaissance Survey: Conducted to identify specific locations within the study area based on the nature and type of pedestrian activities.
- Land Use Activity Survey: Identified different land use types around the intersection to understand their impact on pedestrian flow.
- Pedestrian Volume Count Survey: Measured pedestrian volumes throughout the day to determine peak hours.
- Pedestrian Characteristics Survey: Collected data on pedestrian flow speed, density, and flow rate.
- Visual Walking Survey: Assessed crosswalk features and related infrastructure.

2. Model Development:

- Base Map Integration: The map of the selected intersection was integrated into PTV VISSIM to replicate the actual environment.
- Road and Traffic Input Modelling: Modelled roads and embedded vehicle inputs were inserted into the software. This included data on current traffic conditions and vehicle flow patterns around the intersection.
- Pedestrian Flow Characteristics: Key pedestrian flow characteristics such as speed, density, and flow rate were incorporated into the simulation to assess the PLOS accurately.

3. Simulation and Analysis:

- Scenario Testing: Various scenarios, including changes in pedestrian and vehicle volumes, were tested to evaluate their impact on PLOS.
- Solution Implementation: Proposed solutions such as the creation of bypass routes to facilitate smoother pedestrian and vehicle movement were simulated and their effectiveness analyzed.

4. Results Interpretation:

- The simulation results highlighted the critical factors affecting pedestrian safety and comfort at the unsignalized intersection. These included the volume of vehicle traffic, pedestrian density, and crossing times.
- Based on the simulation outcomes, recommendations were made to improve pedestrian facilities and overall intersection performance.

By utilizing PTV VISSIM software, this study was able to develop a comprehensive model that provided insights into pedestrian interactions at an unsignalized intersection and suggested practical solutions to enhance pedestrian level of service.

5. RESULT

The study evaluated the Pedestrian Level of Service (PLOS) at signalized intersections in India, focusing on pedestrian behaviors and the effectiveness of crossing facilities. The analysis included data collection from signalized intersections, taking into account various factors such as pedestrian space, flow rate, and average waiting time.

For Location 1, Sathagalli Intersection:

- Pedestrian space: 1.8 m²/pedestrian
- Flow rate: 0.75 pedestrians/meter/minute
- Average waiting time: 6.523 seconds
- Jam density: 4.95 pedestrians/meter
- Free flow speed: 2.4 meters/second

These values were compared with the Indian Roads Congress (IRC) guidelines, which specify:

- Pedestrian space: 1.3-1.9 m²/pedestrian
- Flow rate: 21-27 pedestrians/meter/minute
- Average waiting time: 3-13 seconds
- Maximum free flow speed: 1.2 meters/second

Based on these comparisons:

- The pedestrian level of service for pedestrian facilities was rated as **D**.
- The pedestrian level of service for road crossing was rated as **B**.

The higher-than-expected free flow speed indicates that pedestrians at the intersection are moving faster than the IRC guidelines suggest, potentially due to lower congestion or better-designed facilities.

5. CONCLUSION

This study identified several factors significantly affecting pedestrians' perception of safety, convenience, and efficiency at signalized intersections. Key findings include:

- **Pedestrian Delays:** The study found that delays had a greater impact on PLOS than other factors. Increased delays reduced perceived efficiency and convenience.
- **Intersection Performance**: The Sathagalli intersection, classified as LOS D for pedestrian facilities, indicates restricted movement and frequent speed adjustments due to potential conflicts. The road crossing, classified as LOS B, provided enough space for pedestrians to move freely without much delay.

The study suggests that urban planners and transport officials should focus on improving pedestrian signals and reducing delays to enhance the pedestrian experience at intersections. The findings can aid traffic engineers in developing strategies to improve pedestrian safety and service levels at similar intersections across urban India.

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