MODELLING THE LEVEL OF SERVICE OF PEDESTRIANS UNDER HETEROGENEOUS TRAFFIC CONDITIONS

PROJECT REPORT

Submitted by

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TKM20CETE10

to

the A P J Abdul Kalam Technological University

in partial fulfilment of the requirements for the award of the Degree

of

Master of Technology

in

Transportation Engineering

DEPARTMENT OF CIVIL ENGINEERING

T.K.M. College of Engineering, Kollam

July 2022

DECLARATION

I undersigned hereby declare that the project report “Modelling the Level of Service of Pedestrians Under Heterogeneous Traffic Conditions”, submitted for partial fulfilment of the requirements for the award of degree of Master of Technology of the APJ Abdul Kalam Technological University, Kerala is a bonafide work done by me under supervision of Meenu Tomson, Assistant Professor. This submission represents my ideas in my own words and where ideas or words of others have been included, I have adequately and accurately cited and referenced the original sources. I also declare that I have adhered to ethics of academic honesty and integrity and have not misrepresented or fabricated any data or idea or fact or source in my submission. I understand that any violation of the above will be a cause for disciplinary action by the institute and/ or the University and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been obtained. This report has not been previously formed the basis for the award of any degree, diploma or similar title of any other University.

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CERTIFICATE

Certified that the project entitled **'MODELLING THE LEVEL OF SERVICE OF PEDESTRIANS UNDER HETEROGENEOUS TRAFFIC CONDITIONS'** is completed successfully by **NISHA MARY D'CRUZ, TKM20CETE10** during **2020-2022** in partial fulfilment of the requirements for the award of the Degree of Master of Technology in Transportation Engineering of the A P J Abdul Kalam Technological University.

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ACKNOWLEDGEMENT

I take this opportunity to express my deep sense of gratitude and sincere thanks to all who helped me to complete the project successfully.

I am deeply indebted to my guide, **Meenu Tomson,** Assistant Professor, Department of Civil Engineering, for her valuable guidance, timely suggestions and constant encouragement during the course of the thesis work.

I am grateful to the project coordinators, **Dr. Kavitha Madhu,** Associate Professor, **Meenu Tomson,** Assistant Professor, and **Jijin A.,** Assistant Professor, Department of Civil Engineering, for their precious assistance and esteemed supervision throughout the completion of this project.

I am thankful to **Dr. Sajeeb R.**, Professor and Head of the Department of Civil Engineering, for his kind support.

I express my gratitude to the Officers of the District Police Command Centre, Kollam City who spent their valuable time and by providing with the necessary videographic evidence required for this project.

Finally, I extend my thanks to my family and friends, for their support in the successful completion of my thesis work.

Above all, I thank God almighty for helping me to complete this project.

NISHA MARY D'CRUZ

ABSTRACT

Walking forms the basic as well as sustainable mode of transportation. A good strategy for addressing the social and environmental problems related to traffic and transportation is to encourage people to walk and use public transportation. Policymakers must prioritise the needs and expectations of pedestrians in order to encourage individuals to choose walking as their preferred form of transportation. Therefore, urban transportation networks should establish a secure and enjoyable walking environment.

The aim of the study is to identify the various factors affecting pedestrian level of service at sidewalks of Kollam district in Kerala, India. Thereby, estimating the significant factors by conducting Pearson correlation at 95% confidence interval using SPSS software. Based on significant factors, best-fit regression model was developed among different regression methods. Ridge regression is found to be the best-fit model, with an accuracy of 97.14%. The threshold values for PLOS, pedestrian density and space were estimated using k-means clustering. In order to evaluate, the aspects of the walking environment that primarily determine the degree of service provided to pedestrians, this study looks into a number of pedestrian-related issues. To improve the quality of sidewalks and make the city more walkable, city planners can establish new strategies and policy interventions with the help of the proposed model and threshold values.

Keywords: *Walking, Pedestrians, Modelling, Pedestrian Level of Service, Heterogeneous Traffic Conditions, Regression, Clustering.*

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ABBREVIATIONS

HCM	:	Highway Capacity Manual
MAE	:	Mean Absolute Error
MLR	:	Multiple Linear Regression
LOS	:	Level of Service
PLOS	:	Pedestrian Level of Service
SPSS	:	Statistical Package for the Social Sciences
SW	:	Sidewalk
RMSE	:	Root mean square error

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Walking is the most basic yet an indispensable mode of transportation since the dawn of human civilisation. Every typical trip includes a considerable amount of walking. Therefore, when designing the urban environment and transportation infrastructure, the need of pedestrians should be taken into account just like the demands for motor vehicles. The most important element of the road networks is pedestrians. Everyone who is alive today is a pedestrian. According to the World Health Organization (WHO, 2013) a pedestrian is any individual who travels at least in part by walking. A sustainable transportation system should offer flexibility and mobility in a way that is both safe and good for the environment (Marisamynathan & Vedagiri, 2019). One of the finest sustainable transportation options that works effectively for relatively short distances in metropolitan areas is walking (Georgiou et al., 2021). Therefore, walking forms the sustainable and healthy mode of transportation (Carreno et al., 2002) and it serves as their primary form of mobility on a daily basis. Comparing walking to other forms of transportation, it takes less space. A sustainable city's foundation is thought to be walking. Additionally, walking is quite inexpensive, as it uses less public infrastructure and has lower direct user expenses than both cars and public transportation. Numerous advantages of walking include improved personal health, neighbourhood vitality, economic growth, and environmental sustainability.

In India the traffic is mostly heterogeneous in nature (Sahani & Bhuyan, 2016) and in major cities; pedestrian accident rates are highest. Pedestrians are the most vulnerable road users. Risks to pedestrians have grown in recent years. Motor cyclists, bicyclists and pedestrians are one of the most vulnerable road users and accounts to about, more than half of all road traffic fatalities (WHO, 2018; Shinar, 2012). According to Central Road Research Institute, with studies based on hospital records, pedestrian deaths account for between 22% and 35% of all traffic fatalities, with about 80% of these accidents involving pedestrians (MoUD, 2008). Increasing rate of motor vehicles in India cause environmental pollution, congestion and parking problems. These problems can be solved by promoting non-motorized transportation and by providing better facilities. However, there aren't enough appropriate design standards for safer pedestrian infrastructure. Because pedestrians' needs are so frequently disregarded in transportation design, construction, and management, they are losing space. Policymakers must prioritise the needs and expectations of pedestrians if they want to encourage more people to use walking as a means of transportation. To achieve this objective safe and comfortable walking environment should be created in urban transportation systems. The pedestrian friendly environment cannot be developed just by laying a footpath or putting in signals. Thus, for the effective implementation of the walkable environment, planners, designers and decision makers have to define and evaluate the elements which support the built environment in order to strengthen the walking facilities.

The majority of pedestrian movement in metropolitan areas takes place on the sidewalk next to the carriageways. Sidewalks allow for the separation of automobile and pedestrian traffic. To improve traffic flow, the sidewalk's width has occasionally been decreased or eliminated. Platoons might form as a result, which would slow down their walking. If there aren't enough places for pedestrians to walk on the sidewalk, there may be a higher chance that they will collide with another road user. Therefore, it is crucial to give pedestrians access to secure and practical infrastructure facilities.

Transportation planners use the level of service as a measures to assess the level of service provided by transportation facilities (Marisamynathan & Lakshmi, 2018). The quality of service is a measure of how comfortable, convenient, safe, and secure a pedestrian feels. The level of service rendered to pedestrians in India in terms of their safety, security, comfort, and convenience at sidewalks cannot be properly evaluated because there is no appropriate method for it (Marisamynathan & Lakshmi, 2018). This study's objectives are to identify the various elements that affect the level of service offered to walkers on sidewalks, to propose a method for assessing the pedestrian level of service using both quantitative and qualitative data, and to, lastly, estimate the threshold values.

1.2 PROBLEM STATEMENT

Human safety is the primary concern of all nations. In urban transportation networks, safe and comfortable walking environment must be provided for pedestrians.

People frequently choose not to walk if there is no pleasant environment for it because of the contact with heavy motor vehicle traffic and packed small roads. Safe and practical non-motorized transportation provides several benefits, including less traffic jams, lower air and noise pollution, less demand for parking spaces and roads, increased social interaction, economic growth, higher cost-effectiveness, better public health, and a cleaner environment. One of the main modes of transportation on Indian metropolitan streets are by pedestrians. In India, planning and control of transportation generally ignores pedestrians, and they are more prone to accidents and fatalities. Pedestrian fatalities make up between 40% and 60% of all fatal traffic accidents in urban areas of developing nations like India (Mukherjee & Mitra, 2019). According to MoRTH 2019 report, 25,858 pedestrians were killed across the country. Therefore, decreasing or eliminating the risks that pedestrians encounter is crucial for lowering the number of injuries caused by traffic. For reducing pedestrian’s risk, safe, efficient and comprehensive facilities prioritizing the need of pedestrians are required. The urban condition models developed for western countries do not accurately reflect Indian situations because there are no provisions for them. To improve amenities for pedestrians in India, a study on pedestrians is required. One of the metrics used to assess sidewalks from a pedestrian's perspective in terms of perceived safety, security, convenience, and comfort is the pedestrian level of service.

1.3 RESEARCH SIGNIFICANCE

The statistics regarding fatality of pedestrians is alarmingly increasing. Various factors that affect PLOS has to be identified and addressed, so that improvement measures can be suggested to provide better pedestrian facility. It leads to decrease the number and severity of pedestrian crashes. Also, by providing better pedestrian facility, safety, comfort, and ease of movement of pedestrians can be improved. Thereby, encouraging walking practice. Walking has many benefits such as reduction of negative impacts on environment, improves the life expectancy of future generation, reduce the negative impacts due to lack of physical activity, reduce the per capita rate of resource use and greenhouse gas emissions. Therefore, encouraging a healthy public life, building sustainable neighbourhoods, improving social life, and boosting the economy all depend upon planning and designing for walking.

1.4 OBJECTIVES

The objectives of the proposed study are as follows:

- To identify the various parameters affecting pedestrian level of service at sidewalks
- To find the best-fit model for sidewalks among different regression methods
- To estimate the PLOS ranges at sidewalks by adopting k-means clustering

1.5 GAPS IDENTIFIED

For highly varied traffic flow situations like India, the pedestrian level of service (PLOS) for sidewalks is not well defined, which is one of the major gaps found during the extensive literature review. Additionally, very few studies on PLOS have considered both qualitative and quantitative factors.

1.6 SCOPE

The study aims to assess the facilities and status of the current sidewalks. The study's main focus is on the sidewalks of Kollam district. Also, based on qualitative and quantitative data, the suggested method can be utilised to determine the amount of service provided to pedestrians at sidewalks. Based on information gathered from user perception surveys and video graphic surveys, the degree of service provided to pedestrians is estimated.

1.7 ORGANIZATION OF REPORT

The thesis is structured into nine main chapters. Chapter one describes the background of the study, problem statement, research significance, objectives, gaps identified and scope of the study.

Chapter two reports the literature review on the principles of pedestrian facilities, its terminology, level of service and the various factors affecting pedestrian level of service.

Chapter three discusses the methodology of work. Data collection and different methods of regression adopted for the study are described in this chapter.

Chapter four discusses about study area and data collection. Different types of data such as qualitative and quantitative data collected are discussed in this chapter.

Chapter five reports the analysis of the survey data and identification of significant parameters. Analysis of quantitative data, qualitative data, reliability test, descriptive statistics of the variables affecting PLOS and finally identification of significant variables affecting PLOS are discussed in this chapter.

Chapter six reports the analysis of the best-fit PLOS model. Brief description of machine learning techniques and the implementation of python on different regression methods such as multiple linear regression, random forest regression and ridge regression and adoption of the best-fit model and finally its validation are discussed in this chapter.

Chapter seven reports the PLOS classification. Algorithm of k-means clustering and the threshold values of PLOS, pedestrian density and pedestrian space are discussed in this chapter.

Chapter eight presents the policy recommendations based on the study, for the improvement of sidewalks facilities and chapter nine describes the major findings of the study.

CHAPTER 2

LITERATURE REVIEW

2.1 GENERAL

This chapter reviews the various literature related to pedestrian studies. Factors affecting PLOS are reviewed from the literatures.

2.2 PRINCIPLES OF PEDESTRIAN FACILITIES

The five most important criteria to keep in mind when designing and planning pedestrian infrastructure are safety, security, continuity, comfort, and liveability (IRC: 103, Draft). These ideas make walking more attractive than using a personal vehicle, especially over short distances.

- **Safety** – To reduce injuries and fatalities from collisions with motorised vehicles, pedestrians should be given protection. No matter their age, gender, or disability, everyone should be allowed to cross the street and walk securely.

- **Security** – Walking pedestrians should be protected against criminal activity. All pedestrians should feel safe utilising the facilities, including women, children, and the elderly.

- **Continuity** – Pedestrians should have a continuous walking space free from any obstacles. All pedestrians, including those in wheelchairs, those who are blind, caregivers with strollers, and senior citizens, should be able to cross the street without interruption.

- **Comfort** – A well-shaded, well-drained, spacious, and clean walking environment should be offered to pedestrians. They should be comfortable while moving around, waiting at the bus stop, and sitting.

- **Liveability** – A well-shaded, well-drained, spacious, and clean walking environment should be offered to pedestrians. They should be comfortable while moving around, waiting at the bus stop, and sitting.

2.3 TERMINOLOGY

The different terminologies used to describe pedestrians are as follows (IRC: 103-2012, Indo- HCM, 2017):

- **Pedestrian speed** is the average speed at which people walk, measured in metres per second
- **Pedestrian flow rate** is the number of pedestrians that pass a point in a given period of time, such as 15 minutes or a minute.
- **Pedestrian flow per unit of width** is the average pedestrian flow, expressed in pedestrians per minute per metre (p/min/m), per unit of effective walkway width.
- **Pedestrian density** is the average number of people walking on a walkway, measured in pedestrians per square metre (p/m^2).
- **Pedestrian space** is the average area allotted to each pedestrian in a walkway, measured in square metres per pedestrian.
- **Platoon** refers to a group of pedestrians who are unintentionally strolling together due to signal control and other factors.
- **Sidewalk surface** is defined as the floor on which a person walks in the pedestrian environment.
- **The sidewalk's width** should be broad enough for people to walk on them, keep their distance from the traffic, and stay clear of street furniture, obstacles, and other people.
- **The obstruction** may take any shape or form, including a trash can, a tree, or an electric pole that is on the sidewalk. The walkway should be constructed so that no obstructions interfere with the comfort of pedestrians.
- **Potential for vehicular conflict:** If sidewalks are unprotected from traffic or lack guard rails, walkers using them may occasionally be in danger from collisions with moving vehicles. Facilities that separate pedestrians from cars include raised footpaths and grade-separated areas. They can significantly lessen conflicts and potential collisions between vehicles and pedestrians.
- **Continuity:** Continuous sidewalks are those that don't frequently rise and fall in elevation. For the comfort of all pedestrians especially elderly and disabled ones sidewalks should be continuous. Uncomfortable sidewalks can force people to use the carriageway because they are uncomfortable.

- **Encroachments** are the buildings, items, or goods that pass down the sidewalk. Encroachment may make it less comfortable for people to stroll on sidewalks. The amount of encroachment should be kept to a minimum such that pedestrian access to the pavement is unaffected.
- **Availability of crossing facilities:** There should be enough crossing points along sidewalks to allow both motor vehicles and pedestrians to pass safely.
- **Security:** One of the key elements influencing the decision to walk is feeling safe and secure. By installing sufficient street lighting, having police patrol at night, using CCTV cameras, and other measures, safety and security can be guaranteed. Pedestrians should feel safe during any time of the day.
- **Comfort:** The footpath needs to include facilities so that people can feel comfortable from the strong sun and rain. The presence of trees, public restrooms, benches, and trash cans on the footpath at appropriate locations is a sign of comfort.
- **Walk environment:** Going on a walk should always be enjoyable. The environment and state of the sidewalks influence how people walk. As a result, sidewalks ought to be tidy and devoid of trash.
- **Socio- demographic factors:** A number of factors, including the pedestrian's gender, age, occupation, the size of their travel group, and the destination of their trip, have an impact on their speed.
- **Amenities and attractions:** Presence of natural features or parks, cinemas, cultural centres, retail trade/ services, public comfort stations, public transportation accessibility, presence of parking facilities affect PLOS.
- **Ease of movement and accessibility:** Land should be well accessible for parking facilities, public transportation, parks, shopping centres and cultural centres.
- **V/C Ratio:** The number of pedestrians who use the pathway in an hour divided by the footpath's capacity.

2.4 LEVEL OF SERVICE

The quantitative stratification of a performance measure is called level of service. It serves as a benchmark for how transportation planners evaluate the level of service provided by transportation facilities (Marisamynathan & Lakshmi, 2018). From the perspective of a traveller, it describes how effectively a transportation facility or service performs. LOS are described as the "qualitative metrics that represent operational circumstances within a traffic stream and their perception by motorists and passengers" in the Highway Capacity Manual.

One of the most well-known criteria for expressing how well a road performs from the perspective of travellers is level of service. It simply refers to how well a transportation facility can accommodate a road user. As pedestrians form the most vulnerable road users, pedestrians must be considered while designing various road components. This is our responsibility as transportation planners. Pedestrians are more likely to be involved in accidents, than other road users, according to recent accident research. Therefore, it is important to consider pedestrian level of service when designing a transportation infrastructure.

2.5 PEDESTRIAN LEVEL OF SERVICE

The Highway Capacity Manual's 1985 publication first introduced the notion of pedestrian level-of-service. It was one of the recent topics that HCM introduced. It is the quantitative tool for evaluating the operational conditions of facilities. It indicates the level of comfort the facility offers pedestrians as they use it. Pedestrian level of service measures how satisfied a pedestrian is with the safety, comfort, and convenience of sidewalk amenities (Bivina & Parida, 2019). It serves as a guide for developing requirements for pedestrian facilities and outlines the environmental characteristics of a pedestrian space. There should be ample room for safe and comfortable walking in a pedestrian facility. The width should be given based on the number of pedestrians, whether they are expected or not, the type of street (arterial, collector, or local), and the nearby land use. The idea of vehicle traffic flow is primarily the foundation for many researchers' recommendations for designing and planning for pedestrians. Comfort, ease, safety, security, and attractiveness are additional environmental elements that affect the walking experience and, consequently, the perceived level of service, and they should be taken into account.

IRC: 103-2012 specifies six service levels that can be stated as:

Table 2.1: Qualitative LOS Grades

LOS	DESCRIPTION
A	Ideal pedestrian conditions
B	Reasonable pedestrian conditions
C	Basic pedestrian conditions
D	Poor pedestrian conditions
E	Pedestrian environment is unsuitable
F	All walking speeds are severely restricted

- **LOS A** is a situation where pedestrian conditions are good and there are very few things that can harm pedestrian LOS
- **LOS B** means that there are adequate pedestrian conditions, but a few variables have an impact on pedestrian comfort and safety. LOS B is a suitable norm because LOS A is the ideal
- **LOS C** denotes the presence of fundamental pedestrian conditions; however, a variety of important aspects have an impact on pedestrian comfort and safety
- **LOS D** means that there are poor pedestrian circumstances and that there are numerous or serious individual factors that have a negative impact on pedestrian LOS. There are obvious safety concerns in the pedestrian environment and little comfort for pedestrians
- **LOS E** denotes an inadequate pedestrian environment. This condition arises when all, or almost all, of the variables impacting pedestrian LOS are insufficient
- All walking speeds are severely constrained at **LOS F**, and the only way to move forward is via shuffling. It is inevitable and frequent that there would be contact

with another pedestrian. Movements that cross or reverse the flow are nearly difficult. The flow is unpredictable and uneven.

Figure 2.1: Qualitative LOS A

(Source: https://www.deccanchronicle.com/nation/current affairs/160518/interlocked-footpaths-to-save-thiruvananthapuram-from floods.html)

Figure 2.2: Qualitative LOS E

(Source:https://www.downtoearth.org.in/blog/governance/pedestrianaccessibility -needs-to-come-out-of-the-gaps-between-cars-64297)

Here in the above figures, LOS A represent excellent condition and LOS E represent poor condition.

2.6 FACTORS AFFECTING PEDESTRIAN LEVEL OF SERVICE

PLOS is a popular technique for evaluating the effectiveness of sidewalk facilities and can be useful in developing future development plans. At earlier days, PLOS was evaluated based on the sidewalk's width, pedestrian traffic, and geometric features (Highway Capacity Manual, 2000). According to the study, the volume and speed of motorised vehicles have an impact on the degree of service provided to pedestrians. Additionally, it has been noted that street parking, guard rails, barriers, and sidewalk surface all affect the amount of service provided to pedestrians (Tan et al., 2007). Numerous studies were carried out to assess the degree of service provided to pedestrians. The Highway Capacity Manual established the sidewalk's degree of service based on pedestrian traffic, space, and speed (Highway Capacity Manual 2000).

Previous PLOS studies solely focused at only quantitative factors such as pedestrian speed, flow, and density. The qualitative characteristics of sidewalks are frequently ignored by the quantitative PLOS model that has been created so far. Compared to quantitative criteria, only a small number of research on PLOS have taken into account qualitative factors including comfort, safety, walking environment, and disability difficulties (Bivina et al., 2018). It was determined that the key determinants of the safety-based service level at pedestrian facilities include pedestrian gender, age groups, and platoon size. Additionally, it was discovered that women pedestrians exercised greater caution than men. Additionally, the service level of the bidirectional pedestrian flow was decreased as group sizes increased. It was also noted that the PLOS at pedestrian facilities is impacted by the following factors such as pedestrians with baggage, smartphone usage, pedestrian behaviour, and bidirectional pedestrian flow. It is observed that the size and number of barriers have an impact on how comfortable, pedestrians are.

Qualitative factors are considered in many studies for PLOS evaluation (Bivina et al., 2018; Chandana Mohammed ; Kumar, R. Srinivasa, 2016; Marisamynathan & Lakshmi, 2018). Qualitative factors include both user and physical characteristics of sidewalk. Physical characteristics of sidewalk considered in a study conducted at Chennai (Marisamynathan & Lakshmi, 2018). Sidewalk width, conditions of sidewalk, the presence of barriers and the presence of guardrails are considered in this study. In a study conducted in Hyderabad city (Chandana Mohammed ; Kumar, R. Srinivasa, 2016) considered sidewalk performance as physical attribute along with safety, comfort, vendor's presence, movement easiness and accessibility, and environmental condition. Questionnaire survey was conducted to collect data. Both physical and user characteristics are considered in a study conducted at Indian cities (Bivina et al., 2018). The sidewalk's surface, width, blockage, possibility for vehicular conflict, and continuity were its physical features and the encroachment, accessibility to crossing facilities, security, comfort, and walk environment were its user attributes.

Socio -economic and travel information are considered in some studies (Georgiou et al., 2021; Sangeeth & Lokre, 2019). Age, gender, trip purpose and group size are considered by Sangeeth (Sangeeth & Lokre, 2019). Georgio et. al (Georgiou et al., 2021) considered socio-economic attribute (age, gender) along with qualitative components and the pedestrian streets' characteristics.

The main quantitative factors affecting PLOS are pedestrian flow parameters and sidewalk space (HCM 2010, Indo- HCM 2017). HCM 2010 provides a standardized methodology for finding PLOS based on pedestrian flow rate parameters. Pedestrian flow parameters include pedestrian flow rate, average speed and volume/capacity ratio. Other than flow parameters, vehicular traffic (Georgiou et al., 2021; Marisamynathan & Lakshmi, 2018) was also considered in some studies. Traffic volume was considered in a study conducted at Chennai (Marisamynathan & Lakshmi, 2018). In a study conducted at Greece (Georgiou et al., 2021) considered public transport, traffic and delays.

Table 2.2: Summary of previous pedestrian level of service studies

AUTHOR	FACTORS CONSIDERED
Ahmed et al., (2018)	Pedestrian and vehicular flow rate, average vehicular speed, presence of guardrails, surface condition of sidewalk, number of discontinuities, percentage of pedestrian interact with vendor
Parida et al., (2007)	Sidewalk surface and width, obstruction, potential for vehicular conflict, continuity, encroachment, availability of crossing facility, security, comfort, walking environment

Bivina et al., (2018)	Pedestrian and vehicular flow rate, average vehicular speed, presence of guardrails, surface condition of sidewalk, number of discontinuities, percentage of pedestrian interact with vendor
Bivina et al., (2019)	mobility and infrastructure, comfort and convenience, security, safety
Georgiou et al., (2021)	pedestrian's socio demographic attributes, perceived comfort, pedestrian street's characteristics
Jahan et al., (2020)	width and height of sidewalks, accessibility, surface condition, cleanliness level, drainage facilities, presence of barrier, security from robbery and sexual harassment, lighting facilities, movement of bicycles and motorcycles, vending activities, parking of light vehicles, crowd of passengers for buses
Marisamynathan & Lakshmi, (2018)	speed, density, flow, space, SW width, surface condition, land use type, presence of barriers and street parking, vehicle volume, vehicle speed, presence of guardrails and street vendors, pedestrian volume
Ujjwal & Bandyopadhyaya, (2021)	convenience, safety and security, sidewalk infrastructure, heavy encroachments, night time condition, partial encroachment on sidewalk, traffic on carriageway

2.7 SIDEWALK

A sidewalk is a paved or unpaved path that runs along the road for pedestrians. It is a crucial component of the transportation system that offers a safe walkway for people to use. It is frequently kept apart from motorised traffic. On metropolitan streets, it acts as a barrier by protecting pedestrians from motorised vehicles to ensure safe walking conditions and help to enhance vehicle flow. All sorts of streets where vehicle speed exceed 15 kmph must be provided with sidewalks. All people, including children, the elderly, and people with physical disabilities, can live comfortably and safely on walkable sidewalks. Good sidewalks give people spaces to sit, mingle, and play. If the sidewalks are not provided, the street should be traffic-calmed to keep vehicle speeds below 15 kmph so that people walking and driving can coexist safely. This can be taken into consideration, particularly for local streets and narrow crowded commercial streets.

Similar to roads and railroads, sidewalks should be regarded as a connected and continuous transit infrastructure. They should be provided consistently between all main attractions, trip-makers, and other places where people walk rather than being scattered about wherever it's convenient. The walkways need to be above the level of the carriageway and on both sides of the road, separated by kerbs, in order to be effective. Footpath width should be planned in 3 different zones (IRC: 103, Draft) – pedestrian/walking zone, frontage/dead zone and multiutility zone as shown in Figure 2.3.

Figure 2.3: A footpath in Chennai showing various zones

(Source:https://images.citizenmatters.in/wpcontent/uploads/sites/3/2019/0 7/29132232/Screen-Shot-2019-07-03-at-1.19.45- PM.png)

- **Pedestrian/walking zone**

  It is the unobstructed area designated specifically for people to walk in.
- **Frontage/dead zone**

  It acts as a barrier between the walking area and the property edge.

- **Multi-utility zone (MUZ)**

  In addition to seating, bus stops, IPT (Intermediate Public Transit) stands, trees, play areas for kids, street signs, telecom and electric boxes, on-street vending, and on-street parking, this area also features landscaping and trees.

2.8 DETERMINATION OF PLOS FOR SIDEWALKS ACCORDING TO Indo-HCM, 2017

The initial phase should involve determining the sidewalk based on the nearby land use, such as commercial, institutional, terminal, recreational, or residential. The available sidewalk's width should be measured in the second phase, and the effective width should then be determined. The section of a pathway that may be efficiently used by pedestrians is known as the effective width of the sidewalk, which is the width of the sidewalk excluding the shy distance. The presence of various barriers tends to scare off pedestrians. The table below provides estimated shy distances for the Indian situation based on field observations.

In order to calculate the maximum or peak flow rate, the next step is to observe pedestrian flow (ped/min) from the selected site and convert the peak flow value into flow rate (ped/min/m). In the final step, using the peak flow rate value, PLOS can be identified for any sidewalks given earlier in Table 2.1 above. The flow chart below shows the steps to determine PLOS for sidewalks.

Table 2.3: Estimated shy distance in Indian context

Obstacle	Shy Distance(m)
Beach	0.3-0.5
Kerb (in case of divided carriageway)	0.1-0.2
Kerb (in case of bidirectional)	0.2-0.4
Wall	0.4-0.6
Guardrails	0.4-0.6
Hawkers	0.3-0.5
Light Pole	0.8-1.1
Traffic Signs	0.6-0.8
Traffic Signal Poles and Boxes	0.9-1.2

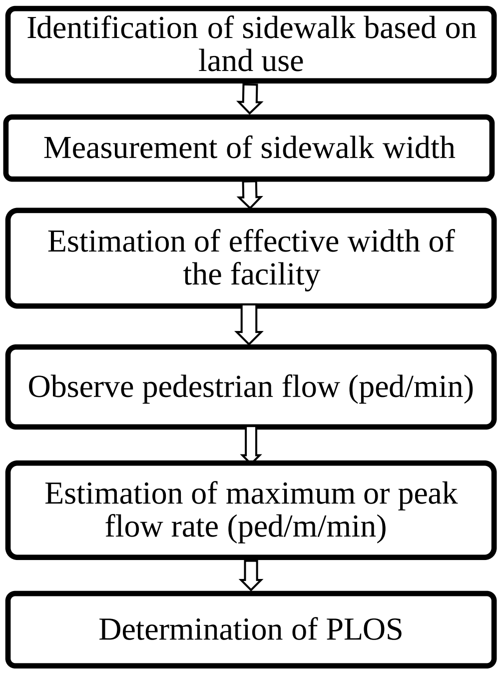


Figure 2.4: Determination of PLOS

(Source: Indo-HCM, 2017)

2.9 METHODS FOR DEVELOPING PEDESTRIAN LEVEL OF SERVICE

Various methods for evaluating PLOS are summarized below. There are two widely used approaches for developing PLOS: regression analysis and a point system (also known as a scalar system). Weights of factors are chosen at random in point system or scalar method, and the results have been found to be biased These limitations can be overcome by using regression analysis.

Point system technique was developed by various PLOS studies (Dixon 1996, Bivina et al., 2018). The studies used both qualitative and quantitative data. Dixon considers the fundamental amenities, potential conflicts, conveniences, and provisions for motor vehicle LOS, maintenance, transportation demand management (TDM), and multimodal travel (Dixon 1996). The study conducted at Winter Park; Florida (Jaskiewicz 2000) considered nine qualitative factors. Street boundaries, the complexity of the path network, building articulation, the complexity of how public spaces are distributed, the presence of tents, shelter, and different rooflines, the presence of a buffer zone, the presence of trees, accessibility, and the physical and natural characteristics as well as the condition of the sidewalk are the nine evaluation criteria. The assignment of scores is full based on-site inspection. An analytical point system was developed by Bivina (Bivina et al., 2018) to evaluate PLOS based on pedestrian perception. This study focussed on 10 sidewalk characteristics that include user and physical sidewalk characteristics. Weightage and satisfaction score of each factor assigned by users of sidewalk was the data required for the study. These data were collected through questionnaire survey. PLOS score was calculated from weightage and satisfaction score of each factor.

Regression analysis technique was adopted in various PLOS studies (Georgiou et al., 2021; Jensen, 2007; Landis et al., 2001; Tan et al., 2007). A regression model was developed in these studies. The model used both quantitative and qualitative data. Dandan takes into account factors such as sidewalk width, buffer presence, pedestrian flow characteristics, car and bicycle flow characteristics, obstructions, and frequency of driveway access (Tan et al., 2007). The presence of sidewalks, lateral separation from motor vehicle traffic, barriers and buffers between pedestrians and motor vehicle traffic, the volume and make up of motor vehicles, the effects of motor vehicle traffic speed, driveway frequency and access volume are all taken into account in a study conducted in the Pensacola, Florida, metropolitan area (Landis et al., 2001). Traffic volume surveys and questionnaire surveys were conducted for collecting the data. Jensen (Jensen, 2007) conducted research in a Danish city that took into account walking environment, parked cars, buffer zones, bicycle tracks, pedestrian volume, and sidewalk width. In a study carried out in a Greek city, socio-demographic data (such as gender and age) were taken into account together with qualitative elements and the characteristics of pedestrian streets for LOS calculation as perceived by pedestrians (Georgiou et al., 2021). The mobility aspects of the respondents as well as their perception of their level of perceived comfort and safety are included in the qualitative components. Additionally, other factors including accessibility, parking, public transportation, congestion and delays, and attractiveness of the land use were also examined at.

PLOS methods can also be classified based on data used for PLOS evaluation namely, quantitative and qualitative method. Qualitative method is based on qualitative data and are collected from pedestrian perception survey. This helps to access the quality of pedestrian facility in terms of comfort and safety. Dixon (1996), Jackiewicz (2000) and Bivina et al., (2018) evaluated PLOS using qualitative method. Quantitative method is based on quantitative data. Pedestrian flow, volume, speed, and pedestrian space are the various quantitative data used for finding PLOS. These data were generally collected by video- graphic and field investigation survey.

HCM 2010 and Indo- HCM 2017 provide qualitative method for finding PLOS. Description of these methods is given below.

HCM 2010 analysis pedestrian LOS based on pedestrian flow rate and sidewalk space. The pedestrian flow rate integrates pedestrian speed, volume, and density. HCM's pedestrian LOS model is based on a scale from A to F. A represent the best and F represents the worst travelling condition.

Based on essential flow criteria for five various land uses for footpaths, **Indo- HCM 2017** created PLOS. For each land use in the context of India, six LOS, numbered from LOS A to LOS F, are defined. Commercial, institutional, terminal, recreational, and residential land uses are the five that are taken into consideration.

2.10 SUMMARY

In this chapter, the various factors affecting PLOS and the different methods used for calculating PLOS were reviewed. The factors affecting PLOS are broadly divided into two, qualitative and quantitative factors. The qualitative factors are sidewalk surface, encroachment, obstructions, vehicular conflict (raised footpath, guard rails), longitudinal continuity, availability of crossing facility, security (street lighting, police patrolling, CCTV camera), comfort, walk environment, sidewalk performance, ease of movement and accessibility, amenities and attractions and socio-demographic factors (age, gender, education, employment). Quantitative factors are sidewalk width, pedestrian flow rate, pedestrian speed, pedestrian density, pedestrian space, traffic volume. It was found that no previous works has been carried out on modelling the PLOS using different regression methods in machine learning.

CHAPTER 3

METHODOLOGY OF WORK

3.1 GENERAL

A brief explanation about the methodology followed in the study is given in this chapter. The methodology includes literature review, data collection, identification of significant variables affecting PLOS, development of best-fit PLOS model, PLOS classification and policy recommendations. Figure 3.1 shows the flow chart of the research methodology. The various factors affecting pedestrian level of service at sidewalks were identified through the extensive literature review of previous studies. The summary of previous pedestrian level of service studies was shown in the Table 2.2 above.

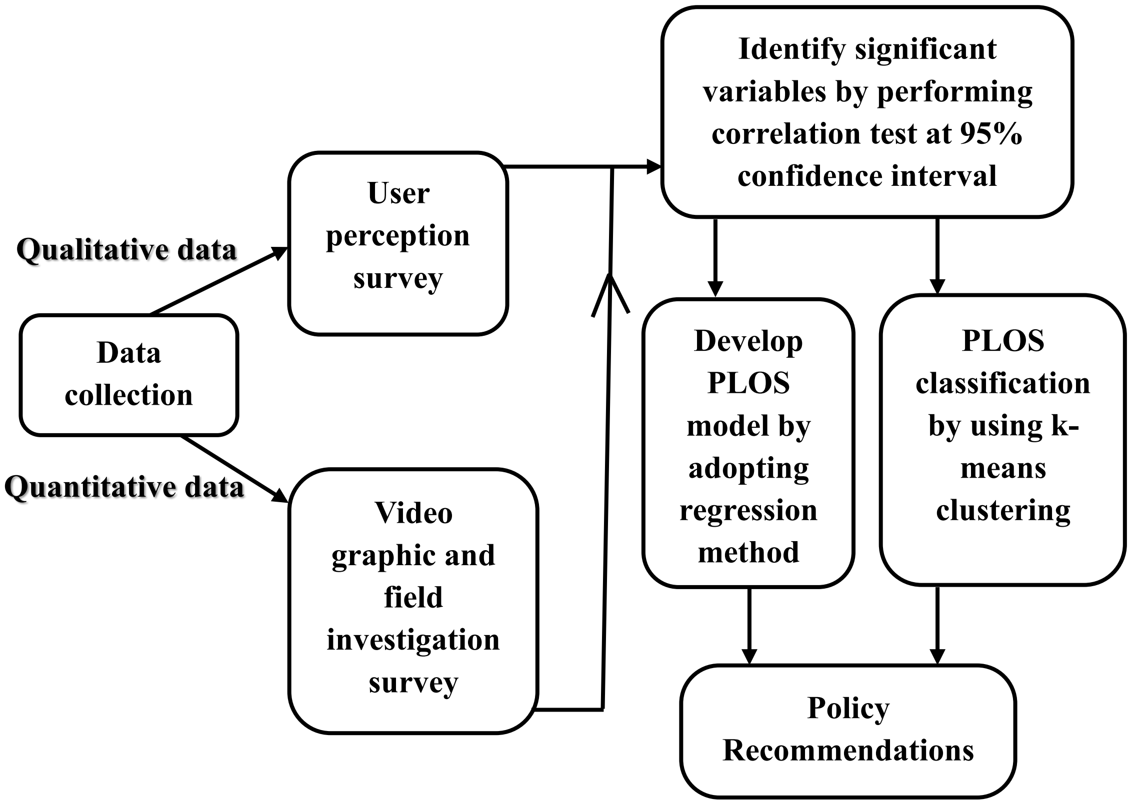


Figure 3.1: Flow chart of methodology of work

3.2 PILOT STUDY

Based on the extensive literature review the parameters such as speed, density, flow, space, sidewalk width, sidewalk surface condition, land use type, presence of barriers, presence of street parking, vehicle volume, vehicle speed, presence of guardrails, presence of street vendors, pedestrian volume, lighting facilities, CCTV cameras, police patrolling were identified. And to confirm these parameters, a pilot survey was carried out at the selected sidewalks. After the survey, the two parameters such as CCTV cameras, and police patrolling were eliminated because the pedestrians were satisfied with these factors. The selected variables with their measures are shown in Table 3.1 below.

Table 3.1: Variables affecting PLOS at sidewalks and their measures

Variables	Measure
Speed	Scalar
Density	Scalar
Flow	Scalar
Space	Scalar
SW Width	Scalar
SW surface condition	Ordinal
Land use type	Nominal
Presence of barriers	Nominal
Presence of street parking	Nominal
Vehicle volume	Scalar
Vehicle speed	Scalar
Presence of guardrails	Nominal
Presence of street vendors	Nominal
Pedestrian volume	Scalar
Lighting facilities	Nominal

3.3 DATA COLLECTION

For this study two types of data are required namely qualitative data and quantitative data. For collecting quantitative data video- graphic survey and field investigation survey was used. Qualitative data was collected from questionnaire survey and the reliability of these questionnaire was checked using Cronbach alpha reliability test (Taherdoost, 2018). Survey was conducted among people using the sidewalk, through direct interview.

3.4 IDENTIFICATION OF SIGNIFICANT VARIABLES AFFECTING PLOS

For the development of a pedestrian level service model, the significant variables were determined by the Pearson correlation test. Using the SPSS 25.0 software, Pearson correlation test was carried out with a 95% confidence interval. The Pearson correlation measures how strongly two variables are correlated linearly. Its range of values is from -1 to 1, with -1 denoting negative correlation, 0 denoting no correlation, and 1 denoting positive correlation. A strong correlation is stated to exist if the coefficient value is between 0.50 and 1. The value is considered to be of medium correlation, if value falls between 0.30 and 0.49. When the value is less than 0.29, the correlation is considered to be weak.

3.5 DEVELOPMENT OF BEST-FIT PLOS MODEL

Random forest regression model, multiple linear regression model and ridge regression model were developed using the significant variables obtained from Pearson correlation and from this, the model with lower RMSE and MAE and higher accuracy is taken as the best-fit model.

3.5.1 Regression Methods

The relationship between a dataset's dependent and independent variables can be discovered using predictive modelling approaches like regression analysis. It is frequently employed when the goal variable has a range of continuous values and the dependent and independent variables are linked either linearly or non-linearly. In order to model time series, forecast, and demonstrate causal links between variables, regression analysis techniques are used. When knowledge of the independent variables is available, regression analysis is used to forecast either the value of the dependent variable or the impact of an independent variable on the dependent variable. The following is a list of various regression analysis methods that can be used to make predictions.

Multiple Linear Regression Model

A number of explanatory variables are combined in a statistical process called multiple linear regression (MLR), also referred to as multiple regression. Modelling the linear relationship between the explanatory (independent) factors and response (dependent) variables is the aim of multiple linear regression. Because multiple regression takes into account several explanatory variables, it can be thought of as an extension of ordinary least-squares (OLS) regression. A statistician can predict the value of one variable based on the knowledge of another variable by using the simple linear regression function. Only two continuous variables—an independent variable and a dependent variable—can be utilised in a linear regression. The independent variable is the element that is used to calculate the dependent variable. A multiple regression model incorporates a number of explanatory factors.

The general model framework is given below (Marisamynathan & Vedagiri, 2017):

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_n X_n \quad \text{Eq.1}$$

where,

Y= dependent variable,

$X_{1\text{-}n}$= explanatory variables,

$\beta_{1\text{-}n}$= estimated parameters from model, and

β_0= constant.

Ridge Regression Model

Any data that exhibits multicollinearity can be analysed using the model tuning technique known as ridge regression. This technique carries out L2 regularisation. Predicted values differ much from real values when the problem of multicollinearity arises, least-squares are unbiased, and variances are significant. The presence of nearly linear connections among the independent variables is known as multicollinearity or collinearity. Multicollinearity can lead to erroneous estimations of the regression coefficients, inflated regression coefficient standard errors, and reduced model predictability. Even if L2 regression weights are minimal, they are still not zero.

The cost function for ridge regression (Kumar & Sahu, 2021):

$$CF_{L2} = \sum_{i=1}^{n} \left(w.x_i + b - y_{act_i}\right) + \lambda w^2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{Eq.2}$$

where,

λ (≥ 0) is the regularization constant,

b is the bias/intercept,

w is the weight to a set of data points,

y_{act_i} is the dependent variable,

x_i is the independent variable.

The penalty term is lambda. λ given here is denoted by an alpha parameter in the ridge function. So, we may regulate the penalty term by varying the values of alpha. The penalty is greater with larger alpha values, which reduces the magnitude of coefficients. It shrinks the parameters. It is therefore employed to avoid multicollinearity. By shrinking the coefficients, it lessens the complexity of the model.

Random Forest Regression Model

An ensemble learning technique is used for classification and regression in the supervised learning algorithm known as random forest. In contrast to boosting techniques, random forest is a bagging approach. In random forests, the trees grow in parallel, therefore there is no interaction between them as they develop. An ensemble method is a strategy that combines predictions from various machine learning algorithms to provide predictions that are more accurate than those from any one model. An ensemble model is a model made up of numerous models. Trees used for decision making are sensitive to the particular data used for training. The resulting decision tree and, consequently, the predictions, can differ significantly if the training data are altered. Additionally, decision trees have a high risk of overfitting, are computationally expensive to train, and have a tendency to locate local optima because they are unable to reverse a split. We use random forest, which demonstrates the power of integrating numerous decision trees into one model, to address these flaws. Random forest works by building a large number of decision trees during training and then producing the mean prediction of each tree. A random forest, which aggregates many decision trees with certain useful alterations, is a meta-estimator (i.e., it combines the outcome of multiple forecasts).

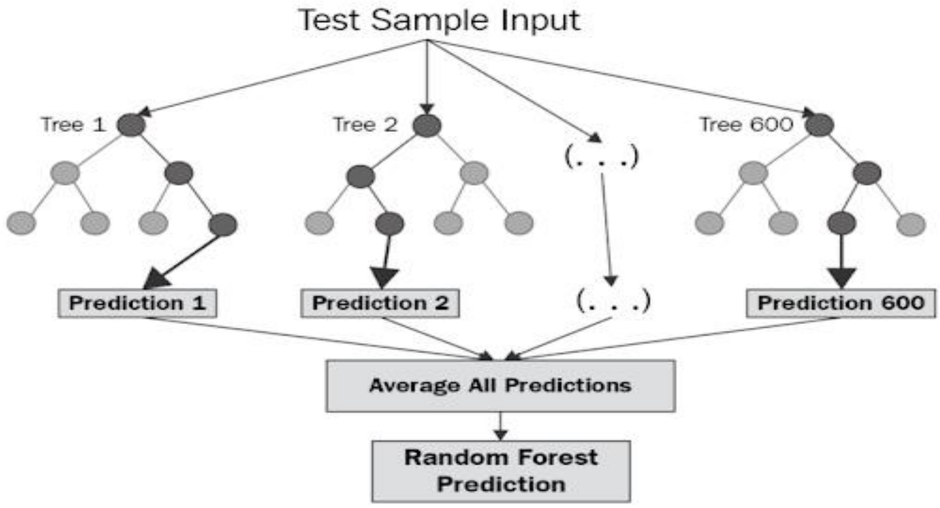


Figure 3.2: Random Forest Structure

(Source: https://builtin.com/data-science/random-forest-python)

3.6 PLOS CLASSIFICATION

For finding the PLOS ranges k-means clustering was carried out in SPSS 25.0 software. A well-known hard clustering approach called K-means groups the data items into K-clusters so that each one belongs to only one cluster. One of the partitioning techniques is K-means clustering, and each cluster will be represented by a determined centroid. There will be a minimum distance between each data point in the cluster and the computed centroid.

CHAPTER 4

STUDY AREA AND DATA COLLECTION

4.1 GENERAL

This chapter gives the details of selected sidewalks and description of data collection. For this study two types of data were collected namely qualitative data and quantitative data. The methods adopted for collecting these data are described in this chapter.

4.2 STUDY AREA

To cover the typical pedestrian behaviour, vehicular traffic and roadway conditions, eight sidewalks were selected from Kollam district, in Kerala, India. The data were gathered at peak times at the chosen study areas, which are in the city centre of Kollam and have varied types of land use. The selected sites and their pictures are shown below.

Table 4.1: Selected sidewalks with their land use type

Sl No:	Sidewalks	Land use Type
1	Ammachiveedu Collectorate	Institutional
2	AR Camp Kollam Corporation	Commercial
3	Chemmamukkau - Ayathil Road	Mixed
4	Chemmamukkau-College Junction	Mixed
5	College Junction SN College	Institutional
6	Chinnakkada	Commercial
7	Kochupilamoodu-Beach Road	Recreational
8	Railway Station Road	Transport Terminal

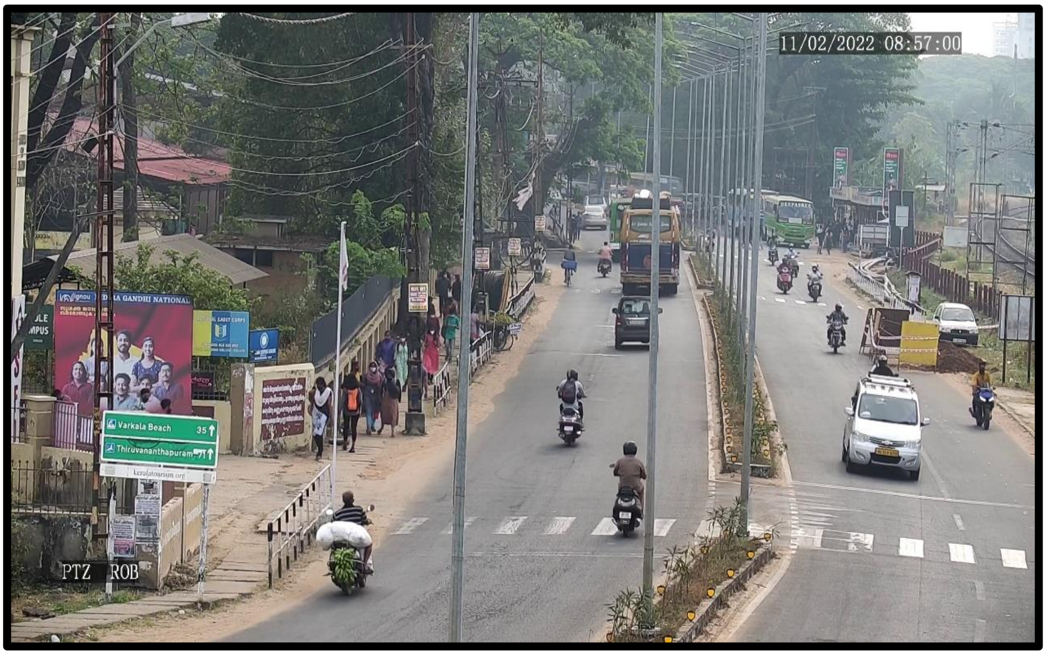


Figure 4.1: Pedestrian sidewalk of College Junction SN College Road in Kollam District

(Source: Kerala Police video records, February 11, 2022)

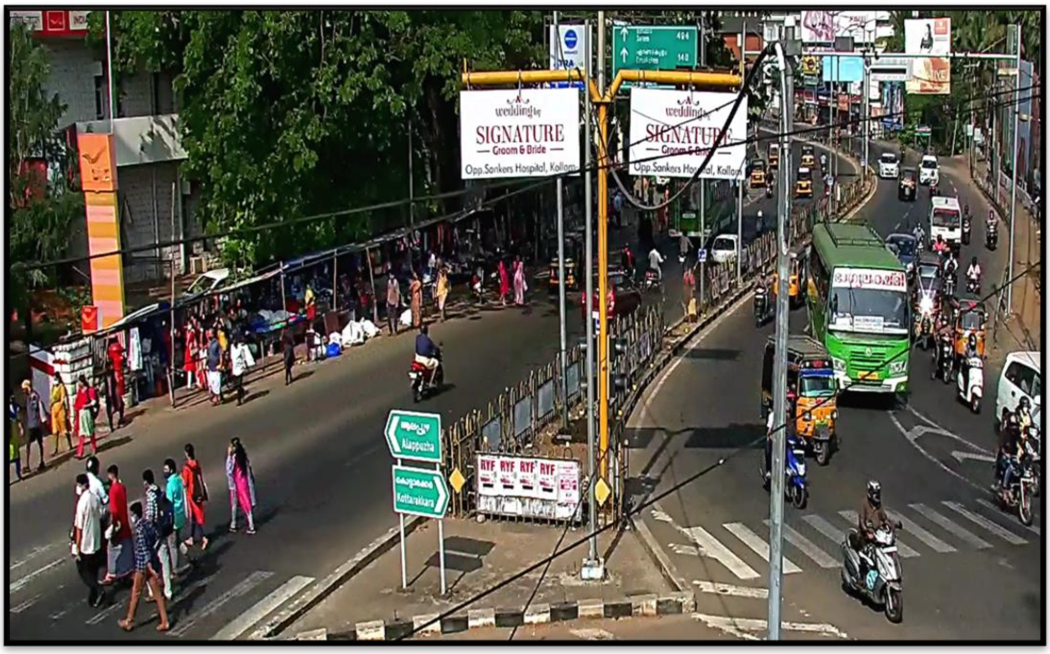


Figure 4.2: Pedestrian sidewalk of Chinnakkada Main Junction Road in Kollam District

(Source: Kerala Police video records, January 24, 2022)

4.3 DATA COLLECTION

Quantitative data and qualitative data are required for the study. Quantitative data is collected for assessing pedestrian speed, density, flow, space, vehicle volume, vehicle speed and pedestrian volume. For this video-graphic survey was used. All these factors mentioned above, of pedestrians using that facility during peak one hour was extracted manually from video-graphic survey. Sidewalk inventory data includes characteristics of sidewalk such as sidewalk width, SW surface condition, land-use type, presence of barriers, presence of street parking, presence of guard rails, presence of street vendors and lighting facilities. The sidewalk inventory data were collected by field investigation survey. Qualitative data was required to understand pedestrian perception regarding with respect to safety, security, comfort and convenience. Pedestrian perception is obtained from questionnaire survey. Data were collected through direct interview of pedestrians. About 588 people participated in this survey. The people from all age group were surveyed. The questions were properly explained and they were asked to rate from 1 to 5 for each question.

4.3.1 Video –graphic survey

The most effective technique for gathering information about pedestrians is the video graphic survey approach, which has been widely adopted. Data on selected sidewalks video data were gathered from the police control room. It consists of pedestrian, traffic and sidewalk characteristics of site, which affect the pedestrian level of service. The video graphic study recorded pedestrian activity on the walkways and covered a 25 m section of the trap length. In the lab, the necessary data were manually retrieved. Data extraction may take longer with this method, but the benefits include more accurate data (Marisamynathan & Lakshmi, 2018), long-term analysis, and a permanent record of events. The various parameters are described as:

- Speed: The distance travelled (trap length=25 m) is divided by the pedestrian's journey time. (denoted as m/s)
- Density: The average number of pedestrians per square foot within a sidewalk is known as density. (denoted by ped/m^2)
- Flow: The quantity of people crossing a certain location (the beginning of the trap length) in a given amount of time. (denoted as ped/min)

- Space: Inverse pedestrian density in space. (denoted as m^2/ped)
- Vehicle volume is the number of cars that pass in a 15-minute period on a road that is parallel to the sidewalk. (denoted as veh/15 min)
- Trap length divided by journey duration equals vehicle speed. (measured in m/min)
- The number of pedestrians who pass the length of the trap in an hour is known as the pedestrian volume. (denoted as ped/h)

4.3.2 Field Investigation survey

Sidewalk inventory data was collected by field investigation survey. From field investigation survey, sidewalk width, sidewalk surface condition, land-use type, presence of barriers, presence of street parking, presence of guard rails, presence of street vendors and lighting facilities were collected. The various parameters are as follows:

- SW width is a scalar term that refers to the width of particular sidewalks as determined by a calibrated measuring tape. (written in m)
- SW surface condition: Very good (1), Good (2), Average (3), Poor (4), and Very Poor (5).
- There are six different types of land use: institutional, commercial, transportation hub, recreational, residential, and mixed (Combination of any two-land use type)
- Barriers: 0 indicates no barriers, 1 indicates the presence of trees, poles, boxes, or drainage, and 2 indicates the combination of any two barriers.
- Street parking: 0 indicates that it is prohibited, while 1 indicates that it is allowed.
- Guardrails: 0 case (no guardrails) or 1 case (guardrails present).
- The number of street vendors present is either 0 (not occupied) or 1 (occupying a sidewalk).
- Street lighting facilities: 0 no street lighting and 1 street lighting

4.3.3 User Perception Survey

To better understand how pedestrians perceive their degree of safety, comfort, security, and convenience when using the sidewalk, a questionnaire survey was conducted. The pedestrians were asked to rate their overall satisfaction with the facilities on the sidewalk in the questionnaire survey. Before asking for their level of satisfaction and asking them to rate from 1 (good) to 5 (poor) for all categories, each pedestrian was given an explanation of the significance and meaning of the criteria they had already been shown in the survey questionnaire form. It was highlighted to the respondents that this study needs their perception of the level of difficulty if they were to use that particular sidewalk. In addition, socio-demographic information was collected and it represented the characteristics of people surveyed. Gender and age were included as socio-economic variables. The questionnaire is included as appendix A. Also, to check the reliability of these questionnaire, Cronbach alpha reliability test were carried out. It is known as the most appropriate method of reliability (Taherdoost, 2018).

4.4 SUMMARY

The study area and the methods used to collect the data were discussed. The selected sidewalks with their pictures are also mentioned here. The different methods used such as quantitative data collected through video-graphic survey and field investigation survey and qualitative data collected by questionnaire survey are discussed herewith.

CHAPTER 5

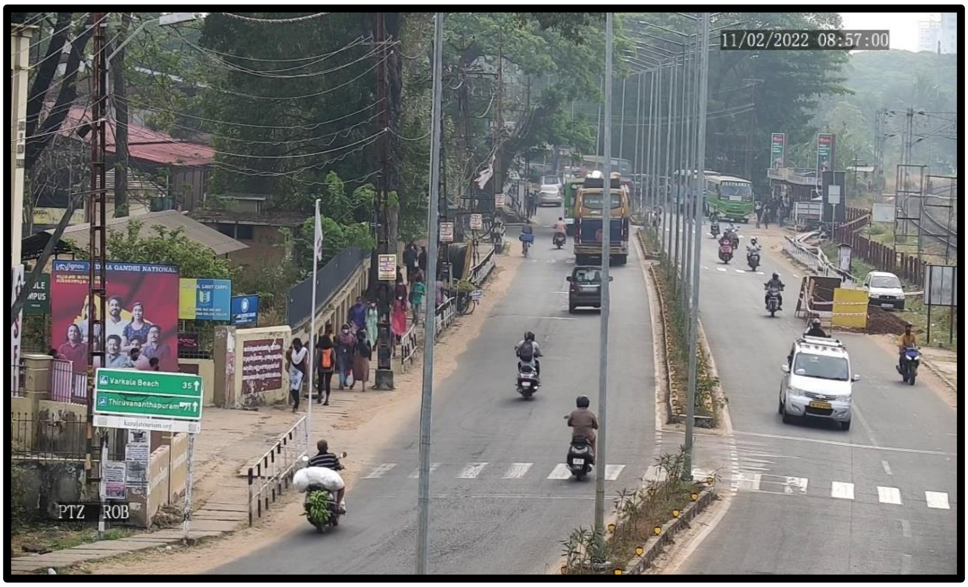
ANALYSIS OF SURVEY DATA AND IDENTIFICATION OF SIGNIFICANT PARAMETERS

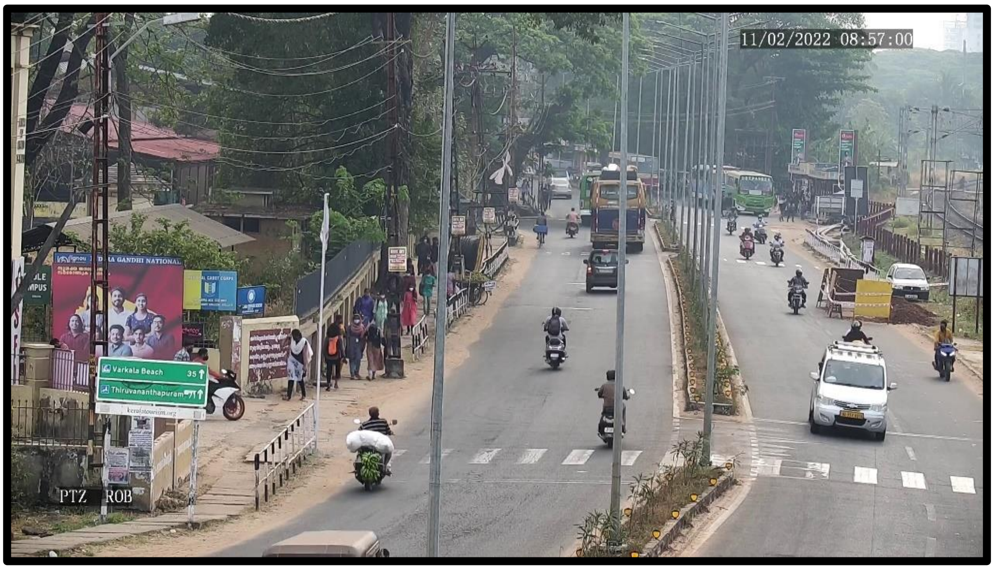
5.1 GENERAL

This chapter explains the analysis of survey data and the identification of significant parameters from among different parameters. In this chapter data collected from questionnaire survey i.e., socio-demographic and user perception score are analysed. Also, the data extracted from video as well as field investigation data are analysed.

5.2 ANALYSIS OF QUANTITATIVE DATA

The required videographic data such as pedestrian speed, density, flow, space, vehicle volume, vehicle speed and pedestrian volume is extracted from the collected video tapes by using VLC media. This video was extracted with recording ratio of 3 and extracted 6653 images from the 1 h video. The variables extracted from the video are shown in Table 5.1 below. The Figure 5.1 below shows the sample representation of the image's extraction using VLC media.

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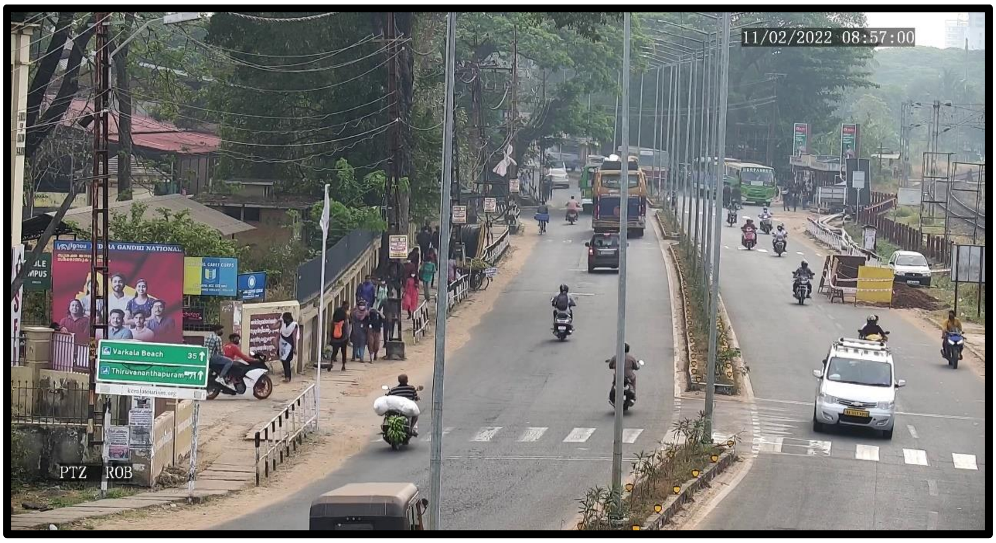
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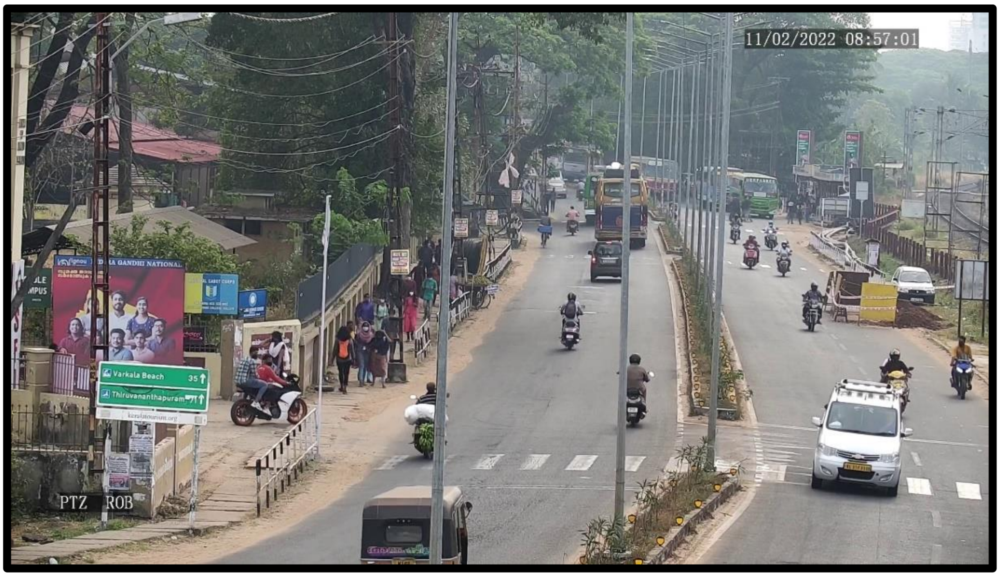
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Thiruvananthapuram
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Figure 5.1: Images extracted using VLC media

(Source: Kerala Police video records, February 11, 2022)

From field investigation survey, data such as sidewalk width, sidewalk surface condition, land-use type, presence of barriers, presence of street parking, presence of guard rails, presence of street vendors and lighting facilities were collected. The data collected are tabulated in the Table 5.2 below.

Table 5.1: Quantitative data extracted from the video

Sidewalk	Pedestrian speed(m/s)	Pedestrian density (ped/m^2)	Pedestrian flow (ped/min)	Space (m^2 /ped)	Vehicle volume (veh/15min)	Vehicle speed (km/hr)	Pedestrian volume (ped/hr)
Ammachiveedu Collectorate	0.97	0.19	9.5	5.53	335	34	823
AR Camp Kollam Corporation	0.85	0.15	10.1	6.66	297	30	803
Chemmamukkau - Ayathil Road	0.93	0.24	10.4	4.16	441	28	1096
Chemmamukkau- College Junction	0.99	0.2	11.1	5	377	31	993
College Junction SN College	0.82	0.47	33.42	2.13	633	35	2770
Chinnakkada	1.53	0.347	17	2.88	523	38	1245
Kochupilamoodu- Beach Road	1.06	0.18	8.7	5.56	301	32	797
Railway Station Road	1.15	0.37	11.66	2.7	473	35	983

Table 5.2: Data collected through field investigation survey

Sidewalk	SW width (m)	Land use Type	SW surface condition	Presence of barriers	Presence of street parking	Presence of guard rails	Presence of street vendors	Lighting facilities
Ammachiveedu Collectorate	1.8	Institutional	3	1	1	1	0	0
AR Camp Kollam Corporation	2.6	Commercial	2	2	0	1	0	1
Chemmamukkau - Ayathil road	1.8	Mixed	4	1	1	1	0	0
Chemmamukkau- College Junction	2	Mixed	3	2	1	1	0	1
College Junction SN College	1.7	Institutional	4	2	0	1	0	1
Chinnakkada	2.3	Commercial	3	0	1	1	1	1
Kochupilamoodu- Beach Road	1.5	Recreational	2	2	0	0	0	1
Railway Station Road	1.2	Transport Terminal	5	2	0	0	0	0

5.3 ANALYSIS OF QUALITATIVE DATA

Questionnaire survey was conducted to find pedestrian perception regarding quality of sidewalk. The total population of Kollam district **(Census Report, 2011)** was 2,635,375. The sample size was calculated using online sample size calculator. The sample size obtained was 385. Therefore, a total of 588 responses were collected. The responses collected from each sidewalk are shown below.

- Ammachiveedu Collectorate sidewalk - 59 responses
- AR Camp Kollam Corporation sidewalk - 53 responses
- Chemmamukkau-Ayathil sidewalk - 61 responses
- Chemmamukku –College Junction sidewalk - 93 responses
- College Junction SN College sidewalk - 103 responses
- Chinnakkada sidewalk - 99 responses
- Kochupilamoodu-Beach Road sidewalk - 63 responses
- Railway Station Road sidewalk - 57 responses

Here, average perceived LOS score is calculated by taking the average weightage score. A weighted average is the average of a data set that recognizes certain numbers as more important than others. The relative importance of each data point is determined by the weights that are assigned by the weighted average. In statistical analysis, weighted averages are frequently employed. A weighted average, in which each value in a data collection is given an equal weight, can be more accurate than a simple average. A weighted average is more descriptive than a simple average because the final average value in a weighted average represents the proportional importance of each observation. Additionally, it has the effect of improving the accuracy and smoothing out the data. The user perception score of corresponding sidewalks is represented in the Table 5.3 below.

Table 5.3: Selected sidewalks with perceived LOS Score

Sidewalk	Average perceived LOS score
Ammachiveedu Collectorate	2.7
AR Camp Kollam Corporation	2.1
Chemmamukkau - Ayathil Road	3.6
Chemmamukkau - College Junction	2.9
College Junction SN College	4
Chinnakkada	3.2
Kochupilamoodu-Beach Road	2.8
Railway Station Road	4.5

Here, Cronbach's alpha reliability test was carried out using SPSS 25.0 software to check the reliability statistics of the questionnaire. Here the Cronbach's alpha value obtained was 0.715, the value between 0.7 to 0.9 is considered to be highly reliable (Taherdoost, 2018). Therefore, it indicates the reliability scale of questionnaire. The socio-economic characteristics of the respondents are displayed in the pie charts given below. Socio-economic characteristics include gender and age.

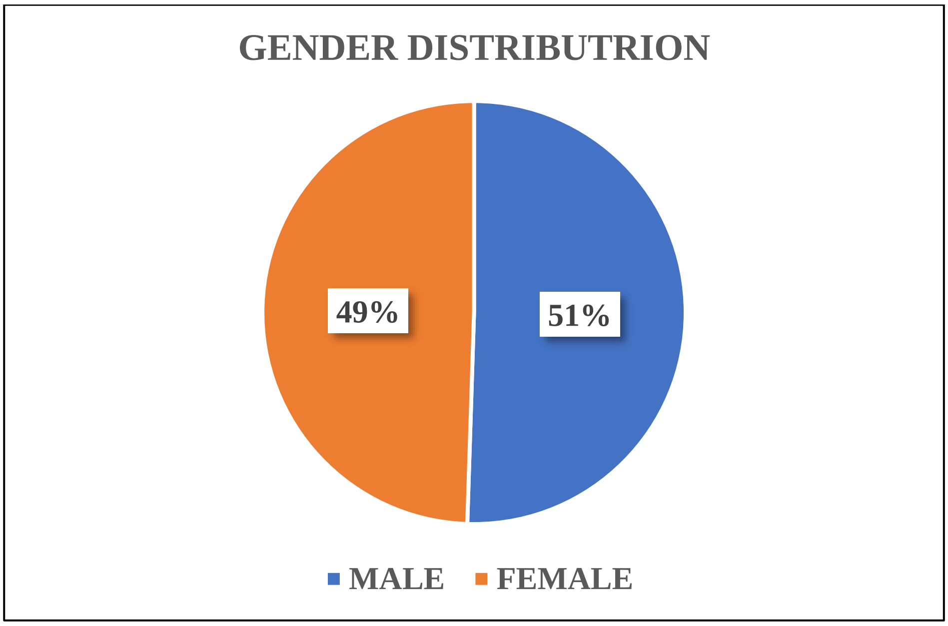

Figure 5.2: Gender Distribution

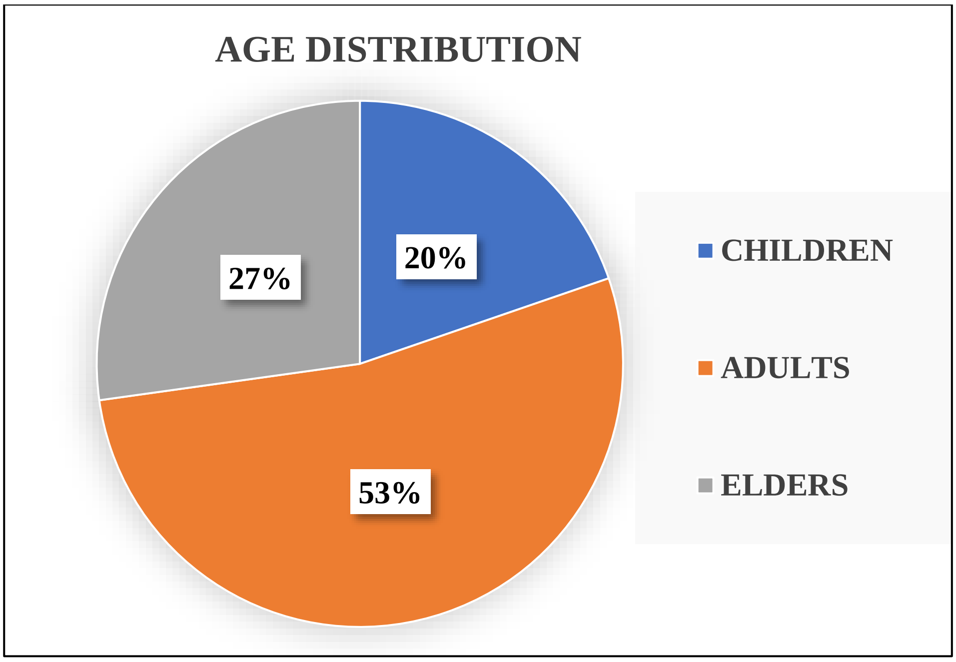

Figure 5.3: Age Distribution

A total of 588 pedestrians participated in the questionnaire survey, 297 males and 291 females. In that, about 20% of pedestrians were children, 53% were adults and 27% were elderly pedestrians.

5.4 DESCRIPTIVE STATISTICS OF SELECTED VARIABLES AFFECTING PLOS

The descriptive statistics of the selected parameters were found out using SPSS 25.0 software. The descriptive statistics are represented in the Table 5.4 below.

Table 5.4: Descriptive statistics of selected variables affecting PLOS

Variables	Mean	Std. Deviation	Minimum	Maximum
PLOS score	3.271	0.8240	2.1	4.5
Pedestrian speed	1.0443	0.24289	0.82	1.53
Pedestrian density	0.27814	0.119209	0.150	0.470
Pedestrian flow	14.3971	8.82249	8.70	33.42
Space	4.2314	1.72926	2.13	6.66
SW surface condition	3.29	1.113	2	5
SW width	1.843	0.4721	1.2	2.6
Land use type	2.71	1.799	1	6
Presence of barriers	1.43	0.787	0	2
Presence of street parking	0.43	0.535	0	1
Vehicle volume	429.00	125.947	297	633
Vehicle speed	33.14	3.388	28	38
Presence of guard rails	0.71	0.488	0	1
Presence of street vendors	0.14	0.378	0	1
Pedestrian volume	1216.71	705.339	797	2770
Lighting facilities	0.57	0.535	0	1

5.5 IDENTIFICATION OF SIGNIFICANT PARAMETERS AFFECTING PLOS

The Pearson correlation test was used to determine the significant variables for the level of service model development. Table 5.5 shows the results of the Pearson correlation test, with the perceived level of service score as the dependent variable and the chosen variables as the independent variables, using SPSS 25.0 software with a 95% confidence interval.

Table 5.5: Pearson Correlation Results

Variables	Pearson correlation value	Significance
PLOS score	1.000	-
Pedestrian speed	0.131	0.390
Pedestrian density	0.818	0.012
Pedestrian flow	0.447	0.157
Space	-0.883	0.004
SW surface condition	0.937	0.001
SW width	-0.703	0.039
Land use type	0.162	0.364
Presence of barriers	0.099	0.416
Presence of street parking	-0.119	0.400
Vehicle volume	0.753	0.025
Vehicle speed	0.318	0.243
Presence of guard rails	-0.314	0.247
Presence of street vendors	-0.038	0.468
Pedestrian volume	0.490	0.132
Lighting facilities	-0.373	0.205

From Table 5.5, it is clear that pedestrian density, space, sidewalk surface condition, sidewalk width, and vehicle volume have ‘p’ value less than 0.05. These factors have significant effect on the pedestrian level of service score at sidewalks. Therefore, the level of service model is developed using these significant parameters.

5.6 SUMMARY

The analysis of survey data such as qualitative data and quantitative data were discussed. Then, the reliability of the questionnaire was checked. Also, the descriptive statistics of the independent and dependent variables were found out. Finally, the most significant parameters among all the parameters were found out which is further used for model development.

CHAPTER 6

DEVELOPMENT OF BEST-FIT PLOS MODEL

6.1 GENERAL

This chapter explains the development of best-fit PLOS regression model. The factors identified in the correlation test were considered as the most probable primary factors affecting pedestrian’s safety, security, comfort and convenience. Random forest regression model, multiple linear regression model and ridge regression model were developed using those significant variables obtained from Pearson correlation. Regression model describes the relationship between one or more independent variables and a dependent variable. The model was developed in python using machine learning. The codes were run on google colab.

6.2 MACHINE LEARNING

With the use of machine learning (ML), which is a form of artificial intelligence (AI), software programmes can predict outcomes more accurately without having to be explicitly instructed to do so. In order to forecast new output values, machine learning algorithms use historical data as input. The way in which a prediction-making algorithm learns to improve its accuracy is a common way to classify traditional machine learning. There are four fundamental strategies: reinforcement learning, semi-supervised learning, unsupervised learning, and supervised learning. The kind of data that data scientists wish to predict determines the type of algorithm they use. Regression modelling is a supervised machine learning method in which data scientists give algorithms labelled training data and specify the variables they want the algorithms to look for associations between. Both the input and the result of the algorithm are described. In supervised machine learning, the data scientist must train the system with both labelled inputs and desired outputs.

6.3 PYTHON IMPLEMENTATION ON METHODS

- Data pre- processing step
    - Importing libraries such as numpy, pandas, etc.
    - Filtering the required data
    - Splitting the data set for training and testing

- Fitting the algorithm to the training set
- Predicting the test set result

Expected outcomes

- The best fit model for the given type of dataset

6.4 MULTIPLE LINEAR REGRESSION MODEL (MLR)

MLR is the extension of linear regression (Kumar & Sahu, 2021). It is a statistical method for examining the relationship between a single dependent variable and a number of independent variables. (Etemadi & Khashei, 2021). The goal is to forecast the value of a single dependent variable, using independent variables whose values are known. The python script for performing MLR model is shown in the Figure 6.1 below.

PYTHON SCRIPT

```
import pandas as pd
import numpy as np
data = pd.read_excel('/content/drive/MyDrive/Colab Notebooks/SPSS PEARSON-fin new.xlsx')
data
print("Rows:",data.shape[0])
print("\nColumns:",data.shape[1])
print("\nColumn names:",data.columns)
print("\nNull Values are:\n",data.isnull().sum())
print("\nUnique Values are:\n",data.nunique())
df = data.filter(['PEDESTRIAN DENSITY','SPACE','SW SURFACE CONDITION','SW WIDTH','VEHICLE VOLUME','PLOS SCORE'], axis=1)
df
x = df.drop(columns='PLOS SCORE')
y = df['PLOS SCORE']
from sklearn.model_selection import train_test_split
from sklearn.linear_model import LinearRegression
model = LinearRegression()
x_train, x_test, y_train, y_test = train_test_split(x, y, test_size = 0.3)
y_predict = model.predict(x_test)
y_predict
errors = abs(y_predict - y_test)
print('Mean Absolute Error:', round(np.mean(errors), 2), 'degrees.')
mape = 100 * (errors / y_test)
accuracy = 100 - np.mean(mape)
print('Accuracy:', round(accuracy, 2), '%.')
import math
from sklearn.metrics import mean_squared_error
rmse  = math.sqrt(mean_squared_error(y_test,y_predict))
rmse
```

Figure 6.1: Python script for Multiple Linear Regression Model

6.5 RIDGE REGRESSION MODEL

A method for analysing multiple regression data with multicollinearity is ridge regression (Panzone et al., 2021). Multicollinearity occurs when there are high correlations between more than two predicted variables. The regression model using the L2 regularization technique is termed as Ridge regression. It is the regularized form of linear regression (Kumar & Sahu, 2021). It helps keeping the parameters regular or normal. The model coefficients will change as we tune the lambda parameter. The python script for performing ridge regression model is shown in the Figure 6.2 below.

PYTHON SCRIPT

```
import pandas as pd
import numpy as np
data = pd.read_excel('/content/drive/MyDrive/Colab Notebooks/SPSS PEARSON-fin new.xlsx')
data
df = data.filter(['PEDESTRIAN DENSITY','SPACE','SW SURFACE CONDITION','SW WIDTH','VEHICLE VOLUME','PLOS SCORE'], axis=1)
df
x = df.drop(columns='PLOS SCORE')
y = df['PLOS SCORE']
from sklearn.model_selection import GridSearchCV
from sklearn.linear_model import Ridge
ridge=Ridge()
parameters={'alpha':[1e-15,1e-10,1e-8,1e-3,1e-2,0.1,5,10,20,30,35,40,45,50,55,100]}
ridge_regressor=GridSearchCV(ridge,parameters,scoring='neg_mean_squared_error',cv=5)
ridge_regressor.fit(x,y)
print(ridge_regressor.best_params_)
print(ridge_regressor.best_score_)
from sklearn.model_selection import train_test_split
x_train, x_test, y_train, y_test = train_test_split(x, y, test_size = 0.2)
clf = Ridge(alpha=0.1)
clf.fit(x_train,y_train)
prediction_ridge=ridge_regressor.predict(x_test)
df=pd.DataFrame({'Actual':y_test, 'Predicted Ridge':prediction_ridge})
df
errors = abs(prediction_ridge - y_test)
print('Mean Absolute Error:', round(np.mean(errors), 2), 'degrees.')
mape = 100 * (errors / y_test)
accuracy = 100 - np.mean(mape)
print('Accuracy:', round(accuracy, 2), '%.')
```

```
import math
from sklearn.metrics import mean_squared_error
rmse  = math.sqrt(mean_squared_error(y_test,prediction_ridge))
rmse
```

Figure 6.2: Python script for Ridge Regression Model

6.6 RANDOM FOREST REGRESSION MODEL

The method chooses random samples from the specified data set for the random forest regression model. For each sample that is chosen, the algorithm creates a decision tree. Afterwards, each decision tree will yield a forecast result. Every anticipated result will be voted on, and for regression, the mean is used. The ultimate prediction will be the outcome with the most vote. The python script for performing ridge regression model is shown in the Figure 6.3 below.

PYTHON SCRIPT

```
import pandas as pd
import numpy as np
data = pd.read_excel('/content/drive/MyDrive/Colab Notebooks/SPSS PEARSON-fin new.xlsx')
data
x1 = data.drop(columns=['PLOS SCORE','SIDEWALK'])
y1 = data['PLOS SCORE']
df = data.filter(['PEDESTRIAN DENSITY','SPACE','SW SURFACE CONDITION','SW WIDTH','VEHICLE VOLUME','PLOS SCORE'], axis=1)
df
x = df.drop(columns='PLOS SCORE')
y = df['PLOS SCORE']
from sklearn.model_selection import train_test_split
x_train, x_test, y_train, y_test = train_test_split(x, y, test_size = 0.2)
from sklearn.ensemble import RandomForestRegressor
regressor = RandomForestRegressor(n_estimators = 1000, random_state = 42)
regressor.fit(x_train, y_train)
y_pred = regressor.predict(x_test)
df=pd.DataFrame({'Actual':y_test, 'Predicted':y_pred})
df
errors = abs(y_pred - y_test)
print('Mean Absolute Error:', round(np.mean(errors), 2), 'degrees.')
mape = 100 * (errors / y_test)
accuracy = 100 - np.mean(mape)
print('Accuracy:', round(accuracy, 2), '%.')
from sklearn import metrics
print('Root Mean Squared Error:', np.sqrt(metrics.mean_squared_error(y_test, y_pred)))
```

Figure 6.3: Python script for Random Forest Regression Model

6.7 OUTPUT AND COMPARISON OF MODELS

The three models such as multiple linear regression model, ridge regression model and random forest regression model are compared based on the mean absolute error value, root mean square error value and accuracy. And from the above three model, the model with lower MAE and RMSE, and with higher accuracy model is taken as the best-fit model.

Table 6.1: Output of the models

Model	MAE	RMSE	Accuracy
Multiple Linear Regression	0.42	0.55	86.39%
Random Forest Regression	0.24	0.28	92.49%
Ridge Regression	0.07	0.06	97.14%

The RMSE value should be less than 0.5 for good and accurate prediction. The lower mean absolute error i.e., closer to zero shows good prediction. Therefore, the best fit model is ridge regression model, since the accuracy is 97.14%, and lower MAE and RMSE among multiple linear regression model and random forest regression model.

6.8 VALIDATION OF RIDGE REGRESSION MODEL

Data collected from six sidewalk segments are used to formulate ridge regression model and the rest two sidewalks such as Chemmamukkau – College Junction Road sidewalk and AR Camp Corporation sidewalk are used to validate the ridge regression model.

Table 6.2: Comparison between perceived PLOS and model outcomes

Sidewalk	Actual	Predicted
Chemmamukkau – College Junction Road	2.9	2.944141
AR Camp Corporation	2.1	2.011781

Here the model outcomes are close to perceived PLOS. The difference between actual and predicted PLOS are very small that is approximately equal to zero. Therefore, the ridge regression model is valid and significant for the study areas.

6.9 SUMMARY

The three different regression models such as multiple linear regression model, random forest regression model and ridge regression model were compared and among them ridge regression model is the best-fit model for the selected study area. Also, best-fit regression model is valid.

CHAPTER 7

PLOS CLASSIFICATION

7.1 GENERAL

This chapter explains the calculation of threshold values of PLOS, pedestrian density and space by means of k-means clustering in SPSS 25.0 software**.**

7.2 CLUSTERING

To categorise the data, researchers employed data mining tools. By identifying clusters and differences between various data clusters, cluster analysis is regarded as a key tool for classifying data (Marisamynathan & Vedagiri, 2017, 2019). For transportation-related issues including establishing LOS for urban arterial highways, freeways, and vehicles at crossings, the majority of previous studies used k-means clustering (Azimi & Zhang, 2010).

The process of clustering involves grouping the population or data points into a number of groups so that the data points within each group are more similar to one another than the data points within other groups. In simple words, the aim is to segregate groups with similar traits and assign them into clusters.

7.3 PLOS CLASSIFICATION

K-means clustering is used in SPSS 25.0 to classify PLOS, pedestrian density, and pedestrian space depending on various LOS categories. Under the category of partition-based techniques is K-means clustering. The algorithm for performing k-means clustering are as follows (Tokat et al., 2021):

- First, we need to specify how many clusters, K, our method needs to produce.
- Next, randomly select K data points and place each one in a cluster. Briefly, categorize the data based on the number of data points
- Now we compute the cluster centroids
- Iterate the steps below until we identify the ideal centroid, which is the assignment of data points to constant clusters
    - The first calculation would be the sum of squared distances between data

points and centroids

- Each data point must now be assigned to the cluster that is closest to the others (centroid)
- Calculate the cluster centroids for the clusters by averaging all of the cluster's data points

The threshold values calculated for PLOS, pedestrian density and space using k-means clustering are tabulated in the Table 7.1 below.

Table 7.1: Ranges of PLOS, Pedestrian Density and Pedestrian Space

LOS	PLOS score	Pedestrian Density (ped/m^2)	Pedestrian Space (m^2 /ped)
A	<2.5	<0.17	>=6.01
B	2.5-3	0.17-0.22	4.8-6.01
C	3-3.4	0.22-0.3	3.52-4.8
D	3.4-3.8	0.3-0.36	2.8-3.52
E	3.8-4.3	0.36-0.42	2.42-2.8
F	>=4.3	>=0.42	<2.42

The operational conditions of the sidewalks were rated as LOS A being the best and LOS F being the worst.

7.4 SUMMARY

The threshold values of PLOS, pedestrian density and space for different LOS categories were discussed. It is found that as PLOS score and pedestrian density increases, the LOS decreases. As the space increases, the freedom to select individual walking speed also increases, thereby increasing the LOS at sidewalks.

CHAPTER 8

POLICY RECOMMENDATIONS

The results of the study have revealed that the five significant variables such as pedestrian density, space, sidewalk surface condition, sidewalk width and vehicle volume are the parameters that the policy makers should improve. Therefore, accessibility and safety-promoting policies is of utmost importance. If the following measures are taken by the policy makers, then sidewalks can offer better pedestrian services.

- Place pedestrians at the top of the transportation hierarchy and redistribute road space by increasing walkways and reducing the width of roads in places with a high pedestrian volume.
- Sidewalk width is one of the key elements affecting pedestrian LOS. Moreover, the width of the sidewalk has an impact on its comfort level. To promote pedestrian comfort and convenience, some places require broader walkways.
- Another most important parameter that affect the pedestrian's sense of safety is the presence of sidewalk surface conditions. As the sidewalk surface condition reaches to poor, the LOS also reaches to poor. It is found that at some locations the sidewalks need to be levelled.
- The frequency of motorist vehicles has significant effect on level of service score. As the frequency of vehicles increases the LOS decreases, which result in decrease in safety level of pedestrians at sidewalks. Therefore, safety measures such as congestion pricing should be implemented where heavy pedestrian traffic is observed in order to reduce the use of private motor vehicles.
- The elimination of cars is not always necessary when making a roadway pedestrian-friendly. But by having fewer parking places available, it may be possible to pursue a policy of reducing private vehicles in the city centre and enhancing public transportation.
- As pedestrian space decreases, the ease of mobility of pedestrians declines which leads to decreased LOS. Therefore, measures should be taken to avoid pedestrian to pedestrian interaction.
- It has been evident that land use plan which incorporates roadway and sideway connectivity with commercial, institutional and residential neighbourhoods tend to

promote walking.

- If individuals feel dangerous in their areas, they are less likely to walk there. High rates of walking and physical activity are associated with low crime rates, low levels of perceived violence, and high levels of neighbourhood trust. Therefore, ensure safety of pedestrians.
- Moreover, a competent committee must be established for the creation and upkeep of pedestrian planning.

CHAPTER 9

CONCLUSIONS

9.1 GENERAL

Walking is the most basic yet an indispensable mode of transportation since the beginning of human civilization. Further, the amenities demanded by roads for faster connectivity and comfort for the automobile users have drastically affected the overall quality of the walking environment. However, the importance of walking in terms of health benefits and necessity cannot be neglected while facilitating modern means of transportation. Hence it is important to provide comfort conditions for pedestrians during road traffic planning in order to encourage the walking practice. The quality of sidewalks is an important criterion that can affect the likelihood of walking. Most studies evaluate pedestrian facilities using quantitative parameters. The present research aims for evaluating the sidewalks considering both qualitative and quantitative data. Within the scope of the research, ridge regression model, with an accuracy of 97.14% was developed and it was found to be the best-fit among other regression models for the study area. This chapter describes the major findings of this research and scope for future studies.

9.2 MAJOR FINDINGS

The major findings of this research are as follows:

- Various parameters affecting pedestrian LOS for the chosen sidewalks were found through literature review and pilot survey. They were speed, density, flow, space, SW width, SW surface condition, land use type, presence of barriers, presence of street parking, vehicle volume, vehicle speed, presence of guardrails, presence of street vendors, pedestrian volume, lighting facilities.
- The significant factors affecting pedestrian level of service were found out by conducting Pearson correlation using SPSS 25.0 software with 95% confidence interval. It was found that pedestrian density, space, sidewalk surface condition, sidewalk width, and vehicle volume were found to have significant effect on pedestrian level of service score at sidewalks. Thus, the level of service model was developed using these significant factors.
- The three different regression models such as multiple linear regression model,

ridge regression model and random forest regression model were developed. And among them, the best-fit model was adopted. The best-fit model for our study area was ridge regression model with an accuracy of 97.14%.

- LOS classification for PLOS, pedestrian density and space were done using k-means clustering and it was found that as PLOS and pedestrian density increases, the LOS decreases i.e., reaching to worst operating conditions of sidewalks. Whereas, space increases LOS increases i.e., reaching to best operating conditions of sidewalks.

9.3 SCOPE FOR FUTURE STUDY

Future studies could focus on the following:

- The various significant parameters affecting PLOS at sidewalks in India varies between different states/cities. In this study, Kollam district of Kerala was only considered and the model and PLOS classification was done based on Kollam district sidewalk conditions. Hence, future investigations could be made for more districts or cities of Kerala. And a comparative analysis could be performed between different districts or cities of Kerala on the various significant factors affecting PLOS at sidewalks.

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APPENDIX A:

USER PERCEPTION SURVEY FORM FOR PEDESTRIAN LOS

1) Gender: ○ Male ○ Female
2) Age: ○ Child(<18years) ○ Adult(18-50years) ○ Elderly(>50years)
3) How do you value the safety level while using the sidewalk?
   1. Very safe
   2. Safe
   3. Fair
   4. Unsafe
   5. Very unsafe
4) How do you value with respect to security while using the sidewalk?
   1. Highly secure
   2. Secure
   3. Average
   4. Unsecure
   5. Highly unsecure
5) How do you value the comfort level while using the sidewalk?
   1. Extremely comfortable
   2. Comfortable
   3. Fair
   4. Discomfortable
   5. Extremely discomfortable
6) Rate your convenient level while using the sidewalk?
   1. Very convenient
   2. Convenient
   3. Moderately convenient
   4. Inconvenient
   5. Highly inconvenient

APPENDIX B:

RESPONSES OF QUESTIONNAIRE SURVEY

Table B1: Responses of Ammachiveedu Collectorate Sidewalk

Sl. No:	Gender	Age	Safety Level	Security level	Comfort level	Convenient level
1	F	Elderly	Fair	Average	Comfortable	Moderately convenient
2	M	Adult	Fair	Secure	Fair	Moderately convenient
3	F	Adult	Safe	Secure	Fair	Moderately convenient
4	M	Elderly	Safe	Secure	Comfortable	Convenient
5	M	Elderly	Fair	Secure	Fair	Inconvenient
6	M	Child	Safe	Secure	Comfortable	Moderately convenient
7	F	Child	Safe	Secure	Fair	Convenient
8	M	Child	Fair	Average	Fair	Moderately convenient
9	F	Child	Safe	Secure	Fair	Moderately convenient
10	M	Child	Fair	Average	Discomfortable	Inconvenient
11	M	Adult	Safe	Secure	Fair	Moderately convenient
12	M	Adult	Safe	Average	Discomfortable	Moderately convenient
13	F	Child	Safe	Secure	Comfortable	Convenient
14	F	Child	Fair	Secure	Discomfortable	Inconvenient
15	M	Adult	Safe	Secure	Discomfortable	Moderately convenient
16	M	Adult	Fair	Average	Fair	Convenient
17	M	Elderly	Safe	Secure	Comfortable	Inconvenient
18	F	Elderly	Fair	Average	Fair	Moderately convenient
19	F	Child	Safe	Secure	Fair	Moderately convenient
20	M	Child	Fair	Average	Discomfortable	Convenient
21	M	Child	Safe	Secure	Discomfortable	Moderately convenient
22	M	Elderly	Safe	Secure	Fair	Convenient
23	F	Adult	Safe	Secure	Comfortable	Convenient
24	F	Adult	Fair	Average	Discomfortable	Inconvenient
25	M	Adult	Safe	Secure	Discomfortable	Moderately convenient
26	M	Child	Safe	Secure	Comfortable	Convenient
27	M	Child	Safe	Secure	Discomfortable	Moderately convenient
28	M	Child	Safe	Secure	Fair	Moderately convenient
29	F	Child	Fair	Average	Comfortable	Inconvenient
30	F	Adult	Safe	Secure	Fair	Moderately convenient
31	M	Adult	Fair	Average	Fair	Moderately convenient
32	M	Adult	Safe	Secure	Fair	Moderately convenient
33	M	Adult	Safe	Secure	Discomfortable	Inconvenient
34	M	Elderly	Safe	Secure	Fair	Moderately convenient
35	F	Elderly	Fair	Secure	Discomfortable	Inconvenient
36	F	Adult	Fair	Secure	Discomfortable	Moderately convenient
37	F	Child	Safe	Average	Discomfortable	Moderately convenient
38	F	Child	Fair	Average	Fair	Inconvenient

39	M	Child	Safe	Secure	Discomfortable	Moderately convenient
40	M	Child	Safe	Secure	Discomfortable	Moderately convenient
41	M	Adult	Safe	Secure	Fair	Inconvenient
42	F	Adult	Safe	Secure	Comfortable	Convenient
43	M	Adult	Safe	Secure	Fair	Inconvenient
44	F	Adult	Safe	Secure	Discomfortable	Inconvenient
45	F	Adult	Safe	Secure	Discomfortable	Moderately convenient
46	M	Child	Safe	Secure	Discomfortable	Moderately convenient
47	M	Child	Fair	Average	Fair	Inconvenient
48	F	Child	Fair	Secure	Discomfortable	Inconvenient
49	F	Child	Safe	Average	Fair	Moderately convenient
50	M	Adult	Safe	Secure	Discomfortable	Inconvenient
51	F	Adult	Safe	Secure	Discomfortable	Moderately convenient
52	M	Adult	Safe	Secure	Discomfortable	Moderately convenient
53	F	Child	Safe	Secure	Fair	Moderately convenient
54	M	Child	Safe	Secure	Fair	Moderately convenient
55	M	Adult	Fair	Secure	Fair	Inconvenient
56	M	Adult	Safe	Secure	Discomfortable	Moderately convenient
57	M	Adult	Fair	Secure	Discomfortable	Inconvenient
58	M	Elderly	Safe	Secure	Discomfortable	Moderately convenient
59	F	Elderly	Fair	Secure	Discomfortable	Inconvenient

Table B2: Responses of AR Camp Kollam Corporation sidewalk

Sl. No:	Gender	Age	Safety Level	Security Level	Comfort Level	Convenient Level
1	M	Adult	Fair	Secure	Comfortable	Convenient
2	M	Adult	Fair	Secure	Comfortable	Convenient
3	M	Adult	Safe	Average	Fair	Moderately convenient
4	F	Elderly	Safe	Secure	Comfortable	Convenient
5	M	Elderly	Safe	Secure	Comfortable	Convenient
6	M	Child	Fair	Average	Fair	Convenient
7	F	Adult	Safe	Secure	Comfortable	Convenient
8	F	Adult	Safe	Secure	Comfortable	Convenient
9	F	Adult	Safe	Highly secure	Comfortable	Convenient
10	M	Adult	Safe	Secure	Extremely comfortable	Very convenient
11	M	Adult	Safe	Secure	Comfortable	Convenient
12	M	Elderly	Very safe	Secure	Comfortable	Convenient
13	M	Elderly	Safe	Secure	Comfortable	Convenient
14	M	Adult	Very safe	Highly secure	Extremely comfortable	Very convenient
15	M	Adult	Safe	Secure	Comfortable	Convenient
16	F	Adult	Safe	Secure	Fair	Convenient

17	F	Child	Safe	Highly secure	Comfortable	Very convenient
18	F	Adult	Very safe	Highly secure	Comfortable	Moderately convenient
19	F	Elderly	Safe	Secure	Comfortable	Convenient
20	M	Elderly	Very safe	Highly secure	Comfortable	Convenient
21	M	Adult	Safe	Secure	Comfortable	Inconvenient
22	M	Adult	Safe	Highly secure	Fair	Convenient
23	M	Adult	Safe	Secure	Comfortable	Convenient
24	M	Elderly	Safe	Highly secure	Fair	Moderately convenient
25	M	Adult	Very safe	Highly secure	Comfortable	Convenient
26	F	Adult	Safe	Highly secure	Comfortable	Convenient
27	F	Adult	Safe	Secure	Comfortable	Moderately convenient
28	F	Elderly	Safe	Highly secure	Comfortable	Convenient
29	F	Child	Safe	Secure	Comfortable	Convenient
30	M	Elderly	Safe	Secure	Comfortable	Moderately convenient
31	F	Elderly	Safe	Secure	Comfortable	Convenient
32	M	Elderly	Fair	Highly secure	Fair	Inconvenient
33	M	Elderly	Safe	Secure	Comfortable	Convenient
34	F	Elderly	Safe	Secure	Comfortable	Moderately convenient
35	F	Adult	Safe	Secure	Comfortable	Convenient
36	F	Adult	Safe	Secure	Comfortable	Very convenient
37	M	Adult	Safe	Highly secure	Fair	Convenient
38	M	Elderly	Very safe	Highly secure	Comfortable	Moderately convenient
39	F	Elderly	Safe	Highly secure	Comfortable	Convenient
40	M	Adult	Safe	Secure	Fair	Moderately convenient
41	M	Adult	Safe	Highly secure	Comfortable	Convenient
42	F	Adult	Safe	Highly secure	Fair	Moderately convenient
43	M	Adult	Very safe	Highly secure	Comfortable	Convenient
44	M	Adult	Safe	Highly secure	Fair	Moderately convenient
45	F	Elderly	Safe	Secure	Comfortable	Convenient
46	F	Adult	Safe	Secure	Comfortable	Convenient

47	M	Adult	Very safe	Highly secure	Fair	Moderately convenient
48	M	Child	Safe	Secure	Comfortable	Convenient
49	M	Child	Very safe	Highly secure	Discomfortable	Inconvenient
50	F	Child	Safe	Secure	Fair	Moderately convenient
51	F	Elderly	Safe	Highly secure	Fair	Moderately convenient
52	M	Adult	Safe	Highly secure	Comfortable	Convenient
53	M	Elderly	Safe	Highly secure	Fair	Moderately convenient

Table B3: Responses of Chemmamukkau-Ayathil Sidewalk

Sl.No:	Gender	Age	Safety Level	Security Level	Comfort Level	Convenient Level
1	F	Adult	Unsafe	Unsecure	Discomfortable	Inconvenient
2	M	Elderly	Very unsafe	Average	Discomfortable	Inconvenient
3	F	Adult	Fair	Average	Extremely discomfortable	Moderately convenient
4	M	Child	Unsafe	Secure	Discomfortable	Very inconvenient
5	F	Adult	Unsafe	Average	Fair	Inconvenient
6	M	Elderly	Fair	Secure	Discomfortable	Highly inconvenient
7	F	Child	Very unsafe	Highly secure	Discomfortable	Moderately convenient
8	F	Child	Unsafe	Secure	Fair	Inconvenient
9	M	Adult	Unsafe	Average	Fair	Inconvenient
10	M	Elderly	Safe	Secure	Extremely discomfortable	Highly inconvenient
11	M	Adult	Unsafe	Average	Fair	Moderately convenient
12	F	Adult	Average	Unsecure	Fair	Highly inconvenient
13	F	Child	Safe	Average	Discomfortable	Inconvenient
14	F	Child	Very unsafe	Average	Fair	Very convenient
15	F	Child	Safe	Average	Comfortable	Convenient
16	F	Child	Fair	Unsecure	Discomfortable	Moderately convenient
17	M	Child	Unsafe	Unsecure	Extremely discomfortable	Highly inconvenient
18	F	Adult	Unsafe	Unsecure	Discomfortable	Inconvenient
19	M	Elderly	Very unsafe	Average	Discomfortable	Inconvenient
20	F	Adult	Fair	Average	Comfortable	Moderately convenient

21	M	Child	Very unsafe	Secure	Discomfortable	Very inconvenient
22	F	Adult	Unsafe	Average	Fair	Inconvenient
23	M	Elderly	Fair	Secure	Discomfortable	Inconvenient
24	M	Adult	Safe	Average	Fair	Moderately convenient
25	F	Adult	Average	Unsecure	Fair	Highly inconvenient
26	F	Child	Safe	Average	Discomfortable	Inconvenient
27	F	Child	Very unsafe	Average	Fair	Inconvenient
28	F	Child	Safe	Average	Extremely discomfortable	Highly inconvenient
29	F	Child	Fair	Unsecure	Discomfortable	Moderately convenient
30	F	Child	Very unsafe	Average	Fair	Inconvenient
31	F	Child	Safe	Average	Discomfortable	Convenient
32	F	Child	Fair	Unsecure	Discomfortable	Moderately convenient
33	M	Child	Unsafe	Unsecure	Discomfortable	Highly inconvenient
34	F	Adult	Unsafe	Unsecure	Discomfortable	Inconvenient
35	M	Elderly	Very unsafe	Average	Discomfortable	Inconvenient
36	F	Child	Fair	Highly secure	Discomfortable	Moderately convenient
37	F	Child	Unsafe	Secure	Fair	Inconvenient
38	F	Adult	Fair	Average	Fair	Inconvenient
39	F	Elderly	Very unsafe	Secure	Extremely discomfortable	Highly inconvenient
40	M	Child	Fair	Average	Fair	Moderately convenient
41	M	Child	Unsafe	Average	Discomfortable	Inconvenient
42	F	Child	Very unsafe	Unsecure	Fair	Moderately convenient
43	F	Child	Fair	Unsecure	Discomfortable	Highly inconvenient
44	F	Child	Unsafe	Secure	Fair	Inconvenient
45	F	Adult	Safe	Unsecure	Discomfortable	Moderately convenient
46	F	Elderly	Unsafe	Unsecure	Discomfortable	Inconvenient
47	F	Elderly	Safe	Average	Discomfortable	Moderately convenient
48	M	Elderly	Unsafe	Secure	Discomfortable	Highly inconvenient
49	M	Child	Safe	Secure	Fair	Moderately convenient
50	M	Child	Fair	Average	Fair	Moderately convenient
51	M	Elderly	Fair	Unsecure	Discomfortable	Inconvenient
52	F	Child	Unsafe	Average	Extremely discomfortable	Highly inconvenient

53	F	Child	Safe	Secure	Fair	Moderately convenient
54	F	Elderly	Unsafe	Unsecure	Extremely discomfortable	Inconvenient
55	M	Elderly	Safe	Secure	Comfortable	Convenient
56	M	Child	Unsafe	Secure	Discomfortable	Highly inconvenient
57	F	Child	Unsafe	Unsecure	Fair	Inconvenient
58	F	Child	Fair	Unsecure	Discomfortable	Moderately convenient
59	F	Child	Safe	Average	Discomfortable	Moderately convenient
60	F	Child	Unsafe	Secure	Fair	Moderately convenient
61	F	Child	Safe	Unsecure	Discomfortable	Inconvenient

Table B4: Responses of Chemmamukkau-College Junction Sidewalk

Sl.No:	Gender	Age	Safety Level	Security Level	Comfort Level	Convenient Level
1	F	Adult	Very safe	Secure	Discomfortable	Convenient
2	M	Elderly	Unsafe	Average	Fair	Convenient
3	F	Adult	Unsafe	Secure	Discomfortable	Highly inconvenient
4	M	Child	Very unsafe	Highly secure	Discomfortable	Very convenient
5	F	Adult	Unsafe	Unsecure	Fair	Inconvenient
6	M	Elderly	Safe	Average	Comfortable	Convenient
7	F	Child	Safe	Highly secure	Discomfortable	Highly inconvenient
8	F	Child	Very unsafe	Secure	Fair	Convenient
9	M	Adult	Unsafe	Average	Discomfortable	Convenient
10	M	Elderly	Safe	Secure	Extremely discomfortable	Convenient
11	M	Adult	Very unsafe	Average	Comfortable	Very convenient
12	F	Adult	Safe	Secure	Fair	Convenient
13	F	Child	Unsafe	Average	Extremely discomfortable	Convenient
14	F	Child	Unsafe	Secure	Fair	Very convenient
15	F	Child	Safe	Average	Discomfortable	Convenient
16	F	Child	Fair	Secure	Discomfortable	Moderately convenient
17	M	Child	Unsafe	Average	Comfortable	Highly inconvenient
18	F	Adult	Safe	Highly secure	Fair	Convenient
19	M	Elderly	Unsafe	Secure	Fair	Convenient

20	F	Adult	Very safe	Average	Discomfortable	Moderately convenient
21	M	Child	Unsafe	Highly secure	Comfortable	Very convenient
22	F	Adult	Safe	Unsecure	Fair	Convenient
23	M	Elderly	Unsafe	Secure	Discomfortable	Convenient
24	F	Child	Unsafe	Highly secure	Discomfortable	Convenient
25	F	Child	Unsafe	Unsecure	Fair	Convenient
26	M	Adult	Safe	Secure	Comfortable	Convenient
27	M	Elderly	Unsafe	Average	Extremely comfortable	Convenient
28	M	Adult	Very safe	Average	Discomfortable	Convenient
29	M	Adult	Safe	Unsecure	Discomfortable	INCONVENIENT
30	M	Elderly	Unsafe	Average	Extremely comfortable	Convenient
31	M	Adult	Safe	Average	Comfortable	Inconvenient
32	F	Adult	Unsafe	Unsecure	Fair	Convenient
33	F	Child	Safe	Average	Discomfortable	Inconvenient
34	F	Child	Unsafe	Average	Fair	Very convenient
35	F	Child	Safe	Average	Discomfortable	Inconvenient
36	F	Adult	Very safe	Highly secure	Fair	Convenient
37	M	Elderly	Safe	Unsecure	Fair	Inconvenient
38	F	Adult	Unsafe	Secure	Comfortable	Convenient
39	M	Child	Unsafe	Highly secure	Discomfortable	Very convenient
40	F	Adult	Unsafe	Average	Fair	Inconvenient
41	M	Elderly	Fair	Secure	Discomfortable	Convenient
42	F	Child	Unsafe	Highly secure	Comfortable	Inconvenient
43	F	Child	Unsafe	Unsecure	Discomfortable	Convenient
44	M	Adult	Safe	Average	Comfortable	Convenient
45	M	Elderly	Unsafe	Secure	Extremely comfortable	Inconvenient
46	M	Adult	Safe	Average	Comfortable	Moderately convenient
47	M	Adult	Unsafe	Secure	Discomfortable	Convenient
48	M	Elderly	Safe	Average	Extremely comfortable	Inconvenient
49	F	Adult	Very safe	Secure	Comfortable	Convenient
50	M	Child	Safe	Highly secure	Comfortable	Very convenient
51	F	Adult	Unsafe	Secure	Fair	Inconvenient
52	M	Elderly	Safe	Average	Comfortable	Inconvenient
53	F	Child	Very unsafe	Highly secure	Discomfortable	Convenient
54	F	Child	Safe	Average	Comfortable	Convenient

55	M	Adult	Very unsafe	Average	Discomfortable	Inconvenient
56	M	Elderly	Unsafe	Secure	Extremely discomfortable	Convenient
57	M	Adult	Very safe	Average	Comfortable	Moderately convenient
58	F	Adult	Unsafe	Unsecure	Fair	Convenient
59	F	Child	Safe	Average	Comfortable	Convenient
60	F	Child	Unsafe	Secure	Discomfortable	Very convenient
61	F	Child	Safe	Average	Comfortable	Convenient
62	F	Child	Unsafe	Secure	Discomfortable	Moderately convenient
63	M	Child	Safe	Average	Discomfortable	Convenient
64	F	Adult	Unsafe	Highly secure	Discomfortable	Convenient
65	M	Elderly	Unsafe	Secure	Fair	Convenient
66	F	Adult	Safe	Average	Comfortable	Convenient
67	F	Child	Very safe	Highly secure	Discomfortable	Convenient
68	F	Child	Unsafe	Secure	Comfortable	Convenient
69	F	Child	Safe	Average	Extremely comfortable	Convenient
70	M	Child	Safe	Highly secure	Comfortable	Very convenient
71	M	Child	Unsafe	Highly secure	Extremely discomfortable	Very convenient
72	M	Adult	Safe	Average	Discomfortable	Convenient
73	F	Elderly	Unsafe	Secure	Comfortable	Inconvenient
74	M	Child	Safe	Highly secure	Extremely discomfortable	Convenient
75	M	Child	Very safe	Highly secure	Comfortable	Inconvenient
76	F	Elderly	Unsafe	Highly secure	Extremely discomfortable	Very inconvenient
77	F	Elderly	Safe	Average	Extremely comfortable	Convenient
78	F	Child	Very unsafe	Secure	Discomfortable	Very convenient
79	F	Child	Unsafe	Highly secure	Discomfortable	Convenient
80	M	Child	Safe	Highly secure	Extremely discomfortable	Very convenient
81	F	Adult	Unsafe	Highly secure	Comfortable	Convenient
82	F	Child	Safe	Secure	Extremely comfortable	Inconvenient
83	M	Elderly	Unsafe	Average	Discomfortable	Inconvenient
84	M	Elderly	Very unsafe	Highly secure	Discomfortable	Inconvenient
85	M	Adult	Safe	Average	Extremely discomfortable	Convenient

86	F	Adult	Unsafe	Highly secure	Discomfortable	Convenient
87	F	Child	Safe	Secure	Discomfortable	Convenient
88	F	Child	Unsafe	Highly secure	Discomfortable	Inconvenient
89	M	Child	Safe	Highly secure	Discomfortable	Convenient
90	M	Adult	Unsafe	Secure	Extremely discomfortable	Convenient
91	M	Elderly	Very safe	Highly secure	Extremely comfortable	Very convenient
92	F	Child	Very unsafe	Average	Extremely discomfortable	Convenient
93	F	Child	Unsafe	Highly secure	Discomfortable	Inconvenient

Table B5: Responses of College Junction SN College Sidewalk

SL.NO	Gender	Age	Saftey Level	Security Level	Comfort Level	Convenient Level
1	F	Adult	Safe	Secure	Comfortable	Inconvenient
2	F	Adult	Safe	Secure	Fair	Convenient
3	F	Adult	Fair	Average	Discomfortable	Moderately convenient
4	F	Adult	Fair	Average	Extremely discomfortable	Inconvenient
5	F	Adult	Safe	Secure	Discomfortable	Inconvenient
6	F	Adult	Safe	Secure	Discomfortable	Highly inconvenient
7	F	Adult	Safe	Secure	Fair	Moderately convenient
8	F	Adult	Unsafe	Secure	Fair	Moderately convenient
9	F	Adult	Safe	Secure	Discomfortable	Inconvenient
10	F	Adult	Safe	Secure	Discomfortable	Moderately convenient
11	F	Adult	Safe	Average	Discomfortable	Highly inconvenient
12	F	Adult	Safe	Secure	Extremely discomfortable	Highly inconvenient
13	M	Adult	Unsafe	Secure	Discomfortable	Inconvenient
14	M	Elderly	Fair	Secure	Discomfortable	Inconvenient
15	F	Adult	Fair	Secure	Discomfortable	Inconvenient
16	F	Adult	Safe	Secure	Fair	Moderately convenient
17	F	Adult	Safe	Secure	Discomfortable	Moderately convenient
18	F	Adult	Fair	Average	Discomfortable	Moderately convenient
19	M	Elderly	Safe	Secure	Fair	Inconvenient

20	M	Elderly	Safe	Secure	Discomfortable	Highly inconvenient
21	F	Adult	Fair	Average	Fair	Moderately convenient
22	F	Adult	Safe	Average	Extremely discomfortable	Inconvenient
23	F	Adult	Safe	Secure	Discomfortable	Inconvenient
24	F	Adult	Safe	Average	Discomfortable	Moderately convenient
25	F	Adult	Fair	Secure	Extremely discomfortable	Inconvenient
26	F	Adult	Fair	Average	Extremely discomfortable	Highly inconvenient
27	F	Adult	Safe	Secure	Discomfortable	Inconvenient
28	F	Adult	Fair	Secure	Fair	Moderately convenient
29	M	Adult	Safe	Secure	Discomfortable	Inconvenient
30	M	Adult	Safe	Secure	Fair	Moderately convenient
31	F	Adult	Fair	Average	Fair	Moderately convenient
32	F	Elderly	Safe	Secure	Discomfortable	Inconvenient
33	M	Elderly	Fair	Secure	Extremely discomfortable	Highly inconvenient
34	M	Elderly	Safe	Secure	Discomfortable	Inconvenient
35	M	Elderly	Safe	Secure	Discomfortable	Inconvenient
36	F	Adult	Safe	Average	Discomfortable	Inconvenient
37	F	Adult	Fair	Average	Extremely discomfortable	Highly inconvenient
38	F	Adult	Fair	Secure	Discomfortable	Inconvenient
39	F	Adult	Fair	Secure	Extremely discomfortable	Highly inconvenient
40	F	Adult	Safe	Secure	Discomfortable	Inconvenient
41	F	Adult	Fair	Average	Discomfortable	Inconvenient
42	F	Adult	Safe	Secure	Fair	Moderately convenient
43	M	Adult	Safe	Secure	Discomfortable	Moderately convenient
44	M	Adult	Safe	Secure	Fair	Moderately convenient
45	F	Elderly	Fair	Average	Discomfortable	Inconvenient
46	F	Elderly	Safe	Secure	Discomfortable	Highly inconvenient
47	F	Adult	Safe	Secure	Comfortable	Convenient
48	F	Adult	Fair	Secure	Discomfortable	Moderately convenient
49	F	Adult	Safe	Secure	Fair	Inconvenient
50	F	Adult	Fair	Average	Extremely discomfortable	Moderately convenient
51	M	Elderly	Safe	Secure	Discomfortable	Inconvenient

52	M	Elderly	Safe	Secure	Fair	Moderately convenient
53	F	Elderly	Fair	Average	Discomfortable	Inconvenient
54	F	Elderly	Safe	Secure	Extremely discomfortable	Highly inconvenient
55	M	Child	Safe	Secure	Discomfortable	Inconvenient
56	M	Adult	Safe	Secure	Discomfortable	Inconvenient
57	M	Adult	Fair	Average	Extremely discomfortable	Moderately convenient
58	M	Adult	Safe	Secure	Discomfortable	Highly inconvenient
59	M	Adult	Fair	Average	Discomfortable	Inconvenient
60	M	Adult	Safe	Secure	Extremely discomfortable	Inconvenient
61	M	Adult	Safe	Secure	Discomfortable	Highly inconvenient
62	M	Adult	Safe	Secure	Discomfortable	Inconvenient
63	F	Adult	Safe	Secure	Fair	Moderately convenient
64	F	Adult	Safe	Secure	Discomfortable	Highly inconvenient
65	F	Adult	Fair	Average	Discomfortable	Inconvenient
66	F	Adult	Safe	Secure	Discomfortable	Inconvenient
67	F	Adult	Safe	Secure	Discomfortable	Highly inconvenient
68	F	Adult	Safe	Secure	Discomfortable	Highly inconvenient
69	F	Adult	Safe	Average	Discomfortable	Inconvenient
70	F	Adult	Fair	Secure	Discomfortable	Moderately convenient
71	F	Adult	Safe	Secure	Discomfortable	Highly inconvenient
72	M	Elderly	Safe	Secure	Extremely discomfortable	Moderately convenient
73	F	Elderly	Safe	Secure	Discomfortable	Inconvenient
74	M	Adult	Safe	Secure	Discomfortable	Inconvenient
75	M	Adult	Safe	Average	Extremely discomfortable	Moderately convenient
76	M	Adult	Safe	Secure	Extremely discomfortable	Highly inconvenient
77	M	Adult	Safe	Secure	Discomfortable	Inconvenient
78	M	Adult	Safe	Secure	Discomfortable	Highly inconvenient
79	M	Adult	Safe	Secure	Discomfortable	Inconvenient
80	F	Adult	Safe	Secure	Discomfortable	Inconvenient
81	F	Adult	Safe	Average	Discomfortable	Inconvenient
82	F	Adult	Safe	Secure	Extremely discomfortable	Highly inconvenient
83	F	Adult	Safe	Secure	Discomfortable	Moderately convenient
84	F	Adult	Safe	Secure	Discomfortable	Inconvenient

85	F	Adult	Fair	Average	Discomfortable	Highly inconvenient
86	M	Adult	Safe	Secure	Extremely discomfortable	Highly inconvenient
87	M	Adult	Safe	Secure	Discomfortable	Highly inconvenient
88	F	Adult	Safe	Average	Discomfortable	Inconvenient
89	F	Adult	Safe	Secure	Discomfortable	Highly inconvenient
90	M	Adult	Safe	Secure	Discomfortable	Highly inconvenient
91	M	Adult	Safe	Secure	Extremely discomfortable	Highly inconvenient
92	F	Adult	Safe	Average	Discomfortable	Highly inconvenient
93	M	Adult	Safe	Secure	Discomfortable	Inconvenient
94	F	Adult	Safe	Secure	Discomfortable	Highly inconvenient
95	F	Adult	Safe	Secure	Discomfortable	Moderately convenient
96	F	Adult	Safe	Secure	Discomfortable	Inconvenient
97	F	Adult	Safe	Average	Extremely discomfortable	Highly inconvenient
98	F	Adult	Safe	Secure	Discomfortable	Inconvenient
99	F	Adult	Fair	Secure	Discomfortable	Highly inconvenient
100	M	Adult	Safe	Secure	Discomfortable	Inconvenient
101	M	Adult	Safe	Secure	Discomfortable	Highly inconvenient
102	F	Adult	Fair	Secure	Discomfortable	Inconvenient
103	F	Adult	Safe	Secure	Extremely discomfortable	Highly inconvenient

Table B6: Responses of Chinnakkada Sidewalk

Sl.No:	Gender	Age	Safety Level	Security Level	Comfort Level	Convenient Level
1	F	Adult	Fair	Secure	Discomfortable	Highly inconvenient
2	M	Adult	Unsafe	Highly secure	Fair	Moderately convenient
3	M	Elderly	Fair	Highly secure	Fair	Highly inconvenient
4	M	Child	Safe	Secure	Discomfortable	Inconvenient
5	M	Child	Unsafe	Secure	Discomfortable	Moderately convenient
6	F	Child	Fair	Highly secure	Fair	Highly inconvenient
7	M	Elderly	Unsafe	Secure	Discomfortable	Inconvenient
8	M	Elderly	Fair	Secure	Fair	Inconvenient

9	M	Adult	Safe	Average	Fair	Moderately convenient
10	M	Elderly	Unsafe	Highly secure	Discomfortable	Inconvenient
11	F	Elderly	Unsafe	Secure	Fair	Inconvenient
12	M	Adult	Safe	Secure	Discomfortable	Inconvenient
13	M	Adult	Unsafe	Highly secure	Extremely discomfortable	Highly inconvenient
14	F	Adult	Unsafe	Secure	Discomfortable	Inconvenient
15	F	Elderly	Unsafe	Average	Fair	Highly inconvenient
16	F	Child	Safe	Secure	Fair	Inconvenient
17	M	Elderly	Unsafe	Highly secure	Extremely discomfortable	Highly inconvenient
18	M	Adult	Unsafe	Secure	Fair	Inconvenient
19	M	Adult	Fair	Average	Extremely discomfortable	Highly inconvenient
20	F	Adult	Unsafe	Highly secure	Extremely discomfortable	Highly inconvenient
21	F	Adult	Unsafe	Secure	Discomfortable	Inconvenient
22	F	Elderly	Unsafe	Highly secure	Extremely discomfortable	Inconvenient
23	F	Elderly	Fair	Secure	Discomfortable	Inconvenient
24	M	Elderly	Fair	Highly secure	Extremely discomfortable	Highly inconvenient
25	M	Elderly	Unsafe	Highly secure	Discomfortable	Inconvenient
26	M	Adult	Safe	Secure	Discomfortable	Inconvenient
27	F	Adult	Unsafe	Highly secure	Fair	Moderately convenient
28	M	Elderly	Unsafe	Secure	Discomfortable	Moderately convenient
29	M	Elderly	Safe	Secure	Discomfortable	Inconvenient
30	M	Adult	Unsafe	Secure	Extremely discomfortable	Highly inconvenient
31	M	Adult	Fair	Highly secure	Discomfortable	Inconvenient
32	F	Elderly	Safe	Secure	Discomfortable	Moderately convenient
33	F	Child	Unsafe	Secure	Discomfortable	Inconvenient
34	F	Elderly	Safe	Highly secure	Discomfortable	Moderately convenient
35	F	Elderly	Unsafe	Secure	Discomfortable	Moderately convenient
36	M	Adult	Safe	Highly secure	Fair	Moderately convenient
37	M	Adult	Safe	Secure	Discomfortable	Inconvenient
38	F	Elderly	Unsafe	Secure	Extremely discomfortable	Highly inconvenient
39	F	Elderly	Safe	Highly secure	Discomfortable	Inconvenient

40	F	Elderly	Unsafe	Secure	Fair	Highly inconvenient
41	F	Child	Safe	Highly secure	Discomfortable	Inconvenient
42	M	Adult	Unsafe	Secure	Extremely discomfortable	Inconvenient
43	M	Adult	Unsafe	Secure	Discomfortable	Inconvenient
44	M	Adult	Safe	Secure	Extremely discomfortable	Inconvenient
45	M	Elderly	Unsafe	Average	Discomfortable	Inconvenient
46	F	Elderly	Unsafe	Highly secure	Extremely discomfortable	Moderately convenient
47	F	Elderly	Unsafe	Secure	Discomfortable	Inconvenient
48	M	Elderly	Safe	Secure	Discomfortable	Inconvenient
49	M	Elderly	Fair	Secure	Fair	Moderately convenient
50	M	Adult	Unsafe	Highly secure	Discomfortable	Inconvenient
51	M	Adult	Unsafe	Highly secure	Fair	Highly inconvenient
52	M	Elderly	Unsafe	Secure	Discomfortable	Inconvenient
53	F	Adult	Unsafe	Highly secure	Discomfortable	Inconvenient
54	F	Adult	Unsafe	Secure	Extremely discomfortable	Highly inconvenient
55	F	Adult	Unsafe	Highly secure	Discomfortable	Highly inconvenient
56	F	Adult	Unsafe	Secure	Discomfortable	Inconvenient
57	M	Elderly	Unsafe	Secure	Discomfortable	Inconvenient
58	M	Elderly	Unsafe	Secure	Discomfortable	Highly inconvenient
59	M	Adult	Unsafe	Secure	Fair	Inconvenient
60	M	Elderly	Fair	Average	Discomfortable	Highly inconvenient
61	M	Elderly	Unsafe	Secure	Fair	Moderately convenient
62	M	Elderly	Unsafe	Highly secure	Discomfortable	Inconvenient
63	M	Elderly	Unsafe	Secure	Fair	Highly inconvenient
64	M	Elderly	Unsafe	Secure	Discomfortable	Inconvenient
65	M	Elderly	Fair	Highly secure	Discomfortable	Highly inconvenient
66	M	Adult	Fair	Highly secure	Fair	Inconvenient
67	M	Adult	Unsafe	Secure	Discomfortable	Highly inconvenient
68	M	Adult	Unsafe	Secure	Fair	Moderately convenient
69	M	Adult	Safe	Highly secure	Discomfortable	Highly inconvenient

70	F	Adult	Unsafe	Secure	Fair	Highly inconvenient
71	F	Adult	Fair	Highly secure	Discomfortable	Inconvenient
72	M	Elderly	Unsafe	Secure	Discomfortable	Highly inconvenient
73	M	Elderly	Safe	Highly secure	Fair	Moderately convenient
74	M	Adult	Unsafe	Highly secure	Extremely discomfortable	Moderately convenient
75	M	Adult	Safe	Highly secure	Discomfortable	Moderately convenient
76	M	Adult	Unsafe	Highly secure	Extremely discomfortable	Inconvenient
77	F	Adult	Safe	Highly secure	Discomfortable	Inconvenient
78	F	Adult	Fair	Secure	Extremely discomfortable	Highly inconvenient
79	F	Elderly	Unsafe	Secure	Fair	Inconvenient
80	M	Elderly	Unsafe	Highly secure	Discomfortable	Inconvenient
81	F	Elderly	Unsafe	Highly secure	Extremely discomfortable	Highly inconvenient
82	F	Elderly	Unsafe	Highly secure	Discomfortable	Inconvenient
83	M	Adult	Unsafe	Secure	Fair	Moderately convenient
84	M	Adult	Fair	Highly secure	Discomfortable	Inconvenient
85	F	Adult	Fair	Secure	Extremely discomfortable	Highly inconvenient
86	F	Adult	Unsafe	Secure	Extremely discomfortable	Moderately convenient
87	M	Adult	Fair	Highly secure	Discomfortable	Highly inconvenient
88	M	Child	Unsafe	Highly secure	Extremely discomfortable	Moderately convenient
89	F	Child	Safe	Secure	Discomfortable	Inconvenient
90	F	Elderly	Unsafe	Highly secure	Discomfortable	Highly inconvenient
91	M	Elderly	Unsafe	Secure	Fair	Inconvenient
92	M	Elderly	Unsafe	Secure	Fair	Inconvenient
93	F	Elderly	Fair	Highly secure	Extremely discomfortable	Highly inconvenient
94	M	Adult	Unsafe	Secure	Discomfortable	Inconvenient
95	F	Adult	Safe	Secure	Discomfortable	Moderately convenient
96	F	Adult	Unsafe	Secure	Fair	Inconvenient
97	F	Child	Unsafe	Secure	Discomfortable	Highly inconvenient
98	M	Child	Safe	Highly secure	Fair	Inconvenient

99	M	Elderly	Unsafe	Secure	Discomfortable	Highly inconvenient

Table B7: Responses of Kochupilamoodu-Beach Road Sidewalk

Sl.No:	Gender	Age	Safety Level	Security Level	Comfort Level	Convenient Level
1	M	Adult	Safe	Secure	Fair	Convenient
2	M	Adult	Fair	Secure	Comfortable	Moderately convenient
3	F	Child	Safe	Secure	Comfortable	Convenient
4	F	Elderly	Very safe	Average	Fair	Inconvenient
5	F	Adult	Safe	Secure	Comfortable	Convenient
6	F	Adult	Fair	Unsecure	Comfortable	Convenient
7	M	Elderly	Safe	Secure	Fair	Moderately convenient
8	M	Elderly	Unsafe	Secure	Comfortable	Convenient
9	F	Child	Safe	Secure	Discomfortable	Convenient
10	M	Adult	Safe	Unsecure	Comfortable	Inconvenient
11	M	Elderly	Very safe	Secure	Extremely comfortable	Convenient
12	M	Adult	Safe	Secure	Discomfortable	Convenient
13	M	Child	Safe	Highly secure	Comfortable	Moderately convenient
14	M	Child	Very safe	Secure	Comfortable	Convenient
15	M	Child	Safe	Secure	Fair	Very convenient
16	F	Child	Safe	Average	Comfortable	Convenient
17	F	Child	Very safe	Secure	Extremely comfortable	Very convenient
18	F	Child	Safe	Secure	Comfortable	Convenient
19	M	Adult	Fair	Highly secure	Comfortable	Moderately convenient
20	M	Adult	Safe	Secure	Fair	Convenient
21	M	Adult	Very safe	Highly secure	Comfortable	Inconvenient
22	M	Elderly	Safe	Secure	Comfortable	Convenient
23	F	Elderly	Safe	Average	Extremely comfortable	Highly inconvenient
24	M	Elderly	Fair	Secure	Fair	Moderately convenient
25	M	Adult	Unsafe	Highly secure	Discomfortable	Inconvenient
26	M	Adult	Fair	Secure	Extremely discomfortable	Moderately convenient
27	M	Adult	Unsafe	Average	Fair	Inconvenient
28	F	Adult	Fair	Secure	Fair	Inconvenient
29	F	Adult	Fair	Secure	Fair	Moderately convenient

30	F	Elderly	Safe	Average	Comfortable	Highly inconvenient
31	F	Child	Unsafe	Average	Discomfortable	Inconvenient
32	M	Child	Unsafe	Secure	Extremely discomfortable	Inconvenient
33	M	Child	Safe	Secure	Discomfortable	Moderately convenient
34	F	Child	Unsafe	Average	Extremely discomfortable	Highly inconvenient
35	F	Child	Unsafe	Unsecure	Fair	Moderately convenient
36	F	Elderly	Unsafe	Secure	Comfortable	Moderately convenient
37	F	Elderly	Fair	Unsecure	Discomfortable	Inconvenient
38	F	Adult	Safe	Secure	Discomfortable	Moderately convenient
39	F	Adult	Safe	Secure	Fair	Inconvenient
40	M	Child	Safe	Secure	Comfortable	Moderately convenient
41	F	Child	Unsafe	Unsecure	Comfortable	Convenient
42	F	Child	Safe	Secure	Discomfortable	Inconvenient
43	M	Elderly	Fair	Average	Extremely discomfortable	Inconvenient
44	M	Elderly	Fair	Average	Discomfortable	Inconvenient
45	M	Elderly	Safe	Secure	Discomfortable	Moderately convenient
46	F	Elderly	Safe	Secure	Discomfortable	Inconvenient
47	M	Adult	Fair	Average	Fair	Convenient
48	F	Adult	Safe	Secure	Fair	Moderately convenient
49	F	Adult	Fair	Average	Discomfortable	Inconvenient
50	F	Adult	Safe	Secure	Discomfortable	Moderately convenient
51	M	Adult	Safe	Secure	Fair	Inconvenient
52	M	Adult	Safe	Secure	Discomfortable	Inconvenient
53	F	Child	Safe	Highly secure	Extremely discomfortable	Inconvenient
54	M	Child	Safe	Secure	Discomfortable	Highly inconvenient
55	F	Child	Fair	Secure	Fair	Moderately convenient
56	F	Child	Unsafe	Average	Discomfortable	Inconvenient
57	M	Adult	Safe	Secure	Fair	Inconvenient
58	M	Adult	Unsafe	Secure	Extremely discomfortable	Highly inconvenient
59	M	Elderly	Unsafe	Secure	Discomfortable	Inconvenient
60	M	Elderly	Unsafe	Average	Discomfortable	Highly inconvenient
61	F	Elderly	Safe	Secure	Discomfortable	Inconvenient
62	F	Elderly	Unsafe	Average	Extremely discomfortable	Highly inconvenient

63	F	Adult	Fair	Average	Discomfortable	Inconvenient

Table B8: Responses of Railway Station Road Sidewalk

SL.No:	Gender	Age	Safety Level	Security Level	Comfort Level	Convenient Level
1	M	Adult	Unsafe	Average	Extremely discomfortable	Highly inconvenient
2	M	Adult	Very unsafe	Average	Discomfortable	Highly inconvenient
3	F	Elderly	Unsafe	Unsecure	Discomfortable	Inconvenient
4	M	Adult	Unsafe	Secure	Extremely discomfortable	Highly inconvenient
5	F	Adult	Unsafe	Secure	Discomfortable	Inconvenient
6	M	Adult	Unsafe	Average	Discomfortable	Highly inconvenient
7	M	Elderly	Unsafe	Average	Extremely discomfortable	Highly inconvenient
8	M	Elderly	Very unsafe	Average	Discomfortable	Inconvenient
9	F	Elderly	Unsafe	Secure	Discomfortable	Highly inconvenient
10	F	Adult	Very unsafe	Average	Extremely discomfortable	Highly inconvenient
11	M	Adult	Very unsafe	Unsecure	Discomfortable	Inconvenient
12	M	Adult	Unsafe	Unsecure	Extremely discomfortable	Highly inconvenient
13	M	Elderly	Unsafe	Secure	Discomfortable	Inconvenient
14	M	Elderly	Unsafe	Unsecure	Extremely discomfortable	Highly inconvenient
15	M	Adult	Unsafe	Unsecure	Discomfortable	Inconvenient
16	M	Adult	Unsafe	Average	Extremely discomfortable	Highly inconvenient
17	F	Adult	Unsafe	Average	Extremely discomfortable	Inconvenient
18	F	Adult	Very unsafe	Average	Extremely discomfortable	Highly inconvenient
19	F	Elderly	Unsafe	Average	Discomfortable	Inconvenient
20	M	Elderly	Unsafe	Secure	Extremely discomfortable	Highly inconvenient
21	M	Adult	Unsafe	Secure	Discomfortable	Inconvenient
22	M	Adult	Unsafe	Average	Extremely discomfortable	Highly inconvenient
23	M	Elderly	Very unsafe	Average	Discomfortable	Inconvenient
24	F	Adult	Very unsafe	Secure	Discomfortable	Highly inconvenient
25	M	Adult	Very unsafe	Average	Discomfortable	Inconvenient
26	M	Adult	Very unsafe	Average	Discomfortable	Highly inconvenient
27	F	Elderly	Unsafe	Average	Discomfortable	Inconvenient

28	M	Elderly	Unsafe	Unsecure	Extremely discomfortable	Highly inconvenient
29	F	Adult	Very unsafe	Unsecure	Discomfortable	Inconvenient
30	F	Adult	Very unsafe	Secure	Extremely discomfortable	Highly inconvenient
31	M	Adult	Unsafe	Secure	Discomfortable	Inconvenient
32	M	Elderly	Unsafe	Secure	Extremely discomfortable	Highly inconvenient
33	M	Elderly	Unsafe	Secure	Discomfortable	Inconvenient
34	F	Elderly	Very unsafe	Average	Extremely discomfortable	Highly inconvenient
35	F	Elderly	Very unsafe	Secure	Discomfortable	Highly inconvenient
36	F	Adult	Very unsafe	Average	Extremely discomfortable	Inconvenient
37	M	Adult	Unsafe	Average	Discomfortable	Inconvenient
38	M	Adult	Safe	Average	Discomfortable	Highly inconvenient
39	M	Elderly	Unsafe	Average	Discomfortable	Inconvenient
40	M	Elderly	Unsafe	Average	Extremely discomfortable	Inconvenient
41	F	Elderly	Unsafe	Average	Discomfortable	Inconvenient
42	F	Adult	Unsafe	Average	Extremely discomfortable	Highly inconvenient
43	M	Adult	Unsafe	Secure	Discomfortable	Inconvenient
44	M	Adult	Very unsafe	Average	Discomfortable	Highly inconvenient
45	M	Elderly	Unsafe	Average	Extremely discomfortable	Inconvenient
46	F	Elderly	Unsafe	Average	Extremely discomfortable	Highly inconvenient
47	F	Adult	Unsafe	Average	Discomfortable	Inconvenient
48	M	Adult	Very unsafe	Secure	Discomfortable	Inconvenient
49	M	Elderly	Unsafe	Secure	Extremely discomfortable	Highly inconvenient
50	M	Elderly	Unsafe	Average	Extremely discomfortable	Highly inconvenient
51	M	Adult	Unsafe	Secure	Extremely discomfortable	Highly inconvenient
52	F	Adult	Unsafe	Average	Discomfortable	Inconvenient
53	M	Adult	Unsafe	Average	Discomfortable	Highly inconvenient
54	M	Adult	Very unsafe	Average	Discomfortable	Inconvenient
55	M	Elderly	Very unsafe	Average	Extremely discomfortable	Inconvenient
56	F	Adult	Unsafe	Average	Extremely discomfortable	Highly inconvenient
57	F	Elderly	Unsafe	Unsecure	Discomfortable	Inconvenient

APPENDIX C:

REGRESSION MODELS

MULTIPLE LINEAR REGRESSION

Import Data

```
[ ] import pandas as pd
    import numpy as np
```

Read Files

```
[ ] data = pd.read_excel('/content/drive/MyDrive/Colab Notebooks/SPSS PEARSON-fin new.xlsx')
    data
```

	SIDEWALK	PLOS SCORE	PEDESTRIAN SPEED	PEDESTRIAN DENSITY	PEDESTRIAN FLOW	SPACE	SW SURFACE CONDITION	SW WIDTH	LAND USE TYPE	PRESENCE OF BARRIERS	PRESENCE OF STREET PARKING	VEHICLE VOLUME	VEHICLE SPEED	PRESENCE OF GUARD RAILS	PRESENCE OF STREET VENDORS	PEDESTRIAN VOLUME
0	CHEMMAMUKKAU - AYATHIL ROAD	3.6	0.93	0.240	10.40	4.16	4	1.8	6	1	1	441	28	1	0	1096
1	kochupilamoodu-beach	2.8	1.06	0.180	8.70	5.56	2	1.5	4	2	0	301	32	0	0	797
2	chinnakkada	3.2	1.53	0.347	17.00	2.88	3	2.3	2	0	1	523	38	1	1	1245

Splitting the dataset for training and testing in 70:30 ratio

```
[ ] from sklearn.model_selection import train_test_split
    from sklearn.linear_model import LinearRegression

    model = LinearRegression()

    x_train, x_test, y_train, y_test = train_test_split(x, y, test_size = 0.3)
```

Fitting the model and finding its accuracy

```
[ ] y_predict = model.predict(x_test)
    y_predict

    array([1.90193655, 2.82959281, 4.21469085])
```

```
# Calculate the absolute errors
errors = abs(y_predict - y_test)
# Print out the mean absolute error (mae)
print('Mean Absolute Error:', round(np.mean(errors), 2), 'degrees.')

# Calculate mean absolute percentage error (MAPE)
```

```
[ ]
# Calculate mean absolute percentage error (MAPE)
mape = 100 * (errors / y_test)
# Calculate and display accuracy
accuracy = 100 - np.mean(mape)
print('Accuracy:', round(accuracy, 2), '%.')
```

```
Mean Absolute Error: 0.42 degrees.
Accuracy: 86.39 %.
```

```
import math
from sklearn.metrics import mean_squared_error
rmse  = math.sqrt(mean_squared_error(y_test,y_predict))
rmse
```

```
0.545550621069416
```

RIDGE REGRESSION

Import Data

```
[ ] import pandas as pd
    import numpy as np
```

Read Files

```
[ ] data = pd.read_excel('/content/drive/MyDrive/Colab Notebooks/SPSS PEARSON-fin new.xlsx')
    data
```

	SIDEWALK	PLOS SCORE	PEDESTRIAN SPEED	PEDESTRIAN DENSITY	PEDESTRIAN FLOW	SPACE	SW SURFACE CONDITION	SW WIDTH	LAND USE TYPE	PRESENCE OF BARRIERS	PRESENCE OF STREET PARKING	VEHICLE VOLUME	VEHICLE SPEED	PRESENCE OF GUARD RAILS	PRESENCE OF STREET VENDORS	PEDESTRIAN VOLUME
0	CHEMMAMUKKAU - AYATHIL ROAD	3.6	0.93	0.240	10.40	4.16	4	1.8	6	1	1	441	28	1	0	1096
1	kochupilamoodu-beach	2.8	1.06	0.180	8.70	5.56	2	1.5	4	2	0	301	32	0	0	797
2	chinnakkada	3.2	1.53	0.347	17.00	2.88	3	2.3	2	0	1	523	38	1	1	1245

Splitting dataset into x and y

```
[ ] x = df.drop(columns='PLOS SCORE')
    y = df['PLOS SCORE']
```

Ridge Regressor

```
[ ] from sklearn.model_selection import GridSearchCV
    from sklearn.linear_model import Ridge

    ridge=Ridge()
    parameters={'alpha':[1e-15,1e-10,1e-8,1e-3,1e-2,0.1,5,10,20,30,35,40,45,50,55,100]}
    ridge_regressor=GridSearchCV(ridge,parameters,scoring='neg_mean_squared_error',cv=5)
    ridge_regressor.fit(x,y)
```

```
GridSearchCV(cv=5, estimator=Ridge(),
             param_grid={'alpha': [1e-15, 1e-10, 1e-08, 0.001, 0.01, 0.1, 5, 10,
                                   20, 30, 35, 40, 45, 50, 55, 100]},
             scoring='neg_mean_squared_error')
```

```
[ ] print(ridge_regressor.best_params_)
    print(ridge_regressor.best_score_)

    {'alpha': 0.1}
    -0.20277387435595456
```

Splitting the dataset for training and testing in 80:20 ratio

```
from sklearn.model_selection import train_test_split


x_train, x_test, y_train, y_test = train_test_split(x, y, test_size = 0.2)
```

Fitting the Ridge model and finding its accuracy

```
[ ]
    clf = Ridge(alpha=0.1)
    clf.fit(x_train,y_train)
    #Ridge()

    Ridge(alpha=0.1)
```

```
[ ]
    prediction_ridge=ridge_regressor.predict(x_test)
```

```
[ ] y_test

    7    2.9
    5    2.1
    Name: PLOS SCORE, dtype: float64
```

```
[ ] df=pd.DataFrame({'Actual':y_test, 'Predicted Ridge':prediction_ridge})
    df
```

	Actual	Predicted Ridge
7	2.9	2.944141
5	2.1	2.011781

```
[ ] # Calculate the absolute errors
    errors = abs(prediction_ridge - y_test)
    # Print out the mean absolute error (mae)
    print('Mean Absolute Error:', round(np.mean(errors), 2), 'degrees.')
```

```
    # Calculate mean absolute percentage error (MAPE)
    mape = 100 * (errors / y_test)
    # Calculate and display accuracy
    accuracy = 100 - np.mean(mape)
    print('Accuracy:', round(accuracy, 2), '%.')

    Mean Absolute Error: 0.07 degrees.
    Accuracy: 97.14 %.
```

```
[ ] import math
    from sklearn.metrics import mean_squared_error
    rmse  = math.sqrt(mean_squared_error(y_test,prediction_ridge))
    rmse

    0.06975282583746499
```

RANDOM FOREST REGRESSION

Import Data

```
[ ] import pandas as pd
    import numpy as np
```

Read Files

```
[ ] data = pd.read_excel('/content/drive/MyDrive/Colab Notebooks/SPSS PEARSON-fin new.xlsx')
    data
```

	SIDEWALK	PLOS SCORE	PEDESTRIAN SPEED	PEDESTRIAN DENSITY	PEDESTRIAN FLOW	SPACE	SW SURFACE CONDITION	SW WIDTH	LAND USE TYPE	PRESENCE OF BARRIERS	PRESENCE OF STREET PARKING	VEHICLE VOLUME	VEHICLE SPEED	PRESENCE OF GUARD RAILS	PRESENCE OF STREET VENDORS	PEDESTRIAN VOLUME
0	CHEMMAMUKKAU - AYATHIL ROAD	3.6	0.93	0.240	10.40	4.16	4	1.8	6	1	1	441	28	1	0	1096
1	kochupilamoodu-beach	2.8	1.06	0.180	8.70	5.56	2	1.5	4	2	0	301	32	0	0	797
2	chinnakkada	3.2	1.53	0.347	17.00	2.88	3	2.3	2	0	1	523	38	1	1	1245

Splitting dataset into x and y

```
[ ] x = df.drop(columns='PLOS SCORE')
    y = df['PLOS SCORE']
```

Splitting the dataset for training and testing in 80:20 ratio

```
[ ] from sklearn.model_selection import train_test_split

    x_train, x_test, y_train, y_test = train_test_split(x, y, test_size = 0.2)
```

Fitting the Random Forest model and finding its accuracy

```
[ ] from sklearn.ensemble import RandomForestRegressor
    regressor = RandomForestRegressor(n_estimators = 1000, random_state = 42)
    regressor.fit(x_train, y_train)

    RandomForestRegressor(n_estimators=1000, random_state=42)
```

```
[ ] y_pred = regressor.predict(x_test)
```

```
[ ] df=pd.DataFrame({'Actual':y_test, 'Predicted':y_pred})
    df
```

	Actual	Predicted
1	2.8	2.7248
2	3.2	3.5949

```
[ ] from sklearn import metrics
    print('Mean Absolute Error:', metrics.mean_absolute_error(y_test, y_pred))
    print('Mean Squared Error:', metrics.mean_squared_error(y_test, y_pred))
    print('Root Mean Squared Error:', np.sqrt(metrics.mean_squared_error(y_test, y_pred)))
```

```
Mean Absolute Error: 0.23505000000000487
Mean Squared Error: 0.08080052499999656
Root Mean Squared Error: 0.28425433154130925
```

```
# Calculate the absolute errors
errors = abs(y_pred - y_test)
# Print out the mean absolute error (mae)
print('Mean Absolute Error:', round(np.mean(errors), 2), 'degrees.')

# Calculate mean absolute percentage error (MAPE)
mape = 100 * (errors / y_test)
# Calculate and display accuracy
accuracy = 100 - np.mean(mape)
print('Accuracy:', round(accuracy, 2), '%.')
```

```
Mean Absolute Error: 0.24 degrees.
Accuracy: 92.49 %.
```