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Evaluation of Road Conditions for Walkability on Main Roads in the Miraflores District, Lima, 2023.

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Abstract: The research "Assessment of Road Conditions for Walkability on Main Roads in the District of Miraflores, Lima, 2023" analyzes the conditions of three key avenues in Miraflores during 2023, focusing on comfort, visual quality, and pedestrian safety. The mixed methodology employed, combining field research and statistical analysis, proved effective. A significant alignment was found between researchers' findings and user perceptions. Main deficiencies center around comfort and road safety, highlighting the importance of improving pedestrian comfort with more seating, shade, and wider sidewalks. Visual quality is satisfactory due to urban maintenance. Practical recommendations, such as tree implementation and furniture stripes, are proposed. In summary, the study provides valuable insights to enhance pedestrian safety and comfort in Miraflores.

Keywords: comfort, road conditions, safety, visual quality, walkability.

1. Introduction

Walkability is a measure that allows us to perceive and evaluate the quality of road configuration and public spaces, enabling users to travel on foot. It is linked to the sustainability of the city, due to its benefits such as reducing pollution from motor vehicles and improving pedestrian health. Report N°022-2022 from the Office of the Ombudsman [1] indicates that the rate of traffic accidents due to poor road infrastructure increased by 43.07% compared to the year 2020.

According to Report N°001-2019 from the Office of the Ombudsman [2], the city's roads are not prepared for pedestrians to walk comfortably or safely because vehicle drivers do not respect traffic regulations, resulting in a series of traffic accidents.

Urban roads are the setting for traffic, vehicles serve as the means, and the human factor, whether it be the driver, pedestrian, or passenger, is the protagonist. Ultimately, the safety of circulation depends on their behavior. In the city of Lima, the number of people killed in traffic accidents in 2022 was 3300, despite the Office of the Ombudsman [3] stating that road conditions and the environment contribute directly and indirectly to approximately 28% of traffic accidents, and that State intervention in designing and constructing streets with lower speeds can reduce traffic accidents by 40%.

Furthermore, it concludes that the Metropolitan Municipality of Lima, Provincial Municipality of Callao, and District Municipalities have lacked a rights-based approach in their actions related to road infrastructure within their jurisdiction, as conditions persist that jeopardize safe circulation at identified critical points. Additionally, it found that 71% of the roads and 86% of the sidewalks evaluated were in poor condition, 74% of the ramps were not universally accessible, only 12% of points had traffic lights, 31% of points were not marked for pedestrian crossings, and there was a significant lack of maintenance and upkeep in vertical signage.

Compliance with road safety regulations is essential to control and reduce the number of accidents suffered by pedestrians in the city of Lima.

The assessment of walkability in Miraflores is essential to promote urban sustainability by encouraging non-polluting means of transportation. In a densely populated and tourist district, it faces challenges such as obstacles and lack of signage on the roads. This study seeks to identify and address problems, benefiting the community and providing valuable information for urban traffic authorities, contributing to a safer and more comfortable environment for pedestrians in Miraflores.

Issues and State of the Art

In recent years, some research on the topic of Walkability has emerged, although very few studies have related it to road infrastructure and its regulations. A study [4], showed an evaluation of 10 avenues in the city of Brisbane, Australia, a rapidly growing and developing urban area. For this research, 100 meters on each of the avenues under study were monitored to measure the quality of urban design. A table was used to quantitatively evaluate the image, enclosure, human scale, transparency, and complexity of the selected roads [5], adding up the weighted values at the end, thus quantifying the set of design qualities. They concluded that the majority of the evaluated roads located outside the city center had low-quality design, especially in terms of human scale. Additionally, they found that there was no relationship between the quality of design and the socioeconomic level of the area and that streets with lower scores lacked shade. Noise negatively influenced the image, and the lack of urban furniture and vegetation was unpleasant for pedestrians.

The walkability is a priority for urban quality of life [6], but comprehensive and sensitive tools are required to measure it and make urban design decisions. They propose a method that combines fieldwork, expert evaluation, and statistical analysis of relevant data to measure walkability on 12 streets in the city of Athens, Greece. They considered dimensions such as pedestrian infrastructure, safety, comfort, aesthetics, and proximity to services. The results showed that the method helps differentiate the walkability of streets with different characteristics and identify areas that require improvement. The research discussion revolves around potential applications and challenges for its use in urban design.

A study [7] propose a methodology based on three criteria to measure walkability: Infrastructure and traffic, Urbanity, and Environment and activities. Information was gathered through literature review, fieldwork, and interviews. They used an evaluative table with a scale ranging from very walkable to not walkable. They suggest reducing vehicular accessibility and improving walkability capacity. They indicate that infrastructure and traffic should create safe spaces for walking, with defined sidewalks and crossings. They mention that deviations increase pedestrians' travel time, as do the number of

crossings or if crossings are at the same level, and if traffic volumes and speeds cause noise and pollution, affecting walkability. They also highlight the importance of design for universal accessibility, and whether pedestrian routes lead to public transport stops easily. Additionally, they point out that the level of walkability is related to the priority of private car use [8], reducing car dependence can lead to sustainable, equitable, and livable cities.

One of the objectives [7] was to develop a walkability measurement methodology using easily accessible data, with a small sample of neighborhood-level cases, without the use of specialized software such as GIS, and suitable for planners' use. They conclude that for a larger scale than that of a neighborhood, the approach could be complemented with Geographic Information Systems tools. Additionally, they mention that interviews revealed discrepancies between the perception of researchers and that of street users, and that making cities more walkable is necessary for sustainable urban development.

In the publication "Synthetic Walkability Index, Methodology" [9] point out that an avenue with a wide, tree-lined sidewalk, good lighting, seating, urban furniture, signage, road safety, and adequate illumination, contributes to people considering walking as an interesting mobility option and a comfortable journey. They argue that the sidewalk width in residential areas should be three meters and in commercial areas five meters. It should be ensured that there is greenery with trees covering at least 80% of the street length or that there is a tree every 8-15 meters along a sidewalk. Regarding sidewalk width, they indicate that for pedestrian comfort, there should be three zones: a) a service zone for commerce, b) a pedestrian circulation zone, c) a zone for urban furniture and trees. The first should have a width of one meter, and if there are restaurants, it should be two and a half meters wide. The second, for pedestrians to walk without obstacles, should measure a minimum of three meters wide. The third should not be less than one meter wide. This results in sidewalks being at least five meters wide on a commercial avenue and three meters wide on a residential avenue.

For a neighborhood with a high volume of pedestrians [10], improvements should focus on sidewalks: providing shade, ensuring good and safe crossings, seating, and facilities for cyclists. They found that the respondents did not perceive the lighting. These conditions should be derived from field observations and interviews with users. They identify two types of components in sidewalks: the static component, which is the infrastructure, and the dynamic component, which includes cyclists and vehicles. This dynamic component appears unexpectedly, with behavior that can create insecurity in pedestrians' perception and may not be identified in the images from the reviewed literature.

"Urban Mobility Plan of Miraflores" [11]: This study identified various pedestrian accessibility issues in the Miraflores district, such as the lack of sidewalks and signage, the presence of obstacles on sidewalks, among others. These problems can affect walkability on the district's main roads and could be addressed through improvements in road conditions.

"Pedestrian safety" [12]: This report highlights the importance of improving safety conditions for pedestrians in urban areas and indicates that assessing pedestrian safety can be a fundamental step in achieving this goal.

The article "Walking Capacity and Its Relationships with Health, Sustainability, and Livability: Elements of the Physical Environment and Assessment Frameworks" [13] highlights the importance

of walking in urban design, benefiting health, quality of life, and sustainability. It examines how elements such as connectivity, accessibility, and green areas influence the feasibility of walking. It also reviews various assessment frameworks and indices that employ subjective, objective, and distinctive approaches, tailored to different contexts. These tools evaluate walking capacity in diverse cultural, environmental, and national settings.

"Identification of urban landscape elements promoting walking in Santiago" [14]: The study aims to identify urban landscape elements that either facilitate or hinder walking within six peri-central neighborhoods of Greater Santiago. Through 120 walking interviews conducted with residents between September and November 2018, perceptions of pedestrians regarding their pedestrian environments were recorded. Findings indicate that wide sidewalks, trees, and mixed land use promote walking, while narrow and poorly maintained sidewalks, intersections, and motorized traffic inhibit it. Based on these results, recommendations for urban planning and street design to encourage walking are proposed.

At the Congress for the New Urbanism [15], it was noted that streets should be designed to encourage walking and reduce the number and duration of car trips, as seen in New York City, where distances to subway stations, museums, playgrounds, shops, and other urban facilities are 10 to 15 minutes away, so many New Yorkers do not need to own a car [16].

Walkability is increased with mixed land uses, as they reduce distances to urban amenities [17], but not only mixed uses are needed, but also public spaces for pedestrian circulation to be comfortable, inviting, and safe, with wide, illuminated sidewalks, free of obstacles [18]; protection from the sun and rain; benches; ornamentation such as fountains or gardens [19]. The configuration of urban space should encourage walking. Landscaping, human scale, vegetation with shade-providing trees, and good architecture are motivators for walking [20], [21]. Additionally, road safety [22] because, as long as pedestrians, cyclists, and drivers do not respect the rules, it is not very useful to create an entire infrastructure that will be poorly used [23]. Pedestrian crossings using high stairs, either at height or underground, discourage walkability (24) [24]. Economic weakness, cultural factors, and crime rates are related to walkability so that if there is more crime, the city is less walkable, if the economy is good and there is a lot of culture, walkability is high [25].

Comfort for walking

Comfort for walkability is a subjective dimension that can vary from one person to another depending on their preferences and personal needs and can have a significant impact on the pedestrian's perception and choice to walk as a means of transportation [7]. The quality of urban furniture for walking comfort can be measured through four points: direct observation of the physical condition of the elements, as well as their functionality and degree of maintenance, using checklists or observation protocols detailing aspects to evaluate, such as cleanliness, wear and tear, safety, accessibility, ergonomics, among others. Surveys of users who use urban furniture elements to assess their satisfaction level with the use and characteristics of the furniture. Technical evaluation conducted by experts in urban design, architecture, or civil engineering. Comparative analysis with similar elements in other cities or urban areas. This comparison can be based on aspects such as functionality, design, aesthetics, accessibility, safety, durability, and others.

A study [6] identify three dimensions of comfort for walkability: environmental, physical, and social:

Table 1. Dimensions for walkability. Adapted from Stasinopoulos and Lathouras (2019)

Environmental comfort	Physical Comfort	Social Comfort
Air quality	Universal accesibility	Population density
Ambient noise	Pavement quality	Land use diversity
Water quality	Presence of green areas and shade	Community and social cohesion
Temperature and relative humidity	Urban furniture quality	Sense of security
Visual quality	Lighting	Presence of public and private services
Olfactory quality	Signage and orientation	

The quality of the soil or pavement [7] is the ability of the pavement to provide a safe, comfortable, and accessible surface for pedestrians. Quality pavement for walkability should be suitable for the needs and characteristics of pedestrian traffic and adapt to the urban environment in which it is located. Pavement with irregularities or slipperiness can increase the risk of accidents due to trips, falls, and injuries. High-quality pavement can be smooth, level, non-slip, and durable, making it safer for pedestrians.

Pedestrian flows have a substantial positive correlation with commercial activities, with the centrality of the local network (spatial syntax), the width of sidewalks, and functional density [26]. Sidewalk width affects walkability, so they must be wide enough for pedestrians to walk and separate from traffic and avoid urban furniture, obstacles, and other pedestrians [27]. The pedestrian circulation zone should be comfortable and accessible; for residential areas, only the circulation zone should have a minimum width of 1.8-2.4m, and in commercial areas, a minimum of 2.4 to 4.5m wide. Additionally, consideration must be given to stay zones, to place urban furniture without obstructing the continuous circulation of pedestrians and allowing them to pass comfortably. The furniture zone can be considered to have a width between 0.60m to 4m, in which case it can be divided into two zones, occupying both edges of the sidewalk, depending on the required design [28].

Shade provides protection against direct solar radiation, shielding pedestrians' eyes and protecting them from excessive heat and sun effects, especially in summer. For shade to be effective in walkability, it must [7]:

1. Cover as much of the street or sidewalk surface as possible, especially in areas with high sun exposure.

2. Be tall enough to allow pedestrians to walk underneath it without having to bend down.

3. Have sufficient depth to protect pedestrians from direct solar radiation, especially during the hottest hours of the day.

4. Be uniform and uninterrupted, so pedestrians do not have to constantly walk from shade to direct sunlight.

5. Be clean and well-maintained to ensure it does not pose a danger to pedestrians.

People interact with the surrounding exterior through their senses: visual, auditory, olfactory, tactile, and kinesthetic perception, with visual perception providing approximately 80% of the information we receive from the environment [29]. There are factors that also influence the perception of an environment regarding the quality of spaces. For example, if the walking surface is uncomfortable, this can negatively affect the perceptual experience. When elements of space do not complement or interfere with their intended function, overall quality may decrease. Therefore, the attributes of a space define and conceptualize the landscape from its visual quality [30].

Preferences in the aesthetics of an urban space (built and natural elements) are significantly related to the values, education, culture, and lived experiences of the user or observer [30]. New Urbanism has ten principles, considering Architectural Quality and Urban Design that emphasize aesthetics, with human-scale architecture and beauty in the environment, featuring buildings close to the street with porches, windows, doors, and tree-lined streets [15]

The aesthetic quality of an environment is fundamental for walking to become an interesting travel option, involving the presence of pleasant environments and good design of space and urban furniture. For example, a wide, tree-lined sidewalk, well-lit and equipped with resting areas and benches [9].

Road Factors: These are factors or elements that influence the design, planning, and operation of traffic routes such as streets or avenues. These road factors can have a significant impact on the experience of road users. Road factors in urban design and planning can create more pedestrian-friendly environments, reduce car dependency, and promote a healthier and more sustainable lifestyle [31].

*Walkability :*The term "Walkability," which began to be used in the early 21st century, refers to how pedestrian-friendly a place is, where most daily activities, such as work, shopping, and leisure, can be accessed on foot without depending on a car [19].

Urban Configuration: It refers to the arrangement, distribution, and organization of elements that make up an urban environment, such as streets, buildings, public spaces, infrastructure, and green areas. According to Prinz [32], it is composed of the landscape image of the city and its location, the landscape and settlement forms related to the city's profile, urban image or forms of public spaces, street space or street form, facades, and the forms of each building.

Walkability Comfort: Walkability comfort refers to the quality of the pedestrian's experience in their urban environment, namely, how the pedestrian feels when walking through a specific urban area, and how factors such as accessibility, floor quality, safety, presence of vegetation and shadows, lighting, ambient noise, and other aspects that may affect walking satisfaction influence their experience [7]. Shade provides protection against direct solar radiation, helping to reduce exposure to intense heat and ultraviolet rays. In a city like Lima, with a hot climate in summer, having shade on paths helps prevent heat fatigue and potential sunburns. Therefore, considering shade for pedestrian comfort is important [33]. Fundamental factors characterizing walkability comfort include cohesion, materials used, terrain inclination, environmental conditions, sidewalk width, presence of vegetation, and surface [34].

Visual Quality: It refers to the aesthetic and visual appreciation of the elements comprising the urban environment, including architecture, street design, parks, squares, building facades, urban furniture,

and natural elements such as trees and gardens. The visual quality of the urban landscape is based on the aesthetics, harmony, and visual coherence of these elements, contributing to the identity and culture of a place. When considering the definition of visual quality of a specific urban environment, two fundamental aspects must be considered: the observation scale and context. When assessing the level of visual complexity of an environment, it's essential to consider the observation scale, as an environment may appear complex when observed up close but simple when viewed from afar, or vice versa [35].

Road Safety: It comprises actions aimed at preventing or avoiding the risks of accidents for road users and reducing negative social impacts due to accidents [36].

Safe Infrastructures: Refers to reducing the probability of accidents and minimizing consequences in case of occurrences through the planning, design, and construction of roads and their associated elements to minimize risks and promote the safety of all users [37]. It involves secure conditions for pedestrians, cyclists, and drivers such as correct road geometry, lighting, signage, pedestrian crossings, intersections, and separation between different traffic flows [31].

Universal Accessibility: Its concept encompasses planning, design, construction, and maintenance of the environment considering the needs and capacities of all individuals, ensuring comfort, safety, and personal autonomy for everyone. Regulations apply to various areas, such as roads and public spaces. Therefore, it's essential to have physical, visual, tactile, and audible signage that facilitates safe walkability. For people with visual impairments, tactile paving is recommended, which, through changes in textures on surfaces, helps guide walking [38].

2. Methodology

The study was conducted in the district of Miraflores, in the city of Lima, the capital of Peru, in 2023. Miraflores is located on the shores of the Pacific Ocean, between the coordinates 12°07′15″ south latitude and 77°01′44″ west longitude, at an altitude of 79 meters above sea level. It is an urban area with an extension of 9.62 km2. The average annual temperature is 18°C, and in summer, it can reach up to 30°C. It has a desert climate, with an average annual relative humidity of 82.8% (See figure 1-a). Due to the stratus cloud cover, which occurs in winter with persistent drizzle, the maximum temperature does not exceed 20°C. In summer, the maximum temperature is higher than 24°C. Relative humidity ranges between 85% and 86% [39]. Solar radiation is intense due to its location near the equator (See figure 1-b).

a) Climate of the city of Lima. The maximum temperature (red line) and the minimum temperature (blue line) average daily with the bands of percentiles 25th to 75th, and 10th to 90th. The thin dashed lines represent the corresponding perceived average temperatures. From Weather Spark. Consulted in July 2023. Source: https://es.weatherspark.com/y/20441/Clima-promedio-en-Lima-Perú-durante-todo-el-año#Sections-Precipitation

b) Solar radiation in Peru is usually high to extremely high throughout the year due to the proximity to the Equator. On consultation on October 22, 2023, in the spring season of the southern hemisphere, the forecast for maximum UV radiation (clear sky and solar noon) for the city of Lima was extremely

high. Source: National Meteorology and Hydrology Service (SENAMHI), at https://www.senamhi.gob.pe/?p=radiacion-uv

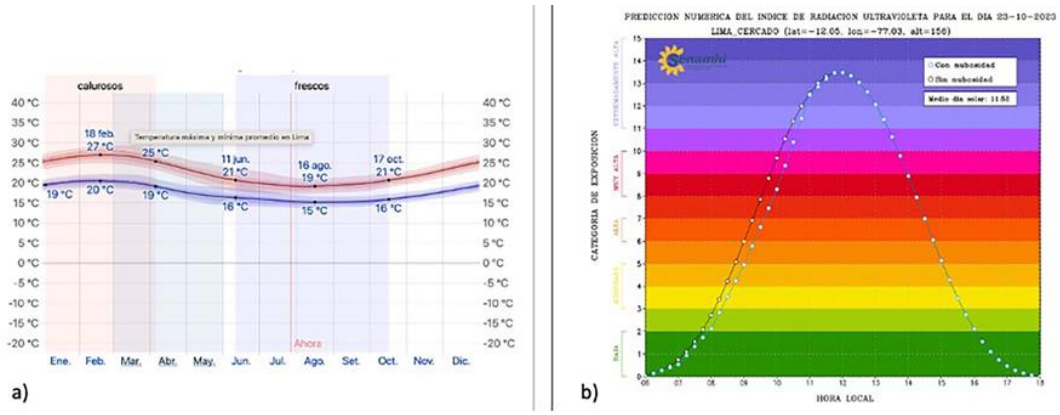


Figure 1. Average temperatures and solar radiation in the city of Lima, Peru.

From the main residential-commercial streets of Miraflores, five blocks on three avenues were selected: Avenida Pardo, Avenida Arequipa, and Malecón de la Reserva (see Figure 2). These cases represent a significant sample of residential-commercial streets in the district.

With this selection, a detailed evaluation of the road conditions and walkability on these streets was possible, obtaining very specific and detailed results regarding the issues and opportunities for improvement on these particular streets.

The results from these three streets in Miraflores are not generalizable to all the main streets in the district. However, they provide a valuable starting point for future research or the implementation of improvements on these specific streets.

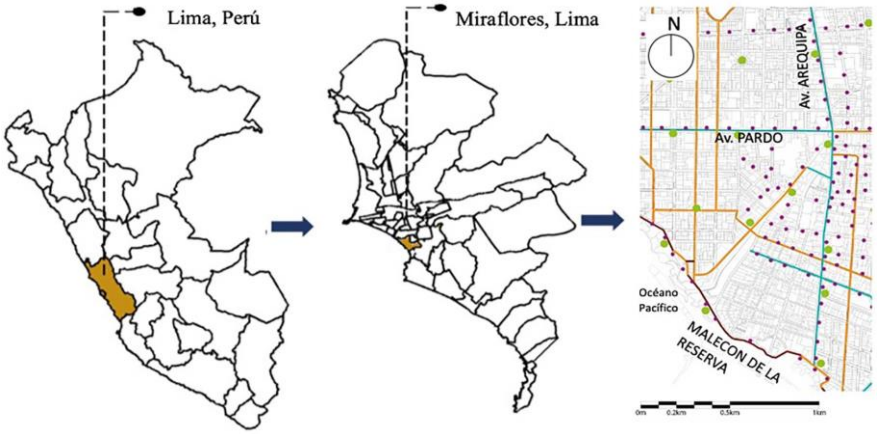


Figure 2. Location of the streets Pardo Avenue, Arequipa Avenue, and Malecón de la Reserva, in the Miraflores district, city of Lima, country Peru.

An integrated methodology was adopted to evaluate road conditions on three avenues in Miraflores district. A documentary analysis was conducted using sources such as books, magazines, and tools like Google Earth and Google Street View. Instruments were designed, such as checklists and a short questionnaire for user interviews. Data collection included field observations, photographs, videos, and interviews. Data organization and analysis were carried out using tables and graphs in Excel,

allowing for an understanding of the road conditions and their impact on walkability. The study comprised four phases: the first involved the selection of case studies and a review of literature covering concepts, standards, regulations, and precedents. The second phase included a field visit and spatial data collection. The third phase involved analysis, comparison, and interpretation of results, while the last phase focused on discussion and recommendations (see Figure 3).

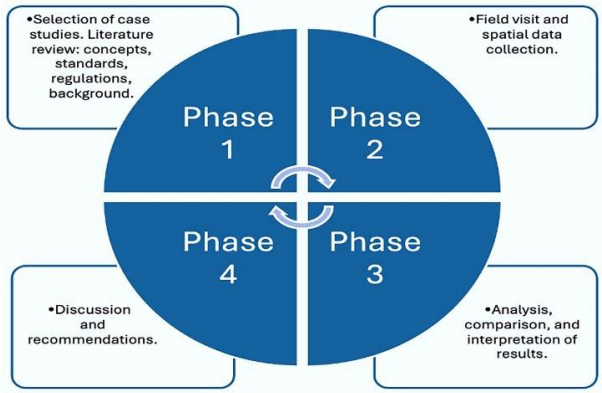


Figure 3. Methodology, Phase

3. Results In this section, the results of the compliance checklists and interviews for the three case studies are described. As shown in Figures 4-11, the compliance checklists feature an observation column displaying photographs illustrating the evaluation.

Variable	Dimension	Indicator	Items	Yes/No Achieve	OBSERVATIONS
ROAD CONDITIONS	PEDESTRIAN COMFORT	SEAT AVAILABILITY	Seats are available every 20 meters along the central sidewalk, while on the side sidewalks, seats are positioned at the corners of intersections. It is noted that the quantity of seats is sufficient for the pedestrian traffic.	YES	
		SHADE UNIFORMITY	Central sidewalk has a 60% shade coverage	YES	
			Lateral sidewalk has a 0% shade coverage	NO	
		SIDEWALK WIDTH	The central sidewalk has a width of 3.00 m. for pedestrian circulation and cycle path	YES	
			The side sidewalk has a minimum 2.4m wide for pedestrian circulation	YES	

Figure 4. Road conditions, pedestrian comfort, José Pardo Avenue.

Variable	Dimension	Indicator	Items	Yes/No Achieve	OBSERVATIONS
ROAD CONDITIONS	VISUAL QUALITY	LANDSCAPE SETTING	The location of the trees on the central sidewalk is with wide crowns covering the entire sidewalk. Well-maintained green area. Urban furniture design. Ornamental pavement treatment. Ornamental green area treatment.	YES	
		CLEANING AND MAINTENANCE	Clean sidewalks. Well maintained furniture.	YES	
	ROAD SAFETY	ROAD INTERSECTIONS	Intersections of roads with well-defined and marked pedestrian crossings. Design and condition of ramps at well-defined corners. Lighting: poles (streetlights with two lamps) on the central sidewalk -Lighting poles on the side sidewalks. Traffic lights. Vertical signaling using poles with signs	YES	
		MATERIALS AND PAVEMENTS	Horizontal marking on the road pavement with color lines. Tactile signage on ramps.		

Figure 5. Road conditions, visual quality and road safety, José Pardo Avenue.

Variable	Dimension	Indicator	Items	Yes/No Achieve	OBSERVATIONS
ROAD CONDITIONS	PEDESTRIAN COMFORT	SEAT AVAILABILITY	Central median. Seats are available at least every 100 meters. The quantity of seats is sufficient for the number of pedestrians	YES	
			Side sidewalks. They do not have seats, only at bus stops	NO	
		SHADE UNIFORMITY	Central median The sidewalk on the block has at least 50% shade	YES	
			Side sidewalk It only has shadows from buildings in some blocks.	NO	
		SIDEWALK WIDTH	Central median The sidewalk has a minimum width of 2.4 meters for circulation (traffic lane).	YES	
			Side sidewalk The sidewalk has a minimum width of 2.4 meters for circulation (travel lane)	YES	

Figure 6. Road conditions, pedestrian comfort, Arequipa Avenue

Variable	Dimension	Indicator	Items	Yes/No Achieve	OBSERVATIONS
ROAD CONDITIONS	VISUAL QUALITY	LANDSCAPE SETTING	Central median: 1 tree/6m spacing Well-maintained green area Urban furniture design Ornamental pavement and green areas treatment	YES	
			Side sidewalk 1 tree/6m spacing Well-maintained green area Urban furniture design Ornamental pavement and green areas treatment	NO	
	ROAD SAFETY	ROAD INTERSECTIONS	Central median Intersections of roads with well-defined and marked pedestrian crossings.	YES	
			Side sidewalk Intersections of the roads with well-defined and marked pedestrian crossings	NO	

Figure 7. Road conditions, visual quality and road safety. Arequipa Avenue

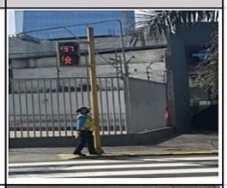
Variable	Dimension	Indicator	Items	Yes/No Achieve	OBSERVATIONS
ROAD CONDITIONS	ROAD SAFETY	ROAD INTERSECTIONS	Central median and side sidewalk Pedestrian traffic lights	YES	
			Central median and side sidewalk The condition of the ramps at corners is poor, lacking maintenance.	NO	
			Central median and side sidewalk Nighttime illumination (general for intersections, pedestrian pathways	YES	
		MATERIALS AND PAVEMENTS	Central median and side sidewalk Vertical signage	YES	
			Central median and side sidewalk Tactile signage Horizontal signage	YES	

Figure 8. Road conditions, road safety. Arequipa Avenue

Variable	Dimension	Indicator	Items	Yes/No Achieve	OBSERVATIONS
ROAD CONDITIONS	PEDESTRIAN COMFORT	SEAT AVAILABILITY	East sidewalk (building): There are no seats. West sidewalk (promenade): Seats only on block 1.	NO	
			East sidewalk: Buildings without seats. West sidewalk: Insufficient seating	NO	
		SHADE UNIFORMITY	East sidewalk: No tree shade, only building shade until 10 am. West sidewalk: No shade.	NO	
		SIDEWALK WIDTH	The east sidewalk ranges from 1.80 to 1.2 meters wide, with some obstacles present.	NO	
			The west sidewalk has a width ranging from 1.50m to 2.4m.	YES	

Figure 9. Road conditions, pedestrian comfort, Malecón de la Reserva (waterfront) Avenue.

Variable	Dimension	Indicator	Items	Yes/No Achieve	OBSERVATIONS
ROAD CONDITIONS	VISUAL QUALITY	LANDSCAPE SETTING	East sidewalk has no trees. West sidewalk has very few trees.	NO	
			East sidewalk lacks public green space. West sidewalk has 10% of well-maintained green area.	YES	
			The east sidewalk lacks urban furniture. The west sidewalk has a limited amount of urban furniture without special design	NO	
			The east sidewalk lacks ornamental pavement treatment, while the west sidewalk has only 5% coverage.	NO	
			East sidewalk has no green area. West sidewalk has ornamental treatment of green areas.	YES	
		CLEANING AND MAINTENEANCE	Sidewalks are clean, with wear due to salt air. Furniture is well-maintained (clean).	YES	

Figure 10. Road conditions, visual quality and road safety, Malecón de la Reserva (waterfront) Avenue.

Variable	Dimension	Indicator	Items	Yes/No Achieve	OBSERVATIONS
ROAD CONDITIONS	ROAD SAFETY	ROAD INTERSECTIONS	The east sidewalk has intersections of roads without pedestrian crossings	NO	
			Pedestrian traffic light to cross from the east sidewalk to the west sidewalk: at the end of block 1 and at the intersection with Larco Avenue.	NO	
			Design and condition of ramps at corners is average.	YES	
			Low-intensity nighttime lighting and some luminaires are not functioning.	NO	
		MATERIALS AND PAVEMENTS	Insufficient vertical signage. Tactile signage only at the intersection with Larco Avenue.	NO	
			Almost non-existent horizontal signage	NO	

Figure 11. Road conditions, road safety, Malecón de la Reserva (waterfront) Avenue.

Regarding Pedestrian Comfort on Arequipa Avenue (see Figure 12), 67% of the respondents believe that the number of seats in the central median is insufficient, and the same percentage find them comfortable. On Pardo Avenue, everyone confirms that there are enough seats, with 83% finding them comfortable. On the Malecón de la Reserva, respondents' perception coincides with the researchers' observation as there are no available seats.

Regarding the question of whether the shade from the trees is sufficient, on Arequipa Avenue, according to the interviews, more than 65% believe it is not sufficient, which aligns with the researchers' observation since there are few trees on the side sidewalks where pedestrians walk. On Pardo Avenue, 83% of respondents mentioned that the shade from the trees was sufficient. The researchers noted that there was good tree shade in the central median, while there were no trees on the side sidewalks. On the Malecón de la Reserva, respondents' answers coincide with the researchers' observation, as there are no trees providing shade on either of the sidewalks.

Regarding the question about the width of the sidewalks, on Pardo Avenue, 67% of respondents consider them adequate, with a central median of 3m and side sidewalks of 2.4m, evaluated as appropriate by the researchers. On the Malecón de la Reserva, 67% also perceive it as suitable; the West sidewalk meets the 2.4m width, although 3m is suggested for sports activities and walking pets. However, the East sidewalk is narrow, ranging from 1.2m to 1.8m, with obstacles such as plants and furniture, leading some pedestrians to step down onto the road or form queues due to insufficient width.

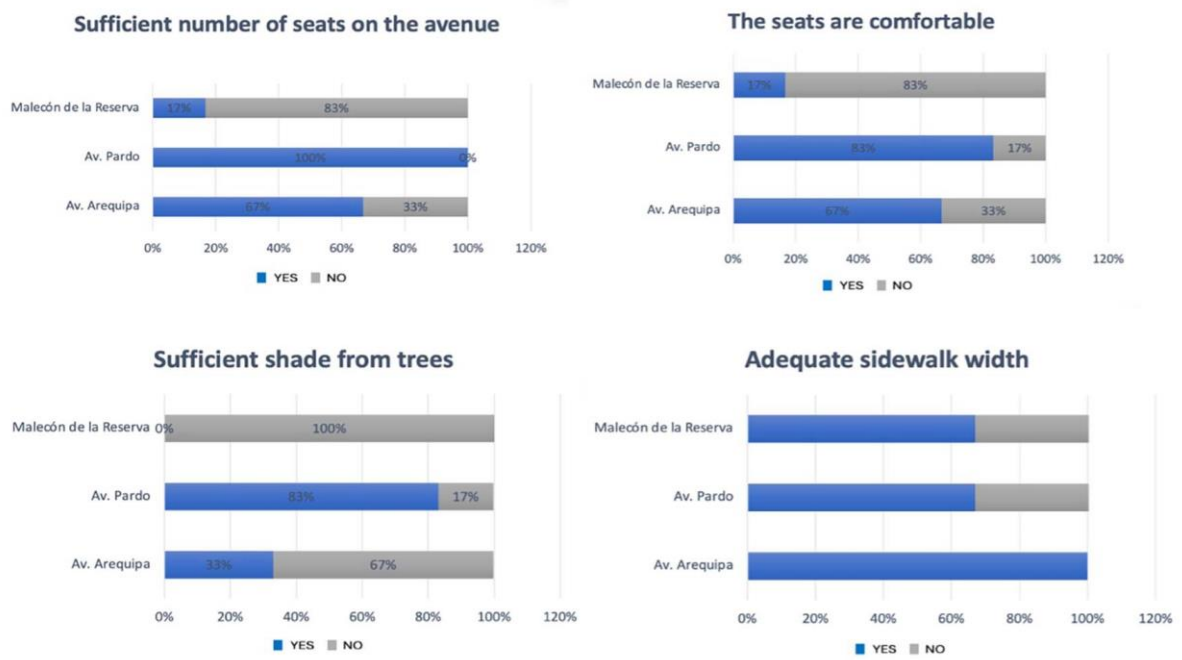


Figure 12. Interview Results: Road Conditions Variable, Pedestrian Comfort Dimension.

Regarding Visual Quality, on Arequipa Avenue, 100% of the respondents and researchers agree that it presents a pleasant urban landscape with trees in the central median. On Pardo Avenue, 83% of the respondents find the landscape pleasant, supported by well-maintained vegetation and well-treated furniture according to the researchers. On the Malecón de la Reserva, 100% of the respondents agree that the landscape is pleasant due to its sea view, being a visual attraction that invites stopping and contemplating the maritime landscape from the sidewalk.

On Arequipa Avenue, 100% of the respondents and researchers agree that the avenue is clean, highlighting the presence of garbage dispensers. On Pardo Avenue, 100% of the respondents also perceive good cleanliness, supported by the researchers' observations. On the Malecón de la Reserva, 67% consider the cleanliness adequate, although the researchers find it clean, but affected by wear and tear due to environmental salinity, being by the sea.

Regarding Road Safety, on Arequipa Avenue, 100% of the interviewees agree with the researchers on safety at intersections, supported by signage and ramps. On Pardo Avenue, 83% perceive safety at crossings, although difficulties may arise due to drivers' lack of respect, despite good signage. On the Malecón de la Reserva, half feel safe; while the west sidewalk lacks intersections, the east presents challenges for crossing the road, with only two crossing points and deficiencies in safety measures, such as the lack of pedestrian crossings and ramps, and the absence of tactile paving on the avenue.

Regarding nighttime lighting, on Arequipa Avenue, 100% of the interviewees and researchers agree that it is adequate, thanks to the use of human-scale street lamps in the central median. On Pardo Avenue, 83% of interviewees consider the lighting adequate, supported by good illumination on sidewalks and the central median according to researchers. However, on the Malecón de la Reserva, only 33% of interviewees and researchers indicate problems, such as low light intensity and defects in some luminaires.

On Arequipa and Pardo avenues, 100% of interviewees perceive road safety, consistent with researchers' observations. However, on the Malecón de la Reserva, only 50% feel safe while traversing it. Pardo Avenue and Arequipa Avenue are thoroughfares with high pedestrian traffic due to commercial activity, offices, and residences. In contrast, the Malecón de la Reserva, with more residences than businesses and ocean view, has fewer pedestrians, generating a perception of lower safety.

The road conditions analyzed on these avenues in the Miraflores district, regarding visual quality, show an acceptable percentage of 92%, while for road safety, they stand at 78%, and they are at 58% progress for pedestrian comfort, as observed in Figure 13. Researchers believe that it is necessary to propose measures and improvements in general for better pedestrian comfort and road safety on the district's avenues.

Figure 13. Interview results: The road conditions on the avenues.

4. Discussion

About the proposed methodology, analyzing around 500m on three important avenues in the Miraflores district allowed us to achieve the objectives, similar to the research achievement "Urban Design Quality and Walkability: Audit of the Secondary Streets of an Australian City" by Hooi and Pojani [4], which analyzed 100m on ten important avenues in Brisbane, Australia, or the research by Stasinopoulos, P., & Lathouras, D. [6] where they measured walkability on twelve streets in the city of Athens.

We combined fieldwork, researcher evaluation, and statistical analysis of data provided by interviewed users for the comfort, safety, and aesthetic conditions, similar to the methodology used by Knapskog et al. [7] and Stasinopoulos, P., & Lathouras, D. [6]. In those studies, the results allowed identifying areas that required improvements, which was also possible in the present research.

The results obtained by the researchers significantly coincided with those expressed by the interviewed users, unlike Knapskog et al. [7] who indicated that the interviews showed discrepancies between the researchers' perception and that of the street users.

In the methodology used, information gathering was proposed through fieldwork and interviews, with attribute tables for the evaluation performed through literature review. The team considered that an

evaluative compliance table was more conclusive than a scale one, without losing the qualitative focus. Knapskog et al. used an evaluative walkability table with a scale ranging from very walkable to not walkable, noting that, as part of the methodology, it was useful for the researchers to provide descriptive reports of what was observed at each of the four analyzed nodes, coinciding with the methodology of the present research where the compliance evaluation tables present photographic views describing the successes and problems observed by the researchers.

According to what researchers have observed and supported by the interviewees, the improvement of safety conditions for pedestrians is very important, including lighting, signage and traffic lights, tactile paving, ramps with good design and in good condition, as also noted by the World Health Organization [12] Baobeid et al. [13] and Herrman-Lumecke et al. [14].

The road conditions that do not meet pedestrian comfort for walkability are the number of seats and the presence of trees providing shade on the sidewalks. In addition, some sidewalks that do not have a comfortable width should be reviewed. Comparing the sidewalk width dimensions recommended by NACTO [28], the widths of the sidewalks in the analyzed cases are insufficient, as they have not considered the strips for necessary urban furniture such as streetlights, trash cans, benches, signage, hydrants, trees, and others. Neither have they considered strips to promote activities adjacent to businesses such as tables and chairs, planters, spaces for queuing. In the analyzed avenues, the dimensions coincide with the circulation strips given by NACTO but not considering space for furniture generates obstacles for pedestrians.

In terms of visual quality for walkability, the road conditions do meet the requirements, being the major quality of the district's avenues. Researchers observed the presence of municipal staff cleaning the furniture.

The road conditions that do not meet safety standards for pedestrian use include inadequate lighting, insufficient signage, malfunctioning traffic lights, and poorly designed ramps at the intersections of avenues, particularly in residential areas. In addition to good infrastructure, respect for traffic rules by vehicle drivers and pedestrians is essential to prevent traffic accidents in the district.

The importance of having shade on sidewalks, especially through trees that provide it, is a condition of comfort required by pedestrians and demonstrated in the literature such as in Hooi and Pojani [4], Gao et al. [10], and Alvarez de Celis et al. [9], which indicate that there should be a tree every 8-15 meters on a sidewalk. In the side sidewalks of Av. Arequipa, as well as on the Malecón de la Reserva, there is a lack of trees, which on sunny days causes discomfort to pedestrians, as well as posing a health hazard due to Lima's extremely high levels of solar radiation throughout the year.

The widths of the sidewalks on the central berms of the avenues in Miraflores are greater than or equal to five meters, but on the side sidewalks, the widths are less than five meters in commercial areas and less than three meters on the eastern sidewalk of the Malecón de la Reserva, generating discomfort because people obstruct each other or because some element such as furniture or vegetation has not been considered in a strip for this purpose. Alvarez de Celis et al. [9] consider that the minimum width of the sidewalk in residential areas should be three meters and in commercial areas five meters, which includes strips for furniture, circulation, and staying when there are adjacent restaurants and other services.

The perception of insecurity at the intersections of Pardo or Arequipa avenues may not be due to infrastructure, as traffic lights, signage, and in some cases traffic calming measures such as speed bumps on the Malecón de la Reserva are observed. Instead, it could be attributed to dynamic factors such as motor vehicles and bicycles, as observed on-site by the researchers, coinciding with what was indicated by Gao et al. [10].

5. Conclusions

- The road condition that is most developed is visual quality.
- Road conditions that do not meet pedestrian comfort for walkability include: lack of seating, absence of trees, sidewalks with insufficient width.
- Road conditions that do not meet road safety for walkability include: lighting, signage, traffic lights, and ramp design on residential roads.
- For sidewalk width on commercial avenues, it is recommended to consider zones for furniture, circulation, and stay, therefore a minimum sidewalk width of five meters is recommended. For sidewalk width on residential avenues, a minimum of three meters is recommended, considering zones for furniture and circulation.
- The implementation of shade-providing trees along all sidewalks of the roads is necessary not only to address pedestrian discomfort on sunny days but also to mitigate the extremely high levels of solar radiation that occur throughout the year in the city of Lima.
- The results of this research open opportunities to continue investigating the status of road conditions regarding walkability on other main roads in the city.

6. Conflict of Interest Statement

The authors Tania Cama as responsible author and Oswaldo Facho and Liliana Delgado as co-authors are researchers from the Faculty of Architecture and Urbanism of the Universidad Nacional Federico Villarreal. The authors declare that they have no conflict of interest in relation to the publication of this manuscript.

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