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Serviceability Analysis of Pedestrian Overhead Bridges and Underpasses

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Abstract

A grade-separated crossing allows a bicycle/pedestrian to continue over or under a barrier without conflict with a vehicle. However, the serviceability of these facilities is compromised in underdeveloped countries, including Pakistan. This research examines the effectiveness of pedestrian bridges and underpasses in terms of their usage by pedestrians. A total of 80,017 pedestrian crossings were observed at four sites (3 overhead bridges and one underpass) for four weeks (one week per site) using manual and video photography. The data about age, gender, and serviceability of each pedestrian was collected and analyzed using the chi-square test, t-test, and descriptive analysis. The study site selection was based on different characteristics, i.e., the number of lanes, type of median barriers, and type of facility (bridge/underpass). The analysis shows that most of the pedestrians (71.83%) did not use the crossing facilities, resulting in the poor serviceability of these structures. A comparison between bridges and underpasses also reveals that underpass usage (62.5%) is statistically more significant than bridge usage (11.62%). There is an effect of age ($p<0.001$) and gender ($p<0.001$) on the serviceability of these facilities as well, with pedestrians aged more than 25 years old and females using the facilities more than their counterparts. The study also provides implications for the effect of barriers and the height of facilities on the serviceability of these facilities. The number of lanes and the presence of a median barrier, as well as the height of the facility (number of steps), are the primary factors influencing the serviceability of grade-separated pedestrian crossings.

Keywords: Pedestrian Bridges; Underpasses; Vehicle Speed; Serviceability; Pedestrian Crossing.

1. Introduction

The pedestrian overpasses and underpasses permit an uninterrupted flow of pedestrian movement separate from vehicle traffic [1]. Sometimes it is essential to fully separate pedestrians from vehicular traffic to improve their safety, as pedestrians are one of the most vulnerable road users with a high involvement in road accidents [1–3]. Research has shown that observing vulnerable road users' behavior has been largely ignored in the literature compared to drivers [4]. Crossing a busy roadway can be risky for pedestrians as they have to identify a gap and cross safely, which varies based on age and gender [5-8]. This problem is much more significant in developing countries, where pedestrians are also highly represented in road traffic accidents [9].

Freeways, railways, and natural barriers can hold back the creation of traditional pedestrian facilities such as sidewalks and on-street crossings and often adversely affect pedestrian facility connectivity, and impact the design of walkable cities [10, 11]. Pedestrian overpasses and underpasses separate pedestrians from motor vehicle traffic and

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provide crossings where no other pedestrian facility is available [12]. Facilities such as overpasses and underpasses are provided in grade-separated infrastructure to keep pedestrians from colliding with vehicles and to avoid congestion caused by high pedestrian volumes. Such pedestrian infrastructure can also be provided if the road has a large number of lanes and is an expressway or highway with high-speed traffic. An overpass is a section of a road or path that crosses over an obstacle, such as another road, railway, or other structure. In contrast, an underpass is a road or pedestrian passage in a tunnel that runs beneath a road or railroad [13].

Walking is the most fundamental and sustainable mode of transportation, and many jurisdictions would like to see increased walking rates to reduce congestion and emissions while also improving public health [14, 15]. However, researchers have noted that people would prefer to walk across a busy road at grade rather than exert effort to climb up and over the bridge [16, 17]. Overpasses should be used only when the number of users justifies the cost [13]. If we look at the cost of these facilities, underpasses range from somewhat less than $1,609,000 to $10,733,000 in total, or around $120 per square foot. Overpasses range from $150 to $250 per square foot, or $1,073,000 to $5,366,000 per complete installation, depending on site conditions [13].

A well-designed pedestrian system can effectively reduce the number of traffic accidents [18] and improve the quality of public transportation [19]. They are optimally designed to allow pedestrians unhindered travel across potential barriers such as high-volume, high-speed motorways, railways, water channels, and valleys, facilitating much-needed accessibility and linkages between land uses. Footbridges and underpasses serve various functions, including revolving complex intersections between modes of transportation and serving as functional urban design elements [20].

The effectiveness of the pedestrian bridge is determined by the number of pedestrians who use it [21]. To ensure that pedestrian bridges provide the maximum return for the cost of construction, they should be located in strategic areas where users do not have to walk far to use them [22]. However, one of the burgeoning issues is the serviceability of these pedestrian infrastructures [23]. Several studies have documented the low usage rates or serviceability of these infrastructures, especially the overhead pedestrian bridges [22]. Literature on this subject shows that footbridge development is common in Global South cities, yet pedestrians rarely use them. In Bogotá, Colombia, 25% of pedestrians showed an inclination to cross the road over a pedestrian bridge [24]. Despite differences in regions and countries, research suggests pedestrians rarely use these overpasses. Some of the studies explored during the review have shown that serviceability remains low, averaging 26% in Tanzania [25], 26% in India [26], 49.5% in Mexico City [27], and 19–74% in Malaysia [28].

There has been little research on the serviceability of these pedestrian infrastructure facilities and the factors that affect their serviceability of these facilities. As a result, in this study, we investigated the serviceability of grade-separated pedestrian crossings in Pakistan and compared it to the literature on the serviceability of these facilities, especially in developing countries. Based on the study's objectives, the following research questions are formulated.

- What is the serviceability of pedestrian facilities in Pakistan, and are there differences between the serviceability of underpasses and overhead bridges for pedestrians?
- Does the serviceability of pedestrian bridges or underpasses is affected by demographics (age and gender) and time of the day?
- Does the type of median barrier and the number of lanes affect the serviceability of a pedestrian facility?
- Does the height of a pedestrian facility impact the serviceability of a pedestrian facility?

2. Background

Previous research has focused on the effective operation of underpasses and overpasses in various contexts [5, 22, 29–31]. The separation pedestrian crossing is a structure that eliminates collisions between pedestrians and vehicles on the road, which can be found above or below the roadway [32, 33].

Pedestrian crossings should ensure that people can move across them safely, comfortably, efficiently, and economically while minimizing the negative environmental impacts. These targets are mutually dependent [16]. Efficiency here is a measure of quality, i.e., capacity. Safety is determined by traffic layout, geometry, and pedestrian and driver visibility. Traffic conditions translate into lost time [34]. For urban development, the pedestrian system should be well-designed, safe, and convenient. Every street in a city has a pedestrian zone as its primary component. It is a zone that shapes social interactions, safety, and the quality of life of people in a city by ensuring the smooth, comfortable, and conflict-free movement of pedestrians and public transportation users [35]. As a result, pedestrian priority becomes a significant and fundamental phenomenon for urban development, benefiting the quality of life in a city [35].

The AASHTO Guide for the Planning, Design, and Operation of Pedestrian Facilities recommends that pedestrian overpasses be at least 8 feet wide. The width should be increased if the sidewalk leading up to the overpass is wider. If the overpass accommodates bicyclists, the width should be at least 14 feet. Depending on the length of the overpass, it might be necessary to increase its width to counteract any visual perceptions of narrowness. Similar guidelines apply to underpasses. Minimal widths should be between 14 and 16 ft., but the underpass width should be increased if the underpass is longer than 60 ft.

On a bridge with traffic signals under it in Ankara, Turkey, the percentage of pedestrians using the bridge was the lowest, at 6.3 percent. A bridge with escalators had the highest serviceability, 62.9 percent. On a bridge with six stairways, the usage rate was 20 percent [22]. Similarly, despite a nearby pedestrian underpass, 22% of pedestrians in Delhi, India, accepted the risk [29]. Again, in Iran, elderly pedestrians generally cited exhaustion and carrying occasional baggage as reasons for not using bridges. Younger pedestrians cited being in a hurry and wanting to save time as reasons for not using bridges. Escalators may appear to be a good solution for increasing the use of pedestrian bridges, primarily because they address the problems of elderly pedestrians. However, the presence of traffic signals beneath a bridge may reduce the use rate. Furthermore, dense vegetation and tall barriers may sway the decisions of a sizable number of pedestrians. Because the effect of the availability of pedestrian signals on the pedestrian's decision to cross at a specific location was relatively high, proper traffic control can further encourage pedestrian crossings at designated locations [36].

Similarly, the findings on the factors influencing the function of this structure revealed that the most influential factor in increasing the usage rate was the perception of the footbridge as a safe crossing. In contrast, the most commonly cited reason for not using the footbridge was a lack of time. Furthermore, in terms of some proposed procedures to increase usage rates, barriers were the most commonly suggested solution in the literature to increase footbridge usage [30, 37].

In Malaysia, the pedestrian bridge is used by 65 percent of the population. The most frequently cited reason for not using the footbridge was a lack of time, as the pedestrian considers the ascent of stairs and walking along the footbridge deck a waste of time [30]. Similarly, in Kenya, 9,045 pedestrians used the pedestrian footbridge over the weekend, accounting for 30% of the total number of pedestrians who used the pedestrian footbridge during the week. Because no ramp was provided to allow the physically challenged to use the footbridge, cyclists and the physically challenged used it the least [31]. Similarly, in Turkey, observations revealed that 46 percent of pedestrians did not use the overpass to cross the road, preferring to make illegal crossings rather than using safe routes or crossing outside the overpasses to reduce their walking distance/time. As a result, overpasses are not always as effective as anticipated. Overpass inefficiency can occur for various reasons, including illegal crossings near overpass locations. The most important factors influencing the use rate are the time lost from using the overpass and the perceived inadequacies of the overpass [5].

Similarly, various models have been implemented in China to study spatial pedestrian violations. According to the findings, the median, land use type, and number of lanes are the most critical variables in spatial violation [38]. The current study aims to add to the literature about the serviceability of these facilities by using all these variables.

3. Methodology

3.1. Site Selection and Preliminary Survey

The four sites selected in this study were based on the location of these facilities in a densely populated area and the varying geometric characteristics, such as the type of median (Figure 1). Before carrying out the actual data collection, a preliminary survey of the area where the facility is located was conducted to identify the sites for pedestrian observation.

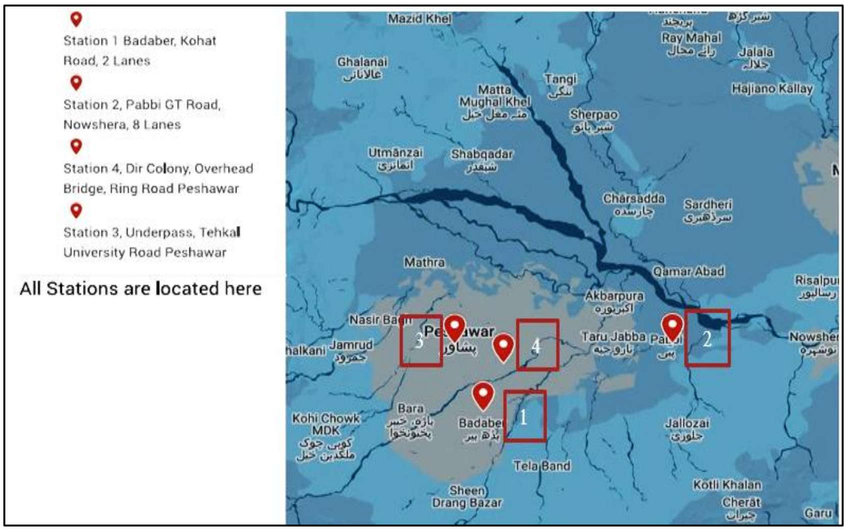


Figure 1. Location of all four sites

Following the survey of the structures, the road characteristics were noted. Table 1 provides the characteristics of all four sites observed for this study.

Table 1. Characteristics of all stations

Station	Type of facility	Type of median barrier	Road Lanes
Station 1	overhead bridge	concrete block	4
Station 2	overhead bridge	fences with huge gaps	6 (with 2 extra lanes as service street)
Station 3	underpass	green belt	6
Station 4	overhead bridge	fences with a jersey barrier	6

3.2. Data Collection

Pedestrian volume counts, both grade-separated and at-grade, were collected during peak hours at each site for one week. Four peak hours were identified at each site using a pilot survey, a) Morning peak hour for school traffic, b) Morning peak hour for home-work commute, c) Afternoon peak hour for school break, and d) Evening peak hour for the work-home commute.

Two observers independently coded the data on a codebook. A pilot survey was conducted to test the codebook before collecting the actual data. Data for grade-separated pedestrian crossings were collected manually, while data for at-grade pedestrians were collected using video photography. The pedestrian data (both at-grade and grade-separated) is divided into four groups, based on gender (Male/Female) and age (>25 and 25). The age and gender of the pedestrian were visually estimated.

3.3. Data Analysis

All the analyses are carried out on SPSS (IBM Statistics 20). An alpha level of 0.05 was maintained for all statistical tests. The on-site data was imported into Microsoft Excel and then to SPSS. All the variables are coded numerically. Please note that serviceability is coded as 1.00 if the facility is used, while 0 is used when the pedestrian opts not to use the facility.

4. Results

4.1. Descriptive Results

Table 2 presents the descriptive values of all variables studied in this research effort. The results are presented in terms of the serviceability due to demographics (age and gender), observation sites, station type, and the observation sites' infrastructural properties (number of lanes, median type, and height of facility).

Table 2. Descriptive results of all stations

Variable	#	Serviceability Mean (SD)
	Demographics	
	Gender	
Male	58229	0.179 (0.38)
Female	21788	0.25 (0.43)
	Age	
Less than 25 years old	36451	0.264 (0.44)
More than 25 years old	43566	0.143 (0.35)
	Observation Sites	
Station 1 (Overhead)	4734	0.05 (0.21)
Station 2 (Overhead)	41667	0.04 (0.18)
Station 3 (Underpass)	12905	0.63 (0.49)
Station 4 (Overhead)	20711	0.31 (0.46)
	Station Type	
Overhead pedestrian bridge	67112	0.116 (0.321)
Underpass for pedestrians	12905	0.625 (0.484)

Observation Sites' properties		
Number of Lanes		
6	75283	0.21 (0.41)
4	4734	0.1 (0.21)
Median Barriers		
Concrete Blocks	4734	0.045 (0.207)
Fences with jersey barriers	20711	0.3 (0.49)
Green Belts	12905	0.625 (0.484)
Fences with huge gaps	41667	0.032 (0.178)
Height of Facility		
15 ft	12905	0.63 (0.49)
18 ft	20711	0.30 (0.49)
20 ft	41667	0.03 (0.18)
24 ft	4734	0.05 (0.21)
Time of the Day		
7:30-8:30 AM	22488	0.2 (0.36)
8:30-9:30 AM	20587	0.2 (0.4)
2:00-3:00 PM	16675	0.241 (0.43)
4:30-5:30 PM	20267	0.22 (0.42)

4.2. Differences due to Gender, Age, and Type of Pedestrian Facility

Table 2 shows that serviceability is low across most variables, with males and females choosing not to use the pedestrian facility, with the serviceability of 17.94% and 24.93%, respectively. The difference between males and females in terms of serviceability was checked using T-test, and we found a significant effect of gender, t (80015) = -22.134, p<0.0001, which shows that females are using the facilities significantly more than their counterparts.

When checked for differences due to age, we can see from table 2 that the serviceability among more than 25 years old is much lesser than the younger pedestrians, with a mean difference of 0.121. When checked using a t-test, we found that this difference is statistically significant, t (80015) = 43.266, p<0.0001.

Three sites studied in this research were overhead bridges, while one was an underpass for pedestrians. As shown in table 2, the serviceability is higher for underpass for pedestrians (Mean value = 0.652) than for overhead bridge (Mean value = 0.116). When checked using a t-test, this difference is statistically significant, t (80015) = 150.497, p<0.0001.

4.3. Effect of Observation Sites' Geometric Properties on Serviceability of the Facilities

Data was collected about the site's infrastructural properties, such as the number of lanes, median barriers, and height of the facility, to check its impact on serviceability.

As we can see in Table 2, the lowest serviceability (mean value = 0.03) is in fences with huge gaps where pedestrians could easily cross the median. The effect of the median barrier on serviceability was checked using one-way ANOVA, which shows that statistically significant differences exist across groups due to the median barrier, F(4,80013) = 11470.750, p<0.0001. When further analyses were carried out, we found that concrete blocks (see Figure 2) and fences with huge gaps result in significantly lesser serviceability in the pedestrian facilities as compared to green belts (p<0.001) and fences with jersey barriers (p<0.001).

When we compare the height of the facilities, the highest serviceability is for a height of 15 ft., and the lowest serviceability is seen among 20 ft. and 24 ft. high pedestrian facilities. The effect of height on serviceability was checked using one-way ANOVA and shows significant differences across groups, F (3, 80013) = 11470.750, p<0.0001. When the data was further analyzed using Bonferroni analysis, we found that lesser height results in more serviceability of the facility, as the height of 15 ft results in statistically significantly higher serviceability than the height of 18 ft (p<0.001), 20 ft (p<0.001) and 24 ft (p<0.001) respectively. The differences in 20 ft and 24 ft are not statistically significant (p=0.097).

4.4. Effect of Time on Serviceability of Pedestrian Facilities

As shown in Table 2, the serviceability of the pedestrian facilities is lowest in the morning hours, with only 15.23% and 19.06% of the pedestrians using the facility during these hours. The highest serviceability is during the school break hour, with 24.16% of the pedestrians using the facility. The effect of the time of day on serviceability was checked using one-way ANOVA, which shows that statistically significant differences exist across groups, F (3,80013) = 193.012, p<0.001. Post-hoc Bonferroni analysis indicates statistically significant differences between serviceability across all times (p<0.01). The following sections present the results of each site.

4.5. Station 1 – Overhead Bridge

As shown in Table 2, The serviceability of this overhead bridge is extremely low. Pedestrians having age less than 25 (mean value = 0.062) are more likely to use the facility as compared to older pedestrians (mean value = 0.0286). This difference is statistically significant, $t(4732)$ =5.567), p<0.0001. There is no effect of gender on serviceability, with both males and females opting not to use the facility in high numbers.

In one week, a total of 4,734 pedestrians were observed. The facility was used by only 4.5 percent of pedestrians. Males (age<25) made up a larger proportion of those who did not use the overhead bridge. Furthermore, there is no proper median barrier available at this site, resulting in most pedestrians not using the facility. The highest serviceability is for women less than 25, with 6.7 percent using the facility (See Table 3 and Figures 2, 3).

Table 3. Number of pedestrians against gender and age at station 1

Total Pedestrians observed		Pedestrians not using the facility	Pedestrians using the facility	serviceability
Gender & Age	**Number**	**Number**	**Number**	**Percentage**
M>25	1489	1443	46	3.1
F>25	924	901	23	2.5
M<25	1558	1465	93	6.0
F<25	763	712	51	6.7

Figure 2. Concrete blocks as a median barrier at station

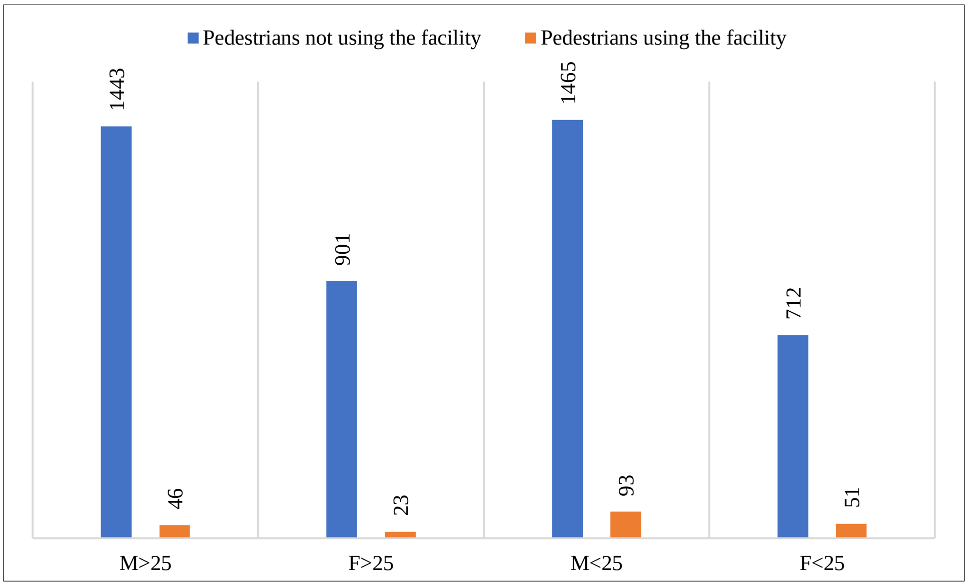


Figure 3. Comparing pedestrians using vs. not using the bridge based on gender and age group

4.6. Station 2 – Overhead Bridge

This station also had lower serviceability, with only 3.27 percent of the pedestrians opting to use it. Pedestrians having age less than 25 (mean value = 0.538) are more likely to use the facility as compared to older pedestrians (mean value = 0.0201). This difference is statistically significant, $t(41665) = 18.79$, $p<0.0001$. Female pedestrians (mean value=0.04) are likelier to use this facility than males (mean value = 0.03). This difference is statistically significant, $t(41665) = -5.132$, $p<0.0001$.

In one week, 41,667 pedestrians were observed. The facility was used by only 3.27 percent of pedestrians. The majority of pedestrians who did not use the facility (station 2) were male (age >25). In terms of % serviceability of age and gender, the males and females less than 25 years old had comparatively higher serviceability with 5.3% and 5.8%, respectively. Because the number of lanes at this station is greater than at the previous station, the facility's serviceability is impacted even further (see Table 4 and Figures 4, 5).

Table 4. Number of pedestrians against gender and age at station 2

Total Pedestrians observed		Pedestrians not using the facility	Pedestrians using the facility	Serviceability
Gender & Age	**Number**	**Number**	**Number**	**Percentage**
M>25	18076	17824	252	1.4
F>25	8008	7736	272	3.4
M<25	12752	12078	674	5.3
F<25	2831	2667	164	5.8

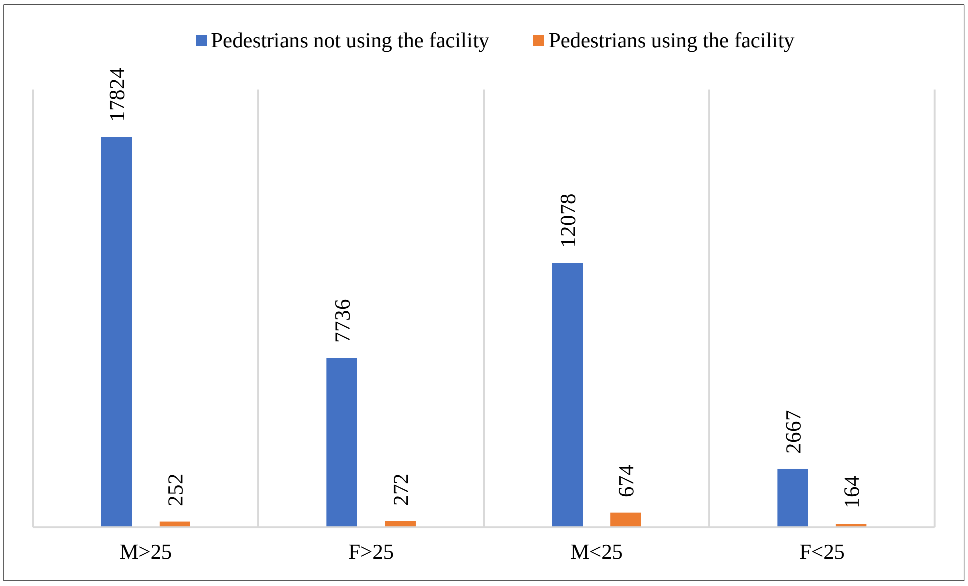


Figure 4. Comparison between Pedestrians using vs. not using the bridge

(a) (b)

Figure 5. Overhead Bridge (Station 2). (a) The current condition of station 2; (b) Gaps in between the fences

4.7. Station 3 – Underpass

The serviceability of station 3 is the highest in the current study, with 62.56% of pedestrians using the facility. Pedestrians with age less than 25 (mean value = 0.6640) are more likely to use the facility than older pedestrians (mean value = 0.5758). This difference is statistically significant, $t(12903) = 10.297$, $p<0.0001$. There is also an effect of gender on serviceability where Males (mean value = 0.6331) are more likely to use the facility than Females (mean value = 0.6122). This difference is statistically significant, $t(12903) = 2.351$, $p<0.5$.

In one week, 12,905 pedestrians were observed. The underpass was used by 62.56 percent of pedestrians. The highest serviceability is for males and females in the younger category, with 66.4% using the facility (see Table 5 and Figures 6, 7).

Table 5. Number of pedestrians against gender and age at station 3

Total Pedestrians observed		Pedestrians not using the facility	Pedestrians using the facility	serviceability
Gender & Age	**Number**	**Number**	**Number**	**Percentage**
M>25	3117	1303	1814	58.2
F>25	2506	1082	1424	56.8
M<25	5141	1727	3414	66.4
F<25	2141	720	1421	66.4

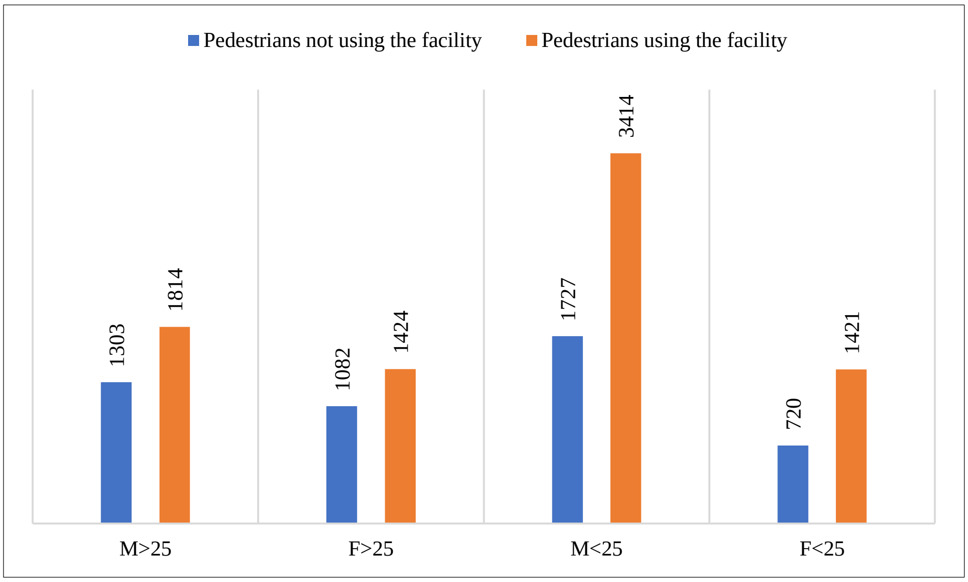
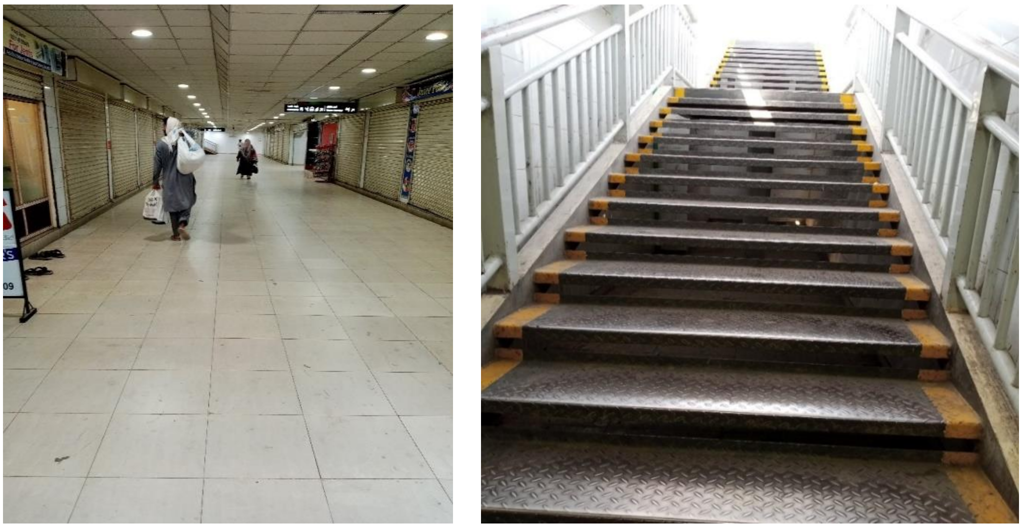


Figure 6. Comparison between Pedestrians using vs. not using the underpass



(a) (b)

Figure 7. Underpass (Station 3). (a) Inside view of underpass; (b) Main entrance of underpass

4.8. Station 4 – Overhead Bridge

Out of the three overhead pedestrian bridge in the current study, this facility had the highest serviceability with 30.07% of the pedestrians using it. Pedestrians having age less than 25 (mean value = 0.3389) are more likely to use the facility as compared to older pedestrians (mean value = 0.2551). This difference is statistically significant, $t(20709)$ =13.151, p<0.0001. There is also an effect of gender on serviceability, Females (mean value = 0.4498) are more likely to use the facility than males (mean value = 0.2580). This difference is statistically significant, $t(20709)$ =-25.448, p<0.0001.

In one week, 20,711 pedestrians were observed. The bridge was used by 30.07% of pedestrians. Fences were used as a median barrier with empty spaces in between where pedestrians could easily cross the road, the bridge's physical condition was poor, and locals threw garbage on the bridge deck; therefore, the majority of males (age<25) prefer to cross the road rather than use the bridge. The highest serviceability is for females aged less than 25 year old (see Table 6 and Figures 8, 9).

Table 6. Number of pedestrians against gender and age at station 4

Total Pedestrians observed		Pedestrians not using the facility	Pedestrians using the facility	serviceability
Gender & Age	Number	Number	Number	Percentage
M>25	6895	5449	1446	21.0
F>25	2551	1587	964	37.8
M<25	9201	6495	2706	29.4
F<25	2064	952	1112	53.9

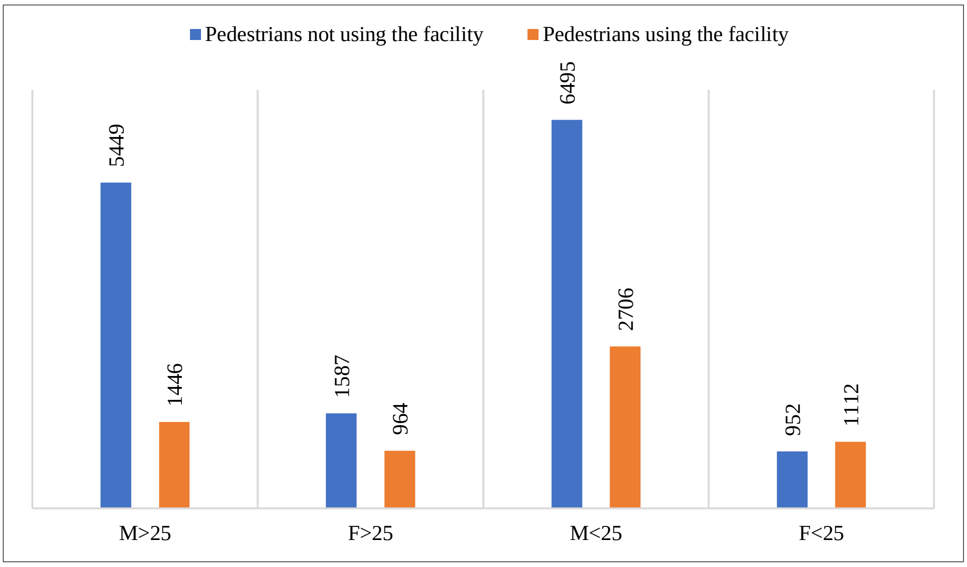


Figure 8. Comparison between pedestrians using vs. not using the bridge

(a) (b)

Figure 9. Overhead bridge (Station 4). (a) View of Ramp facility for bicycle/motorcycle; (b) Fences and Jersey barriers as a median barrier

4.9. Comparison between Bridges and Underpass and the Height of the Facility

The total number of pedestrians recorded on bridges and underpasses is 67,112 and 12,905, respectively. Based on the findings (See Table 7), the overall serviceability of pedestrians is significantly lower than underpasses, with only 11.63% of the pedestrians using the facility across three sites. Age group can also affect the usage of the overhead bridge, with the younger age group more actively using these facilities as compared to the older age groups in both genders (see Table 7).

Table 7. Result comparison of all stations

Station	Result (Percentage use)	Number of Lanes	Type of median barriers	Height in ft* (No. of steps)
Station 1	(4.48 %) overhead bridge	4	concrete blocks	24' (41)
Station 2	(3.27 %) overhead bridge	8 (2 lanes service road)	Fences	20' (30)
Station 3	(62.55 %) underpass	6	Green belt	15' (28)
Station 4	(30.07 %) overhead bridge	6	Fences & jersey barriers	18' (25)

* Height usually has a psychological effect on the serviceability of grade-separated pedestrian crossings. However, the median barriers and the number of lanes have a significant impact on serviceability. The result shows that station 1 has a height of 24' and thus serviceability of 4.48%, whereas station 4 has a height of 18' and serviceability of 30.07%, which is significantly higher than the previous one. The results of underpasses show that at station 3, the green belt acts as a median barrier, so its serviceability is 62.55%

As presented in the findings section, when we compare the height of the facilities, the highest serviceability is for a height of 15 ft., and the lowest serviceability is seen among 20 ft. and 24 ft. high pedestrian facilities. The underpasses observed in this study had far higher serviceability, with infrastructure discouraging passing the roadway illegally.

5. Discussion

As discussed in the background of this study, the lack of facilities such as ramps at the stations also impacts the serviceability of grade-separated pedestrian crossings. Based on the analysis, it is critical to figure out the correct installation of fences and barriers, the installation of ramp facilities, and the effective height of overpasses and underpasses to improve their serviceability.

5.1. Comparison with Other Studies

From Table 8, it is clear that the effectiveness of underpasses is greater than overhead bridges in different countries. Furthermore, the stair's slope greatly impacts the effectiveness of the facility. Proper median barriers can increase the serviceability of the facility. Ramp facility could positively impact the serviceability of the facility, as in a study carried out in Kenya, one of the primary reasons for low serviceability is the absence of a ramp facility.

Table 8. Results comparison with other studies

Country	Result (Serviceability %)	Reasons for less usage	Recommendations	Source
Ankara (Turkey)	6.3% (Overpass)	The high stairs and health reasons.	The stairs' slope should be rephrased	[22]
Delhi (India)	78% (Underpass)	Distance travel to reach the underpass	Traffic police and proper median barriers	[29]
Malaysia	65% (Overpass)	Time loss from using the overpass	Continuous median barrier over a long distance can reduce violation	[30]
Kenya	30% (Overpass)	No ramp to enable the physically challenged to use the bridge	Installation of ramp/elevator facility	[31]
Turkey*	54% (Overpasses)	Time loss from using the overpass	Proper median barrier and presence of law enforcement agency persons.	[38]
Pakistan	62.5% (underpass) & 11.62% (overpasses)	The number of lanes, type of median barriers, and type of facility (bridge/underpass)	A proper median barrier can increase the serviceability	Current study

* The number of steps and slope affects the facility's effectiveness, as demonstrated by the Ankara study (Turkey). A similar study in Kenya found that installing a ramp/elevator can improve the accessibility of pedestrian crossings.

6. Conclusions and Recommendations

The current study adds to the literature on the serviceability of pedestrian overhead bridges and underpasses. The major findings from the study are as follows:

- The study provides evidence that, like other developing countries, the serviceability of pedestrian facilities remains low in Pakistan and that, in comparison, underpasses have significantly higher serviceability compared to overhead bridges.
- The current research also provides empirical evidence that there is an effect of age and gender on the serviceability of these facilities, with females and older pedestrians using these facilities much more than their counterparts.

- The study also provides evidence that if there is space available between medians for pedestrians to cross, they will choose it much more often than in places where there is limited space in medians.
- The number of lanes can impact the serviceability, as at stations where the number of lanes was six, the serviceability was significantly higher than at stations with four lanes.
- The height of the facility (number of stair steps) has a relationship with serviceability, with increasing height resulting in lower serviceability. The station with 15 ft of height has the highest serviceability (63%) as compared to other stations with 18 ft of height (30%), 20 ft of height (3%), and 24 ft height (5%).

These results have implications for both academics and practitioners to further understand the behavior and improve the infrastructure for safe active travel, as it has huge potential to contribute to sustainable urban transportation [39]. However, as noted by recent research, just inserting these facilities in a city does not guarantee their utility [40]. The reliance of many transportation authorities on building 'footbridges' as a means of maintaining uninterrupted traffic flow is a case in point. The potential of pedestrian facilities to reduce the risk of injury to pedestrians should be taken very seriously by policymakers, urban planners, and academics [39]. The current study provides the geometric characteristics that result in improving the serviceability of these facilities.

Based on the extensive observations in this research, the results show that the serviceability of pedestrian overpasses remains very low compared to underpasses, which is also the case with other research studies carried out in developing countries [22, 28–31, 38]. The paper summarizes pedestrian bridges and underpasses' serviceability in Pakistan and compares it with other developing countries. Based on the findings, it is clear that pedestrians prefer to use underpasses over bridges due to the psychological effect of the height (number of steps) of the overhead bridges. The lack of proper median barriers was the primary cause of grade-separated pedestrian crossings' poor serviceability. Proper fencing can improve the facility's usability, as described above. The number of lanes directly correlates with the serviceability of grade-separated pedestrian crossings.

Based on these findings, there are several future research recommendations for academics to understand these facilities' low serviceability further. Questionnaire survey/one-on-one interview with jaywalkers and pedestrians who use the facility to obtain feedback on improving the facility to enhance its serviceability. This can help understand both groups' attitudes, subjective norms, and perceived behavioral control as per the theory of planned behavior [41]. To obtain vehicle volume data, vehicle composition based on different types of vehicles, and the speed of vehicles moving over or under the grade-separated pedestrian crossing to develop a regression model of vehicle data with jaywalkers to see how they impact the traffic flow.

7. Declarations

7.1. Author Contributions

Conceptualization: F.E.G. and M.S.R.; Data curation: F.E.G. and M.S.R.; Formal analysis: F.E.G., M.S.R., and A.D.; Investigation: F.E.G. and M.S.R.; Methodology: F.E.G., M.S.R., A.D., and M.A.; Supervision: F.E.G., A.D., M.A., M.N.S., and M.S.; Writing—original draft: F.E.G. and M.S.R.; Writing—review & editing: F.E.G., M.S.R., A.D., M.A., O.J., M.N.S., and M.S. All authors have read and agreed to the published version of the manuscript.

7.2. Data Availability Statement

The data presented in this study are available on request from the corresponding author.

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7.5. Conflicts of Interest

The authors declare no conflict of interest.

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