

Assessment of pedestrian infrastructures of road transport: A case study of Jimma Town

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Abstract: Pedestrian infrastructures are a critical part of the sustainable transportation system of a city across the world. The key risks to pedestrians are well documented, including infrastructure in terms of the lack of dedicated pedestrian facilities, such as sidewalks, crossings, and raised medians. This paper aimed to assess pedestrian infrastructures of the road transport system in Jimma city. The P-index (Pedestrian-index) method was used to evaluate pedestrian infrastructures, computed with the formula containing the four pedestrian indicators: mobility, safety, pedestrian facility, and accessibility indicator. For this method, sixteen road segments were selected. The result of the mobility indicator shows that the star rating obtained was two stars, which means impaired mobility for the pedestrian. For safety, a 1-star of star-rating was obtained, indicating that the road segments were very unsafe. For the facility indicator, the star-rating value was 2-star which shows inadequate pedestrian facility. For the accessibility indicator, two star-rating was obtained, meaning there was poor accessibility to land uses by walking. Overall P-index value has got a 2-star rating that, which indicates that the existing roads were unfavorable to a pedestrian walking.

Keywords: infrastructures, pedestrian, P-index, star-rating

1. Introduction

Transport plays a crucial role in urban development by providing access for people to education, markets, employment, recreation, health care, and other vital services. Different researches and common sense of society tell us that providing sidewalks and safe street crossing is essential to making a street safe for pedestrians (Retting, 2003). Because of the shifts in transportation modes and land-use patterns, the level of spatial accessibility to various service providers has been dramatically changed in large North-American metropolitan areas (Larsen& Gilliland, 2008). In recent years, the terms "walkability" or "walkable" have been widely used in relevant research papers, along with the increasing research interest in the relationship between built environments (ETA, 2016). Pedestrian infrastructures are a critical part of the sustainable transportation system of a city across the world. The key risks to pedestrians are well documented, including infrastructure in terms of the lack of dedicated



pedestrian facilities, such as sidewalks, crossings, and raised medians. (Moudon, 2006) revealed that walking is the most basic form of transportation. The terms "walkability" and "walkable" have been widely used in research papers on building environments and walking behavior concerning pedestrians. However, traditional planning of the cities pays less attention to walking activity than motorized travel.

Because walking as a travel mode represents only one-fiftieth of the amount of vehicle travel in terms of person miles, conventional planning considers walking a minor mode (Litman, 2003). For this reason, the quality of walking environments has little support in conventional planning (Moudon, 2006). However, starting from the recent time, the concepts of walkable communities and walkability have been receiving increased research interest and attention with the growing body of findings that walkability is related to public welfare (Ewing, 2006). Many mobility-impaired individuals, such as the elderly and children, may have limited access to a car, and a number of individuals do not own private cars. For this reason, it is widely believed that the disparities in access to essential services between advantaged and disadvantaged communities (usually low-income inner-city neighborhoods) have been amplified because of differences in vehicle ownership rates (Bader, 2010).

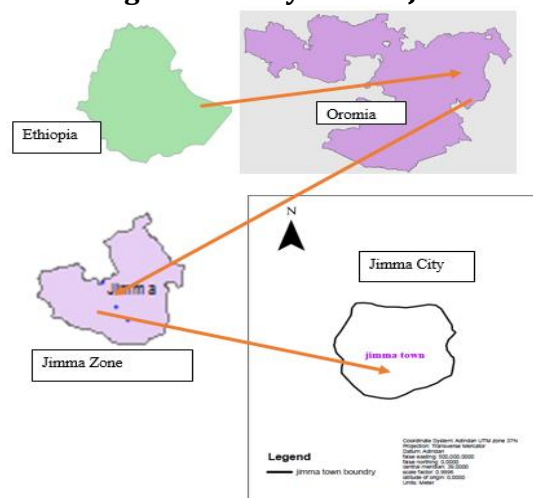
On the other hand, as researchers have identified, studies on walkability and walkable neighborhoods have been extending beyond mere transportation concerns (Moudon, 2006). Considerable evidence suggests that the contents and structures of a built environment impact people's physical activity and highly influence people's health was found by researchers from healthcare fields (Moudon, 2006). Different authors widely argue that residents living in neighborhoods with high accessibility tend to walk more than those with low accessibility (Cervero & Duncan, 2003). The lack of qualitative assessment of pedestrian facilities was pointed out (e.g., street width, block length, traffic, and safety) (Leather, 2011). The width of the sidewalk, the space between the sidewalk and street, and the availability of amenities structures are predictors of pedestrian travel, perceived safety, and quality of the pedestrian environment (Marshall and Garrick, 2010). It was reported that the entire streets of Jimma city were uncomfortable for pedestrian movement, and most of the local streets were highly irregular and poorly laid (NDP Report, 2016).

2. Materials and methods

2.1 Study area

Jimma city, the capital city of Jimma zone, Oromiya National Regional state, is located in the southwest part of Ethiopia and 348 km away from the capital city. This city is at an average altitude of 1700m above sea level, and its astronomical location is 7° 4' North Latitude and 36° 5' East Longitude. It has a total area of 46.23 km² (4623 ha).

Figure 1: Study area of Jimma city



Source: Extracted from GIS

2.2. Pedestrian infrastructures

According to Tilahun and Li (2015), among the factors that affect the likelihood of people walking and taking to transit, the most important and identified factors were revealed and include the amount of time it takes to walk to transit and important locations, perceptions of crime safety, and availability of the sidewalks. In the case of the perceived measures method, the data is formed based on the people's perception within the built environment, which is usually collected through self-reported approaches, such as surveys and interviews (Kelly, 2010).

Abley (2005) defined walkability as "the extent to which the built environment is walking friendly" in his paper presented to New Zealand's Land Transport. The pedestrian infrastructures were analyzed by using the method of P-index. This P-index method was first developed in Malaysia and was used for rating pedestrian infrastructures within a given city (area) as an equation (Nabila, 2013). Different researchers also reused and modified it (Nabila,2015). The P-Index computation is dependent upon a set of four indicators, mobility (M), safety (S), facility (F), and accessibility (A), that form the premise of a suitable pedestrian pathway. The functional relationship between the P-Index (P) and the criteria is given in Eq. (1)

$$P=f(M,S,F,A) \tag{1}$$

The functional relationship of the linear form was applied, and Eq. (1) can be represented by the linear equation of Eq. (2) and subjected to the constraint of Eq. (3):

Now, taking this functional relationship as a linear form of nature,

$$P=b_1M+b_2S+b_3F+b_4A \tag{2}$$

$$\sum_{i=1}^4 b_i=1.0,0\leq b_i\leq 1 \tag{3}$$

Where M is: Mobility indicator; S is: Safety indicator; F is: Facility indicator; A: Accessibility indicator, and $b_1, b_2, b_3,$ and b_4 : are the coefficients representing the weighted value of each of the four parameters.

From Eq. (3), It follows that if $b_1=b_2=b_3=b_4=b=0.25$, then P is reduced to a simple average given by Eq. (4):

$$P = b (M +S +F +A)= (M+S+F+A)/4 \tag{4}$$

By considering the above relationships, when $b_1=b_2=b_3=b_4=b=0.25$, all of the four criteria or parameters have equal importance reflected by the equal weightage.

Table 1: Interpretation of the P-index value		
P-index value	Star rating	Description
0-20	★	Hostile towards pedestrians
21-40	★★	Unfavorable to pedestrians
41-60	★★★	Walkable
61-80	★★★★	Supportive towards pedestrians
81-100	★★★★★	Very pedestrian friendly

Table 2: Summaries of the interpretation of the mobility (M), safety (S), facility (F), and accessibility (A) indicator values and their corresponding star rating

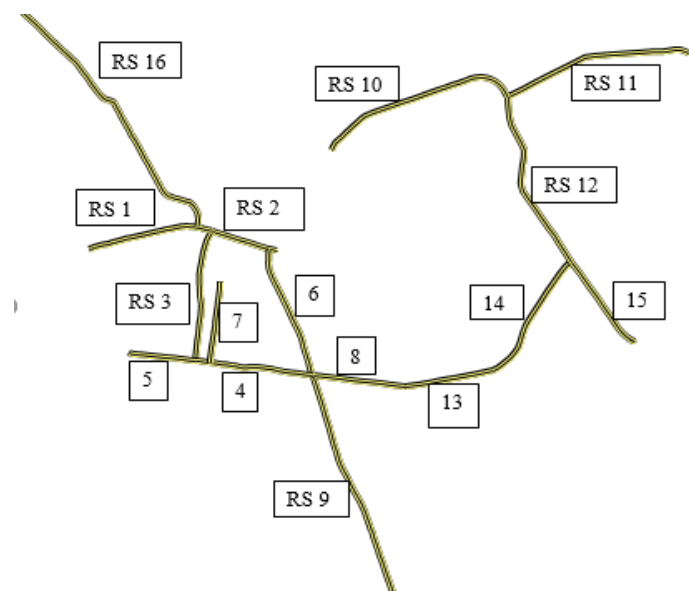
Indicator value	Star rating	Interpretation of Indicator Values			
		Interpretation of the M-indicator value	Interpretation of the S-indicator value	Interpretation of the F-indicator value	Interpretation of the A-indicator value
0-20	★	Little or no mobility	Very unsafe for walking	Non-existence or negligible pedestrian facility	Land uses inaccessible by walking
21-40	★★	Inadequate mobility	Unsafe for walking	Inadequate pedestrian facilities	Poor accessibility to land uses by walking
41-60	★★★ ★★★	Fair mobility	Walk with caution	Moderate availability of pedestrian facilities	Moderate accessibility to land
61-80	★★★★ ★★★★	Good mobility	Safe to walk	Good pedestrian facilities	Good accessibility to land uses by walking
81-100	★★★★★	Excellent mobility	Excellent safety for pedestrian	Excellent pedestrian facilities	Excellent accessibility to land

2.3. Sampling technique and size

Field observation

The criteria for selecting the road segments were: road segments located within an area that attract more number of road users due to the availability of various infrastructures; road segments characterized by a higher number of pedestrian movements, more vulnerable to traffic accidents, and relatively dense vehicle. Sixteen (16) road segments located within Jimma City were selected to be assessed using the *P*-Index method.

Figure 2: Selected road segments with their codes



Source: extracted from GIS

2.4. Source of data

The primary source of data was used. Several methods were used to gather the needed primary data, including field observation and field measurements.

2.5. Data collection method

2.5.1. Primary data collection method

Observation and field measurement

Field measurement was conducted to get the values of the parameters like the number of crossing facilities, length of physically and spatially separated sidewalks along the road segments, and the number of existing bollards and ramps.

Computation of mobility indicator

For each road segment, the length of pedestrian pathways is measured on both sides of the road, regardless of whether the road is single or dual-carriageway. The value of the M-indicator was determined by Eq. (5).

$$M = \left(\frac{0.5Dc}{D} \right) * 100 \quad (5)$$

Where, Dc: total length of paved pedestrian pathway, calculated on both sides of roads (km); D: total length of roadway, calculated one-way (km).

Computation of safety indicator

The S-indicator was computed according to Eq. (6)

$$S = \left(\frac{0.5D_{sp}}{D} \right) * 100 \quad 0 \leq D_{sp} \leq DC \quad (6)$$

Where, D_{sp}: total length of spatially and physically separated paved pedestrian pathway, calculated on both sides of roads (km); Dc: total length of paved pedestrian pathway, calculated on both sides of roads (km); D: total length of roadway, calculated one-way (km).

Determination of facility indicator

The F-Indicator was computed by using Eq. (7).

$$F = \sum_{i=1}^n \left(\frac{0.5B_i + 0.5R_i + Z_i}{3n} \right) * 100, \quad (7)$$

where,

$$B_i \text{ and } R_i = \begin{cases} 2, & \text{if available on both side} \\ 1, & \text{if available on one side} \\ 0, & \text{if absent} \end{cases}$$

B_i: bollard facility; R_i: Ramp facility; and Z_i: zebra crossing facility.

Accessibility indicator

Becho Bore kebele was taken as the circle of approximate walking distance. There are three types of land uses in Jimma city, and these include Residential (R), Commercial (C), and Institutional (I) land uses ($k = 3$). The value of the A-indicator was determined by using Eq. (8)

$$A = \frac{\sum_{j=1}^k L_j}{K} * 100 \quad (8)$$

Where, L_j: households' percentage (%) within walking distance to land uses j, $j = 1, 2 \dots k$

3. Results and discussion

3.1. Measured lengths of road segments

Table 3: Selected road segments with their measured lengths

Road segment	Road Segment Name	Total length(km)
1	Arat-Anbessa to Gibe Hall	0.682
2	Arat-Anbessa to Aweytu River	0.312
3	Arat-Anbessa to Merkato (Hirmata CBE branch)	0.765
4	Merkato to Bus Station	0.660
5	Merkato to Seka bar	0.387
6	Aweytu River to Bus Station	0.778
7	CBE Main Branch to City Center Building	0.452
8	Bus Station to Hassen Garage	0.506
9	Bus Station to Shanan Gibe Hospital	1.246
10	Kochi Bajaj Tera to Dipo	0.945
11	Kochi Bajaj Tera to Jimma Teachers College	1.114
12	Kochi Bajaj Tera to Honey land Hotel	1.055
13	Hassan Garage to St. Michael church	0.618
14	From St. Michael church to Honey land Hotel	0.779
15	Honey land Hotel to Commodity Exchange Station	0.355
16	Variety Café to Sares Tax Station	1.684

3.2. Evaluation of mobility indicator (M-indicator)

Table 4: Values of mobility indicator (M-indicator)

Road segment	Road Segment Name	Length of the pedestrian pathway (Km)	Mobility
1	Arat-Anbessa to Gibe Hall	0.788	57.77
2	Arat-Anbessa to Aweytu River	0.574	91.99
3	Arat-Anbessa to Merkato (Hirmata CBE	1.216	79.48
4	Merkato to Bus Station	0.583	44.17
5	Merkato to Seka bar	0.539	69.64
6	Aweytu River to Bus Station	1.458	93.70
7	CBE Main Branch to City Center Building	0.077	8.52
8	Bus Station to Hassen Garage	0.507	50.08
9	Bus Station to Shanan Gibe Hospital	0.417	16.73
10	Kochi Bajaj Tera to Dipo	0.013	0.69
11	Kochi Bajaj Tera to Jimma Teachers College	0.377	16.92
12	Kochi Bajaj Tera to Honey land Hotel	0.069	3.27
13	Hassan Garage to St. Michael church	0.749	60.60
14	From St. Michael church to Honey land Hotel	0.779	50.00
15	Honey land Hotel to Commodity Exchange	0.317	44.65
16	Variety Café to Sares Tax Station	1.431	42.49
Total		9.894	40.10

Using Eq. (5), the overall value of the mobility indicator of the pedestrian infrastructure in Jimma city was:

$$M = \left(\frac{0.5Dc}{D} \right) * 100 = 40.1$$

D = 12.338 Km Dc=9.894 Km

The overall *M*-value was 40.1. Moreover, the corresponding star rating was two stars, which means impaired pedestrian mobility along the road segments within Jimma city. This result was analogous to the result obtained by some researchers (Nabila, 2015). From Table 6, 37.5% (6 in number) of road segments were within the range of 41-60 mobility indicator value, indicating that most roads were provided with fair mobility. In-and-out land access has to be allowed by road segments to the desired destinations as much as possible but along with the varied modes of travel (i.e., with the use of

a pedestrian sidewalk or mobility) comes satisfying the need for safety and quality of the road environment for all of its users (Refaat & Kafafy, 2014). Many pedestrian walkways (sidewalks) are needed through the total lengths of the roadway, especially at the higher volumes of pedestrians and vehicles.

3.3. Calculation of safety indicator (S-indicator)

Table 5: Values of safety indicator (S)

Road segment	Road Segment Name	Length of spatially and physically separated, paved pedestrian path (km)	Safety
1	Arat-Anbessa to Gibe Hall	0.021	1.54
2	Arat-Anbessa to Aweytu River	0.000	0.00
3	Arat-Anbessa to Merkato (Hirmata)	0.022	1.44
4	Merkato to Bus Station	0.000	0.00
5	Merkato to Seka bar	0.000	0.00
6	Aweytu River to Bus Station	0.110	7.07
7	CBE Main Branch to City Center	0.000	0.00
8	Bus Station to Hassen Garage	0.000	0.00
9	Bus Station to Shanan Gibe Hospital	0.096	3.85
10	Kochi Bajaj Tera to Dipo	0.000	0.00
11	Kochi Bajaj Tera to Jimma Teachers	0.000	0.00
12	Kochi Bajaj Tera to Honey land	0.000	0.00
13	Hassan Garage to St. Michael church	0.000	0.00
14	From St. Michael church to Honey	0.000	0.00
15	Honey land Hotel to Commodity	0.000	0.00
16	Variety Café to Sares Tax Station	0.000	0.00
Total		0.249	1.01

Using Eq. (6), the overall value of the safety rate of pedestrian infrastructure in Jimma city was:

$$S = \left(\frac{0.5D_{sp}}{D} \right) * 100 = 1.01$$

The computed overall S-value was 1.01, indicating a star rating of 1 star, which means the existing road segments were very unsafe for walking. All 16 road segments have a safety indicator value within the range of 0-20, which indicates that the road segments were very unsafe for walking.

3.4. Computation of facility indicator (F-indicator)

Table 6: Facility indicator (F) values

Road segment	Road Segment Name	N	B _i	R _i	Z _i	0.5B _i +0.5R _i +Z _i	Facility (F)
1	Arat-Anbessa to Gibe Hall	7	0	0	6	6	28.57
2	Arat-Anbessa to Aweytu River	2	0	2	3	4	66.67
3	Arat-Anbessa to Merkato (Hirmata CBE)	6	0	0	7	7	38.89
4	Merkato to Bus Station	3	0	0	7	7	77.78
5	Merkato to Seka bar	4	0	0	1	1	8.33
6	Aweytu River to Bus Station	2	0	0	3	3	50.00
7	CBE Main Branch to City Center Building	4	0	0	1	1	8.33
8	Bus Station to Hassen Garage	3	0	0	7	7	77.78
9	Bus Station to Shanan Gibe Hospital	5	0	0	3	3	20.00
10	Kochi Bajaj Tera to Dipo	6	0	0	5	5	27.78
11	Kochi Bajaj Tera to Jimma Teachers College	5	0	0	6	6	40.00
12	Kochi Bajaj Tera to Honey land Hotel	3	0	0	1	1	11.11
13	Hassan Garage to St. Michael church	5	0	0	4	4	26.67
14	From St. Michael church to Honey land Hotel	5	0	0	4	4	26.67
15	Honey land Hotel to Commodity Exchange	2	0	0	2	2	33.33
16	Variety Café to Sares Tax Station	5	0	0	5	5	33.33
Total		67	0	2	65	66	32.84

$$F = \sum_{i=1}^n \left(\frac{0.5Bi + 0.5Ri + Zi}{3n} \right) * 100$$

Using Eq. (7), the overall facility rate of pedestrian facilities in Jimma city was: =32.84

The overall value of the *F*-indicator was 32.84. Moreover, the corresponding star rating was two stars, which shows inadequate pedestrian facilities in the city's road segments. 50 % (8 in number) of the selected road segments have a facility indicator value within the range of 21-40, indicating that most roads were provided with inadequate pedestrian facilities. Generally, the possible problems with crosswalks for pedestrians are that motorists are estimated to be less alert to pedestrians crossing at other locations, and pedestrians at crosswalks may be less alert to potentially conflicting vehicle traffic (Chen, 2011). Marked crosswalks indicate optimal or preferred locations for pedestrians to cross and help designate right-of-way for motorists to yield to pedestrians. Marked crosswalks warn motorists to expect pedestrian crossings and indicate preferred crossing locations. Pedestrians are sensitive to out-of-the-way travel, and reasonable accommodations should be made to make crossings both convenient and safe at locations with adequate visibility

3.5. Accessibility indicator (A-indicator)

Table 7: Accessibility indicator (A)

Observed land use	Percentage(%) with in selected walking distance
Residential (R)	29.7
Institutional (I)	17.5
Commercial (C)	55.2

Using Eq. (8), the overall accessibility rate of pedestrian infrastructures in Jimma city was: =34.13

The overall computed *A*-value was 34.13. The star-rating corresponding to this value was two stars, meaning there was poor accessibility to land uses by walking. This moderate value was obtained because most land uses were not located within the selected walking distance (i.e., within the selected kebele). The effect of this value has been checked by varying the coefficients' values in the general equation of the *P*-index.

3.6. Determination of pedestrian index (P-index) Value

The summary of the *P*-Index (*P*) for all of the selected Road Segments in Jimma city (where $b_1=b_2=b_3=b_4=0.25$) is shown in Table 8.

Table 8: Values of P-index with the corresponding star-rating

Road segment	Road Segment Name	M	S	F	A	P-index	Star rating
1	Arat-Anbessa to Gibe Hall	57.77	1.54	28.57	34.13	30.50	★★
2	Arat-Anbessa to Aweytu River	91.99	0.00	66.67	34.13	48.20	★★★
3	Arat-Anbessa to Merkato (Hirmata CBE branch)	79.48	1.44	38.89	34.13	38.49	★★
4	Merkato to Bus Station	44.17	0.00	77.78	34.13	39.02	★★
5	Merkato to Seka bar	69.64	0.00	8.33	34.13	28.03	★★

6	Aweyту River to Bus Station	93.70	7.07	50.00	34.13	46.23	★★★
7	CBE Main Branch to City Center Building	8.52	0.00	8.33	34.13	12.75	★
8	Bus Station to Hassen Garage	50.08	0.00	77.78	34.13	40.50	★★
9	Bus Station to Shanan Gibe Hospital	16.73	3.85	20.00	34.13	18.68	★
10	Kochi Bajaj Tera to Dipo	0.69	0.00	27.78	34.13	15.65	★
11	Kochi Bajaj Tera to Jimma Teachers College	16.92	0.00	40.00	34.13	22.76	★★
12	Kochi Bajaj Tera to Honey land Hotel	3.27	0.00	11.11	34.13	12.13	★
13	Hassan Garage to St. Michael church	60.60	0.00	26.67	34.13	30.43	★★
14	From St. Michael church to Honey land Hotel	50.00	0.00	26.67	34.13	27.78	★★
15	Honey land Hotel to Commodity Exchange Station	44.65	0.00	33.33	34.13	28.03	★★
16	Variety Café to Sares Tax Station	42.49	0.00	33.33	34.13	27.49	★★
Total		40.10	1.01	32.84	34.13	27.02	★★

Table 9: Summary of an overall assessment of pedestrian infrastructures in Jimma city

Indicators	Marks obtained	Rating	Meaning
Mobility(M)	40.1	★★	Inadequate mobility
Safety(S)	1.01	★	Very unsafe to walking
Facility (F)	32.84	★★	Inadequate pedestrian facility
Accessibility(A)	34.13	★★	Poor accessibility to land uses by walking
P-index	27.02	★★	Unfavorable to pedestrian

3.7. Effect of variability of the four pedestrian indicator's coefficients (b)

$\sum_{i=1}^4 bi$ In this method of P-index, the assigned coefficients use a simple average method in which its values are less than or equal to 1, = 1, $0 \leq bi \leq 1$.

Table 10: Values of the P-index and the corresponding star rating of the selected road segments with the various coefficients of the four indicators

Road segment	Road Segment Name	M	S	F	A	P-index if b1=b3=0.3 b2=b4=0.2	Star rating for coe.in col.7	P-index if b1=b3=b4=0.3, b2=.1	Star rating For coe.incol. 9
1	Arat-Anbessa to Gibe Hall	57.8	1.54	28.6	34.13	33.04	★★	36.3	★★
2	Arat-Anbessa to Aweytu River	92.0	0	66.7	34.13	54.42	★★★	57.84	★★★
3	Arat-Anbessa to Merkato(Hirmata CBE branch)	79.5	1.44	38.9	34.13	42.63	★★★	45.89	★★★
4	Merkato to Bus Station	44.2	0	77.8	34.13	43.4	★★★	46.82	★★★
5	Merkato to Seka bar	69.6	0	8.3	34.13	30.22	★★	33.63	★★
6	Aweytu River to Bus Station	93.7	7.07	50	34.13	51.35	★★★	54.06	★★★
7	CBE Main Branch to City Center Building	8.5	0	8.3	34.13	11.88	★	15.29	★
8	Bus Station to Hassen Garage	50.1	0	77.8	34.13	45.18	★★★	48.6	★★★
9	Bus Station to Shanan Gibe Hospital	16.7	3.85	20	34.13	18.62	★	21.64	★★
10	Kochi Bajaj Tera to Dipo	0.7	0	27.8	34.13	15.37	★	18.78	★
11	Kochi Bajaj Tera to Jimma Teachers College	16.9	0	40	34.13	23.9	★★	27.32	★★
12	Kochi Bajaj Tera to Honey land Hotel	3.3	0	11.1	34.13	11.14	★	14.55	★
13	Hassan Garage to St. Michael church	60.6	0	26.7	34.13	33.01	★★	36.42	★★
14	From St. Michael church to Honey land Hotel	50	0	26.7	34.13	29.83	★★	33.24	★★
15	Honey land Hotel to Commodity Exchange Station	44.6	0	33.3	34.13	30.22	★★	33.63	★★
16	Variety Café to Sares Tax Station	42.5	0	33.3	34.13	29.57	★★	33	★★
Total		40.1	1.01	32.8	34.13	28.91	★★	32.22	★★

Changing the values of the coefficients for the four indicators have no more effect on the overall P-index value and the corresponding star rating. Road segments located within the Jimma city were not provided with adequate infrastructure. There was no safety, adequate crossing facility, or enough accessibility.

4. Conclusions

The observed result showed that the existing pedestrian infrastructure is unfavorable to pedestrians walking in the town's vicinity. From the value of the mobility indicator, the provided mobility is inadequate for the movement of the people along the road segments, indicating the lack of sidewalks and walkways. In this town, the provided infrastructure for the pedestrian is very unsafe for

walking, which shows that the existing street lacks safety considerations, and the constructed sidewalks are not separated from the motor vehicle paths. The result obtained in this study also shows inadequate pedestrian facilities, including crosswalks, ramps, and bollards. Poor accessibility to land uses of the road segments was also observed, which is unsuitable for moving people on foot. In this study, the level of availability and comfortability of pedestrian infrastructures of the road transport system was shown with the help of four pedestrian indicators: mobility, safety, accessibility, and pedestrian facility. Some of the most important results of this study are the following.

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