Improvement to Pedestrian Walkway Facilities to Enhance Pedestrian Safety-Initiatives in India

Basavaraj Kabade, K. T. Nagaraja, Swathi Ramanathan, A. Veeraragavan, P. S. Reashma

Abstract**—**Deteriorating quality of the pedestrian environment and the increasing risk of pedestrian crashes are major concerns for most of the cities in India. The recent shift in the priority to motorized transport and the abating condition of existing pedestrian facilities can be considered as prime reasons for the increasing pedestrian related crashes in India. Bengaluru City – the IT capital hub of the nation is not much different from this. The increase in number of pedestrian crashes in Bengaluru reflects the same. To resolve this issue and to ensure safe, sustainable and pedestrian friendly sidewalks, Govt. of Karnataka, India has implemented newfangled pedestrian sidewalks popularized programme named Tender S.U.R.E. (Specifications for Urban Road Execution) projects. Tender SURE adopts unique urban street design guidelines where the pedestrians are given prime preference. The present study presents an assessment of the quality and performance of the pedestrian side walk and the walkability index of the newly built pedestrian friendly sidewalks. Various physical and environmental factors affecting pedestrian safety are identified and studied in detail. The pedestrian mobility is quantified through Pedestrian Level of Service (PLoS) and the pedestrian walking comfort is measured by calculating the Walkability Index (WI). It is observed that the new initiatives taken in reference to improving pedestrian safety have succeeded in Bengaluru by attaining a level of Service of ‘A’ and with a good WI score.

Keywords**—**Pedestrian safety, pedestrian level of service, right of way, Tender SURE, walkability index, walkway facilities.

I. Overview of Pedestrian Infrastructure Facilities in India

WALKING is one of the most important travel modes in India because of the social and economic conditions. However, there is lack of attention towards the pedestrians, their concerns and needed facilities. The basic facilities pedestrians require are segregated sidewalks that avoid conflicts between other pedestrians and motor vehicles, safe crossing facilities and other environmental-friendly walkway facilities to ensure a comfortable walking environment. The recent shift in the priority to motorized transport needs and the deteriorating condition of existing pedestrian facilities worsened the scenario and increased the pedestrian risk throughout the country. Most of the pedestrian sidewalks in India today are showcased by inadequate width, lack of supporting street furniture, frequent utility repair works, illegal parking, and street vendor encroachment which forces the pedestrian to walk on the carriageway risking their life.

Accident statistics in India reveal an increase of 2.5% in road accidents from 4,89,400 in 2014 to 5,014,23 in 2015 [1], [2]. The pedestrian comprises 37% of the total deaths from road accidents and nearly 35% of pedestrian accidents have happened near sidewalks [3]. Karnataka, one of the popular states in southern India with a population of 61.09 million, stands fourth among all states in the country in the number of accidents and fatalities reported in 2015. Bengaluru, the urban IT Capital of Karnataka, added 4,828 road accidents with 331 fatal pedestrian accidents [4].

Most urban roads in Bengaluru are an example of traffic chaos, broken sidewalks, hanging cables, clogged drains, overflowing sewage and haphazard street lights, as well as transformers and telecom fixtures. Temporary fixes with poor design and construction results in repeated digging and repairs of the same road, continuously draining the city’s coffers, while doing little to enhance the quality of the roads, and thereby, the quality of road users.

The Government of Karnataka has shown leadership in addressing this colossal wastage by improving the quality of the most basic mobility infrastructure. One such initiation is popularized under project Tender SURE (Specifications for Urban Road Execution), where guidelines have been developed for the design of urban streets and implemented with pedestrians as the prime focus. This was the first kind of project in India aiming to improve pedestrian infrastructure facilities and increasing the level of safety.

The paper describes the details of Tender SURE design guidelines and its successful implementation at various locations in Bengaluru city. Further, to analyze the performance of the new infrastructure, a few walkability studies were conducted.

II. Tender SURE – The New Approach in Urban Street Design

Tender SURE is about getting the urban road right by applying a whole and new sustainable approach in designing and implementation in the urban roads. The distinctive focus of Tender SURE is the movement and safety of pedestrians

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and cyclists, consistent traffic flows and travel lane widths, and the intelligent re-laying of all sub-terrain utilities by integrating with various government bodies. In addition, other walkway facilities like parking spaces, street landscaping trees, designated spaces for street vendors, segregated waste disposal places, adequate lighting facilities, signage, ramped sidewalks, and required junction improvements on roadways, etc., were also incorporated in the design aspects.

III. Tender SURE – Planning Standards

The standards provided for various Right of Way elements are based on the type of urban roads like arterial, sub-arterial, collector and local roads and are in accordance with the guidelines of Tender SURE and the Ministry of Road Transport and Highways.

A. Right of Way

As the right of way of road network varied, the design considered the average road width or the minimum road width in the road segments. Based on the space availability, the number and width of lanes, width of parking lane, cycle line and sidewalk lanes are designed.

B. Design Speed

A design speed of 80 km/h, 60 km/h, 50 km/h and 30 km/h was chosen as design speed for arterial, sub-arterial, collector street and local street roads as in accordance with guidelines provided by Indian Road Congress [5].

C. Travel Lane

Referring to the standards and also considering the space constrain, a traffic lane width of 3 m, 3 m, 2.75 m and 2.5 m were chosen for arterial, sub-arterial, collector and local roads. The travel lane width is designed was of uniform and consistent width.

D. Geometric Elements

The horizontal geometry, horizontal and vertical alignment, and super elevation were designed as per IRC guidelines [5], [6]. A cross slope of 2.5% is considered for the main travel lane and 3% for the pedestrian sidewalk. The alignment of the road network was retained at most places unless there was a need to address it.

E. On-Street Parking

A parallel parking with standard size of 2.75x6 m was chosen for the parking lane. Appropriate locations were identified in the road network for public, private and intermediate transport vehicles. Few slots of 1x2 m are allocated in between for two wheeler parking.

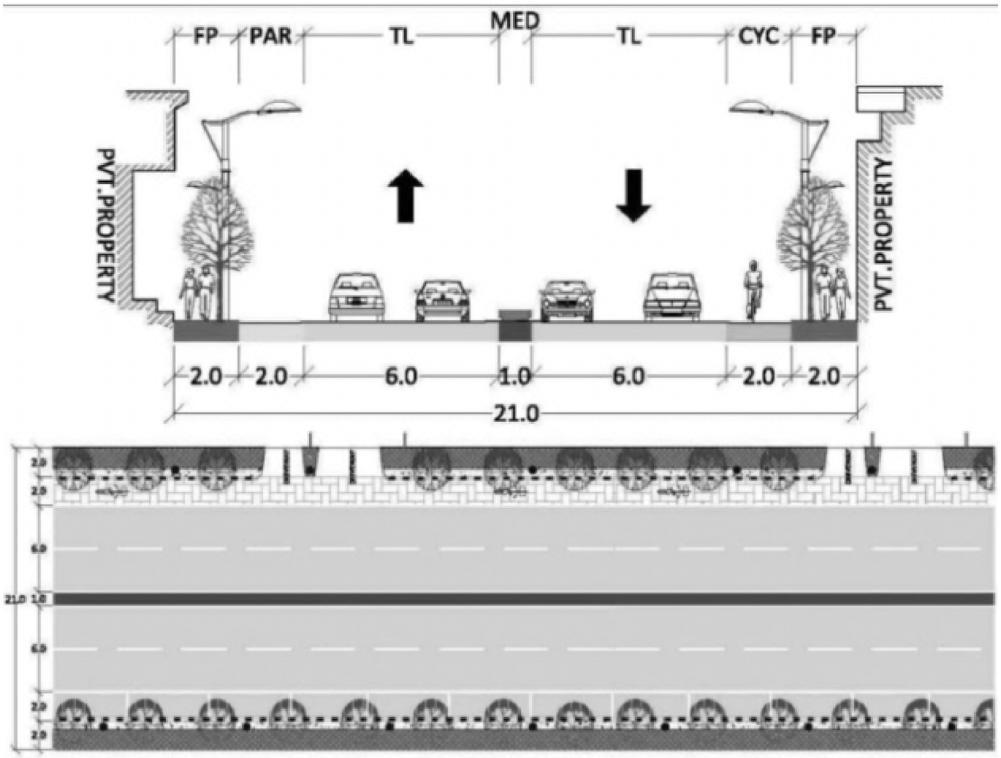

Fig. 1 Cross section of RoW as per the Tender SURE design guidelines

F. Landscape Strip

A landscape strip is provided on all roads along the street light strip. Dedicated spaces of 1x1 m to 1.5x1.5 m units are carved out of Right of Way (RoW) at appropriate places to accommodate the hawkers/vendors activities. Public toilets and solid waste collection bins were also incorporated in the design and apposite locations were identified in the road network.

Preliminary field investigations were carried out to analyze the feasible design options. Topographic surveys, traffic and pedestrian volume count surveys, and soil deflection tests were performed before deriving at the design development. Topographic survey captured the site features like location of side drains, existing pavement cross section elements, position of traffic islands, bridges, flyovers, property identification, and also the location of trees, man holes, utility lines and other electrical lines. The traffic volume count survey resulted in the calculation of the present volume/capacity ratio. The road network was also characterized with its pedestrian movements by the pedestrian volume count survey. Benkelman Beam deflection and related soil tests were conducted for structural evaluation of the existing pavement.

IV. Tender SURE –Design Development

The Tender SURE design guidelines have been framed based on the planning standards and the responses of the field investigations and data collected from various surveys. The design of RoW includes design of travel lane, sidewalk, non-motorized lane, utilities and other drains, parking lane, street furniture, and signage and intersections with their materials and dimension. As per the design standard, a minimum width recommended for the travel lane, sidewalk, non-motorized lane, parking are 3 m, 1.5 m, 3 m and 1.5 m, respectively. A typical cross section of RoW with Tender SURE specifications is shown in Fig. 1.

The design guidelines also specify the material specification and the dimensions of the cross sectional elements. For instance, 60 mm shot blasted interlocking tiles for the pedestrian sidewalk and 8 m height LED lights for better visibility have been recommended. In addition to the cross sectional elements, design guidelines have been drafted for road design (design of overlay, paver block, sidewalk, non-motorized lane, parking lane), above grade street fixtures (street light, road markings, signage, signal poles) and below grade utilities (storm water drains, water supply drains, sewers, power cables, telecom lines, gas lines, etc.). More details of the specifications are presented in Fig. 2.

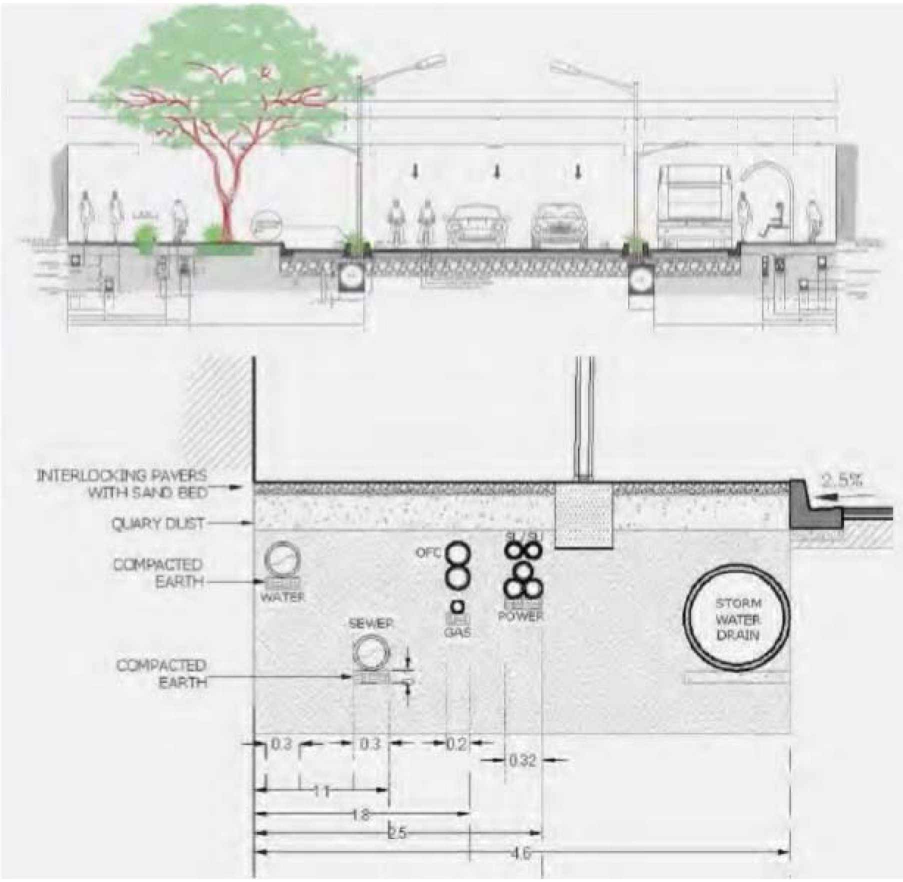

Fig. 2 Tender SURE design guidelines

V. Tender SURE –Implementation at Seven Locations in Bengaluru City

The Tender SURE infrastructure initiatives have planned to be implemented at various urban roads at different phases in Bengaluru City, Karnataka. It has been successfully implemented at seven central business district areas at present, including Vittal Mallya Hospital Road, Cunningham Road, Residency Road, St. Mark's Road, Museum Road, Commissariat Road and Richmond Road. The network of these seven roads has their importance in supporting business/commercial hubs, historical structures, public buildings, and schools, etc. The purpose of the redesign of the urban street is to support these functions, in addition to catering to the needs of pedestrians and non-motorized transport users. The road network selected for phase one implementation is shown in Fig. 3.

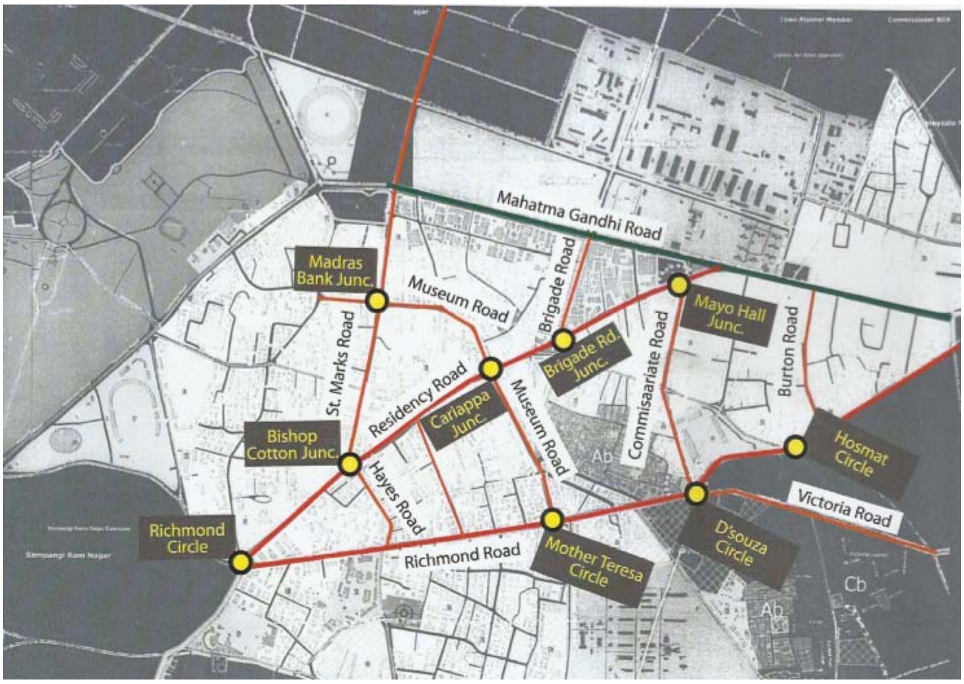

Fig. 3 Tender SURE road network

TABLE I
TENDER SURE DESIGN SPECIFICATIONS

Road Name & Type	RoW [A]	Travel Lane	Sidewalk	Cycle Lane	Parking Lane
Residency Road (arterial)	25 to 31	3L	2 + 2	1.5 + 1.5	2
Richmond Road (arterial)	15 to 24	4L	2 + 2	1.5 + 1.5	2
	11.5 to 15	2L	1.5+ 1.5	1.5 + 1.5	0
St. Mark's road (sub arterial)	15 to 17	2L	2 + 2	2	2
	19 to 23	3L	2 + 2	1.5 + 1.5	0
Cunningham road (sub arterial)	19 to 24	2L	2 + 2	1.5 + 1.5	2
Vittal Mallya Hospital road (collector)	16 to 20	3L	2 + 2	1.5 + 1.5	2
Commissariat road (collector)	18 to 21	3L	1.5 + 1.5	1.5 + 1.5	0
Museum road (collector)	13.5 to 18	3L	1.5 + 1	1 + 1	0
	26 to 31	3L+3L	2 + 2	1.5 + 1.5	0

[A] all dimensions are in meter (m).

The design specifications of the RoW for all seven locations are listed in Table I.

The implementation of Tender SURE at the above locations have been photographed and displayed in Fig. 4.

VI. WALKABILITY STUDIES ON TENDER SURE SIDEWALKS

Since pedestrian safety is a major concern, it becomes necessary to assess the performance of the new Tender SURE sidewalks and measure the walking conditions. Such a measure helps in evaluating the present sidewalk facilities and also for prioritizing the needs for further improvements.

Fig. 4 Tender SURE infrastructure at Richmond road, Bengaluru

Several indices have been developed in the past two decades that evaluate and quantify the walkability conditions of a sidewalk [7]-[19]. Most of these measures were either based on quantitative variables to determine the extent of the current level of service of a sidewalk, while others analyze pedestrian perception and qualitative variables, and rate the facility. Among the various indices, the common approach to assess the performance of pedestrian facilities is by calculating the PLoS and rating the sidewalk by deriving the WI. Different methods have been practiced to calculate these indices [20]. The most referred to is the Highway Capacity Manual, which has defined the PLoS of sidewalks based on pedestrian density, space, and flow [21].

Guidelines for pedestrian sidewalks and the recommended PLoS levels have been drafted for Indian conditions [22], [23]. In India, a WI was used in one of the studies commissioned by the Ministry of Urban Development (MOUD). This study indexed 30 cities of all sizes on walkability and assessed them based on the availability of sidewalks on major arterial roads, and the overall facility rating by pedestrians themselves [24]. The perception of pedestrians was gauged on the availability and quality of sidewalks, obstructions, maintenance, lighting, security from crime, safety of crossings, and other qualitative factors. A low rank indicates inadequate and substandard pedestrian facilities.

The present study attempts to quantify the Tender SURE pedestrian sidewalk performance through PLoS and rate the facility by its WI.

A. Data Collection

The present study analyses the Tender SURE pedestrian infrastructure at four locations – Vittal Mallya Hospital Road, Cunningham Road, St. Mark's Road and Residency Road.

B. PLoS of Present Tender SURE Sidewalks

A quantitative assessment of the existing pedestrian facilities was carried out and the PLoS level is calculated. The data for pedestrian movements in both directions is collected during morning peak hour on a typical weekday. A pedestrian grid of a known cross sectional area was considered at each sidewalk. The pedestrian movements on these grids were recorded by videography for two hours (8.00 – 10.00) in the morning. The data pertaining to pedestrian speed, flow, and density is later extracted from these video files. The following section summarizes the data extraction process. A snapshot of the pedestrian grid is shown in Fig. 5.

Fig. 5 Pedestrian grid chosen on tender SURE sidewalks

Determining Speed of Pedestrians: Pedestrian speed is the average pedestrian walking speed (m/s). The speed data is extracted as follows:

- A random pedestrian about to enter the grid is selected and monitored through the entire grid length. The entry and exit time of the pedestrian in the grid is noted. The walking time is calculated by subtracting the grid entry time from the time of exit. The walking speed is then calculated by dividing the grid length by the walking time.

Determining Pedestrian Space and Density: The Pedestrian Space is the average area provided for each pedestrian in a footpath, whereas the density is the average number of pedestrians per unit of area within a footpath. The pedestrian space and density follows an inverse relationship. The pedestrian density data is extracted as follows:

- Density of the area is obtained by counting the total number of pedestrians in the pedestrian grid and dividing it by the area of the pedestrian grid. This is calculated by selecting a random pedestrian in the middle of the pedestrian grid and counting the other pedestrians within the grid. The counted number of pedestrians divided by the grid area gives the pedestrian density. The inverse of pedestrian density is taken as the pedestrian space.

Determining Pedestrian Flow Rate: Pedestrian flow rate is the number of pedestrians passing a point per unit time, expressed as pedestrians per 15 minutes or pedestrians per minute. The following are the steps involved in extracting the pedestrian flow rate data:

The pedestrians crossing the grid for every 15 minutes at peak hour is counted. The pedestrian flow is calculated by dividing the 15-minute pedestrian volume by the width of the grid. This flow value per minute gives the flow rate in pedestrians/min/m. The peak 15-minute volume is reported as the flow rate in pedestrians/min/m.

The data were extracted and the pedestrian characteristics at the four locations are presented in Table II. This data is obtained from the field, and then analyzed to understand the suitability of the facility in terms of level of service measurement for the recorded pedestrian volume. Highway Capacity Manual (HCM) and Indian Road Congress (IRC) guidelines on Pedestrian facilities have been referred to, to derive the present PLoS level [21], [22].

TABLE II
PEDESTRIAN CHARACTERISTICS AT TENDER SURE SIDEWALKS

Road Name	Pedestrian Volume[a]	Pedestrian Density[b]	Flow[c] (p/m)	Flow Rate[d] (p/m/Min)	PLoS
Vittal Mallya Hospital road	688	0.16	55.71	3.71	A
Cunningham road	995	0.29	104.33	6.96	B
Residency road	287	0.06	13.48	0.9	A
St. Mark's road	358	0.13	41.67	2.78	A

[a] pedestrian volume is presented in pedestrians per hour, [b] pedestrian density is in pedestrians per square meter, [c] pedestrian flow is in pedestrians per meter, [d] pedestrian flow rate is in pedestrians per meter per minute.

The Tender SURE pedestrian sidewalk provides a level of service A and B which enables pedestrians to move in desired paths without any conflicts with other pedestrians. They are able to walk at selected speed and enjoy sufficient space for their movement. The details of the qualitative assessment are presented in the next section.

C. WI of Tender SURE Sidewalks

The qualitative assessment of sidewalks is crucial for the evaluation and design of sidewalks. The sidewalk performance can be derived based on pedestrians perception. Information collected from pedestrians is used to predict a set of qualitative variables to determine the extent to which a sidewalk's current level of service meets a pedestrian's expectation. The present study investigates the qualitative assessment and computes the WI of Tender SURE sidewalks.

The WI considers two aspects: significance of available sidewalk facilities and user satisfaction while experiencing the sidewalk. Refer to (1) for the calculation of WI.

$$WI = \sum A_i \times B_i \quad (1)$$

where Ai is the importance weightage for physical and user characteristics and Bi is the satisfaction rating for physical and user characteristics. The factors evaluated in physical characteristics were sidewalk surface, sidewalk width, obstruction, potential for vehicular conflict, continuity and the user factors were encroachment, availability of crossing facilities, security, walk environment and comfort.

The importance weightage was assigned by transportation planners/engineers after field assessment. The satisfactory ratings were collected from the pedestrians through a questionnaire survey. The rating was performed on a scale of 1 to 5 for weightage (1=immaterial, 2=least importance, 3=important, 4= very important and 5=most important) and for satisfaction (1=poor, 2=satisfactory, 3=good, 4=very good, 5=excellent) with respect to 10 sidewalk attributes.

The collective pedestrian satisfactory responses on the physical and user characteristics of Tender SURE sidewalks is summarized and presented in Fig. 6 for one location. Similar exercises were repeated for all the other locations and the calculated WI is listed in Table III.

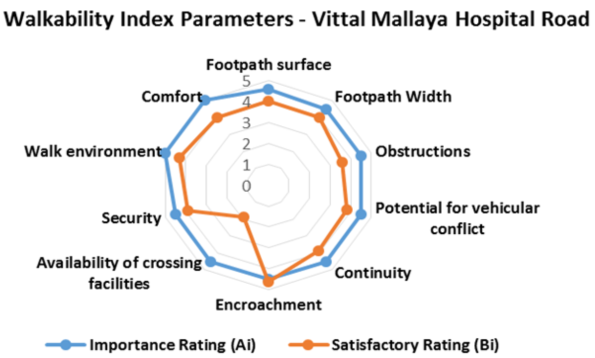

Fig. 6 WI parameters at Vittal Mallya Hospital Road

TABLE III
WI OF TENDER SURE SIDEWALKS

Road Name	WI
Vittal Mallya Hospital road	176
Cunningham road	174
Residency road	199
St. Mark's road	190

The value of the WI explains the quality of Tender SURE walkway facilities and the walking environment. A score of 250 would be the maximum walkability score to attain. The present values are closer and indicates the quality of service. This analysis also helps in analyzing the areas where further improvements are required.

VII. CONCLUSION

The initiative taken by Karnataka government popularized as Tender SURE projects adopts unique design guidelines for improving the urban road design and pedestrian safety. The project has been successfully implemented at seven locations in Bengaluru city and showcases the prime example by prioritizing the pedestrian essentials in first place. The design guidelines adopted is summarized in the paper. The performance of the sidewalk infrastructure has evaluated both quantitatively and qualitatively. The pedestrian flow characteristics are studied and analyzed in quantitative assessment while the pedestrian perception on sidewalk environment is captured in qualitative analysis.

A volume of 300-700 pedestrians per hour was observed at the sidewalk. Each pedestrian has an average space of 4.5 m^2/p and above and enjoys walking with a walking speed varying from 0.7 to 1.9 m/s. The flow rate varied from 0.9 to 7 pedestrian per metre per minute. The present pedestrian flow characteristics were compared with HCM and IRC guidelines and the PLoS was identified as "A" at three locations and "B' at one location. The qualitative analysis through pedestrian rating on a scale of 1-5, resulted in a WI value of 150 and above.

The initiative taken by the Karnataka government popularized as Tender SURE projects adopts unique design guidelines for improving urban road design and pedestrian safety. The project has been successfully implemented at seven locations in Bengaluru City and showcases the prime example by prioritizing the pedestrian need in first place. The design guidelines adopted have been summarized in the paper. The walkability studies on these pedestrian sidewalks resulted in PLoS level A and PLoS level B, and with a good public perception also confirms the success of the Tender SURE initiative.

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