Pedestrian Level of Service: A Review of Factors and Methodology

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Abstract Level of service (LOS) is a qualitative or quantitative measure of the operation condition of a facility. The quantitative assessment indicates the flow condition, and the qualitative assessment presents the satisfaction level of users with the facility. Generally, six categorizations are used for LOS. The LOS or the Measures of Effectiveness change with the type of facility. Despite the technological advancement in the transportation sector, the need to walk has not diminished. This warrants the evaluation of pedestrian facilities. This paper reviews the works done related to pedestrian facilities and focuses on the identification of the factors which influence the LOS and the methodologies adopted to arrive at the LOS for a facility. Various influencing factors being identified are pedestrians' personal characteristics, roadway characteristics, traffic characteristics, operational characteristics, pedestrian perception, pedestrian speed, pedestrian delay and pedestrian behavioural characteristics. Various approaches have been used by different researchers to arrive at categorized LOS for different pedestrian facilities. These are regression analysis, point system, GA Fuzzy clustering approach and C-mean clustering approach.

Keywords Pedestrians · Facilities · Factors · LOS · Methodologies

1 Introduction

The technological advancement in vehicle technology has assisted in the increased level of motorization across cities and countries. This is one pointer to improvement in the living standard of people, but it has negative externalities like environmental degradation, increase in social inequality, increase in expenditure on imported

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A. Dhamaniya et al. (eds.), *Recent Advances in Traffic Engineering*, Lecture Notes in Civil Engineering 377, https://doi.org/10.1007/978-981-99-4464-4_1

fuel, etc. So, there is a need to adopt efficient and safe modes of transportation. Walking has been reported as the preferred mode for short-distance commuting. Its share varies across countries. In Beijing, approximately 61% of total trips are by pedestrians [1, 2]. 40% of total trips are dependent on walking in rural households [2, 3]. In India, it is reported that 10.9% of trips are made by public transport, 0.7% by intermediate transport, 15.8% by bicycles and 64.7% on foot [2, 4].

Pedestrians can be defined as persons who sit, walk and stand in public spaces. They may use crutches, walking sticks or wheelchairs. They may be of any age group and profession like children, adults, teenagers, people with disabilities, elderly persons, workers, shoppers and residents. Pedestrian safety is a major problem, and many bottlenecks are experienced by pedestrians in mixed traffic conditions. The limited space available on the road leads to conflicts between pedestrians and vehicles. A study reveals that China, Russia and India is having the highest number of pedestrian deaths [5]. According to The Global Status Report on Road Safety [2, 6], "1.25 million deaths per year are reported in a total of 180 countries. 60% of pedestrian accidents in urban areas are reported in Low and Middle-Income countries". Since pedestrians are major road users, higher attention shall be given to increasing their walkability and safety.

Pedestrian facilities can be classified as interrupted or uninterrupted flow facilities. Various facilities are crosswalks, sidewalks, stairways, ramps, pedestrian overbridges, or underpasses and escalators. The operational quality of these facilities is measured by the LOS. Safety, delay, comfort and convenience are the important factors considered in determining the level of service for pedestrian facilities. HCM defines six levels of service from A to F, where 'A' represents the best possible condition while 'F' represents the worst possible condition of a facility.

The LOS is based on quantitative and qualitative measures. In terms of flow, it is closely related to capacity. It evaluates the facility based on certain measures of effectiveness. The measure of effectiveness varies with the type of facility. Categorisation of the LOS is done based on various methodologies. The measures and methodologies are discussed in the subsequent sections.

2 Factors and Methodologies for LOS at a Facility

2.1 Crosswalks

In this type of facility, there is an interaction between vehicular movement and pedestrian movement. These are more critical locations due to the interactions. These facilities can be classified as signalized, un-signalized and mid-block crosswalks. The crossings can also be classified as at-grade and grade separated. At-grade crossings are those at which pedestrians cross at the carriageway level or 100 mm above that, while grade-separated crossings are those where pedestrians cross the carriageway at a different level. At-grade crossings are further classified as crossing at an intersection or at a mid-block (away from the intersection) which may be controlled or uncontrolled. At signalized crossings, a particular signal time is provided for the pedestrians to cross while for the rest of the time they have to wait at the kerb side. The influencing factors and methodologies for determining the LOS are discussed in the following sub-sections for different facilities.

Signalized crosswalks Delay is an important parameter for evaluating the LOS of pedestrian crosswalks at signalized intersections [7]. Traffic characteristics, delay, crossing behaviour of pedestrians and operational characteristics are the factors considered in the evaluation of LOS at signalized intersections in HCM 2010 [8]. Turning manoeuvres are complex movements because they increase pedestrian delay and reduce pedestrian safety. The effect of turning vehicles on pedestrians' safety as well as delay is also studied [9–11].

By using observational studies, pedestrian opinion surveys and simulation approaches, the effect of bidirectional flow on area occupancy and speed has been studied [12, 13]. It has been found that most of the studies have not given importance to pedestrian safety, comfort and convenience.

It has also been observed that the unsafe behaviour of pedestrians leads to many crashes [14, 15]. The thresholds are also being reported for bidirectional flows with consideration given to walking speed, pedestrian flow and pedestrians' opinions [16].

A fuzzy clustering technique is used to arrive at LOS [5]. The pedestrian delay, crossing time, speed, volume of pedestrians and density were also reported to affect the pedestrian LOS at signalized intersections under mixed traffic conditions [5].

Unsignalized crosswalks These are the intersections in which pedestrians are exposed to free-flow traffic. These are difficult to analyse because it is based on acceptable gaps in vehicular flow by the pedestrian. The pedestrian gap acceptance is the major factor in these cases. Other factors are found similar to crosswalks at signalized intersections. Pedestrians' perception of safety and comfort is considered in determining the LOS [17, 18].

Mid-block crosswalks These are hazardous crossing locations and are completely different from signalized and un-signalized intersection crosswalks. These are provided for a pedestrian to cross the street safely. These can be marked or unmarked, signalized or unsignalized, or assisted by a crossing volunteer. Controlled crossing locations may have simple traffic signals or pelican signals, or they are marked with zebra lines. Uncontrolled crossings are more critical locations. These may have higher chances of hazardous pedestrian-vehicle interaction due to uncontrolled speeds and higher waiting times [19, 20].

At mid-blocks, pedestrians have to wait for a longer time before getting the required gap in the vehicular stream. In developing countries, pedestrian behaviour is not considered while in developed countries, pedestrian behaviour, as well as driver behaviour, is reported. It is reported that with an increase in vehicle speed, volume, crossing width, and length of traffic signal cycles, pedestrians face higher difficulty in crossing the road, whereas the presence of marked crosswalks, restricted medians and traffic signals reduces pedestrian difficulty [20, 21]. Group behaviour is also considered in the analyses [22, 23]. *The review of the literature indicates that none of the studies has considered pedestrian safety and crossing difficulty as the measure of effectiveness for evaluating the LOS.*

2.2 Sidewalks

Sidewalks are the facilities that are placed parallel to the traffic facilities. These are raised paths along the roadside, and these are separated from vehicular traffic. These are designed for universal access, i.e., by pedestrians of all age groups, persons with disabilities and persons using assistive devices. LOS of these facilities shall be defined considering all the users. Mostly, measurable attributes like pedestrian flow rate and pedestrian speed are used to define the LOS on sidewalks [24, 25]. It is reported that pedestrians face a problem when choosing walking speed on sidewalks [26]. Qualitative measures like pedestrian safety, sidewalk continuity, comfort, security and convenience are also used [27, 28]. It is also reported that appropriate safety and comfort guarantee a suitable environment for pedestrians irrespective of users' physical limitations [28]. Most of the studies have focused on users' perceptions and did not tell how to quantify combined methods or environmental factors. LOS is also defined based on factors like the availability of sidewalks, a lateral separation between pedestrians and vehicles, traffic volume, and the speed of vehicles [29, 30]. Pedestrian space and evasive movements are also considered in studies. It is reported that the evasive movement explains the pedestrians' LOS in a better way [31]. Recent studies have proposed LOS considering persons with disability and wheelchair users [32–34].

The design standards do not consider the diverse users like pedestrians with disability and wheelchair users in developing countries like India.

2.3 Stairways

Stairways are the facilities that are used to ascend or descend and allow vertical movements. A study conducted in the USA used pedestrian space and flow rate to define LOS quantitatively. Time-lapse photography was used to collect the data and a relationship between human convenience, speed and volume was developed. The study proposed to include illumination, riser dimension and location in the analysis [35]. Another study in China also used a quantitative approach and considered factors like safety, environment, conflict and accessibility. It concluded that the congestion level, presence of informatory signs and clear visibility affect the LOS [36].

Another study was conducted on undivided stairways at a suburban station in Mumbai, India. The variables used were pedestrian space, flow rate, walking speed and volume/capacity ratio. The k-mean clustering approach was used. Pedestrian characteristics were classified based on age. The speed density relation was found non-linear, therefore for the speed-flow relation, two regime modal was developed. Average hourly pedestrian volume was used for the analysis. Further analysis was done with the help of STATISTICA. The study reported that pedestrians in China need more space in LOS D to F as compared to India and USA. It also reported that in India, the space tolerance is higher [37].

Another study was conducted at a metro station in Shanghai, China. The interaction index was used for the analysis. The whole area was divided into four locations. Further analysis was done by building EXODUS. Four parameters were used for analysis, namely volume, frequency rate (FR), distance travelled and congestion waiting time [38].

2.4 Walkways

Walkways are the paths or defined spaces used by pedestrians. A study conducted in India used a clustering algorithm to arrive at LOS categories based on flow rate, volume/capacity ratio, speed and average pedestrian space [39].

Another study, which was conducted in Rome and Munich, used qualitative analysis to arrive at LOS categories considering attributes like comfort, convenience, attractiveness, system coherence, safety, continuity and security [40]. A study conducted in the Philippines used both qualitative as well as quantitative approaches and considered factors like convenience, safety, continuity, system coherence, level of congestion and safety [41]. Another qualitative study used comfort as a major attribute for LOS categorisation [42].

A study conducted in China used horizontal distances, longitudinal distances, the frequency and behaviour of pedestrians who used the facility as variables. It concluded that safety, illegal vendors and security affects the LOS [43]. A study conducted in Malaysia developed a relationship between safety, connectivity, comfort and accessibility, and did a Pearson correlation analysis [44].

2.5 Foot-Over Bridge

A study was conducted in South Korea in which pedestrian area (m^2), pedestrian speed (m/min), pedestrian density (ped/m^2), delay and pedestrian flow rate (ped/min/m) were used as attributes [45].

Table 1 presents the attributes used by different researchers to arrive at LOS of a facility, and Table 2 presents the methodologies adopted by various researchers.

Table 1 Factors affecting the LOS of pedestrians' crosswalks, sidewalks, stairways and walkway facilities

Author, Country	Factors considered for LOS
Milazzo II et al. [7], The United States	Pedestrian crossings behaviour, crosswalk width, and length, crossing facilities, traffic conflicts, delays to pedestrians
Baltes and Chu [21], The United States	Turning movements, presence of pedestrian signals and cycle length, signal spacing, and width of painted medians
Zhang and Prevedouros [46], The United States	Perceived safety and comfort, corner radius dimension, crossing distance, roadway space allocation, presence/ absence of right-turn channelization island, traffic signal characteristics, pedestrian delay, conflicting and turning traffic flow, mid-block 85^{Th} percentile speed of the vehicle on street being crossed
Steinman and Hines [9], The United States	Crossing distance, roadway space allocation, presence/ absence of right-turn channelization island, and Perceived safety and comfort
Muraleetharan et al. [47], Japan	Crosswalk width and length, crossing facilities, traffic conflicts, delays to pedestrians
Petritsch et al. [48], United States	Corner radius dimension, crossing distance, roadway space allocation, presence/ absence of right-turn channelization island, and Perceived safety and comfort
Lee et al. [13], Hong Kong	Turning vehicles and through vehicles, pedestrian bidirectional flow, area occupancy, pedestrian delay, walking speed
Hubbard et al. [10], United States	Crosswalk characteristics, right-turn traffic volume, the pedestrian direction of travel, pedestrian arrival rate
Alhajyaseen et al. [12], Japan Nagraj and Vedagiri) [49], India	Turning vehicles and through vehicles, pedestrian bidirectional flow, area occupancy, pedestrian delay, walking speed
Chutani and Parida [23], India	Vehicular flow, pedestrian crossing speed, group size, waiting time
Zhao et al. [22], China	The volume of two-way motor vehicles, the distance between marked-unmarked crosswalks
Kadali and Vedagiri [50], India	Vehicle speed and number of vehicles encountered, age of rolling and gender of participants, rolling behaviour of pedestrian, and speed change behaviour of pedestrian
Mohan et al. [51], India	Space, and flow rate
Marisamynathan and Vedagiri [52], India	Pedestrian volume, Vehicle volume, Delay and land use
Asadi-Shekari et al. [53], Malaysia	Pedestrian speed
Tanaboriboon and Guyano [54], Thailand	Space and flow rate
Miler at el. [55], U.S.A	Safety and environment
Kim et al. [56], South Korea	Surface and environment
Yadav et al. [57], India	Safety, comfort, convenience and gender

(continued)

Table 1 (continued)

Author, Country	Factors considered for LOS
Muraleetharan and Hgiwara [58], Japan	Vehicle speed, crossing and traffic control
Saha et al. [59], Bangladesh	Gender and age
Botma [60], Netherlands	Vehicle characteristics and roadway geometry
Jensen [30], Denmark Asadi-Shekari et al. [53], Malaysia	Roadway geometry, pedestrian behaviour and environmental factors
Kang et al. [61], China Kim at el. [31], South Korea	Capacity-based factors, vehicle characteristics and roadway geometry
Muraleetharan et al. [47], Japan	Environmental factors, pedestrian behaviour and roadway geometry
Petritsch et al. [62], The United States	Environmental factors, vehicle factors and pedestrian behaviour
Polus et al. [24], Israel	Density, space and flow rate
Sisiopiku et al. [63], U.S.A	Flow rate, width, surface and v/c ratio
Al-Azzawi and Raeside [64], UK	Density, flow rate and delay
Christopoulou and Pitsiava-Latinopoulou [65], Greece	Width
Marisamynathan and Lakshmi [66], India	Width, vehicle volume, surface and obstructions/friction
Landis et al. [29], U.S.A	Lateral separation, vehicle speed, vehicle volume, safety, comfort and environment
Jaskiewicz et al. [67], U.S.A	Surface, obstructions, width and accessibility
Ferreira et al. [33], Brazil	Surface, width and crossing
Octaviana and Moreno Freydig [68], Indonesia	Comfort
Stairways	
Fruin [69], U.S.A	Pedestrian flow rate and pedestrian space
Lee and Lam [36], China	Accessibility, conflict, environment and safety
Shah et al. [37], India	Flow rate, space/pedestrian, walking speed and v/c ratio
Hu et al. [38], China	Interaction index
Walkways	
Sahani and Bhuyan [39], India	Flow rate, speed, average pedestrian space and v/c ratio
Sarkar [40], Italy	Attractiveness, safety, system coherence, security, convenience and continuity
Gacutan et al. [41], Philippines	Safety, continuity, level of congestion, convenience and system coherence
Sarkar [42], India	Comfort

(continued)

Table 1 (continued)

Author, Country	Factors considered for LOS
Shan et al. [43], China	Macro and micro level indicators (frequency, longitudinal distance before and after interactions, horizontal distance before and after interactions, etc.)
Zakaria and Ujang [44], Malaysia	Accessibility, comfort and safety

3 Level of Service Guidelines

3.1 IRC 103:2022—Guidelines for Pedestrian Facilities [73]

The guidelines have considered five principles for the safe design of pedestrian facilities. These are safety, security, continuity, comfort and liveability. It defined the level of service as a “qualitative measure used to determine how well a facility is operating from a traveller’s perspective”. Width is considered the main factor for designing facilities. The width will be dependent on the street type, expected and current pedestrian flow, and adjoining land use.

Table 3 presents the pedestrian LOS for walking infrastructure and index values according to walkability type.

3.2 Indo-HCM 2017 [74]

INDO-HCM 2017 provides methodologies to arrive at pedestrian LOS for four pedestrian facilities namely crosswalks, sidewalks, stairways and foot-over bridges. Pedestrian flow (ped/min/m) is suggested to define LOS on a sidewalk catering to different land uses like commercial, terminal, institutional, residential and recreational.

The following methodology is used to arrive at LOS threshold values:

(i) Identification of the type of land use
(ii) Sidewalk width measurement
(iii) Calculating the effective width of the facility
(iv) Recording pedestrian flow and identifying maximum flow rate (ped/min)
(v) Determination of the PLOS

In the case of a crossing facility, the delay is used as an influencing attribute. The average delay at a crossing facility is calculated and used to define the LOS. Flow (ped/min/m), speed (m/min) and space (m^2/ped) are used as the attributes to define LOS at stairs. The effective width of the stairs is used for this purpose. Speed (m/min), space (m^2/ped) and flow (ped/min/m) are used as attributes to define LOS on a foot over-bridge. The effective width of the stairs and bridge is used while calculating the

Table 2 Methodologies used for arriving at LOS for crossing, sidewalks, stairways and walkway facilities

Author, Country	Analysis method
Crossing facility	
Milazzo et al. [7], U.S.A	Linear relationship
Zhang and Prevedouros [46], U.S.A	Regression
Steinman and Hines [9], The U.S.A	Point system
Petritsch et al. [48], The U.S.A	Pearson correlation analyses and stepwise regression
Murraleetharan et al. [47], Japan	Stepwise multiple, regression model
Nagraj and Vedagiri [49], India	Stepwise regression
Jensen [70], Denmark	CLM stepwise regression
Bian et el. [18], China	Stepwise regression
Zhao et al. [22], China	Stepwise regression
Ye et al. [15], China	Linear regression technique
Sidewalk facility	
Polus et al. [24], Israel	Linear-speed density regression
Tanaboriboon and Guyano [25], Thailand	Linear relationship
Sarkar [27], U.S.A	Point system
Muraleetharan et al. [47], Japan	Linear relationship
Kim et al. [71], The U.S.A	Linear relationship
Hidayat et al. [72], Thailand	Multiple linear regression
Christopoulou and Pitsiava-Latinopoulou [65], Greece	Point system
Kang et al. [61], China	Ordered probit
Kim et al. [31], Korea	Multiple linear regression
Stairways	
Fruin [69], U.S.A	Quantitative analysis by time-lapse
Lee and Lam [36], China	Quantitative analysis
Shah et al. [37], India	K-mean clustering approach
Hu et al. [38], China	Analysis on Building Exodus Software
Walkways	
Sahani and Bhuyan [39], India	Affinity propagation clustering method
Sarkar [40], Italy	Qualitative analysis
Gacutan et al. [41], Philippines	Qualitative analysis
Sarkar [42], India	Qualitative analysis
Shan et al. [43], China	Quantitative survey
Zakaria and Ujang [44], Malaysia	Pearson correlation

Table 3 The LOS criteria for walking infrastructure and index values according to walkability type

LOS considered	Service volume of pedestrian facility of unit width, pedestrian/h/metre (ped/h/m) in both directions				
	Commercial	Institutional	Terminal	Recreational	Residential
LOS-B	1285	1145	1360	1360	1430
LOS-C	1800	1600	1900	1900	2000
Walkability type	*Index value*				
A	>4.5				
B	<4.5–4.2				
C	<4.2–3.8				
D	<3.8–3.5				
E	<3.5–3.1				
F	<3.1				

attributes' values determined. Table 4 presents the LOS criteria given in Indo-HCM (2017) for different facilities.

3.3 Highway Capacity Manual 2010 [8]

The guidelines provide the procedure for determining the LOS of the walkways and stairways, as well as for shared-use paths. Walkways are considered as paved paths, plazas and ramps that are located more than 35 feet from urban streets as well as the streets which are reserved for pedestrian traffic on a part-time basis or full basis. In the case of walkways, pedestrian zones, pedestrian paths, ramps (grade up to 5%), walkways and plaza areas are considered. The flow is considered random and platoon-type. Six categories of LOS are defined. Average space (ft^2/p), flow rate (p/min/ft) and average speed (ft/s) are used as attributes. Also, the V/C ratio is calculated and used for LOS categorisation.

For LOS categories on a stairway, average space (ft^2/p), flow rate (p/min/ft) and V/C ratio are used as attributes. These are presented in Table 5.

The guidelines which are followed in different countries are different in many respects. Indo HCM has considered the human ellipse as $0.35\text{m} \times 0.51\text{m} = 0.18\text{m}^2$ while US-HCM (HCM 2000) has considered the human ellipse as $0.46 \times 0.61\text{m} = 0.28\ \text{m}^2$. For Indian conditions, footpaths are designed for LOS-B and LOS-C (in case of resource constraints). The width of the footpaths varies with the type of facility. While the US guidelines have considered their analysis boundaries for designing pedestrian facilities. The manual has the formula for calculating the effective width of walkways. The guidelines have given separate LOS criteria for walkways with the random pedestrian flow and walkways with platoon flow.

Table 4 LOS criteria according to INDO-HCM 2017 for sidewalks, crosswalks, stairways and foot-over bridge

INDO HCM 2017						
Sidewalks (ped/min/m)						Crosswalks
LOS	Commercial	Institutional	Terminal	Recreational	Residential	Pedestrian delay (s)
A	≤13	≤13	≤15	≤12	≤16	≤5
B	>13–19	>13–19	>15–26	>12–20	>16–23	5–10
C	>19–30	>19–27	>26–32	>20–32	>23–34	11–25
D	>30–47	>27–36	>32–68	>32–54	>34–47	26–45
E	>41–69	36–42	>68–78	>54–91	>47–59	46–80
F	Variable	Variable	Variable	Variable	Variable	>80
Stairways						
LOS	*Flow (ped/min/m)*	*Speed (m/min)*	*Space (m^2/ped)*			
A	≤10	≥42.6	≥2.5			
B	>10–22	>37.2–42.6	>1.50–2.5			
C	>22–46	>31.2–37.2	>0.75–1.50			
D	>46–55	>28.2–31.2	>0.50–0.75			
E	>55–70	>24.2–28.2	>0.40–0.50			
F	Variable					
Foot over bridge						
LOS	*Flow (ped/min/m)*	*Speed (m/min)*	*Space (m^2/ped)*			
A	≤12	≥56.78	≥4.89			
B	>12–17	>55.03–56.78	>3.3–4.9			
C	>17–27	>51.08–55.03	>1.9–3.3			
D	>27–38	>45.65–51.08	>1.2–1.9			
E	>38–52	>30.91–45.65	>0.6–1.2			
F	Variable	<30.91	<0.6			

4 Discussion

A review of factors affecting LOS and methodologies used to arrive at the categorisation of LOS has been discussed in this paper. The following emerges out of the discussion:

Table 5 The LOS criteria according to HCM 2010 for walkways and stairways

Average flow criteria for walkways					Platoon adjusted criteria for walkways	
		Related measures				Related measures
LOS	Average space (ft^2/p)	Flow rate (p/min/ft)	Average speed (ft/s)	v/c	Average space (ft^2/p)	Flow rate (p/min/ft)
A	>60	≤5	>4.25	≤0.21	>530	≤0.5
B	>40–60	>5–7	>4.17–4.25	>0.21–0.31	>90–530	>0.5–3
C	>24–40	>7–10	>4.00–4.17	>0.31–0.44	>40–90	>3–6
D	>15–24	>10–15	>3.75–4.00	>0.44–0.65	>23–40	>6–11
E	>8–15	>15–23	>2.50–3.75	>0.65–1.00	>11–23	>11–18
F	≤8	Variable	≤2.50	Variable	≤11	>18
Stairways						
LOS	*Average space (ft^2/p)*	*Flow rates (p/min/ft)*	*v/c ratio*			
A	>20	≤5	≤0.33			
B	>17–20	>5–6	>0.33–0.41			
C	>12–17	>6–8	>0.41–0.53			
D	>8–12	>8–11	>0.53–0.73			
E	>5–8	>11–15	>0.73–1.00			
F	≤5	Variable	Variable			

a. More studies are being carried out on crosswalks, followed by studies on sidewalks and walkways. Quite a less studies are carried out on other pedestrian facilities. This needs to be strengthened (Refer to Fig. 1).

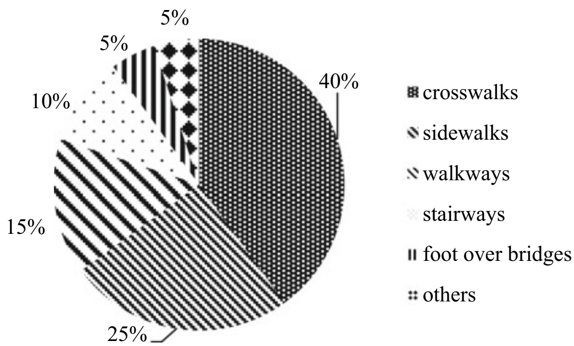


Fig. 1 Number of studies on different facilities

b. A regression-based analysis is done to arrive at LOS values in most of the studies. It is followed by the development of other types of pedestrian LOS models. Qualitative assessment is carried out in quite lesser studies. This needs to be incorporated along with the quantitative analysis to get an overall idea of a facility LOS (Refer to Fig. 2).
c. The influencing factors are examined concerning their effectiveness on the LOS of a facility [2]. Factors have been categorized and their influence on interrupted and uninterrupted pedestrian facilities has been summarized in Fig. 3. A scale of 0 to 5 is used for the purpose. '0' means there is no effect and '5' means it highly affects the LOS of a type of facility. It can be noted that pedestrian and traffic characteristics and geometric factors affect the LOS most. The rest of the factors are either not influencing or influencing either type of facility.

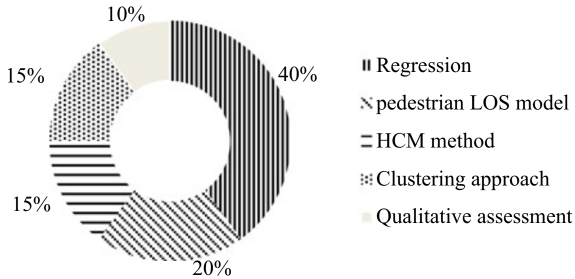
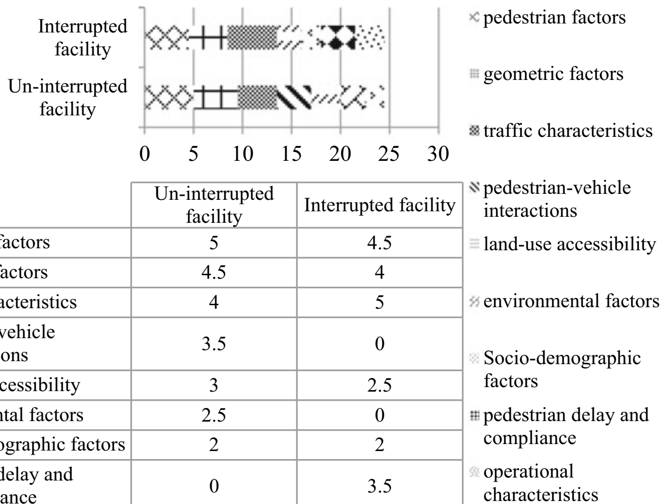


Fig. 2 Methods used for categorization of LOS for different pedestrian facilities



	Un-interrupted facility	Interrupted facility
pedestrian factors	5	4.5
geometric factors	4.5	4
traffic characteristics	4	5
pedestrian-vehicle interactions	3.5	0
land-use accessibility	3	2.5
environmental factors	2.5	0
Socio-demographic factors	2	2
pedestrian delay and compliance	0	3.5
operational characteristics	0	3

Fig. 3 Categorization of factors and their influences on LOS of pedestrian facilities

5 Conclusion

A review of factors and methodologies is presented in this paper. The factors which influence pedestrian facilities are broadly classified as roadway characteristics, traffic characteristics, pedestrian personal characteristics, operational characteristics, and land use and accessibility characteristics.

For sidewalks facilities: density, flow rate, width, traffic volume, age, space and obstructions are used as quantitative factors while safety, the volume of pedestrians, and vehicle speed are used as qualitative factors. For crosswalks facilities: volume of vehicles and pedestrians, delay, space, and flow rate were used as quantitative factors while traffic control, safety, and surface were used as qualitative factors. For stairways facilities: flow rate, space and congestion were used as quantitative factors while comfort, accessibility and safety were used as qualitative factors. For walkways facilities, flow rate, space and width were used as quantitative factors while safety, accessibility and comfort were used as qualitative factors. Delay is the most important parameter at crosswalk locations.

The regression method is widely used for evaluating the LOS for crosswalks and sidewalks.

It is concluded from the literature that developed countries like the U.S.A., are focusing on the quantitative as well as qualitative methods for evaluating the LOS for sidewalks facilities while other countries like India, are focusing on qualitative methods. Qualitative as well as quantitative factors were used for determining LOS for crosswalk facilities in countries like the U.S.A., Japan, and India.

There is a difference between developed and developing countries in terms of operational conditions, roadway, pedestrian density at crosswalks locations, pedestrian behaviour, culture, and driver behaviour. Driving rules are different in different countries, so the behaviour of pedestrians is also different, which ultimately affects the LOS. It is very difficult to design pedestrian facilities in developing countries because these are populous countries and have a mixed mode of transport.

The important factor which is noticed in the literature is that the studies are less focused on the person with a disability. More studies are needed for pedestrians with disability at railway stations on stairs, circulation areas and ramps. For pedestrian with a disability, there is no common factor available to normalize their impact under mixed conditions in developing countries while designing such facilities because these type of pedestrians affects the speed and sight distances. Due to the lack of traffic regulations, the crossing behaviour of these pedestrians become very complex in developing countries. Further, the geometric dimensions are not properly designed keeping in mind the pedestrian with disability.

In developing countries, sidewalks are not properly available for pedestrians or there is discontinuity, so they share the lanes. Ultimately their proper evaluation is needed for the upgradation of the facility. Due to this, there is a change in mode shift. Further, due to the non-availability of adequate gaps, free left turns are more complicated at crossings and roundabouts, so studies are needed to cater to this issue.

More studies are needed on the combined effects of quantitative and qualitative factors in developing countries. There is a lack of studies with fewer traffic regulations at uncontrolled intersections in developing countries. Studies are lacking in proper evaluation of unprotected mid-block crosswalk locations. Further, there is a need to improve traffic rules, lighting at night, lighting by reflective markings, and provisions to improve street hawkers' conditions and improve pedestrian facilities.

Factors like pedestrian age, gender, walking with or without baggage and the purpose can be considered while evaluating the LOS at signalized mid-block locations. The effect of optimizing signal control on the LOS can be studied. LOS for pedestrian flows at escalators needs to be studied.

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