LEVEL OF SERVICE CRITERIA OF URBAN WALKING ENVIRONMENT IN INDIAN CONTEXT USING CLUSTER ANALYSIS

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ABSTRUCT

Pedestrian Level of Service (PLOS) is a quantitative term which represents the quality of service of walking facilities. In this study an attempt has been made to define levels of service provided by the off-street pedestrian facilities in mid-sized cities of India, taking pedestrian space, flow rate, volume to capacity ratio and average walking speed as the Measure of Effectiveness (MOE). As defining PLOS is a classification problem, it has been observed that Self Organized Map (SOM) one of the clustering methods is used to classify the ranges of different measure of effectiveness in this regards. From the study it is observed that average space of >15.67 meter/pedestrian, flow rate of ≤0.063 pedestrians/second/meter width, average speed of >1.22 meter/second and volume to capacity ratio of ≤0.4 pedestrian can move in their desired path at LOS 'A' without changing movements and it is the best condition for off-street facilities. But situation considered to be PLOS 'F' at which movement is severely restricted and frequent collision among pedestrians occurs, parametric ranges expressed as average space ≤4.48 meter/pedestrian, flow rate of >0.145 pedestrians/second/ meter width, average speed of ≤0.62 meter/second and volume to capacity ratio of >1.00.The ranges of the parameters used for LOS categories found in this study for Indian cities are different from that mentioned in HCM (2010) because of differences in population density, traffic flow condition, geometric structure and some other factors.

1 INTRODUCTION

Indian cities have traditionally been cities of walkers, and many urban dwellers rely on walking, cycling and public transport for their daily travel. However, with the exponential increase in motorization, limited attention has been paid to pedestrian and public transport facilities. A change in focus is required which will allow people, not vehicles, to reclaim the urban environment. Growing motorization has also lead to a dramatic increase in the number of pedestrian fatalities and accidents, and high levels of air pollution-particularly exposing pedestrians who walk to work or access public transport to reach their destinations. There are few initiatives to promote the improvement of walking in Indian cities. The few civil society organizations and non government organizations working in this area can play key roles in promoting improvements on walk ability and pedestrian facilities in their cities. As Pedestrian Level of Service (PLOS) is an essential part for highly heterogeneous traffic flow on urban corridors in India, in this study an attempt has been made to define LOS criteria for mid-sized cities. Defining the PLOS criteria is a module of LOS analysis procedure of urban off-street pedestrian facilities. These methodologies affect the planning, design, and operational aspects of transportation projects as well as the allocation of limited financial resources among competing transportation projects. This envisages the importance of suitable methods that should be adopted while defining the PLOS criteria of urban streets in the context of cities in India. Considering the importance of LOS analysis for urban off-streets pedestrian facilities in Indian context, an in-depth research was carried out in the present study. In this study two important mid-size cities (population less than a million), Bhubaneswar and Rourkela of Odisha state, India are taken as the study area. By using video data collection procedure all the field data like speed of pedestrian, effective walkway width and pedestrian hourly volume are collected. For the determination of different LOS categories parameters like flow rate, pedestrian space and Volume to Capacity (V/C) ratio are calculated. Then with the help of SOM clustering, ranges of PLOS are determined in establishing the evaluation criteria for PLOS of off-street pedestrian facilities in urban Indian context. The overall framework of this study is illustrated in **Fig. 1**.

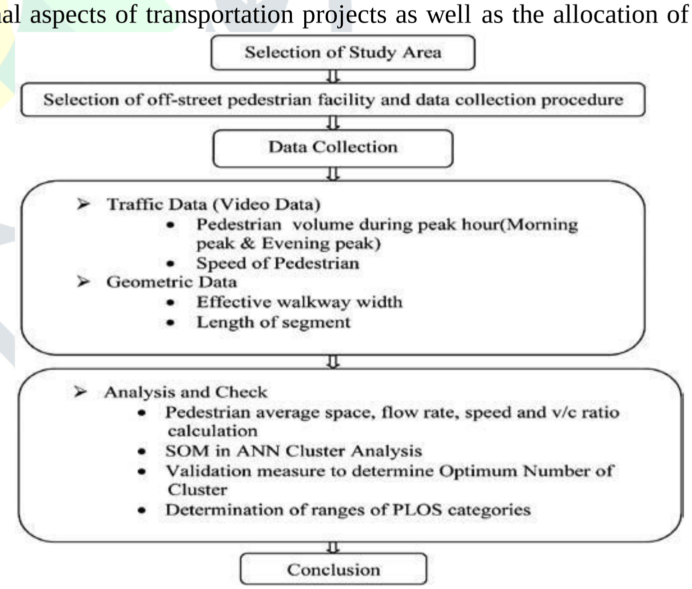


Fig. 1 Overall Framework of the Study

2.BACK GROUND OF THE STUDY:

2.1 General

HCM (2000) describes that the LOS criteria for pedestrian flow are based on subjective measure, which can be imprecise. However, it is possible to define ranges of space per pedestrian, flow rates and speeds, which then can be used to develop quality-of-flow criteria. It defines six LOS categories for pedestrian facilities. The HCM (2010) also designates six LOS from "A" to "F," for pedestrian facility, with LOS "A" representing the best operating conditions and LOS "F" the worst. It uses distinct average pedestrian space values as boundaries for the various LOS. HCM (2010) stated that as volume and density increase, pedestrian speed declines. As density increases and pedestrian space decreases, the degree of mobility afforded to the individual pedestrian declines, as does the average speed of the pedestrian stream. According to HCM 2000 pedestrian facilities can be of two types that are uninterrupted and interrupted. When pedestrian facilities are not affected by any motorized modes of travel then the facility is known as the uninterrupted pedestrian facility or off-street pedestrian facilities and vice versa. Several studies have been performed relating to the analysis of PLOS of pedestrian facilities. IRC:103-2012 has defined six ranges of pedestrian space and flow rate to provide PLOS categories in Indian condition, where LOS A is having pedestrian space >4.9 m_2/p and flow rate ≤12 p/min/m. Dandanetal. (2007) quantificational analyzed the correlation between the pedestrian LOS and the affected factors; then on the basis of the analysis of urban roads with typical road transect form it interpreted that the factors which significantly affected the pedestrian LOS were the bicycle volume, the vehicle volume, the pedestrian volume, driveway access frequency and the distance between sidewalk and vehicle lane and also a pedestrian LOS model has been developed with the significant variables. Muraleetharan and Hagiwara (2007) focused on examining the influence of overall LOS of sidewalks and crosswalks on pedestrian route choice behaviour and attributes affecting overall LOS of sidewalks and crosswalks. Smith (2009) suggested that perceptions as well as objective assessment of the environment are significant in different ways in predicting walking behaviour. In Indian cities pedestrian's side walk behaviour is different from that of pedestrians in developed countries. In this regard Rastogietal. (2011) discussed about the development of adjustment factors for effective design of pedestrian facilities on the basis of pedestrian walking speeds under influences like age and gender, land uses, temporal variations, cell phone usage, carrying baggage while walking and moving in groups; on three types of facilities, e.g., sidewalks, wide-sidewalks, and precincts. The authors observed that pedestrians in India cross slower than their counterparts in other countries. Male pedestrian were found to cross the road faster (1.22 m/s) than female pedestrian (1.11 m/s) irrespective of road system and land use of surrounding area. The authors suggested that the design speed for specific locations such as school and recreational area can be taken as 0.98-0.99 m/s and the places where older pedestrian are dominant, a design speed of 0.79 can be adopted. Laxman et al. (2010) have carried out a study for medium-sized cities in India and analyzed the pedestrians flow characteristics under mixed traffic condition. The authors observed that the free-flow speed of Indian pedestrian is 80 m/min which is higher than that for China and Singapore, but slightly lower than that in Germany.

2.2 SIDEWALK

Several factors have been observed to influence the service level of pedestrians while in movement along the sidewalk. Petritsch et al. (2006) incorporated traffic volumes on the adjacent roadway and exposure (i.e., crossing widths) at conflict points with intersections and driveway and the study reveals that traffic volumes on the adjacent roadway and the density of conflict points along the facility are the primary factors in the LOS model for pedestrians travelling along urban arterials with sidewalks. Sisiopiku et al. (2007) compared the various pedestrian sidewalk assessments and shown that the same sidewalk segment may receive multiple LOS ratings when different assessment methods are considered and the fact applies to sidewalks located on both urban and campus-like environments. Houten et al. (2007) stated that because pedestrian signal violations at mid-block crosswalks are associated with pedestrian crashes, it is important to improve pedestrian signal compliance at these locations. One way to improve compliance is to decrease pedestrian delay by reducing minimum green time. Miller et al. (2008) investigated the approach speed and passing clearance that seg-way devices exhibit on encountering a variety of obstacles on the sidewalk. Keegan and Mahony (2003)indicated that the countdown timer units induced a reduction in the number of individuals who crossed during there man(do not walk)signal and as a result of the positive outcome in terms of the analysis, the countdown timer-units are being introduced on a phased basis to a wider area in Dublin city.

2.3 Clustering

Self-Organizing Map (SOM) is one of the techniques in Artificial Neural Network (ANN) having the inherent capability to learn the pattern of input and to detect regularities and shows the correlations in their input with respect to its output. The application of SOM in ANN for this particular problem is to cluster the service levels provided by the urban off-street facilities measured by various parameters. Lingra (1995) compared grouping of traffic pattern using the Hierarchical Agglomerative Clustering and the Kohonen Neural Network methods in classifying traffic patterns. It has been mentioned that the Kohonen neural network integrates the hierarchical grouping of complete patterns and the least-mean-square approach for classifying incomplete patterns. It is advantageous to use hierarchical grouping on a small subset of typical traffic patterns to determine the appropriate number of groups and change its parameters to reflect the changing traffic patterns. Such an approach is useful in using hour-to-hour and day-to-day traffic variations in addition to the monthly traffic-volume variation in classifying highway sections. Florio and Mussone (1995) have taken the advantage of application of ANN in classification problem to develop the flow-density relationship of a motorway. The author defined the stability and instability of spacing of vehicle in traffic stream. Sharma et al. (1994) studied and compared the learning ability of both supervised and unsupervised type of learning method for clustering. Al-Garni and Abdennour (2008) developed a technique using the ANN to detect and count the vehicles plying on road from the video graph data. Yang and Qiao (1998) used neural network to classify traffic flow state. Author applied a self-organizing neural network pattern recognition method to classify highway traffic states into some distinctive cluster centres. Jian-ming (2010) developed a combined ANN and Genetic Algorithm method for the prediction of traffic volume in Sanghai Metropolitan Area. The accuracy of prediction of traffic volume of future traffic improved significantly with this combined algorithm. Cetineretal. (2010) developed a back propagation Neural Network traffic flow model for prediction of traffic volume of Istanbul City. The model uses the historical data at major junctions of the city for prediction of future traffic volume. From the background of this study it has been observed that there is a significant body of research featuring new ways of evaluating pedestrian service levels on urban sidewalks. These studies recommend everything from small amendments to the HCM's

PLOS calculation to completely new LOS methodologies, depending on local needs and characteristics. These studies suggest that the current tool for measuring pedestrian LOS prescribed by the HCM may not take into account important differences in pedestrian characteristics, location characteristics, and flow characteristics when evaluating midsized Indian City sidewalks. The issue is how to determine the threshold values for partitioning different PLOS categories. SOM clustering is the method that is applied to define urban off-street pedestrian LOS categories in this study. The major objectives of this study are:

- To estimate the optimum number of PLOS categories using various cluster validation parameters and
- To determine the ranges of PLOS categories using various Measure of Effectiveness (MOE) for urban off-streets facility in urban India context.

3.ARTICIAL NEURAL NETWORK(ANN):

ANN is the result of academic investigations that use mathematical formulations to model nervous system operations. The resulting techniques are being successfully applied in a variety of everyday business application. ANN is used to learn pattern and relationship in data. The ANN mimics the human ability to adapt to changing circumstances and the current environment. They learn from the events that have happened from past apply this learning to future environment. ANN consists of many nodes i.e. processing unit analogous to neuron in the brain. Each node has a node function and also some local parameters. Modification of local parameter changes the node function. Neural network may be of single or multiple layers. Single layer consists of input neurons and output neurons. Multi layer artificial neural network consists of input layer, output layer and hidden layer. There are various types of ANN like Feed forward neural network, Radial basis function network, Self-organizing Map (SOM), recurrent neural network. For this study, SOM which is best among ANNs for clustering of data issued.

3.1 SELF-ORGANIZING MAP(SOM)

A self-organizing map is a type of artificial neural network that is trained using unsupervised learning to produce a low-dimensional (typically two-dimensional) map. Self-organizing maps are different from other artificial neural networks in the sense that they use a neighbor-hood function to preserve the topological properties of the input space. A self-organizing map consists of nodes. A weight vector is associated with each node and the weight vector is of the same dimension as the input data vectors. The usual arrangement of nodes is a regular spacing in a hexagonal or rectangular grid. The self-organizing map describes a mapping from a higher dimensional input space to a lower dimensional map space. The procedure for placing a vector from data space onto the map is to first find the node with the closest weight vector to the vector taken from data space. Once the closest node is located it is assigned the values from the vector taken from the data space.

3.2 Architecture Of ANN And Parametersused

The architecture of the ANN is shown **Fig.2**.SOMalgorithmisusedinthis research to train the Input data. SOM basically has 2 layers architecture, containing Input and Output layer. The input layer contains nodes, through which input data is given to the neural network. The number of nodes varies according to the dimension of input data set. In this study the input layer contains 120 nodes because 120 data points are utilized for training of neural network. Each node is associated with a weight vector which changes in every iteration during training process. The output layer contains neurons and each neuron corresponds to the centroid of a particular cluster. The shape of the neuron depends upon the topology function. In this study hexagonal topology was chosen.

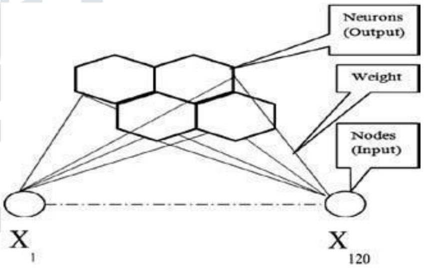


Fig. 2 A Self-Organizing Map (SOM) Neural Network

4.METHODOLOGY:

Off-street pedestrian facility serves only non-motorized traffic and is separated from motor vehicle traffic to the extent that such traffic does not affect their quality of service. There are different categories of exclusive pedestrian facilities: walkways, cross-flow areas, queuing area, underpass, overpass, stairways etc. The LOS thresholds for each category are different, but all are based on the concept of space per pedestrian, which is a measure of pedestrian comfort and mobility. The HCM 2010methodology for determining PLOS categories is followed in this study. Following are the steps shown in **Fig. 3** taken to determine the LOS of exclusive off-street walkways pedestrian facilities.

step: 1

Determination of effective Walkway Width

Effective walkway width is the portion of a walkway that can be used effectively by pedestrians. Various types of obstructions and linear features, discussed below, reduce the walkway area that can be effectively used by pedestrians. The effective walkway width at a given point along the walkway is computed as follows:

$W_E = W_r - W_O$ ...(1) where,

W_E = effective walkway width,

W_r = total walkway width at a given point along walkway, and

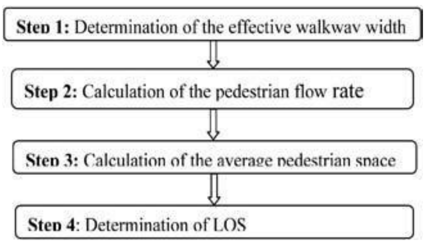


Fig. 3 PLOS Methodology for off-Street Walk-Ways (Source: HCM 2010)

W_O =sum of fixed-object effective widths and linear feature shy distances at a given point along walkway.

step: 2

Calculation of pedestrian Flow rate

An hourly pedestrian demand is used as an input to the analysis. Consistent with the general analysis procedures used throughout the HCM, hourly demand is usually converted into peak 15 min flows, so that LOS is based on the busiest 15 consecutive minutes during an hour:

V_{15} = pedestrian flow rate during peak 15 min (p/h),

V_h = pedestrian demand during analy-sis hour (p/h), and

PHF = peak hour factor.

However, if peak-15min pedestrian volumes are available, the highest 15-min volume can be used directly without the application of a peak hour factor. Next, the peak 15-min flow is converted into a unit flow rate (pedestrians per second per meter of effective pathwidth):

$$V_P = \frac{V_{15}}{15 \times W_E} \quad ...(3)$$

Where,

V_P is pedestrian flow per unit width measured by pedestrian /meter/second (p/m/sec) and all other variables are as previously defined.

step: 3

Calculation of Average pedestrian space

The service measure for walkways is pedestrian space, the inverse of density. Pedestrian space can be directly observed in the field by measuring a sample area of the facility and determining the maximum number of pedestrians at a given time in that area. The pedestrian unit flow rate is related to pedestrian space and speed:

$$A_P = \frac{S_P}{V_P} \quad ...(4)$$

where,

A_P= pedestrian space (meter^2/pedes-trian (m_2/p),

S_p = pedestrian speed (meter/second (m/sec)), and

V_p = pedestrian flow per unit width (p/m/sec).

Volume to Capacity ratio (v/c) Calculation

For determination of PLOS category of off-street pedestrian facility volume to capacity (v/c) ratio is one of the most important factor. For this study pedestrian hourly volume can be found out from video data collection and capacity of side-walks has been taken from IRC:103. Here width of side-walk for 1.5 m, 2 m, 2.5 m, 3 m and 4 m capacities in number of persons per hour in both directions are 800, 1600, 2400, 3200 and4000 respectively.

step: 4 Determine the pedestrian level of service

PLOS categories are to be resolute on the basis of average pedestrian space (A_p). Six no of PLOS designated as “A”to“F” has to determine for off-street pedestrian facilities. Not only on the basis of average space, other related measures like flow rate, average space and volume by capacity ratio are also considered for categorization of PLOS.

5.SOM CLUSTER ANALYSIS AND VALIDATION MEASURE:

5.1 som ClusterAnalysis

Among various types of ANN algorithms, in this study Self-Organizing Map is used for clustering of speed data because of its inherent capability to learn the pattern of input. SOM is trained iteratively being inspired by neural networks in the brain. Self-Organization Map (SOM) uses a competition and cooperation mechanism to achieve unsupervised learning. In SOM, a set of nodes is arranged in a geometric pattern which is typically a 2-dimensional lattice. In the basic SOM algorithm, the neurons are connected to adjacent neurons by neighborhood relation. This dictates the topology, or structure of the map and the arrangement of neuron may be grid, hexagonal or random topology. Usually the neurons are connected to each other via rectangular or hexagonal topology. One can also define a distance between the map units according to their topology relation. The topological relation may be rectangular or hexagon, it should be fixed from beginning. In this research Hexagonaltopologyisused. Each node is associated with a weight vector with the same dimension as the input space. The purpose of the SOM is to find a good mapping. During training, each node is presented to the map so also the input data associated with it. An input weight vector of same dimension as that of input data dimension was given to the ANN. The clustering using SOM algorithm was done in two steps.

step: 1

The input data is compared with all the input weight vectors $m_i(t)$ and the Best Matching Unit (*BMU*) on the map is identified. The *BMU* is the node having the lowest Euclidean distance with respect to the input pattern $x(t)$. The final topological organization of the map is heavily influenced by this distance. *BMU* $m_c(t)$ is identifiedby: For

$$\text{All } i, \| x(t) - m_c(t) \| \leq \| x(t) - m_i(t) \| \quad \text{...(5)}$$

Step: 2

Weight vectors of BMU are updated as

$$m_i(t+1) = m_i(t) + \alpha h_{b(x)i}(x(t) - m_i(t)) \quad \text{.. (6)}$$

Here $h_{b(x)}$ is the neighborhood function, which is

$$h_{b(x)} = \alpha(t) e^{\left(-\frac{\|r_i - r_{b(x)}\|^2}{2\sigma^2(t)}\right)} \quad \text{...(7)}$$

Where $0 < \alpha(t) < 1$ is the learning rate factor which decreases with each iteration. r_i and $r_{b(x)}$ are the locations of neuron in the input lattice. $\alpha(t)$ defines the width of the neighborhood function. The above two steps were repeated iteratively till the pattern in input was processed.

5.2 Validation measure

Cluster validity is concerned with checking the quality of clustering results. It has been mainly used to evaluate and compare whole partitions, resulting from different algorithms or resulting from the same algorithms under different parameters. Common application of cluster validation measure is to determine the correct number of cluster for a set of data (Bensaid et al., 1996). Different validity measures have been proposed in the literature, none of the misperfect by oneself, and therefore several indices are used in this study, such as: Silhouette Index, Davies-Bouldin Index, Calinski-Harabasz Index, Dunn Index, Krzanowski-Lai Index, Weighted inter-intra Index.

A. Silhouette Index(Si)

This index was proposed by Rousseeuw (1987) to evaluate clustering results. Silhouette width is a composite index which reflects the compactness and separation of the clusters. For each data point *i* the Silhouette width is calculated as follows:

$$S(i) = \frac{b(i) - a(i)}{\max\{a(i), b(i)\}} \quad \text{...(8)}$$

Where $a(i)$ is the average distance of a data point *I* to other data pointin the same cluster, $b(i)$ is the average distance of the that particular data point to all the data points belonging to the nearest cluster. The average $s(i)$ of all data points reflects the quality of clustering result. Larger silhouette value signifies good cluster.

b. Davies-Bouldin Index (Dbi) This index is a function of the ratio of the sum of within-cluster scatter to between-cluster separation. This DB index is defined by (Daviesand Bouldin, 1979):

$$DBI = \frac{1}{c} \sum_{i,j=1}^{c} \max_{i \neq j} \left\{ \frac{D_c(i) + D_c(j)}{d_{ce}(i,j)} \right\} \quad \text{...(9)}$$

Here $D_c = \frac{\sum_i \|X_a - C_i\|}{N_i}$ and $d_{ce} = \|C_i - C_j\|$ to cluster *i*. N_i is number of data that belong to cluster *i*. C_i and C_j cluster centre of *I* and *j* cluster. So, when the cluster is compact and far from each other the ratio is small. Consequently Davies-Bouldin index is small for good cluster. Dimitriadou et al. (2002) found that optimal numbers of cluster for a data set is the number of cluster for which the Davies-Bouldin index (DBI) value is the lowest.

C. Calinski-Harabasz Index (Chi) Calinski-Harabasz (1974) suggested the index for cluster validation purpose. This index uses thequotient between the intra-cluster average squared distance and inter-cluster average squared distance.

$$F = \frac{\left[\sum_{i=1}^{n}(X_i - \overline{X})^2 - \sum_{k}^{c}\sum_{i=1}^{n_k}(X_i - \overline{X}_k)^2\right] \Big/ c-1}{\left[\sum_{k}^{c}\sum_{i=1}^{n_k}(X_i - \overline{X}_k)^2\right] \Big/ n-c} \quad \text{... (10)}$$

Here *n* is total number of input data points. *c* is number of cluster. n_k is number of data points in cluster *k* ($k = 1,2,\ldots c$), and X_i and X_k are observation vectors for input data I and the centroid for group *k*, respectively. This parameter was found to be the best global statistic criterion in cluster evaluation by Milligan and Cooper (1985).

D. Dunn index (Di)

The index was formulated by Dunn (1974) in order to check the quality of cluster resulted from a clustering algorithm. The equation is defined by:

$$D_{nc} = \min_{i=1,\dots,nc}\left\{ \min_{j=i+1,\dots,nc}\left(\frac{d(c_i,c_j)}{\max_{k=1,\dots,nc}(diam(c_k))} \right) \right\} (11)$$

Here $d(c_i, c_j)$ is the dissimilarity function between two clusters c_i and c_j defined as $d(c_i, c_j) = \min_{x\in C_i, y\in C_j} d(x,y)$ and diam(c) is the diameter of a cluster which is the measure of dispersion of the clusters. The *diam(c)* of the cluster can be defined as follows.

$$diam\,(C) = \max_{x,y\in C} d(x,y)$$

e. Krzanowski-lai index (Ki) The index of Krzanowski and Lai (KLI) is defined as (Krzanowskiand Lai, 1985):

$$KLI(c) = \left| \frac{DIFF(c)}{DIFF(c+1)} \right| \dots(12)$$

Where,

$$\phi^{(Q)}(X,\lambda) = 1 - \frac{\sum_{i=1}^{n_i} \frac{n_i}{n-n_i} \sum_{j\in\{1,\dots,i-1,i+1\dots k\}} n_j \times \mathrm{inter}(X,\lambda,i,j)}{\sum_{i=1}^{k} n_i \times \mathrm{intra}(X,\lambda,i)}$$

$$DIFF(c) = (c-1)^{\frac{2}{p}} W(c-1) - c^{\frac{2}{p}} W(c)$$

And p denotes the number of features in the data set, c denotes the number of cluster sand $c2$,$W(c)$denotes

$$\mathrm{inter}(X,\lambda,i,j) = \frac{1}{n_i \mathrm{X} n_j} \sum_{\lambda_a=i,\lambda_b=j} S(X_s, X_b) \qquad \mathrm{intra}(X,\lambda,j) = \frac{2}{(n_i-1)\mathrm{X}n_i} \sum_{\lambda_a=\lambda_b=i, b>a} S(X_a, X_b)$$

Here i and j are cluster indices X and X_b are two vertices.

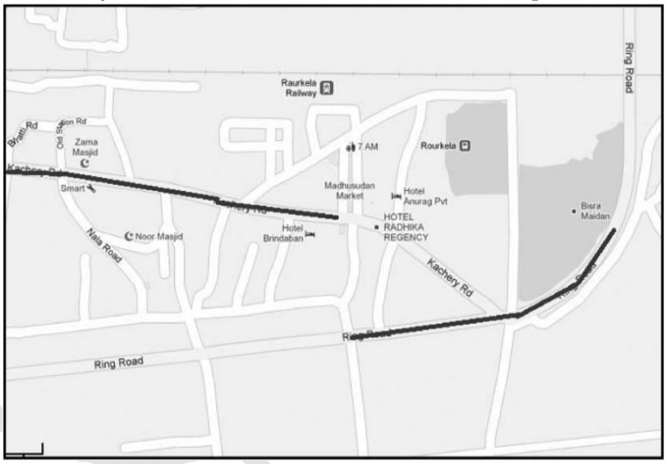
6.STUDY CORRIDOR SAND DATA COLLECTION:

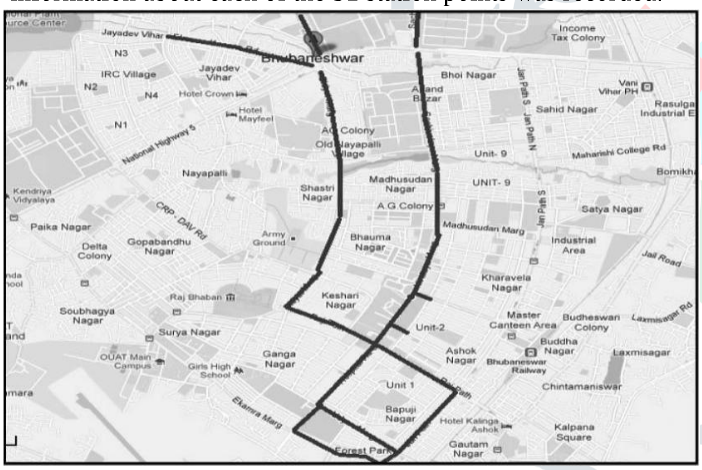
A century of industrialization and technical advancement has brought forth rapid urbanization in India. Statistics on census of India 2011 reveals that about 377 million of the total 1.21 billion population of India lives in urban areas. As per the census Odisha is having 41 million populations, that is 3.14 percent of population of India and the population is closest to country Argentina. However, decadal growth in the urban population of the State, during the last decade (2001-2011) has been enormous with a growth rate of about 26.80 percent, which is nearly that of national growth rate of 31.80 percent. It is noteworthy that the state's population during the last decade has grown by about 13.97 percent while that of the urban population has grown at almost at double this rate. The within cluster sum of square of the partition. Dudoit et al. (2002) suggested that the highest value of Krzanowski-Lai index (KLI) gives the optimal number of cluster for a given dataset.

F. Weighted inter-intra index (Wi)

This index tries to find the optimal number of cluster $_{(Q)}$ by high overall quality of cluster and a small number of cluster k. The quality of cluster is determined as follow:

Two important mid-size cities Bhubaneswar and Rourkela of Odisha state, India are taken up in the present study. Sampled area sees heavy foot traffic, because of sidewalks on the streets and transit points. Another feature of the selected area is the great variety of land uses: residential, commercial, office and institutional (e.g., school, hospital). Often, commuters need to walk at least a short distance to reach their final destinations. Bhubaneswar and Rourkela has straight, wide streets, unlike the narrow, winding, ancient streets found in most Indian cities and also the edge of the side walks are having sufficient distance from the window shopping, so that pedestrian don't have to face problem for that. Streets are arranged in a grid, meeting at signalized intersections that are installed with pedestrian crosswalks. In the surveyed area, almost all the streets have sidewalks on both sides and crosswalks at intersections. Bhubaneswar, the temple city enjoys excellent connectivity with other adjoining regions of strategic importance - however, the passenger transit option needs improvement of greater interaction. Bhubaneswar is primarily an administrative city and a tourism city. Bhubaneswar has emerged as a fast-growing, important trading and commercial hub in the state and eastern India. Tourism is a major industry, attracting about 1.5 million tourists in 2011. Bhubaneswar was designed to be a largely residential city with outlying industrial areas. The economy had few major players until the 1990s and was dominated by retail and small-scale manufacturing. There exists a significant level of disparity within this region in terms of accessibility to major urban centres. At intra urban level, incapacity of the existing traffic and transportation network will create a serious constraint to its future growth. The traffic demand management will play a key role as the role of supply management is near exhaustion. On the other hand Bhubaneswar enjoys a variable level of mobility at different parts of the city. Rourkela, the site for this study is commonly known as the steel city in all over world is one of the largest city located at northern west of the Odisha state. It is situated at the heart of mineral belt .The correct selection of sample sites is an important issue in designing the field survey. In reality, selection of a proper site is not an easy task because different routes need to appear in different LOS conditions to examine the influence of LOS on pedestrian route choice. Sampled area sees heavy foot traffic, because of sidewalks on the streets and transit points. Riders of public transportation (subway, bus, train) usually walk from transit points to their destinations. Another feature of the selected area is the great variety of land uses: residential, commercial, office and institutional (e.g., school, hospital). Often, commuters need to walk at least a short distance to reach their final destinations. Bhubaneswar and Rourkela has straight, wide streets, unlike the narrow, winding, ancient streets found in most Indian cities. Almost all the streets have sidewalks that are separated from the carriageway by small trees and curbs. Since bicycle lanes have not been established in Increasingly, researchers are using video camera to observe and collect data about pedestrians. Video data has plenty of advantages over direct observation: one can collect data from the video carefully back in the office or lab, can easily share video with others to illustrate a point, and there are tools available to automate data collection. High resolution video camera was cities cyclists also use these sidewalks. Streets are arranged in a grid, meeting at signalized intersections that are installed with pedestrian crosswalks. In the surveyed area, almost all the streets have sidewalks on both sides and crosswalks at intersections. Study corridors for the study area are presented in **Fig.4**fixed to the side of the foot-path that is the pedestrian off-street facilities with the help of a tripod stand. Always a length of 4m has been marked to observe the flow of pedestrian. However the start and end point of the stretch having four meter length of the footpath helped in determining the speed of the pedestrian Pedestrian speed and attributes on road features data were collected on a sample of 3,764 pedestrians observed at various sidewalk locations in both of the cities about 62 days in both peak and off-peak hours of working and non-working days. This shows that a large size data set is used for the development of LOS categories in this study. The speed of each pedestrian is recorded by using stopwatch. With the help of stopwatch pedestrian crossing time from the starting point to the end point of the observed portion of the off-street segment was recorded. From which pedestrian speed per meter is calculated and average speed of pedestrian for each segment is taken for further calculation. It is assumed that the average speed of pedestrians on the observed section of the facility represents the average speed of the street segment as a whole. In the same locations, over the same time period, all pedestrians were counted in order to determine sidewalk flow rates, and basic information about each of the 31 station points was recorded.

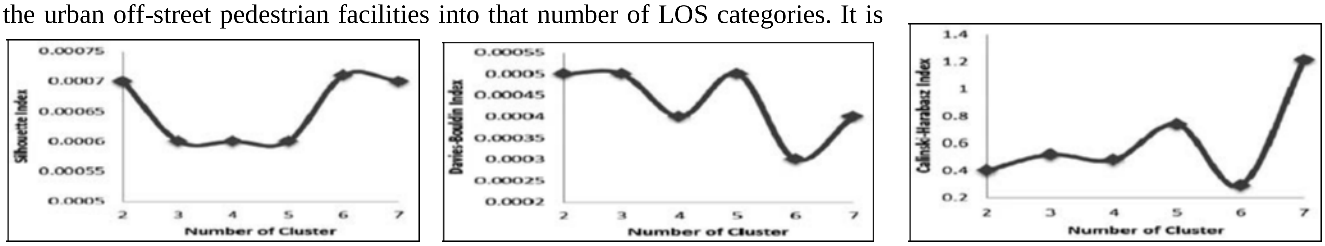




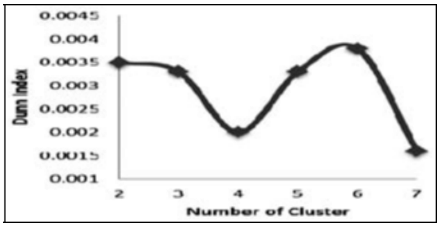
(a) Bhubaneswar Study Corridors
(b) Rourkela Study Corridors

Then the videos loaded to computer to play the recorded videos. Manually the pedestrian peak volume and flow rate were calculated from video data. It is observed that in these two cities pedestrian flow and density are comparatively lower because population sizes of these two cities are less than a million and also mobility due to commercial activities is comparatively lower. Based on these sets of data, two databases were built: a database containing speed and an aggregate database of each of the study locations. This aggregated locational database includes the calculated flow rate based on the count at the location, the effective width of the sidewalk, and land use proportions based on two cities. Effective walkway width is the portion of a walkway that can be used effectively by pedestrians. Various types of obstructions such as trees, electric poles, information signboards projections of road side shops and linear features, reduce the walkway area that could have effectively used by pedestrians.

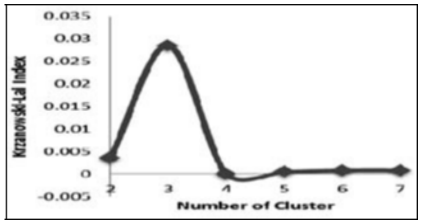
7.RESULTS AND ANALYSIS: The average pedestrian space data acquired through Video Camera was clustered using SOM algorithm of ANN. For determination of the parametric values of validation measures, average pedestrian space data and cluster ranges found from ANN analysis were used. In this research six validation parameters were used. These six number of validation parameters were used to know the optimum number of clusters for these four parameters used; for example data set of average pedestrian space is explained in detail in this study. By knowing the optimum number of clusters we can classify the urban off-street pedestrian facilities into that number of LOS categories. It is always considered that lesser number of clusters is better if variation in validation parameters is minimal.



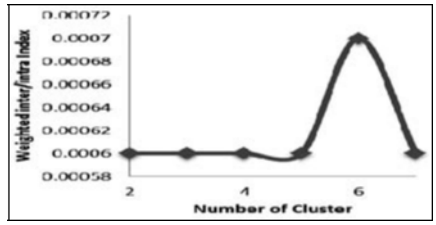
a) Silhouette Index vs. Number of Cluster b) Davies-Bouldin Index vs. Number of Cluster c) Calinski-Harabasz Index vs. Number of Cluster



d) Dunn Index vs Number of Cluster



e)KrzanowskiLai Index vs Number of Cluster



f) Weighted inter/intra Index vs Number of Cluster

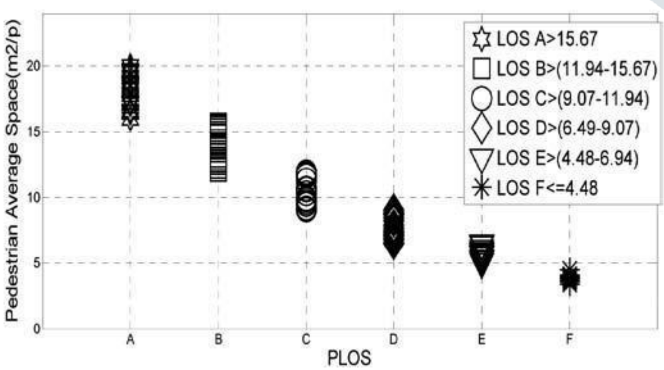
Value of validation parameters were obtained for 2 to 7 number of cluster and were plotted in **Fig. 5** and the validation indices are shown in Table 1. Bolshakova et al. (2005) shows that the largest silhouette value indicates a better quality of clustering result. **Fig. 5(a)** shows that the index value is largest for 6 number of cluster. Also Bolshakova et al. (2005) says that for Davies-Bouldin (DB) a low value indicates the optimum number of cluster. From the **Fig. 5(b)** it is observed that index value is minimum for 6 number of cluster. Dudoitetal. (2002) and Bolshakova et al. (2005) found that the maximum value of Calinski-Harabasz Index, Dunn Index and Krzanowski-Lai Index represents the optimum number of cluster respectively. **Fig. 5(c) and 5(e)** shows that the optimum number of cluster for Calinski-Harabasz Index and Krzanowski-Lai Indexare 7 and 3 respectively whereas from **Fig. 5(d)**, for Dunn index 6 is the optimum number of cluster.

NC	si	Dbi	Chi	Di	Ki	Wi
2	0.0007	0.0005	0.4006	0.0035	0.0036	0.0006
3	0.0006	0.0005	0.5167	0.0033	0.0285	0.0006
4	0.0006	0.0004	0.4771	0.002	0	0.0006
5	0.0006	0.0005	0.7385	0.0033	0.0005	0.0006
6	0.00071	0.0003	0.2908	0.0038	0.0008	0.0007
7	0.0007	0.0004	1.211	0.0016	0.0008	0.0006

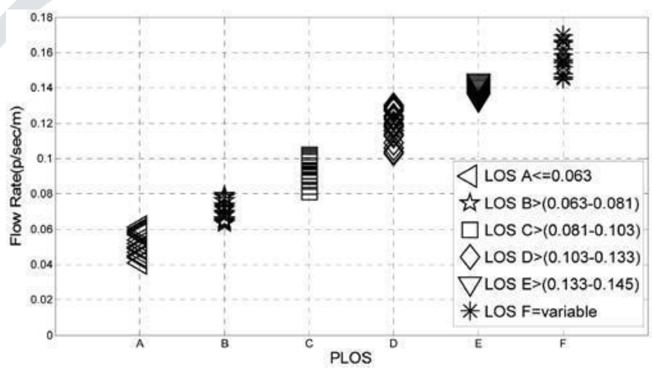
Table1 Numerical Values Of Cluster Validation Measures Using Som Clustering

Here, NC = Number of Cluster, SI= SilhouetteIndex, DBI = Davies-Bouldin Index, CHI = Calinski-Harabasz Index, DI= Dunn Index, KI = Krzanowski-Lai Index, WI = Weighted inter/intraIndex

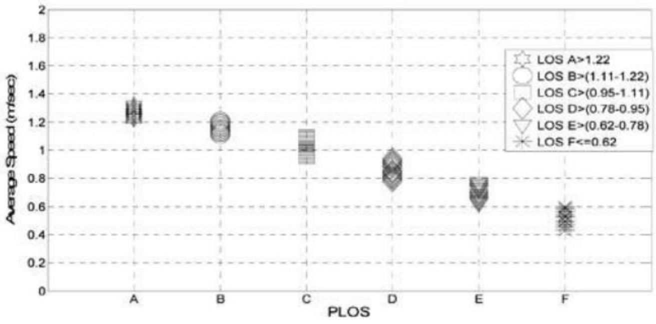
Again Dudoitetal. (2002) found that for Weighted inter/intra Index the first down –tick of the index during searching forward is the optimal number of cluster. In **Fig. 5(f)** it occurs at 6 number of cluster. Out of six validation parameter considered in this study four parameters give the optimal cluster value as 6 which are also same as suggested by HCM (2010). Also it is observed that the other parameters or measure of effectiveness (MOE) that is pedestrian flow, speed and volume to capacity (v/c)ratio considered to define ranges of LOS categories also satisfies classification LOS into six categories. That is the reason for which in this research the urban off-street pedestrian facilities are classified into six categories using the SOM in ANN. After getting the optimum number of clusters as six all the parameters that are the average pedestrian space, speed, flow and v/c ratio data acquired through video data collection was clustered using the SOM algorithm. The different ranges of the parameters are given in different symbols, also the legends in **Fig. 6 (a-d)** gives the ranges. All the clustered ranges of PLOS categories for off-street pedestrian facilities are shown in



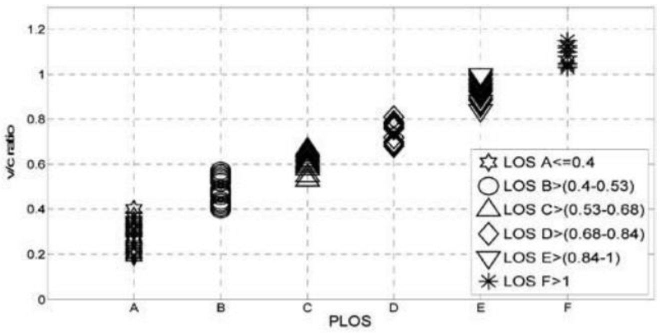
(A) Average Pedestrian Space of PLOS Categories



(B) Flow rate of PLOS Categories



C) Average Travel Speed of PLOS Categories



(D) v/c ratio of PLOS categories Fig. 6 PLOS

From SOM cluster analysis it is found that for PLOS "A" average pedestrian space is greater than 15.67 m_2/p and for PLOS "F" it is less than 4.48 m_2/p.Pedestrians will face frequent contact with other users and speed is restricted when flow rate is greatert han 0.145 p/sec/m and at that time volume to capacity ratio is at extreme level i.e. near about 1. Whereas pedestrians can move at their desired speed at less than 0.064 p/sec/m flow rate and less than 0.4 volume to capacity ratio. This occurs in PLOS "A" condition and here pedestrians move at near about 1.22 m/sec speed. In PLOS "F" speed is about 0.62 m/sec, where it is difficult to walk for a pedestrian. Applying this method it is found that all the ranges for urban off-street pedestrian facilities for six PLOS categories are significantly different from those values mentioned in HCM 2010. In this study, these two cities are having less than a million populations, for which pedestrian movement is comparatively low than the highly populated metropolitan cities. In Indian cities highly heterogeneous traffic flow on the main carriageway occasionally influence the pedestrian's movement on off-street facilities. Due to poor enforcement of laws for traffic on main carriageways as well as the off-street pedestrian facilities, a haphazard movement is perceived. Also it has been observed that inadequate road infrastructures lead to varying geometry conditions creates unwanted confusion to the users. Besides, some of the pedestrian facilities are unauthorized occupied by vendors for their commercial use and installation of advertisements boards. In some cases unplanned utilities such as electric and telephone poles become a natural obstruction to the pedestrian movements on the path. Illegal parking on off-street facilities becomes a common phenomenon for which the pedestrian has to forcefully reduce its speed and divert the direction of movement. For these reasons PLOS ranges in Indian cities are different from other developed countries. In India, social and cultural inheritance is also different as people love to move in platoons, which has a broad effect on off-street movements. Also the physical size of Indian population is also another contributing factor for which the PLOS categories in this study are different from the values described in HCM.

los	**Average space (m_2/p)**	**related measures**			**Comments**
		Flow rate (p/sec/m)	**Average speed (m/sec)**	**v/c ratio**	
A	>15.67	≤0.063	>1.22	≤0.4	Ability to move in desired path, no need to altermovements
B	>11.94-15.67	>0.063-0.081	>1.11-1.22	>0.4-0.53	Occasional need to adjust path to avoid conflicts
C	>9.07-11.94	>0.081-0.103	>0.95-1.11	>0.53-0.68	Frequent need to adjust path to avoid conflicts
D	>6.49-9.07	>0.103-0.133	>0.78-0.95	>0.68-0.84	Speed and ability to pass slower pedestrians restricted
E	>4.48-6.49	>0.133-0.145	>0.62-0.78	>0.84-1.00	Speed restricted, very limited ability to pass slower pedestrians
F	≤4.48	>0.145	≤0.62	>1	Speed severely restricted, frequent contact with otherusers

Table2 Plos Categories For Urban Off-Street Pedestrian Facilities Using Som Clustering

8 CONCLUSION: Over the years, PLOS methods have been developed in a variety of ways for different walking environments and it has been suggested for substantial improvements in the analysis procedures. Majority of these methods and models have been developed by combining models that have been applied to other choice contexts and, as a result, are not suited to universal applications. Various models available are suitable for homogenous traffic flow condition as seen in developed countries. From the background studies it is found that HCM(2010) methodology for the prediction of PLOS can be used for Indian context after due modifications. Hence the PLOS methodology developed in HCM (2010) is adopted in this study. SOM clustering method is used to define PLOS criteria. Different LOS values based on pedestrian space, flow rate, speed of pedestrian and volume to capacity (v/c) ratio are defined from clustering analysis method which gives numeric ranges for LOS categories. From this study it is observed that pedestrian data collection using video cameras is a very simple and accurate procedure. SOM clustering is highly efficient in terms of time saving and provides a very accurate solution to this kind of classification problem. By using SOM cluster analysis, ranges of parameters for six pedestrian levels of service categories i.e. A, B, C, D, and F are defined for off-street walking facility in Indian context; where LOS "A" represents the best operating conditions and LOS "F" the worst. The PLOS ranges defined in this study are significantly different from that mentioned in HCM (2010) because of highly heterogeneous traffic flow on main carriageway, poor enforcement of traffic laws, varying road geometry, unauthorized vendors activities, unwanted obstructions from utilities, and illegal parking on off-street facilities. Considering the local condition, data collection method using video cameras and SOM in ANN clustering techniques can be applied in other countries to define the PLOS categories. One limitation to the application of SOM in ANN cluster analysis is that it require large amount of data set for which is cumbersome. The relationships among the variables at each step of the methodology followed in this study are empirical only. Hence this methodology can be applied to define the PLOS ranges irrespective of city size or population size. In the populated cities of population more than million are having large commercial, industrial, educational and residential activities, which give rises to heavy pedestrian activities. The method followed in this study can be applied to define the PLOS ranges for off-street pedestrian facilities for populated cities as the ranges defined in this study are different; hence similar studies can be carried out for other bigger cities having population size more than a million to develop comprehensive PLOS criteria.

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