Application of Fuzzy Logic in Urban Planning For TIA

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Abstract
Integration and adaptation of artificial intelligent designs with fuzzy inference techniques is an active area of research that can be used to meet the challenges of many urban planning applications. Traffic impact assessment of commercial centers in urban areas are complex and require consideration of multiple factors in planning and design in order to achieve a design plan that is environmentally robust and sustainable. Improper location of these centers often results in a prolonged impact on the economic, social and environmental well being and sustainability of the region. This paper, presents the development of an urban fuzzy inference system (FIS) which is a decision support system to evaluate the location of commercial spaces in an established built environment through the impact measurement of the neighborhood transportation supply system and its collateral characteristics. The impact assessment logic is embedded in the form of an expertly guided rule-base of an FIS. The impact is calculated using the three core characteristics of transport supply system (Node based, Link based and network based), with respect to a measure of travel and traffic characteristics affecting the location and the surrounding built environment neighborhood. GIS has been used as a supportive tool for the data analysis and integration in fuzzy logic system.

Keywords- *Artificial intelligence designs, Fuzzy interface system, Decision support system, environment neighborhood.*

I. INTRODUCTION

Developing economy with cropping urban development projects of unprecedented land use intensity generates and attracts additional traffic flows leading to local or global traffic imbalances. The problems to be solved are the inefficiency of urban transportation system and underlying land use patterns, which negatively affect quality of life, economic efficiency, and the environment. Many groups have contributed to this by establishing sustainable transportation indicators (Alberti [1]; US Environmental Protection Agency (EPA) ; European Environment Agency, 2001; Kenworthy , Laube & Kennedy[2] . In particular, advocacy for various forms of neo-traditional urbanism, compact cities, urban villages and public transport oriented development all aim explicitly to use land use policy and urban design to assist in promoting more sustainable patterns of travel (Aldous[3]; Calthorpe [4]; Ryan and McNally, [5]; Urban Task Force, 1999).The layout of the land use in urban fabric and its collateral impact on traffic are the prime factors to be considered in promoting sustainable urban design and orient environment friendly travel patterns. Conventionally, the intensity of the traffic impact is measured with reference to node and link performance indicators (eg: Node indicators include no. of trips attracted to the land use, parking characteristics etc. The link indicators include level of service indicators on the approaching link, basic traffic characteristics etc).There is a need to measure the system wide impacts of the land use activity to analyze the balance of demand and supply in a transportation system. While mobility enhances productivity, it inevitably leads to congestion and pollution (Camagni et al.[6] .This study presents an approach to measure the relative impacts of the existing commercial centers on traffic considering the system wide impact of the supply system.

2. LITERATURE REVIEW

Literature review has been presented in two aspects - Planning of commercial centers, TIA and its case studies. The problem of location planning for urban distribution centers can be classified as a special case of the more general facility location problems. The facility location problem usually involves a set of locations (alternatives) which are evaluated against a set of weighted criteria independent from each other. The alternative that performs best with respect to all criteria is chosen for implementation. The distinct feature in location planning for urban distribution centers is the consideration of interests of other stakeholders like city residents, municipal administrators etc. The goal is not only to minimize distribution costs but also to conform to sustainable freight regulations of the city and create least negative effects on city residents and their environment. Several approaches have been reported in the literature for solving the facility location problems. Agrawal [7] present a hybrid Taguchi-immune approach to optimize an integrated supply chain design problem with multiple shipping. Sun et al [8] present a bi-level programming model for the location of logistics distribution centers. The most commonly used approaches can be classified as continuous location models, network location models and integer programming models. In continuous location models, every point on the plane is a candidate for facility location and a suitable distance metric is used for selecting the locations. In network location models, distances are computed as shortest paths in a graph. Nodes represent demand points and potential facility sites correspond to a subset of the nodes and to points on arcs. The integer programming models start with a given set of potential facility sites and use integer programming to identify best locations for facilities.

Most of literatures were developed where TIA tries to analyse the overall impact of land use on global traffic activities as crucial link into planning strategies. The Transportation Research Board of USA published the first edition of highway capacity manual and foundation for successful TIA was studied by Jacob Wattenberg [9]. Studies have been carried by Western S Pringler and Pober W [10] to forecast traffic volume in TIA and management of traffic . Tamin[11] argues that in order to get better solutions to problems the macro transportation system should be subdivided into smaller sub systems including need, infrastructure, engineering and management of traffic system. The assessment of traffic was done by TRANSPLAN computer model in area of TIA. Stephen [12] has employed the method of network model to assess the traffic impact on Malls.

3. HYPOTHESIS

The location of the commercial centre in the network topology has an impact on the malfunctioning of existing infrastructure creating traffic mobility problems. The criterions for measurement of these impacts are primarily based on measuring the level of service conditions on the adjacent supply system entities. The factors thus relate to the functional attributes of the commercial centre (node based) and the adjacent road (link based). The neighborhood characteristics of the facility node (Commercial centre) also have profound influence in promoting the mobility of the urban areas. Hence the evaluation of the commercial centre is based considering the network topology / location of the entity in the network as well as the functional characteristic of the entity rather than analyzing in localized scenario considering volume /capacity values. The impact characteristics are multifaceted with multiple objectives to promote effective mobility in the urban areas. The analysis of these multi criterions in a relative platform involves an uncertainty which can best analyzed by fuzzy multicriterion approach. Fuzzy multi criteria analysis approach provides an ideal solution in uncertain situations and it has been attempted by number of researchers for prioritization analysis in different situations. This study attempts to conceptualize fuzzy multi criteria analysis to analyze the existing commercial centers / shopping malls in a network and identify the critical land use centers that worst effects the operational performance in a network. The analysis serves as a tool for road administrators in road development and planning to priorities the mitigation measures in an urban framework.

4. OBJECTIVES OF THE STUDY

The objectives framed in the study are as follows:

1. Develop framework for transportation impact analysis of commercial centers considering the node based, link based and neighborhood network attributes
2. Identification of commercial spaces that pose a significant threat to mobility in the urban areas
3. Conceptualization of fuzzy multi criteria approach and development of fuzzy interface system to analyze the traffic impacts on the supply system

5. METHODOLOGY

Figure 1 shows the outline of the fuzzy interface system . The system consists of input phase where the impact criteria based on node, link and network are derived through road network and traffic characterization studies. The crisp data is obtained from the GIS interface and is standardized with a linear additive function. The fuzzification of the impact criteria activates the linguistic variables which forms an input to the fuzzy interface. This interface is a decision support system where the rules provided by experts and Multi criteria evaluation set up analyze the input forms. The MCE used is the Ideal Point analyses that derives the separation measure from the Ideal Point.

5.1 Concept of fuzzy interface system

The fuzzy set theory was proposed by Zadeh, L. A[13]. in 1965, to represent the uncertainty involved in any situation in linguistic terms. A fuzzy number $\tilde{A}$ is a fuzzy set, and its membership function is $\mu_{\tilde{A}}(x) : R \rightarrow [0,1]$ [Dubois & Prade [14]; Yeou-Geng Hsu et al [15]; Mei-Fang Chen et al [16], where 'x' represents the criteria. A linear membership function is the widely used and the corresponding fuzzy numbers are called Triangular Fuzzy Numbers (TFNs). TFNs are the special class of fuzzy numbers whose membership is defined by three real numbers (l, m, n) i.e. $\mu_{\tilde{A}}(x) = (l,m,n)$, which is pictorially shown in Fig. 2. The TFNs can be expressed as follows.

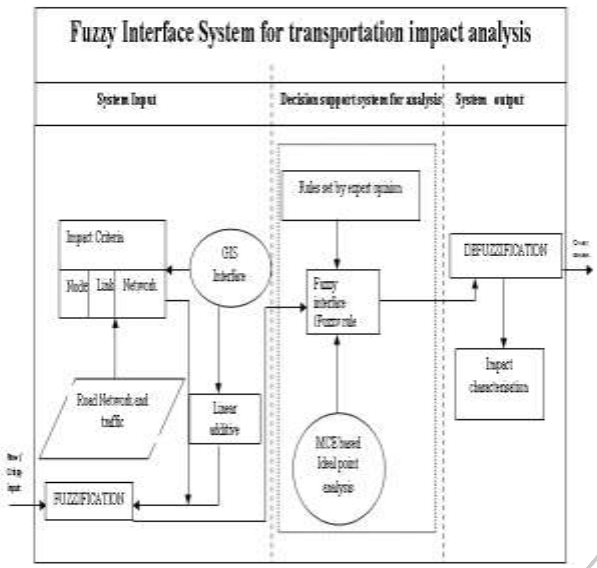

Figure 1. Fuzzy interface system

The impact criteria selected for analysis are given in the table 1 below

Table 1. Impact criteria considered for transportation system evaluation for commercial centers.

Node characteristics	Link characteristics	Network characteristics
•Commercial centre area=CCA	•Volume/Capacity=V/C	•No of intersections=NI
•Trip attraction=TA	•Volume=V	•Road network length=RNL
•Parking occupancy rate=POR	•Headway=H	•Length of major road network=LMRN
•Average reach time/Impedence Length=ART/IL	•Speed=S	
•Impedence=I		
•Queuing length=QL		
•Entry & exit points=EEP		

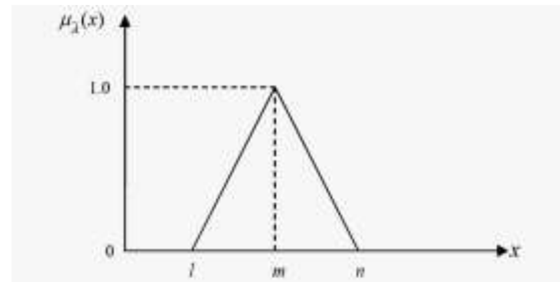

Figure.2. Concept of fuzzy interface system

Note: Definitions regarding the criteria's considered are detailed in the appendix-I

6.STUDY AREA

10 Shopping centres in Hyderabad city are taken as study spots which attract heavy trips in the city. The study sites are listed in the table 2

Table 2. List of study sites in Hyderabad city

Shopping mall	Notation	Location
Life style	SM-I	Kundan Bagh
Inorbit mall	SM-2	Madhapur
Amrutha Mall	SM-3	Somajiguda
City centre mall	SM-4	Banjara Hills
Hyderabad central	SM-5	Punjagutta
GVK one mall	SM-6	Banjara Hills
Babukhan mall	SM-7	Somajiguda
Ashoka metropolitian	SM-8	Banjara Hills
Shoppers stop	SM-9	Begumpet
MPM mall	SM-10	Abids

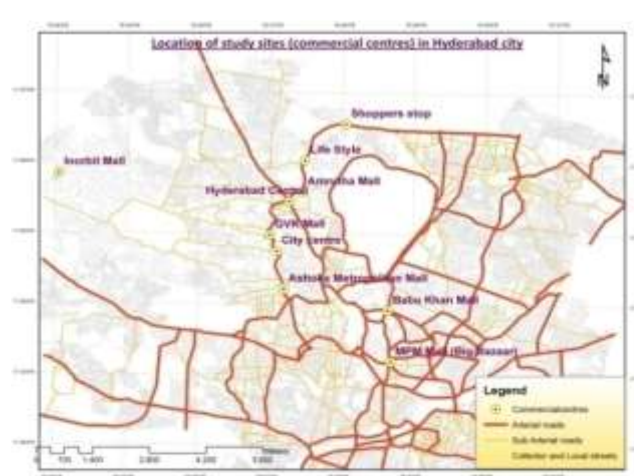

Figure 3. Location of study sites in Hyderabad city

7. APPLICATION OF METHODOLOGY

7.1. Data collection

Primary data has been collected through field investigations as well as expert opinion surveys. The opinion of selected experts from all over city has been sought to ascertain the influence of different parameters on the traffic impact analysis of shopping malls. The criteria's considered are with respect to three severity levels namely low, medium and high.

Further they were asked to indicate their preferences regarding the influence of severity of various parameters in terms of linguistic variables such as Negligible (N), Low (L), Moderate (M), High (H) and Very High (VH) as it would be difficult to express the weights in quantifiable terms. The responses given by a group of 10 experts have been summarized and presented in Table 3.

7.2. Fuzzy interface system prioritization process

7.2.1. Phase-1

Data collected in the field is being normalized in the scale of 0 to 100 with respect to the maximum value in the series through a simple normalization (Linear additive function) as shown below.

Normalized Data Point = (Data Point) x 100 / (Mode of the Data Series) (2)

Further, these values are being arranged into 10 groups with a uniform interval of 10 and ratings have been given, which is presented in Table 5

N=Negligible; L= Low ; M=Medium; H = High ; VH= Very High;

Table 3. Summary of Experts Opinions

Criteria	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10
CCA	VH	VH	VH	H	H	H	H	M	M	M
TA	H	H	H	L	M	M	L	H	H	H
POR	M	M	H	H	L	L	L	L	L	M
ART	L	L	L	M	M	M	M	M	M	M
I	H	H	H	H	VH	VH	H	VH	H	H
QL	VH	VH	M	M	M	M	H	H	H	VH
EEP	L	L	L	L	N	N	N	M	M	M
NCS	VH	VH	VH	VH	VH	VH	VH	VH	VH	VH
NI	H	H	H	M	VH	VH	VH	VH	H	H
RNL	H	H	H	H	H	H	H	VH	M	M
LMRN	L	L	L	L	L	N	N	N	N	N
V/C	H	VH	VH	VH	H	H	H	H	VH	VH
V	H	H	H	H	H	H	M	M	M	H
H	L	L	L	L	M	M	H	H	M	M
S	L	L	L	N	N	N	N	L	L	L

Table 4. Data obtained from field surveys and GIS .

Location	Impact criteria													
	Node point							Neighborhood network			Approaching link			
	CCA	TA	POR	ART/IL	I	QL	EEP	NI	RNL	LMRN	V/C	V	H	S
Units	Sq.mt	Nos.	%	Min/km	Km	No	Rat.	No	Km	Km	Ratio	Pcu/hr	Sec	Km/hr
SM-1	12192	152	76	5.45	5.5	4	4	**83**	12.05	1.08	1.2	7200	5.8	41.3
SM-2	243840	3048	68	2.96	15.2	12	1	44	8.077	0	0.9	1800	6.2	44.6
SM-3	28956	362	80	3.65	4.1	1	4	114	29.9	16.7	1.18	7100	4.7	39.7
SM-4	74676	933	82	4.47	6.7	7	2	91	12.85	1.2	1.16	5600	4.3	33.7
SM-5	76200	953	93	3.4	8.2	7	4	139	16.89	2.2	1.15	7400	2.3	24.5
SM-6	106680	1334	86	5.9	9.3	10	4	71	10.9	1.2	1.2	5800	1.8	22.1
SM-7	24384	305	42	5.2	3.4	1	4	127	13.9	3.0	0.99	4756	2.4	24.5
SM-8	76200	952	48	5.36	4.1	1	4	124	18.3	1.6	1.12	5400	3.4	28.9
SM-9	16459	206	63	3.3	3	0	4	79	12.8	1.0	1.068	6412	4.2	33.2
SM-10	54864	685	36	4.18	4.3	2	4	111	13.7	3.1	1.065	5100	3.1	30.1

Table 5. Ratings for the Normalized Values

Normalized value	0-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90	91-100
Rating	1	2	3	4	5	6	7	8	9	10

The rating matrix are being arranged in a matrix form named as Rating matrix$(R_{ij})_{nXm}$ with each row representing alternative (SM-I, SM-2, …….SM-10) and each column representing criteria. The Rating matrix has been presented in Table 6.

7.2.2.Phase-2

The linguistic variables utilized for expressing the criteria's have been expressed as TFNs. TFNs assigned for various linguistic variables are shown in Table 7.

Table 7. Triangular Fuzzy Numbers (TFNs) for Linguistic Variables

Linguistic Variable	TFN
Negligible	(0,0,1)
Low	(0,0.1,0.3)
Medium	(0.3,0.5,0.7)
High	(0.7,0.9,1)
Very High	(0.9,1,1)

7.2.3. Phase-3

Experts opinion available for the various Criteria's in the form of linguistic variable as presented in Table 3 are being converted into fuzzy numbers. To normalize Differences existing in expert opinion, simple average of fuzzy numbers for all the linguistic variables has been calculated and the corresponding weights are being

Table 6. Rating matrix

(R_{ij})

1	1	9	10	4	4	10	6	4	4	10	10	1	1
10	10	8	5	10	10	3	4	3	1	8	3	1	1
2	2	9	7	3	1	10	9	10	6	9	10	3	2
4	4	9	8	5	6	5	7	5	4	9	8	3	3
4	4	10	6	6	6	10	10	6	7	9	10	7	5
5	5	10	10	7	9	10	6	4	4	10	8	7	5
1	1	5	9	3	1	10	10	5	10	9	7	6	5
4	4	6	9	3	1	10	9	7	6	10	8	5	4
1	1	7	6	2	1	10	6	5	4	9	9	4	3
3	3	4	7	3	2	10	8	5	10	9	7	5	4

worked out and presented in the Table 8. Fuzzy weights for all criteria can be expressed in the form of following row matrix.

$w=(w_1,w_2\ldots\ldots\ldots\ldots w_m)$ (3)

Where, $w_1,w_2\ldots\ldots\ldots\ldots w_m$ are the fuzzy weights for all criteria expressed in Triangular Fuzzy Numbers i.e $w_j=(w_{j1}, w_{j2}, w_{j3})$ $\forall$ j= 1, 2, 3…….M

Table 8. Fuzzy weights for various parameters

Criteria's	Fuzzy weights
CCA	(0.64,0.81,0.91)
TA	(0.48,0.66,0.8)
POR	(0.23,0.29,0.53)
ART	(0.18,0.33,0.51)
I	(0.76,0.84,1)
QL	(0.6,0.76,0.88)
EEP	(0.09,0.19,0.225)
NI	(0.74,0.9,0.97)
RNL	(0.78,0.83,0.94)
LMRN	(0,0.05,0.23)
V/C	(0.8,0.95,1)
V	(0.58,0.78,0.91)
H	(0.26,0.42,0.6)
S	(0,0.06,0.22)

7.2.4. Phase-4

Fuzzy evaluation value (p_i) is then calculated by multiplying the rating matrix with the weight matrix and summed up for all the stretches, which are presented in Table 9. This process is mathematically expressed as follows.

$p_i = \sum_{j=1}^{M} R_{ij} * W_j$, $\forall$ i=1,2,…….N and $\forall$ j= 1,2,3…….M (4)

Table 9. Fuzzy Evaluation Values for all the Commercial centers

Commercial centers	Fuzzy evaluation values
SM-1	(33.9100 42.9800 51.9500)
SM-2	(42.1500 52.2000 61.9650)
SM-3	(39.0300 48.3700 58.0100)
SM-4	(38.6600 48.4200 58.4550)
SM-5	(45.4200 57.1800 69.3800)

SM-6	(44.3000 56.6700 69.3800)
SM-7	(33.3900 42.5500 52.1500)
SM-8	(38.7600 48.9600 58.8600)
SM-9	(29.5900 37.6000 45.4800)
SM-10	(33.5800 42.8200 52.0800)

7.2.5. Phase-5

To establish the relative preference of all the Commercial centre's, difference between all combinations of the fuzzy values has been computed. This is mathematically expressed as

$F_{ij} = (Sm_i - Sm_j)$ ∀ i= 1 to N ∀ j= 1 to N and $i \neq j$ (5)

It is noted that Sm1, Sm2 are triangular fuzzy numbers and hence $(Sm_i - Sm_j)$ are also triangular fuzzy numbers. A sample of these values is presented below.

SM 1-SM 2	(-28.06 -9.22 9.85)
SM 1-SM 3	(-24.2 -5.39 12.92)
SM 1-SM 4	(24.555 -5.44 13.29)
….	…..
SM 9-SM 10	(-22.49 -5.22 11.9)

7.2.6. Phase-6

The fuzzy Preference relation matrix (E) has been developed, to know the degree of preference of commercial centers Sm_i over the Sm_j.

$$E = \begin{bmatrix} e_{11} & e_{12} & \cdots & e_{1N} \\ e_{21} & e_{22} & \cdots & e_{2N} \\ \cdots & \cdots & \cdots & \cdots \\ e_{N1} & e_{N2} & \cdots & e_{NN} \end{bmatrix}$$

Where, e_{ij} is the real number indicates the degree of preference between the respective i^{th} and j^{th} commercial centre's. It has been calculated using positive (A^+_{ij}) and negative (A^-_{ij}) of difference between two fuzzy values$(Sm_i - Sm_j)$.

$e_{ij} = A^+_{ij} / (A^+_{ij} + A^-_{ij})$ Where $(A^+_{ij} + A^-_{ij})$ =Total area of $(Sm_i - Sm_j)$. (7)

Positive and negative areas have been computed using the membership function (UFij (x)) of the values $(Sm_i - Sm_j)$.

An example of computation of e_{ij} is shown below in fig 4. For example, if the

$F_{12} = (Sm_1 - Sm_2) = (-28.06, -9.22, 9.85)$

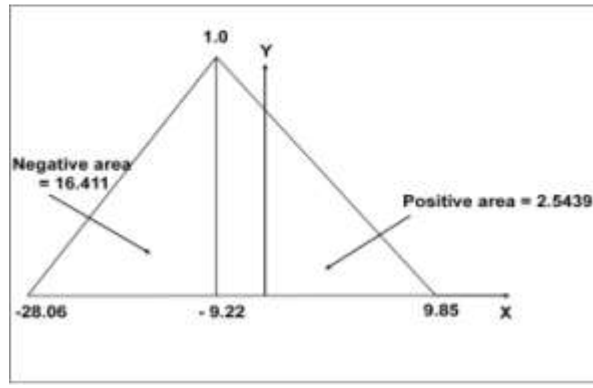

Figure 4. Computation of e_{ij}

Total area from fig=18.955; Positive area=2.5439; Negative area=16.411;

$e_{12} = (2.5439/18.955) = 0.13$

Here $e_{ij} = 0.5$ and $e_{ij} + e_{ji} = 1.0$, if $e_{ij} > 0.5$ the commercial centre Sm_i is to be given priority over stretch Sm_j and vice versa.

Eij =

0.50	0.13	0.25	0.25	0.05	0.06	0.52	0.24	0.77	0.51
0.87	0.50	0.67	0.66	0.19	0.31	0.87	0.65	0.98	0.87
0.75	0.33	0.50	0.50	0.17	0.20	0.94	0.48	0.93	0.76
0.75	0.34	0.50	0.50	0.18	0.20	0.76	0.49	0.93	0.75
0.95	0.81	0.17	0.82	0.50	0.52	0.95	0.81	0.99	0.95
0.94	0.69	0.80	0.80	0.48	0.50	0.94	0.79	1.00	0.94
0.48	0.13	0.06	0.24	0.05	0.06	0.50	0.23	0.75	0.49
0.76	0.35	0.52	0.51	0.19	0.21	0.77	0.50	0.93	0.76
0.23	0.02	0.07	0.07	0.01	0.00	0.25	0.07	0.50	0.76
0.49	0.13	0.24	0.25	0.05	0.06	0.51	0.24	0.24	0.50

7.2.7. Phase-7

Priority Index (PI) for all the commercial centers is computed from the fuzzy preference relation matrix using the following mathematical form.

$(PI)_i = \sum_{j=1}^{n} (e_{ij} - 0.5)$ ∀ i = 1 to N (8)

Based on the PI, all the commercial centers have been ranked and presented in Table 10. The prioritization process, as explained in the above stages is quite complex and cumbersome due to a number of commercial centre's and criterion. Hence, a code has been developed in MATLAB and being used in the present study.

Table 10. Ranking of commercial centers:

Commercial centre	Priority index	Rank
SM 1	-4.50	7
SM 2	-4.13	3
SM 3	-4.24	5
SM 4	-4.25	6
SM 5	-4.04	1
SM 6	-4.06	2
SM 7	-4.51	8
SM 8	-4.23	4
SM 9	-4.77	9
SM 10	-4.51	8

The lowest rank indicates the shopping mall that poses major traffic impact on the users.

8. CONCLUSIONS

The following conclusions have been drawn from the present work.

• The proposed Fuzzy Multi Criteria Decision Making approach is demonstrated with the data

Collected from the field and expert opinion and this approach can be extended for transportation impact analysis for commercial centres in an urban area.

• The developed software interface is expected to help in establishing the priorities with ease and there is no limitation as far as the number of shopping centres in the given network is concerned.

• The centre which has the highest Priority Index (PI) will be given top priority and vice versa.

• The work can be extended by including more number of variables and the same philosophy can be extended for the additional variables considered.

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10.APPENDEX-I

S.No	Type of criteria	Description
Node point		
1.	Commercial centre area(CCA)	The total built up area of the commercial space considering all floors of the building.
2.	Trip Attraction(TA)	The total no of trips attracted towards the commercial centre.
3.	Parking occupancy rate(POR)	The maximum number parking slots occupied by the vehicles to that of total parking spaces available.
4.	Average reach time/Impedance Length (ART/II)	Average travel time to reach the commercial centre by the road user.
5.	Impedance(I)	Average trip length of the road user to the commercial centre.
6.	Queuing length(QL)	The Average of total number vehicles in queue while approaching the commercial centre.
7.	Entry and Exit(EEP)	Location of the entry and exit points of the commercial centre.
Neighborhood link		
8.	No of intersections(NI)	The total number of intersections surrounding the selected commercial centre(Shopping mall).
9.	Road network length (RNL)	Length of total road network length surrounding the commercial centre selected.
10.	Length of major road network(LMRN)	The total length of major highways or arterials surrounding the selected commercial centre.
Approaching link		
11.	Volume/ Capacity(V/C)	The total number of vehicles on the lane to the total capacity of the lane in the approaching link of commercial centre selected.
12.	Volume(V)	The total number of vehicles in the approaching link of the selected commercial centre.
13.	Headway(H)	The average distance between two successive vehicles in the approaching link of the commercial centre selected.
14.	Speed(S)	The average spot speed of the vehicles in the approaching link of commercial centre selected.