CATEGORIZATION OF URBAN TRAFFIC CONGESTION BASED ON THE FUZZIFICATION OF CONGESTION INDEX VALUE AND INFLUENCING PARAMETERS

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Abstract
Traffic congestion is a dynamic phenomenon; it is not possible to determine the actual degree of congestion prevailing on the field using sharp boundaries of the influencing parameters. To overcome this, in this paper we have employed fuzzy concept to fuzzify the two influencing parameters viz. congestion index value and average speed that facilitated the categorization of the congestion status into five different classes i.e. highly congested, high-moderate congested, moderate congested, low congested, least congested as compared to the only two congestion classes determined through the traditionally used congestion index value of the influencing parameters. For each route, pre-defined membership values (between 0 and 1) were assigned to the congestion index value and average speed respectively based on the empirical observations made in the field. Using the same logic, knowledge-based weights were assigned to the five different classes of congestion. Subsequently, fuzzy OR operation was performed on the membership values of the two influencing parameters for each route separately. Finally, different routes of the study area were categorized as one of the five classes of congestion based on the resultant value of the fuzzy OR operation. The research demonstrated that application of the fuzzy concept and knowledge-based congestion weights can provide better realistic status of the congestion in the field as compared to traditionally used congestion index value of the influencing parameters.
Keywords: traffic congestion; fuzzy technique**;** GIS; empirical field observation.

1. INTRODUCTION

The problem of traffic congestion is rising at an alarming rate. In current scenario, most of the global cities are facing huge challenge to control traffic congestion (Boamah 2010). The root cause of the traffic congestion depends upon the nature of supply and demand. Traffic capacity is a fixed parameter which cannot fluctuate over time but demand fluctuates over time, and it is not possible for the transport services to maintain the balance between capacity and demand (Lindsey et al. 2000). The general perception is that the greenhouse gases viz. carbon dioxide increase with the increase in traffic

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congestion. If stop and go driving (congested conditions) is reduced then the increase in greenhouse gases can be controlled (Barth and Boriboonsomsin 2010). The degree of congestion in a route can be used as a parameter to indicate the risk of air and noise pollution in the route. Congestion has dynamic characteristics and it does not have a specific definition, the definition is contextual. The definition depends upon perception which can vary according to the situation. Delays and lower travel speeds are the parameters which characterize congestion or congestion can also be viewed as the queued vehicles, the prime reason for the blockage of roads (Zito et al. 1999). The decrease in speed, the increase in travel time and the increase of vehicle's queue on the road characterize congestion (Lee et al. 2008 & Boamah 2010). Traffic congestion is a dynamic phenomenon and the behavior of congestion depends upon the condition on the roads. Congestion is a growing problem of urban areas. According to Hanson (1995), because of the daily life activities and heterogeneous land use, congestion has spatio-temporal complexity.

According to Taylor et al. (1992), the major congestion indicators are as follows:

- Travel time: The total time from the beginning to the end of the journey.
- Average speed of the journey: It can be determined by dividing the total distance by the time taken to cover that distance.
- Congestion index: It is computed by using the formula (C – C0) / C0 where C is the total travel time and C0 is the free flow time. Free flow travel time can be defined as the time taken to travel the distance when the traffic density is nearly zero.
- Time moving: The total time when the speed is greater than zero.

Proportion stopped time (Fs): It is defined as Cs / C where Cs is the stopped time and C is the total travel time.

Congestion is also defined using V/C ratio where V is traffic volume and C is traffic capacity. If V/C ratio is greater than 1, then the route is congested (Narayanan et al. 2003). According to Taylor et al. (1992), if the value of (C – C0) / C0 is near zero it will indicate very low levels of congestion while an index greater than two generally will correspond to congested conditions. Chen et al. (2009) proposed a way to improve the traffic management system; the mobile agent technology was combined with multi-agent system to handle the uncertainty in traffic in a better way.

It succeeded to handle the uncertainty in dynamic environment. Li and Tsukaguchi (2005) proposed a new approach to analyze the topology of real existing networks. They discussed the relationship between the Origin-Destination pairs and network topologies. It was observed that the pedestrian route choice behavior varies according to the network topology i.e. the topology of the start point and the destination. Godescu et al. (2010) described a qualitative model that links the stock market dynamics with pedestrian dynamics. It was observed that there is a link between the pedestrian movement and the demand of goods Uang et al. (2002) made an attempt to map the impact of congestion information and map scale sizes on driving performance. In the paper, the usage of traditional paper map and electronic route map was compared. According to Koshak (2006), the web-based Geographic Information System (GIS) can be an effective tool to provide broader and easier distribution of the traffic plan. Web-based GIS makes the distribution of the plan easier, wider and cheaper.

The web-interface offers both static and dynamic digital maps that can be used by urban planners and designers and different local authorities. Anh (2003) presented system dynamic approach to study the existing urban transportation situation of Hanoi. In the paper, all causes and effects of traffic congestion were investigated and analyzed by the method. Petty et al. (2002) described a methodology that can be used to measure total, recurrent, and nonrecurrent delay on urban freeways. The methodology uses data from loop detectors and calculates the average and the probability distribution of delays. Jian et al. (2011) proposed a correlation algorithm to map the similarity between the congestion patterns and different links.

The objective of the present study is to categorize the degree of congestion in different routes into various classes viz. highly congested high-moderate congested, moderately congested, low congested and least congested. The idea behind the work is to represent the actual status of congestion in the routes and in order to achieve this task it is required to categorize the congestion status into different classes as above rather than following the traditional method of Congestion Index value that enables categorization of congestion into only two discrete classes i.e. congested or not-congested.

2. MATERIAL AND METHODS

2.1. Description of the study area

The study area selected for performing the present research comprises the Ranchi city, the capital of Jharkhand state, India covered in the Survey of India topo sheet No. 73 E/7 and is bounded by the spatial extension 23° 24' 06'' N to 23° 25' 47'' N and 85° 26' 57'' E to 85° 27' 26'' E. The study area is shown in Figure 1.

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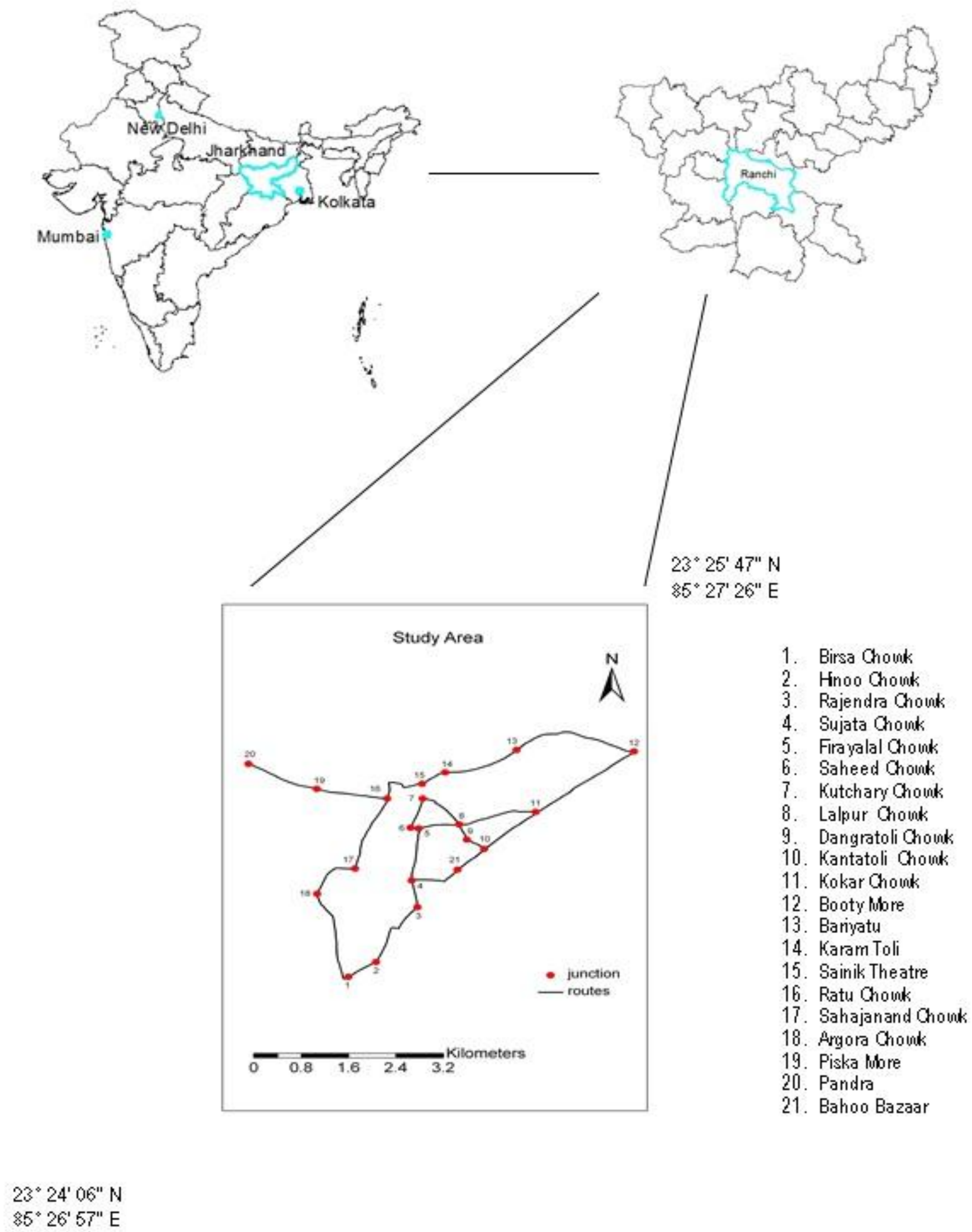

FIGURE 1 - STUDY AREA

In Ranchi, with every year the number of vehicles is increasing (Transport Department, Jharkhand 2011) and especially the rise in the numbers of two wheelers is significant. In Ranchi, the road structure is tree like and few roads are fault intolerant which makes the traffic flow slow. The tree like road structure comprises very few road junctions that results in undesired congestion on the roads and further adds to the traffic congestion in the connecting roads. As far as the link flow is considered, most of the routes are congested because traffic volume is much higher than the capacity of the road. This is further aggravated by the erratic driving induced by the non-occurrence of tracks on the main roads and mixed types of vehicles and public conveyances. The worst of all is the pedestrian movement; people cross anywhere on the road which becomes an additional and a very important factor for the link flow congestion. Transportation is nothing but a spatial interaction that is also primarily influenced by the type of land use occurring by the road side. For example, if the land use is homogeneous i.e. characterized by the presence of almost similar pattern of land use activities (commercial, residential etc.) then the swarming of people can be controlled but if there is heterogeneity in the land use then the road becomes vulnerable to the point congestion because of the pedestrian movement and this is exactly the problem in the city of Ranchi where even in the main roads of the city one can observe people crossing the road anywhere. Now moving the attention from the link flow congestion, if we need to find the reasons for the occurrence of point congestion on the roads, we cannot ignore the street pattern of the city. The streets in the city are not planned at all and so random that leads to the point congestions at all the intersection points. In addition, nuisance group activities on the road including the protest march are the other reasons which act as catalyst for both the point as well as link flow congestion.

2.2. Collection of data

Various traffic parameters required to perform traffic congestion analysis comprise total travel time, average speed, congestion index value, moving time, proportion stopped time that were collected from the field. Since in the study area there occurs significant variation in the traffic congestion throughout the day, we collected these parameters in three different time periods, one representing the lean traffic congestion (between 6 and 8AM), and the other two representing the peak flow conditions i.e. between 10AM and 1PM and between 2PM and 5PM respectively. Since land use type acts as a catalytic force behind traffic congestion, the routes were selected on the basis of land use characteristics. As congestion has dynamic characteristics (Zito et al. 2000), it becomes necessary to measure the congestion indicators in real time so that it gives the actual degree of the congestion in different routes. Moving observer technique (Zito et al. 2000) was used to measure the traffic parameters in real time. In moving observer technique, we drove in the traffic stream and collected the parameters using GPS and stopwatch. The hand held GPS (Juno SB) was used to measure the velocity of the vehicle while driving in the traffic stream and then the data was used as input in GIS for representation of spatial attributes.

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2.2.1. Determination of congestion index value and average speed

Congestion index value and average speed can act as significant indicative parameters to assess the status of congestion in different routes of the study area. Therefore, the congestion index value was computed using the formulae (C-C0) / C0 (Taylor et al. 1992) and the average speed was computed using the formulae (distance between two nodes)/ (time taken to travel the distance) (Table 1) for different routes of the study area to represent the degree of congestion.

TABLE 1 - MEAN CONGESTION INDEX VALUES DETERMINED THROUGH (C-C0) / C0 AND MEAN AVERAGE SPEED OF THE DIFFERENT ROUTES

ROUTE ID	ROUTES	MEAN CONGESTION INDEX VALUES DETERMINED THROUGH $(C-C_0) / C_0$	MEAN AVERAGE SPEED
1	Birsa Chowk to Hinoo chowk	0.85	31.20
2	Hinoo Chowk to Rajendra chowk	0.84	33.32
3	Rajendra chowk to Sujata Chowk	0.66	20.95
4	Sujata Chowk to Firayalal Chowk	2.29	15.55
5	Firayalal Chowk to Saheed chowk	2.22	12.41
6	Saheed chowk to Kutchary chowk	0.59	26.51
7	Kutchary chowk to Lalpur Chowk	1.16	19.36
8	Lalpur Chowk to Dangratoli Chowk	0.63	14.97
9	Dangratoli Chowk to Kantatoli Chowk	1.39	24.75
10	Kantatoli Chowk to Kokar Chowk	0.89	26.84
11	Kokar Chowk to Booty More	0.29	39.26
12	Booty More to Bariyatu	0.01	39.95
13	Bariyatu to Karam Toli	0.09	40.82
14	Karam Toli to Sainik Theatre	0.49	45.62
15	Sainik Theatre to Ratu Chowk	0.77	19.03
16	Ratu Chowk to Sahajanand Chowk	0.89	30.37
17	Sahajanand Chowk to Argora Chowk	0.01	49.73
18	Argora Chowk to Birsa Chowk	0.14	53.23
19	Birsa Chowk to Argora Chowk	0.34	46.42
20	Argora Chowk to Sahajanand Chowk	0.40	47.64
21	Sahajanand Chowk to Ratu Chowk	0.23	31.55
22	Ratu Chowk to Sainik Theatre	1.14	16.68
23	Sainik Theatre to Karam Toli	0.43	44.79
24	Karam Toli to Bariyatu	0.09	40.05
25	Bariyatu to Booty More	0.16	35.00
26	Booty More to Kokar Chowk	0.09	46.13
27	Kokar Chowk to Kantatoli Chowk	0.83	26.85

ROUTE ID	ROUTES	MEAN CONGESTION INDEX VALUES DETERMINED THROUGH $(C-C_0) / C_0$	MEAN AVERAGE SPEED
28	Kantatoli Chowk to Dangratoli Chowk	1.62	22.65
29	Dangratoli Chowk to Lalpur Chowk	0.39	16.88
30	Lalpur Chowk to Kutchary Chowk	1.13	19.43
31	Kutchary Chowk to Saheed Chowk	0.57	26.52
32	Saheed Chowk to Firayalal Chowk	1.15	18.43
33	Firayalal Chowk to Sujata Chowk	1.30	23.68
34	Sujata Chowk to Rajendra chowk	0.49	22.24
35	Rajendra chowk to Hinoo Chowk	2.84	23.06
36	Hinoo Chowk to Birsa chowk	0.82	30.75
37	Ratu Chowk to Piska More	2.62	14.62
38	Piska More to Pandra	1.56	22.53
39	Pandra to Piska More	1.06	27.09
40	Piska More to Ratu Chowk	1.42	21.00
41	Firayalal Chowk to Lalpur Chowk	1.50	18.64
42	Lalpur Chowk to Kokar Chowk	1.21	22.82
43	Kokar Chowk to Lalpur Chowk	1.05	20.94
44	Lalpur Chowk to Firayalal Chowk	1.13	21.39
45	Sujata Chowk to Bahoo Bazaar	1.07	26.41
46	Bahoo Bazaar to Kantatoli Chowk	1.8	16.01
47	Kantatoli Chowk to Bahoo Bazaar	1.68	16.82
48	Bahoo Bazaar to Sujata Chowk	1.48	23.07

2.3. Fuzzy concept for categorization of the congestion index values into different classes of congestion

2.3.1. Fuzzy logic concept.

Fuzzy logic is a many valued logic that allows intermediate values to be defined between zero and one. With the help of fuzzy sets, the vagueness and uncertainties of the real world is handled. The fuzzy set is constructed with the help of degree of membership. To construct a fuzzy set, the concept of linguistic variables are used, a linguistic variable differs from the crisp variable as it is capable to represent the qualitative nature of an entity. The strength of any fuzzy system lies in the fuzzy rules.

2.3.2. Significance of fuzzy logic.

To deal with real life situations where vagueness and uncertainty exist, using sharp boundaries may not lead to the actual picture of the real life; therefore using smooth boundaries to represent the real life situation would be more meaningful.

The objective of the present research is to determine the real status of congestion in the study area. If we follow a rigid criteria based on the congestion index value as discussed in sec 2.2.1., it may not be possible to represent the real life situation of congestion prevailing in all the routes. For example, the routes that are almost congested in the field but are associated with congestion index values tending to 2 may not be categorized as congested. For such routes, fuzzification of the influencing parameters used in the determination of the congestion index is expected to provide the realistic status of the congestion as observed in the field.

2.3.3. Application of fuzzy concepts for determination of congestion status.

In this paper, two weighted sets were constructed namely congestion (C) and average speed (A). In the congestion set, weights were assigned to different routes based on the congestion index value determined by (C-C0)/C0 formulae (Taylor et al. 1992). In the average speed set, weights were assigned to the different routes on the basis of average speed. The congestion weights and average speed weights are provided in Table 2.

TABLE 2 - PREDEFINED WEIGHTS FOR CONGESTION INDEX MEAN AVERAGE SPEED AND CLASS CATEGORY

CONGESTION INDEX VALUE (CIV)	MEAN AVERAGE SPEED (MAS)	CLASS CATEGORY	WEIGHTS
CIV >= 2	MAS<=15	HIGHLY CONGESTED	0.9
1.4 <= CIV < 2	15 < MAS <= 25	HIGH –MODERATE CONGESTED	0.7
1.0 <= CIV < 1.4	25 < MAS <= 35	MODERATELY CONGESTED	0.5
0.5 <= CIV < 1.0	35 < MAS <= 45	LOW CONGESTED	0.3
CIV < 0.5	MAS > 45	LEAST CONGESTED	0.1

Weights were provided to make the sharp boundaries smooth as we do in the case of fuzzy sets. After assigning weights to the congestion and average speed set, fuzzy union operation was performed between the weighted values of the congestion and average speed set. The results of the union operation was categorized into different classes based on class weights namely least congested, low congested, moderately congested, high-moderate congested, and highly congested in increasing order. The union operation was performed with the help of the following formulae:

WAUC(x) = max {WA(x), WC(x)} (Zadeh 1965).

where,

WAUC(x): weighted set resulted from the union operation.

WA(x) : an element in average speed set.

WC(x): an element in the congestion set.

The above equation is non-interactive because weights of both sets do not interact with each other. The two different sets were used in this paper in order to categorize the congestion status into different classes. The first set contains the weights for congestion index value of different routes on the basis of congestion weight table (Table 2) and the second set contains the weights for different routes on the basis of average speed weight table (Table 2).The union operation was performed to consider both the factors i.e. the congestion index value and average speed in order to determine the congestion in a more realistic way.

2.4. Algorithm for categorization of traffic congestion status into different classes

Step 1: construction of a weighted set of congestion containing weights for different routes based on the congestion weight table.

Step 2: construction of a weighted set of average speed containing weights for different routes based on the average speed weight table.

Step 3: performing union operation between the congestion and average speed weighted sets using the formula

WAUC(x) = max {WA(x), WC(x)} (Zadeh 1965).

Step 4: categorizing the results of union operation into different classes namely least congested, low congested, moderately congested, high-moderate congested, and highly congested based on class weights.

In the present study, for each route two different sets of average speed were determined i.e. during the peak hours' in the morning and afternoon respectively from which the mean average speed was calculated. Then the range in the mean average speed in the study area was determined as the difference between the lowest mean average speed and the highest mean average speed recorded for all the routes. The range was then categorized into different intervals on the basis of empirical observations that were assigned weights on the basis of the average speed weight table. In similar

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manner, the mean congestion value was determined for each route based on which the range in the mean congestion index values was determined for the study area. Then the range in the mean congestion index values was categorized into different intervals based on the congestion weight table.

3. RESULTS AND DISCUSSIONS

The status of congestion and average speed in different routes are presented in Table 1 and 2 respectively. Congestion has spatial-temporal complexities; its intensity varies with time and space. In the study area, significant variation in the degree of congestion and average speed can be observed. Table 3 presents the comparison of traffic congestion of the individual routes determined from Congestion Index Value formula (C-C0)/C0 and Fuzzy-weighted approach. It is evident from this table that using the Congestion Index Value formula it is possible to determine the congestion status only for four routes i.e. 4, 5, 35 and 37 whereas the congestion status of the remaining routes remains undefined.

This situation results practically because of some serious limitations of CIV in deciphering the status of congestion such as first, the CIV is designed to evaluate only a single status of congestion in that the routes with CIV greater than 2 are categorized as congested whereas the congestion status of the routes with CIV smaller than 2 remain undefined. Second, all the routes having CIV greater than 2 derive only a single congestion status regardless of how close or far the value is with respect to 2.

Third, routes with CIV close to 2 could be associated with same or nearly same traffic conditions in the field but the crisp characteristic of CIV equation fails to assign any congestion status to such routes. Finally, the CIV formula radically fails to account for the heterogeneity or variation in the traffic congestion in the routes. These limitations inherent with CIV equation restrict its use as a versatile and authentic traffic congestion measure.

The proposed investigation is an attempt to answer the questions mentioned above. Traffic congestion is a challenge not only to urban planners but also to the environmentalists as it can be used as an indicative parameter for air and noise pollution. To monitor and control urban traffic, the actual status of traffic congestion in different routes of the city needs to be known and quantified so that effective policies can be formulated to meet the challenge. If the results of the formulae (C-C0)/C0 are considered for the formulation of policies to alleviate traffic congestion then most of the routes would not come under consideration since their congestion index value is not greater than 2.

Therefore, in the present investigation, the status of traffic congestion was categorized into different classes using congestion index value and average speed to assess the status of traffic congestion in different parts of the city (Table 3). Table 3 shows the five different categories of the status of congestion observed in different routes of the study area determined through fuzzy-based weighting whereas the status of congestion could be categorized into only two classes based on congestion index value equation. Among the 48 routes, in the stretch from Birsa chowk to Booty More, four routes fall under the highly congested category, seven routes as high-moderate congestion category, seven routes as moderately congestion category, three routes as low congested category and three routes as the least congested category. In the stretch from Booty More to Birsa Chowk, two routes fall under the highly congested category, eleven routes as high-moderate congestion category, six routes as moderately congestion category, two routes as low congested category and three routes as the least congested category. It is also observed from the table that are few routes such as routes 3, 6, 8 and 21 that have lower congestion index values (Table 1) based on the congestion index equation while these routes fall into either highly congested class, high-moderate congested, moderately congested determined based on fuzzy-based weighting (Table 3).

This observation is possible since in the formula for congestion index value i.e. (C-C0) / C0 (Taylor et al., 1992), the degree of congestion is dependent on the total travel time and free flow time. To collect free flow time in different routes, a certain time interval was fixed as discussed in the section 2.2; therefore there is a possibility that in some of the routes, the density of traffic was not as lean as it was expected. In that case, the congestion index value would be lower which may misrepresent the actual status of traffic in those routes. With the help of the fuzzy-based weighting approach, not only these kinds of conflicting situations can be overcome but also the degree of congestion can be categorized into an appropriate category.

The difference in the results between the two techniques i.e. the congestion index value (C-C0) / C0 and fuzzy-based weighting approach is presented in Table 3 and is shown in the Figures 2.1, 2.2, 3.1 and 3.2 to represent the status of congestion in different routes.

TABLE 3 - COMPARISON BETWEEN THE CONGESTION STATUS DETERMINED THROUGH CONGESTION INDEX VALUE (CIV) I.E. (C-C0) / C0 AND FUZZY BASED WEIGHTING

ROUTE ID	ROUTES	CONGESTION STATUS BASED ON CIV (C - C0) / C0	CONGESTION STATUS BASED ON FUZZY-BASED WEIGHTING
1	Birsa Chowk to Hinoo Chowk	undefined	moderately congested
2	Hinoo Chowk to Rajendra Chowk	undefined	moderately congested
3	Rajendra Chowk to Sujata Chowk	undefined	high-moderate congested
4	Sujata Chowk to Firayalal Chowk	congested	highly congested
5	Firayalal Chowk to Saheed Chowk	congested	highly congested
6	Saheed Chowk to Kutchary Chowk	undefined	moderately congested

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ROUTE ID	ROUTES	CONGESTION STATUS BASED ON CIV (C - C0) / C0	CONGESTION STATUS BASED ON FUZZY-BASED WEIGHTING
7	Kutchary chowk to Lalpur Chowk	undefined	high-moderate congested
8	Lalpur Chowk to Dangratoli Chowk	undefined	highly congested
9	Dangratoli Chowk to Kantatoli Chowk	undefined	high-moderate congested
10	Kantatoli Chowk to Kokar Chowk	undefined	moderately congested
11	Kokar Chowk to Booty More	undefined	low congested
12	Booty More to Bariyatu	undefined	low congested
13	Bariyatu to Karam Toli	undefined	low congested
14	Karam Toli to Sainik Theatre	undefined	least congested
15	Sainik Theatre to Ratu Chowk	undefined	moderately congested
16	Ratu Chowk to Sahajanand Chowk	undefined	moderately congested
17	Sahajanand Chowk to Argora Chowk	undefined	least congested
18	Argora Chowk to Birsa Chowk	undefined	least congested
19	Birsa Chowk to Argora Chowk	undefined	least congested
20	Argora Chowk to Sahajanand Chowk	undefined	least congested
21	Sahajanand Chowk to Ratu chowk	undefined	moderately congested
22	Ratu Chowk to Sainik Theatre	undefined	high-moderate congested
23	Sainik Theatre to Karam Toli	undefined	low congested
24	Karam Toli to Bariyatu	undefined	low congested
25	Bariyatu to Booty More	undefined	moderately congested
26	Booty More to Kokar Chowk	undefined	least congested
27	Kokar Chowk to Kantatoli Chowk	undefined	moderately congested
28	Kantatoli Chowk to Dangratoli Chowk	undefined	high-moderate congested
29	Dangratoli Chowk to Lalpur Chowk	undefined	highly congested
30	Lalpur Chowk to Kutchary Chowk	undefined	high-moderate congested
31	Kutchary Chowk to Saheed Chowk	undefined	moderately congested
32	Saheed Chowk to Firayalal Chowk	undefined	high-moderate congested
33	Firayalal Chowk to Sujata Chowk	undefined	high-moderate congested
34	Sujata Chowk to Rajendra Chowk	undefined	high-moderate congested
35	Rajendra Chowk to Hinoo Chowk	congested	highly congested
36	Hinoo Chowk to Birsa Chowk	undefined	moderately congested
37	Ratu Chowk to Piska More	congested	highly congested
38	Piska More to Pandra	undefined	high-moderate congested
39	Pandra to Piska More	undefined	moderately congested
40	Piska More to Ratu Chowk	undefined	high-moderate congested
41	Firayalal Chowk to Lalpur Chowk	undefined	high- moderate congested
42	Lalpur Chowk to Kokar Chowk	undefined	high- moderate congested
43	Kokar Chowk to Lalpur Chowk	undefined	high- moderate congested
44	Lalpur Chowk to Firayalal Chowk	undefined	high- moderate congested
45	Sujata Chowk to Bahoo Bazaar	undefined	moderately congested

ROUTE ID	ROUTES	CONGESTION STATUS BASED ON CIV (C - C0) / C0	CONGESTION STATUS BASED ON FUZZY-BASED WEIGHTING
46	Bahoo Bazaar to Kantatoli Chowk	undefined	high- moderate congested
47	Kantatoli Chowk to Bahoo Bazaar	undefined	high- moderate congested
48	Bahoo Bazaar to Sujata Chowk	undefined	high- moderate congested

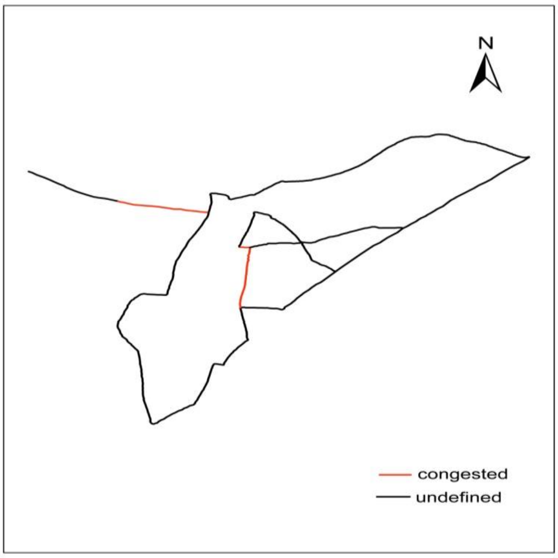

FIGURE 2.1 - STATUS OF CONGESTION FROM BIRSA CHOWK TO BOOTY MORE DETERMINED ON THE BASIS OF (C –C0)/ C0

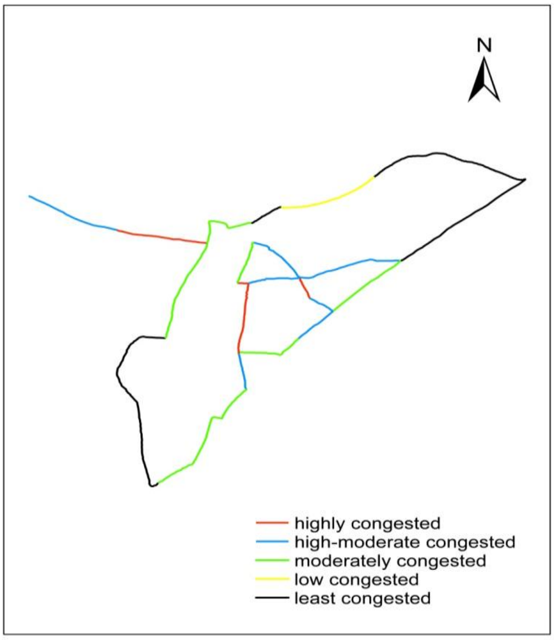

FIGURE 2.2 - STATUS OF CONGESTION FROM BIRSA CHOWK TO BOOTY MORE DETERMINED ON THE BASIS OF WEIGHTING

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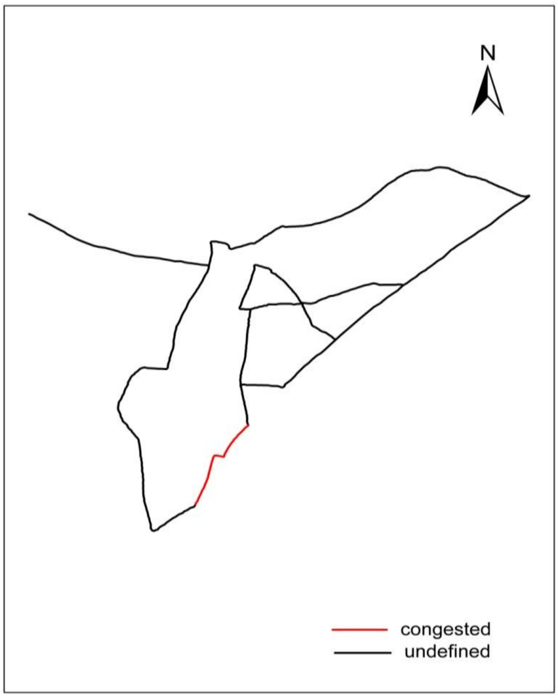

FIGURE 3.1. - STATUS OF CONGESTION FROM BOOTY MORE TO BIRSA CHOWK DETERMINED ON THE BASIS OF (C –C0)/ C0

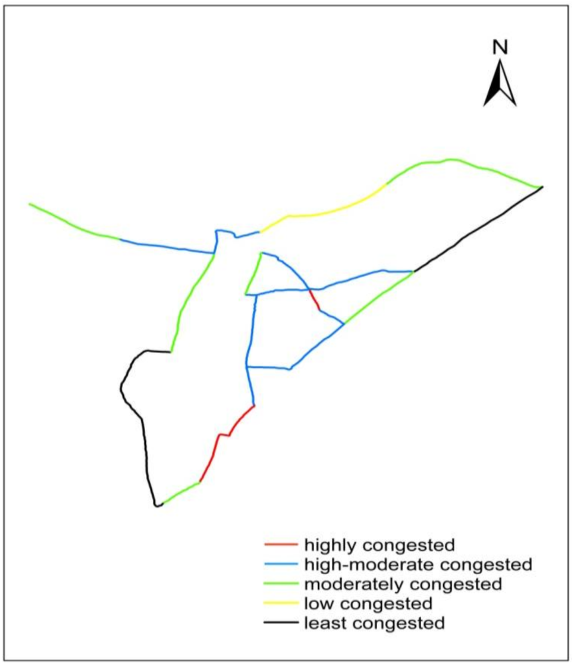

FIGURE 3.2. - STATUS OF CONGESTION FROM BOOTY MORE TO BIRSA CHOWK DETERMINED ON THE BASIS OF WEIGHTING

4. CONCLUSIONS

The research performed in this paper demonstrated that with the help of fuzzy-based weighting concept, the status of congestion in different routes could be categorized into five different classes i.e. highly congested, high-moderate congested, moderately congested, low congested and least congested which otherwise are categorized into only two classes based on the congestion index value concept. Representation of the accurate status of congestion in different routes is necessary for planning purposes. Congestion has spatio-temporal complexities and transitional characteristics. Therefore if it is represented with the help of sharp boundaries then there is a chance that the exact degree of congestion in the routes could be missed. The concept of fuzzy logic was used in this investigation that demonstrated its efficacy in representing the congestion status with the help of smooth boundaries.

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