Uninterrupted Traffic Flow at Junctions with Special Reference to Guwahati City

Mukta Ranjan Singha, Bichitra Kalita

Abstract - In Urban area congestion mostly occurs at the junctions. Junctions are the intersection of roads, where the flow of the vehicles is controlled by traffic police or traffic lights. When the flow of vehicles increases at the junctions, it causes traffic jams and stream of vehicles incur longer waiting time. When there is a crossing at a junction, a stream of vehicle has to wait for others. Sometimes, the longer stream of waiting vehicles at the junctions causes stalemate situation. Design of an uninterrupted traffic flow system at the traffic junctions without have to wait for others will lead to minimize severe traffic congestion. We have proposed a traffic flow system at the junctions to make the flow of traffic streams an uninterrupted flow system. This will also lead to design of a traffic light and traffic police free system at the junctions of urban traffic roads.

Keywords: Urban Traffic Network, Traffic Flow, Traffic Junction, Optimization of Traffic Flow, Traffic path optimization.

I. INTRODUCTION

Congestion of traffic is a solemn experience faced by the traffic users who travel on urban roads. Due to traffic congestion, traffic commuters spoil valuable time, fuel and money. Congestion on urban roads can be mitigated by creating additional infrastructure, however, it is sometimes not feasible or possible to create additional infrastructure due to several reasons, such as unavailability of required fund, unbreakable permanent structure and so on. However, the existing infrastructure may be slightly modified to minimize the congestion on urban roads. As for an example, creation of a bypass over a city may decrease the number of vehicles entered in the city, and thus minimizing traffic loads on urban roads. Congestion sometimes occurs due to unorganized flow of vehicles on urban roads and an organized traffic flow may lead to minimization of congestion. Information and communication technology (ICT) have been used to analyze the vehicle density on roads and can be used to minimize road traffic congestion. Wireless sensors, Mobile phone networks, Vehicular adhoc networks, GPS and GIS systems are few examples which are blended with ICT to control the traffic on urban roads. Urban Traffic Network (UTN) can be considered as a directed graph with finite number of vertices and edges. Once a UTN is represented as a graph, we can find out different paths for the graph as well for the UTN. Random distribution of traffics at different paths of an urban traffic may cause traffic breakdown at the peak hours. Therefore, an optimized allocation of paths is necessary to mitigate the traffic breakdown.

Manuscript received February, 2014.

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A traffic stream is a group of vehicles those are to pass towards a road trough a junction. In general, the traffic stream, when flows through a junction, the flow can be categorized as free flow, merged flow and a crossing. A free flow refers the streams of vehicles without any interruption, which generally available at the left hand directions at the junctions from one road to another road. A merged flow refers to merge of two or more streams of vehicles at the road junction, which are merged together to become a single stream towards another road. However, a crossing may be described as a stream of vehicles which has to wait for another stream which is flowing through the junction. When there is a crossing, it always has to be controlled by traffic lights or traffic police. When the traffic police or light stops a vehicle flow it increases the travel time. Out of all the three categories, free flow incurs zero waiting time and the crossing incurs maximum waiting time. The merged flow incurs extra time to adjust the flow and merge it with other streams. It means that time required for free flow is less than the time required for merged flow and time required for merged flow is less than the time required for crossing. The aim of the developed system is to avoid the crossing and thus allowing only merged flow and free flow through a junction. To do so, the system allowed only free flow and merged flow at the junctions without disturbing the overall traffic network. The flow allocation technique has discussed in two situations. In the first situation, a four road junction which acts as a gateway to the urban traffic network has been taken into consideration for uninterrupted flow system. This type of junction daily incurs numerous vehicles entry and vehicle exit. A four road junction has always crossings, so there may be traffic jam at peak hours mostly in morning and evening time when large number of vehicles enters and exits to and from the urban roads. In the second situation, a busy market in an urban area has been considered to build an uninterrupted flow system. The busy urban area are consists of several market places a there are many three road and four road junctions exists in that urban area. The Guwahati city has been taken as a special reference for the application for the techniques applied in this research work. The capital city of Assam, the Guwahati city, is the gateway to the North East Indian states of Assam, Manipur, Mizoram, Meghalaya, Arunachal Pradesh etc the ancient name of Guwahati was Pragjyotishpur and the place has been a historical importance from the past. It is also important to mention that in 640 AD, the famous Chinese traveler Yuen Chawan visited the city. The city of Guwahati started as a town in 1826 and was connected via railway line with rest of the country. From then the city has been emerged as centre for business, education, medical treatment and political centre of north east India. There are approximately 12 lakh people are residing inside the Guwahati Municipal area as per the census of the year 2005 and it is projected by a study that the population rise to 21 lakhs approximately in the year of 2025.

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II. RELATED WORKS

Congestion control on urban roads has become an important area of research and many research papers and techniques have been published in leading journals of the world. Shortening waiting time at the traffic junctions for the vehicles has been discussed by As'ad Salkham et al, 2008 [1] describes a method ARR-CRL approach which can provide an improvement to lower average waiting time per vehicle compared to the saturation balancing algorithm. Again, a significant improvement over waiting time has been shown by W. Wen,2008 [2] asserts that the average waiting time of cars at every intersection is sharply dropped when the red light duration is 65 s and the green light time duration is 125s. Kenedy Aliila Greyson, 2012 [3] in his discussion described about Inlet and outlet analysis to project the outcome of a road sector status of the known roads which to be anticipated by the traffic users to minimize congestion on urban roads. The reasons for congestion of Bangkok's traffic has been discussed by Y. Tanaboriboon, 1993 [4] discussed many problems including inefficient usage of roads and improper planning of road networks. However he also suggested few solutions including demand management of traffics, improvement of public transit services.

Use of Wireless sensor networks with Information and Communication Technology has become an important facility in controlling urban traffics and to minimize traffic congestion. Edwin Prem Kumar Gilbert 2012, [5] has discussed several ways in using the Wireless Sensor including Smart Car parking, Vehicular telematics and security of intra car.

Ryota Ayaki et al 2012, [6] discussed that the wireless sensor nodes are to be configured with an IP/ Mobile networks and it incurs cost in data collection and processing. However, they have proposed a model and simulate the model for practical use in real time data collection. Fernando Losilla et al 2011, [7]describes about the diversified functionalities of recent wireless sensors in compare to old sensors used for Intelligent Transport Systems.

Use of mobile phone networks with IT'S is also has been an important area of research during few years. Many research papers have been published in this regard to use the mobile phone network as a background data collection system. M. R. Singha et al , 2013 [8] in a research paper emphasized the use of mobile phone network as a background data collection system. The paper also noticed a readymade data collection system can be exploited for efficient urban traffic management. In classifying the urban traffic M. R. Singha et al,2013 [9] also enhanced on mobile phone network can be efficiently used to classify the vehicles on urban roads for efficient urban traffic management. Richard A. Becker et al, 2011 [10], discussed about mobile handoff pattern to analyze and classify the routes of city traffic which helps in finding the traffic volumes on urban roads. While discussing about the density of city bus on urban roads M. R. Singha et al 2013, [11] discussed a method to estimate the city bus and its users using mobile phone networks.

Again, Vehicular adhoc network (VANET) is also used as key data collection facility for urban traffic management. Florian Knorr et al 2012, [12] has discussed a system with VANET to count number of vehicles on a road segment with a crossing time. The method has been developed to control the vehicular congestion by sending the warning message to the drivers for probable traffic congestion on an urban road to prevent traffic breakdown.

III. METHODOLOGY

Traffic jams mostly occurs at the traffic junctions and traffic junctions are mostly two types (i) Three road junction (ii) Four road junction. The five road junctions or more are also available in urban areas; however, they are very less in numbers. Therefore this research paper has been concerned with three road and four road junctions. Moreover, two lane roads are mostly available on urban areas. A three road junction has been shown in fig-1. The junction point is the intersection of three bidirectional roads which has mainly six different types of streams as shown in the figure. The circle in the figure represents junction and the arrows represents streams of vehicles or traffics.

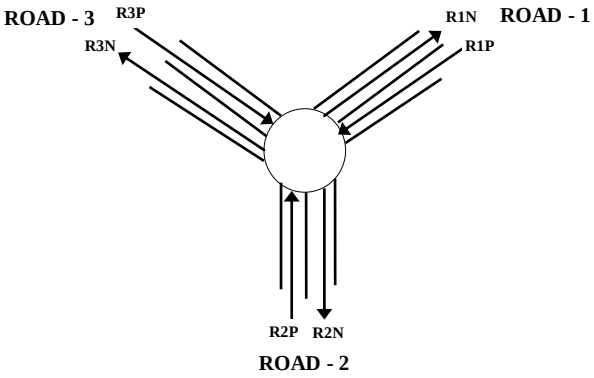

Fig 1: *Streams of traffics of a three road junction*

The ROAD-1 has two vehicle streams R1P and R1N, where R1N means stream coming out from the junction to the ROAD-1 and R1P means the stream which enters to the junction from the ROAD-1. The R2P, R2N for ROAD-2 and R3P, R3N for ROAD-3 also have the same meaning as described for R1P and R1N. The flow matrix of the junction has been shown in Table-1.

Table-1: *Flow matrix of a three road junction*

	R1N	R2N	R3N
R1P	SRT	FF	CC
R2P	CC	SRT	FF
R3P	FF	CC	SRT

The table-1 shows that a stream of vehicle R1P, R2P and R3P can flow to R1N, R2N and R3N. Thus, these two groups of flows are arranged in rows and columns to find all the combinations of flows those may be possible for a three road junction. The table elements may be SRT or FF or CC, where, SRT means Self Right Turn, FF means free flow CC means Conditional (either merge or Crossing). As for an example a stream R1P may flow to R1N but that will be a SRT. i.e. Self Right Turn. Again R1P may flow to R2N as a FF , i.e. a Free flow and R1P may flow to R3N but the flow depends on other stream of vehicles R2P and R3P, so the flow will be CC i.e. Conditional (either merge or crossing). Similarly, a four road junction is a crossing point of four roads and has eight different types of streams as shown in fig-2. It is clear from the figure that all the streams incident or coming out of the junctions can create total sixteen types of valid flows as shown in the Table-2.

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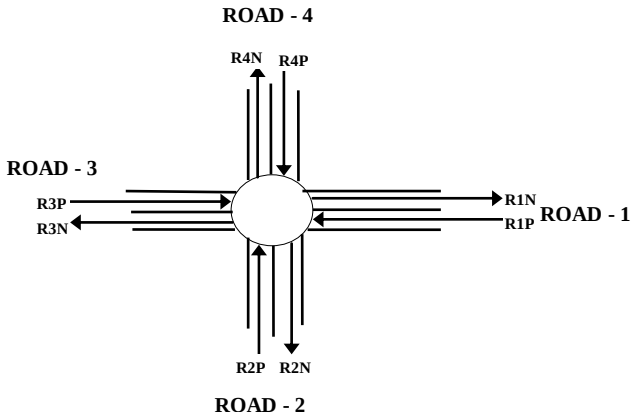

Fig 2: *Streams of traffics of a four road Junction*

Table-2: *Flow matrix of a four road junction*

	R1N	R2N	R3N	R4N
R1P	SRT	FF	CC	CC
R2P	CC	SRT	FF	CC
R3P	CC	CC	SRT	FF
R4P	FF	CC	CC	SRT

Road Junctions and Optimized Connectivity:

(a) Three road junction : A three road junction have three roads incident on the junction and hence there are incoming streams R1P, R2P, R3P and three outgoing streams R1N, R2N, R3N shown in fig-1. Hence, all the three incoming streams may flow towards the outgoing flows with the following few options shown in table-1. We can represent the situation as a graph as shown in Fig-3 below, with several crossings or interruptions shown as C1, C2 and C3.

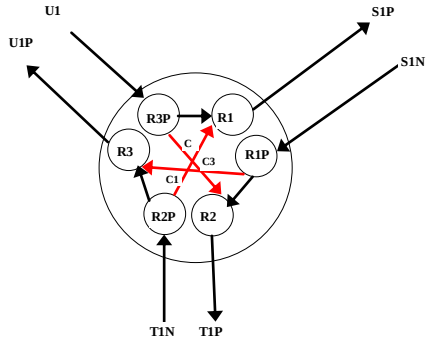

Fig-3: *Three road crossing represented in a graph (Without a self right turn in the Crossing)*

It is clear from fig -3 that three crossing C1, C2 and C3 are created due to the edges R1P → R3N, R2P→ R1N and R3P→ R2N. If we remove any two edges then the free flow may be expected at the three road junction point. However, due to removal of two desired edges some of the flows will cut down. As for an example, in fig-3, removal of the edge R1P → R3N will cut down the flow from R1P to R3N and thus cut down the flow to the edge R3N → U1P.

(b) Four road junction : A four road junction have four roads incident on the junction and hence there are four incoming streams R1P, R2P, R3P, R4P and four outgoing streams R1N, R2N, R3N, R4N as shown in fig-2. Hence, all the four incoming streams may flow towards the outgoing flows with the following options shown in table-2. The situation can be represented as a graph as shown in Fig -4. The fig-4 shows the crossings C1, C2, C3 and C4.

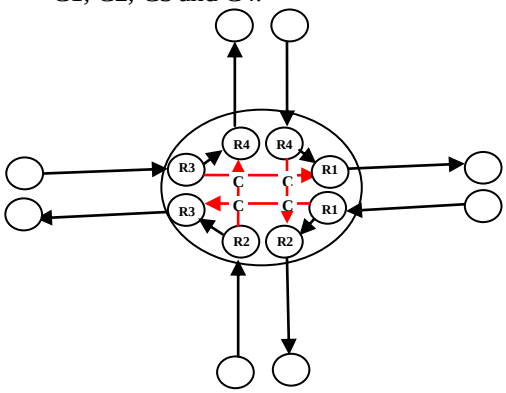

Fig-4: *Four road crossing represented in a graph (Without a Self Right Turn in the Crossing)*

It is clear from fig -4 that three crossing C1, C2, C3 and C4 is created due to the edges R1P → R3N, R2P→ R4N, R3P→ R1N and R4P→ R2N. If, at least two edges are removed then, we can get free flows through the junction. However, in doing so some streams of vehicles cannot flow towards few other roads. As for an example, in fig-4, removal of the edge R1P → R3N and R3P→ R1N will cut down the flow from R1P to R3N and R3P to R1N.

But, the aim of the system is to create free flow or merged flow such that there is no crossing and any flow has not to wait for other without disturbing the overall traffic network. To overcome the situation, other three road junctions around the existing three road junction have been considered to design an uninterrupted flow system. The system also ensures that any flow can reach at all the edges, keeping the system as an uninterrupted flow system. To understand this let us consider the following fig-5.

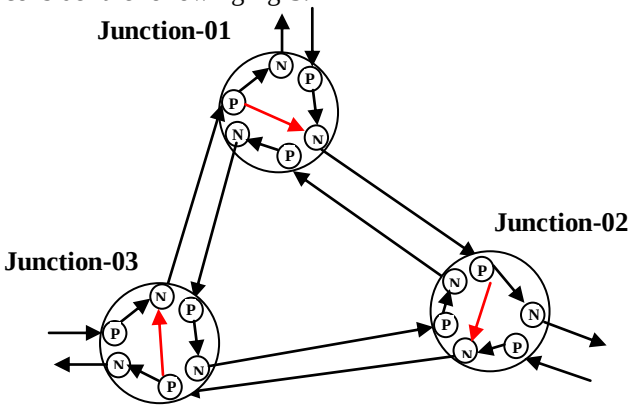

Fig 5: *Optimizing flow at three road junction*

There are three junctions Junction-01, Junction-02, Junction-03 participated in the system at it has been created a free flow as well as merged flow at all the junction for every stream of vehicles. It has been seen that an optimized system can be developed for a group of three road junctions without any problem with all options as shown in fig-5. A different model for a group of three road junction has been shown in the fig-6.

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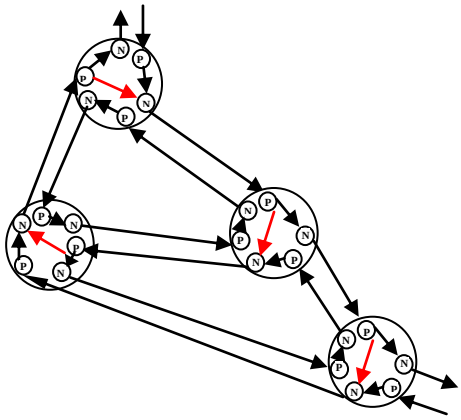

Fig 6: *Optimizing flow at three road junction*

So, in case of group of three road junctions it is always possible to find out an interrupt free flow system in an urban traffic network. However, the same system is not applicable sometimes to four road junction sometimes as shown in fig-7 below:-

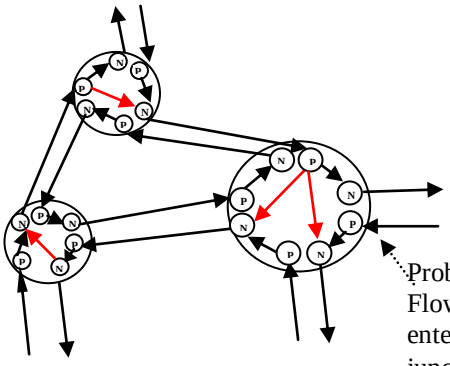

Fig 7: *Four Road Junctions with a problem*

But, reorganizing the flows again an uninterrupted flow system can be designed. An example has been shown in fig-8 where a four road junction is combined with three numbers of three road junctions to represent an uninterrupted flow system. However, in each case there are merged flows.

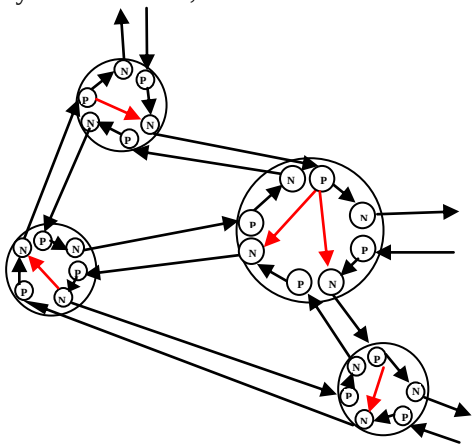

Fig 8: *Four Road Junctions without problem*

IV. CONNECTIVITY OPTIMIZATION AT JUNCTIONS IN GUWAHATI CITY

The techniques described have been applied at two locations of Guwahati city with two different situations. The two places are:-

(a) Jalukbari four road crossing: This crossing has a record of heavy rush at the peak hours like morning 9AM to 12 AM and evening 3PM to 5PM. Because, this junction is gateway connectivity to the Guwahati City from nearby localities and towns of other districts. Thousands of vehicles enter and exits daily through this junction. Presently, there is a construction of an over bridge going on to sort out the congestion problem. However, a model design has been proposed which may also solve the problem of congestion with a minimum cost. The fig-9 represents the line diagram of Jalukbari junction of Guwahati city.

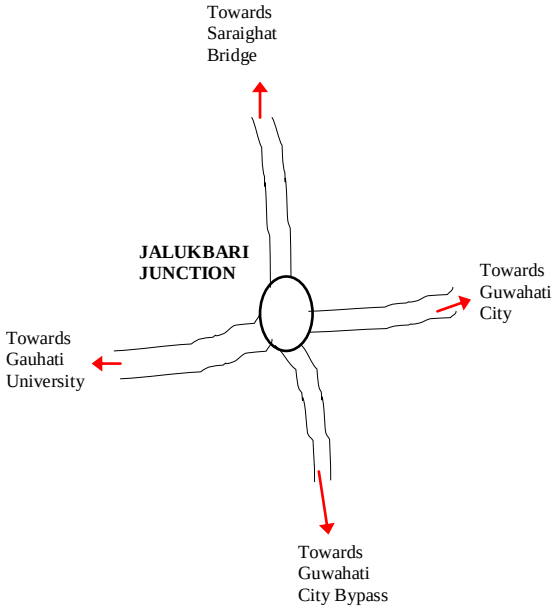

Fig-9: *Jalukbari four Road Junction in Guwahati City*

The Junction can converted and represented as a graph as shown in fig-10. The junction has four inflow streams and four outflow stream of traffics.

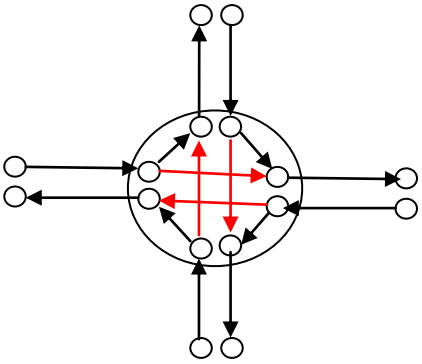

Fig-10: *Graph representation of the Jalukbari Junction*

There are four streams of vehicle flows enters to the junction and there are four free flows, four merged flows and four crossing as shown in fig-10. To make all the flows uninterruptable we have to cut or remove two crossing. But the cut of two flows will disallow some vehicle streams to enter to their desired road. So, cut down of such flows may disturb the overall traffic network. To overcome this situation, three additional junctions have been created nearby the existing four road junction as shown in fig-11. The newly created junctions is not required if the same is already available with the traffic network.

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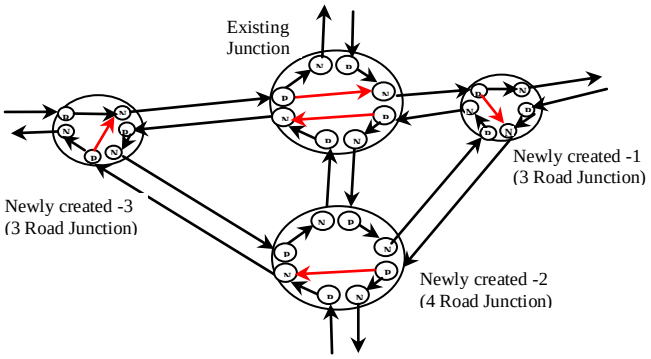

Fig 11: *Uninterrupted flow: Jalukbari Junction*

It has been seen that the system has free flows, merged flow and there is no crossing. At the same time it is also observed that all the streams of vehicles may enter any road from the other.

(b) Fancy Market and its adjacent market areas: The Fancy market of Guwahati city is the heart of business centre of the locality. Numerous people visits busy fancy market area of Guwahati city not only from the inside city areas but also from adjacent localities and cities for different purpose.

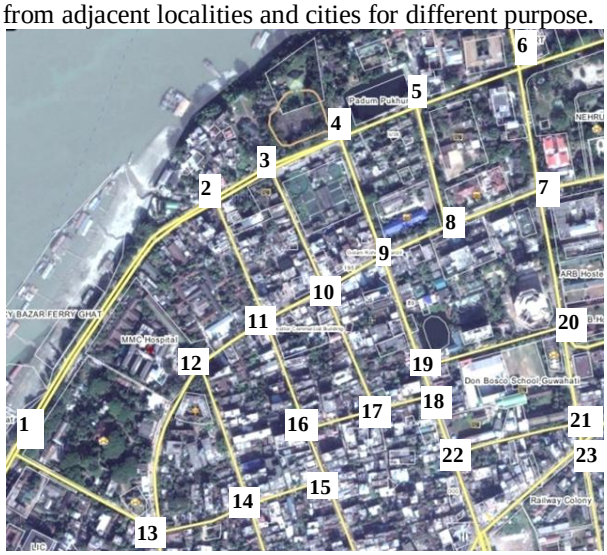

Fig-12: *Fancy Market and adjacent areas of Guwahati (Courtesy: https://www.wikimapia.org)*

So, there is rush at the area for pedestrians as well as vehicles. It has been seen that in peak hours this market area faces rush and congestion. There is an urgent need of optimization of vehicle flow for this part of the city. The fig-12 represents the Satellite Picture of roads and junctions of Fancy Market and its adjacent areas.

The junctions have been numbered from 1 to 23. Most of the junctions represented here are three road junctions and few are four road junctions. The part of the city has many roads and each road has crossing over another. Traffic streams flows from one area to another area of this part and there is traffic jams in peak hours. The Fancy market and its adjacent area consist of four main markets adjacent to each other like Fancy Bazaar, Panbazar, AT Road, and Paltan Bazar. This part of the city is considered as the main business centre and there is a rush of peoples to the area.

The satellite picture shown in fig-12 has been represented as a graph as shown in fig-13

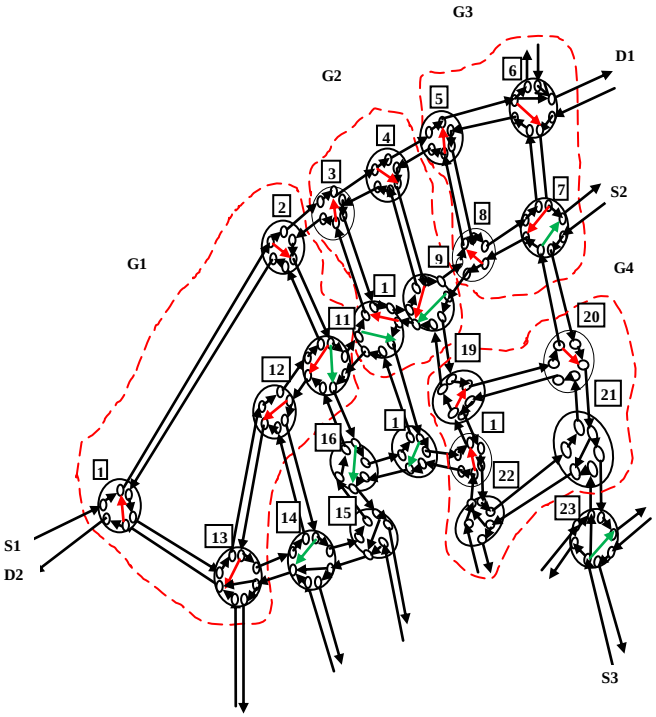

Fig-13: *Graph representation of Fancy Market and its adjacent markets.*

There are eight four road junctions and fifteen three road junctions for the part of the urban traffic network. To make the traffic flows uninterruptable, the traffic junctions are grouped in such a way that there is a path which creates a cycle with adjacent junctions. As for an example junction 1, 2, 11, 12, 13 are considered as a group because it forms a cycle. In this way it has been seen that there are four groups as say G1 (1, 2, 11 12, 13), G2 (3, 4, 9, 10), G3 (5. 6, 7, 8), G4 (19, 20, 21, 22) in fig-13. Once the groups are created, we create an uninterrupted flow structure for all the groups. Now, we shall examine whether any other junction have left for connection with marked group or not. As for an example the junction 14 has been included with group G1 and an uninterrupted flow has been constructed. Similarly junction 15, 16 is also connected with group G1 and an uninterrupted glow has been constructed. This process will continue till all the junctions are included in the uninterrupted flow system. The procedure has been represented as an algorithm presented at the end of this section.

Example of uninterrupted flow as shown in fig-13:

(a) From S1 to D1: The path from S1 to D1 goes through the junctions 1, 2, 3, 4, 5, 6. It has seen that there is no crossing in the path and most of the time the path follows a free flow, except 1, 3, 5 junctions have merged flows in the path.

(b) From S3 to D2 : The path flows through 23,21,22,18,17,16,15,14,13,1 and has no crossing. There are merged flows at junction no. 23, 21, 17, 16, 15, 14, and 13.

(c) From S2 to D2 : The path flows through 7,20,22,18,17,16,15,14,13,1 . And has no crossing. The merged flows are at junction no. 20, 21, 17, 16, 15, 14, 13

From the above example, we can assume that this type of system can be applied in any Urban Traffic Network to observe a traffic flow without crossing.

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The Algorithm:

[1]. Identify the junction groups with cycles. (for the above figure say G1(1, 2, 11 12, 13) , G2(3,4,9, 10), G3(5. 6, 7, 8), G4 (19, 20, 21, 22) .

[2]. Connect internal nodes to form a cycle for internal and external connectivity which shows an uninterrupted flow.

[3]. Repeat the Step-2 until all the groups are connected otherwise go to step 4.

[4]. Identify other junctions which are not still included in the groups.

[5]. Connect them with the adjacent groups which were already formed for interrupted flow system.

[6]. Repeat the step-4 until all the junctions are included in the system.

V.THE LIMITATION AND ADVANTAGES

The methods for achieving an uninterrupted flow at the junction are applicable to each and every urban traffic networks. This uninterrupted flow system will facilitate for a continuous flow of vehicles in each and every urban roads without stopping. However, the method has few limitations too. As for an example a vehicle which to enter a road nearby its location may have to traverse a long distance to reach the destination. Moreover, if the traffic streams are very long then merged traffic stream will show a crossing.

The advantage of the discussed system is it gives an uninterrupted flow system. Moreover, the system does not need a traffic light to control over vehicles because; there is no crossing and no waiting for the stream of vehicles. This facility also leads to minimize or reduce traffic personnel on roads.

VI. CONCLUSION

The system described may be used for the cities where the roads are not wide and there is single lane way system to be created for the urban roads. It is hoped the use of the method will help in reduction of urban traffic congestions.

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