Improving the Traffic Control System by Modifying the Geometry of Roads and Squares by Removing the Discontinuity of Space

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Abstract: This paper presents a review of the existing geometry of the roads and squares and proposes a continuous topological model to solve the existing and upcoming traffic problems. As it is seen that due to discontinuity in traffic flow, public suffers a lot. After a deep study, it was found that the Discontinuity of spaces exists in this existing model and also it is topologically incorrect. The Discontinuity of spaces exists due to the reason that all the traffic signals situated on one road are not equidistant and cross roads create a chaotic situation. Therefore, we introduce a topologically proven model in which we tried to remove discontinuity between spaces and suggested some minor constraints which can be enforced as a part of discipline.

Keywords: Topology, Continuity of spaces, Transport, Traffic, Design of roads.

1 Introduction

In the last decade, the population of India has elevated itself from 1,234,281,170 in 2010 to 1,380,004,385 in 2020 and so is the increase in the number of vehicles registered. As a result of this, there is also rapid increase in the number of accidents, transportation problems in the form of increase in traffic congestion, air pollution, delays and emission of greenhouse gases. The long queues of vehicles result in idling condition, also causes extra fuel consumption. For this, different traffic control measures are taken into action by the Traffic Control Board of India. The existing traffic management technology has been utilized by many people all over the India in several areas. With the development of transport technology, security of transport system has become an important issue, as accidents have been increased day by day over the past few years. Hence, it is very essential to find an effective way to manage the traffic system. In the present world, we are having traditional traffic management system. They are good within them. Still they are lacking few parameters in some aspects. The main motive of research paper is updating the existing traffic technology and improving the efficiency of traffic controlling. The existing technology includes Enforcement of traffic police, Visual stimuli (traffic signals and its rules) and some audible sources for seeking the concentration of the public. The theory proposed in this paper deals with some alterations in the construction of roads such that it could remove traffic signals thereby reducing the work load of traffic police.

Here, the case is related to that situation where there are two roads facing each other and having high traffic and the other two roads which have comparatively very low traffic. A normal traffic scenario consists of each signal with some waiting time. Now the road which has low count of vehicles gets free earlier and the busy road with a large count of vehicle passing through gets blocked for that particular time interval, resulting in traffic congestion and loss of fuel. On an average, in such condition a vehicle consumes more than 20% of the fuel around that time.

A suggested model based on principle of continuity of topological spaces is proposed in this paper. Few researchers contributed and used topology in designing various models.

Norbert [10] [12] says **Topology denotes the connectivity between**, for example, the rooms of a building and their links like doors, or walls.

A.Vella. [1] proposes topology as a generalization of graph theory. Similarly, it also connects two more different packets which divide a long road in many parts. This connectivity may be of different levels. A square connects two packets of straight road but it may also be considered traffic connected to each packet by its boundary common surface.

D. Boltcheva [5] et al. suggested a model for smooth and easy traffic. But to design these packets, only a few actually used the topological methods. S. Raghothama [14][15] et al. discussed about Constructive topological representations.

This paper presents a modified version of it which can remove the discontinuity of space. The discontinuity in space can be defined as it involves a large number of research areas and therefore, this paper focuses on those facts that we conclude to be the most relevant. The main motive of this paper is to study the achievements attained in the last years and to give an overview of possible directions towards future research in the field of traffic management, thereby reducing the number of accidents per year. It also deals with reducing the waiting time of the vehicle owners waiting over the signals.

2 Preliminaries

2.1 Limit point

A point x is a limit point of a set A if every open set containing x meets A.

2.2 Definition of topological space:

Let X be a set. A set T_X of subsets of X is called a topology for X if it satisfies the following three properties:

1. X and $\emptyset$ are elements of T_X.

2. The unions S of every subsets S of T_X is an element of T_X.

3. The intersection $A \cap B$ of every two elements A, B of T_X is an element of T_X.

2.3 Properties of topological space:

A subset A of a topological space X is called closed if X - A is open in X.

Then closed sets satisfy the following properties

1. ϕ and X are closed
2. A, B closed $\Rightarrow\Rightarrow$ A $\cup$ B is closed
3. $\{Ai \mid i \in I\}$ closed $\Rightarrow \bigcap_{i \in I} A_i$ is closed

2.4 Continuity for topological spaces

Definition:

A Function f: X $\rightarrow$ Y is said to be continuous if the inverse image of every open subset of Y is open in X. In other words, if V € Ty, then its inverse image $f^{-1}(V)$ € Tx.

A map f: X $\rightarrow$ Y between topological spaces is a homeomorphism or topological isomorphism if f is a continuous bijection whose inverse map f^{-1} is also continuous.

Remark:
By the remark above, such a homeomorphism induces a one-one correspondence between T_X and T_Y.

Theorem 1: Let f be the identity map from (R2, d2) to (R2, d_∞). Then f is a homeomorphism.
Proof: Since every open set is a union of open neighborhoods, it is enough to prove that the inverse image of an ε-neighborhood is open. This ε-neighborhood is an open square in R2 which is open in the usual metric.

A similar proof shows that the image of an ε-neighborhood in the usual metric (an open disc) is open in d_∞ .

In general, if X is a set with two topologies T_1 and T_2 then the identity map $(X, T_1) \rightarrow (X, T_2)$ is continuous if T_1 is stronger (contains more open sets) than T_2 .

3 Survey

A systematic survey and study of data related to number of vehicles waiting for their signal at high court square, Indore (Madhya Pradesh) was performed for a week and the data obtained was noted in the table 1. Figure.1 show the map of the road and the square which was surveyed. Figure 2 and 3 are the photographs taken of that particular square. The whole study was performed in three different time slots where waiting time of each signal was noted and accordingly the number of vehicles waiting was calculated. The readings were noted in a gap of 40 minutes for two hours and an average of the reading was tabulated. Likewise, there were three time slots chosen from the 24 hours' schedule. The time slots were:

1. 10.30 to 12.30 (office time)
2. 14.30 to 16.30 (noon time)
3. 18.30 to 20.30 (evening time)

The percentage of the total count of different vehicles i.e. for car, bus, auto and all other two-wheeler was calculated in each time interval for morning, afternoon and evening hours. A proper pie chart of volume of the vehicles at the signalized intersection is shown in fig. 5, 6 and 7. From the pie chart, the main information extracted was that in any of the three time slots, the two wheelers were in majority with around 65% of the total traffic and the four wheelers count was 16%. Fig 4 shows different count of vehicles emerging from different ends of the road at that particular square.

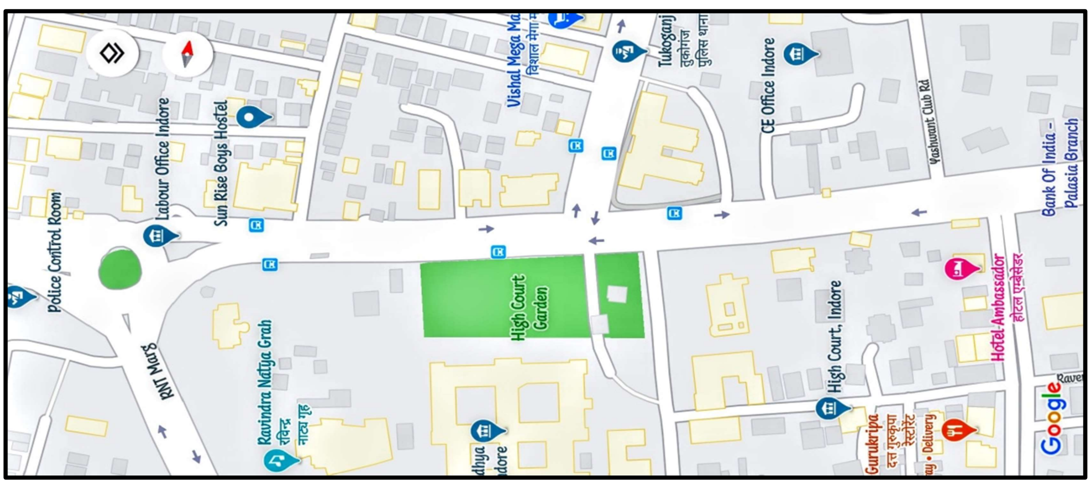

Fig.1 Map of the road surveyed [4].

Fig. 2 Volume of vehicles from Yeshwant road

Fig.3 Volume of vehicles from Treasure Island mall road.

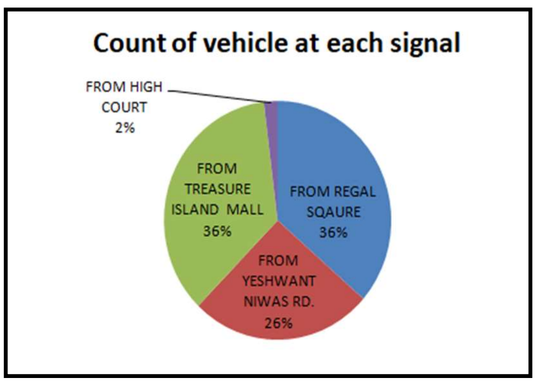

Fig.4 Total counts of different vehicles at signals

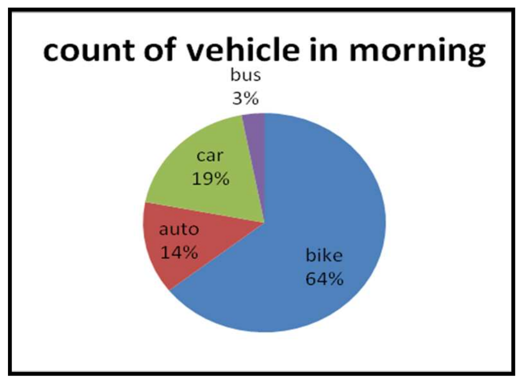

Fig.5 Average volumes of vehicles from 10.30 to 12.30

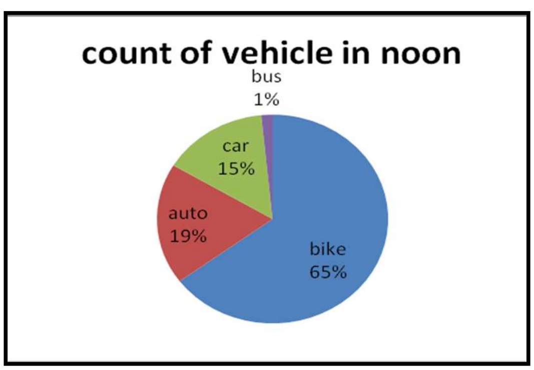

Fig.6 Average volumes of vehicles from 14.30 to 16.30

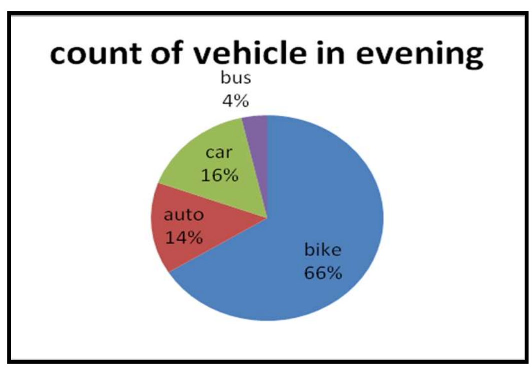

Fig.7 Average volumes of vehicles from 18.30 to 20.30

4 Analysis of Data

Table.1 gives the information of the amount of vehicles passing and the volume of the traffic present in particular time interval, it shows that the volume of the traffic approaching from regal square and Treasure Island road in a particular time interval was much higher and comprised of 115 vehicles (80 two-wheelers and 35 four-wheelers) from each road as compared to the other two roads. The delay time for the three signals more than 65 seconds and from the high court, a very little amount of vehicles were waiting. Due to long waiting time, the road with less volume of vehicle would get free earlier and the roads with high traffic would get insufficient time to clear the road completely and thus the others had to wait for a long time unnecessarily for the signal to open. Also it was observed that more than 70% of the public kept their engines on while waiting for the signal to turn green, which increased in the fuel consumption and the release of harmful gases such as NOx and CO.

Pal and Sarkar (2012) [11] measured the total fuel consumption of different vehicles at signalized intersections using high accuracy instruments. Five red light traffic signals of different traffic volume were surveyed and the fuel loss during idling and delay of vehicles was estimated. On the basis of results obtained, an average fuel would cost Rs.19, and an amount of Rs. 175.00 was exhausted per day at signalized intersections. The results showed that the delay of vehicles was more than 60 seconds that lead to loss of 389.68 liters of diesel and 810.38 litres of petrol. Total loss output work found were Rs. 61,072 per day and Rs. 2, 22, 91,198 per annum. The total fuel consumption for petrol car was 573 ml/hr. and diesel car was 705 ml/hr.

Lim (2012) [7] studied the fuel used up during idling Diesel Trucks. The data generated related to the emission and fuel consumption from the study gives the information that in an average case, a bus could emit 8224 gram/hour of CO2, 144 gram/hour of NOx and could use up approx. 0.82 gallon/hour diesel.

The data was analyzed regarding the average fuel consumption [3]. Only petrol driven vehicle were considered for the test case. The count of vehicles was measured with their idling time. Since almost all the vehicles had their engines on, so the total fuel consumption during the idling time was calculated and tabulated. Now an ideal two wheeler vehicle consumes about 0.0389 ml and a four wheeler consumes an average of 0.21 ml, if they stand ideally for one second, that means 140 ml and 756 ml of fuel is exhausted by two and four-wheeler in one hour respectively. The total fuel consumed in one cycle of the traffic was found to be 0.7467 ml. If we take the average cost of this fuel calculated per hour during idling, it would cost around Rs.4477. Hence the amount would increase to Rs.53724, Rs. 376, 068, Rs. 1,611,720 and Rs. 19,340,640 if we calculate it per day, per week, per month and per year respectively. While surveying the total cost of fuel consumed during idling time was calculated and was properly tabulated in the table 2.

Table.1 Data of the volume of vehicle in different time intervals

DAY		MONDAY			TUESDAY			WEDNESDAY			THURSDAY			FRIDAY		
SIGNAL FROM		REGAL SQAURE	YESHWANT NIWAS RD.	TREASURE ISLAND MALL	REGAL SQAURE	YESHWANT NIWAS RD.	TREASURE ISLAND MALL	REGAL SQAURE	YESHWANT NIWAS RD.	TREASURE ISLAND MALL	REGAL SQAURE	YESHWANT NIWAS RD.	TREASURE ISLAND MALL	REGAL SQAURE	YESHWANT NIWAS RD.	TREASURE ISLAND MALL
STAY TIME		70 SEC	65 SEC	70 SEC	70 SEC	65 SEC	70 SEC	70 SEC	65 SEC	70 SEC	70 SEC	65 SEC	70 SEC	70 SEC	65 SEC	70 SEC
10.30 TO 12.30	TWO WHEELER	78	61	79	82	66	84	84	59	82	80	68	79	85	64	90
	FOUR WHEELER	35	25	32	38	22	36	34	26	31	34	25	35	32	23	42
14.30 TO 16.30	TWO WHEELER	73	51	69	71	60	72	75	55	60	78	52	65	77	53	66
	FOUR WHEELER	39	22	36	36	25	32	34	29	43	33	24	39	35	26	48
18.30 TO 20.30	TWO WHEELER	83	63	81	80	58	85	86	67	88	79	60	84	84	62	82
	FOUR WHEELER	42	31	42	38	34	39	46	39	32	38	32	37	34	36	36

Table.2 Total fuel consumption and cost during idling

SIGNAL	TYPE OF VEHICLE	COUNT OF VEHICLE	TIME (in seconds)	CONSUMPTION OF FUEL (ml/sec)	PRICE OF FUEL(Rs/ml)	COST (In ruppees)	TOTAL COST (In an hour)
1	TWO WHEELER	80	70	0.0389	0.078	16.99152	509.7456
	FOUR WHEELER	35	70	0.21	0.078	40.131	1203.93
2	TWO WHEELER	61	65	0.0389	0.078	12.030603	360.91809
	FOUR WHEELER	25	65	0.21	0.078	26.6175	798.525
3	TWO WHEELER	79	70	0.0389	0.078	16.779126	503.37378
	FOUR WHEELER	32	70	0.21	0.078	36.6912	1100.736
TOTAL		312		0.7467	0.078	RS.149.240	RS. 4477.22

5 Solution of the problem:

Existing geometry of the square is below in figure 8. According to the figure in an existing geometry a normal square consists of vehicles moving in all four directions and following the set of rules related to traffic signals.

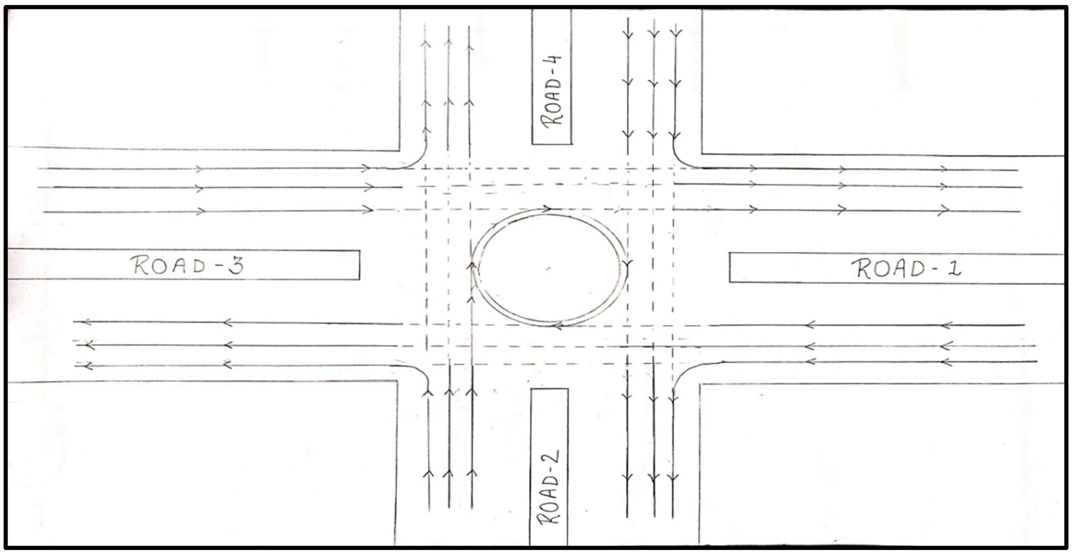

Fig.8 Existing geometry of signalized intersection

5.1 Suggested Model:

Let us consider three signal points P, Q, R in a sequence on a straight road and we say a packet between traffic signals P and Q as a space X and packet between traffic signals Q and R as a space Y. Now on going from X to Y a discontinuity arises because of many constraints like spaces don't have equal sizes and if Y is of smaller size than X, then all the elements (vehicles) of X can't move easily into Y which is almost similar as the discontinuity in two topological spaces. One more thing which is responsible for the discontinuity is intersection between roads and therefore to keep a basic principle of continuity of space in mind we proposed some geometrical changes and shifting the positions of squares so that a discontinuity between spaces can be removed.

Figure 9 is the suggested model which removes discontinuity under certain conditions of traffic rules and with the help of specially designed speed breakers, the speed limits can be controlled as per the need of the traffic

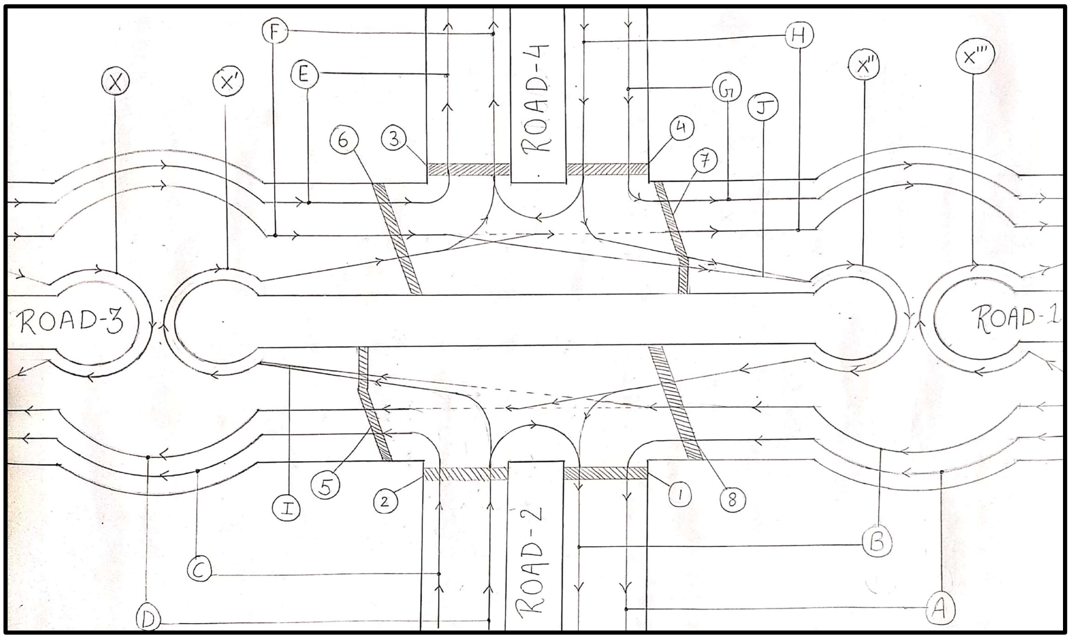

Fig. 9 modified geometry of signalized intersection

The figure 9 represents the modified geometry of the signalized intersection. It consists of different lanes named from A, B, C, D, E, F, G, H, I, J. Also some additional modifications which are made in the diagram regarding this intersection such as speed breakers are named as 1, 2, 3, 4, 5, 6, 7, 8 and the U-turns are labeled as X, X`, X``, X```. Each labeling is explained below.

i) LABELS A, B, C, D, E, F, G, H, I, J are the alphabets assigned to the different roads.
ii) LABELS 1, 2, 3, 4, 5, 6, 7, 8 are the numbers assigned to the speed breakers [6]. Philip A. Weber [13] in his paper discussed the standard for the geometry design of the speed humps. Speed breakers are used to control the speed of the vehicles and to avoid accident and mishaps. The whole concept based on speed breakers is discussed by Mitul Patel [9] et.al, L. R. Kadiyali [8]. The speed breakers are divided as:

- 1, 2, 3, 4 are straight speed breakers
- 6, 8 are tilted speed breakers
- 5, 7 are half- straight and half -tilted speed breakers.

iii) LABELS X, X`, X``, X``` are the U-turns.

Explanation of the diagram:

CASE-I
Let us consider a case where the vehicles are commencing from road 1.
a) Now, the vehicles which have to go to their respective left side will follow the lane 'A', encounter breaker '8' and breaker '1' while turning left and keep following the lane 'A'.

b) The vehicles which have to go straight will follow the lane ‘B’, slow down their speed at the breaker ‘8’and after crossing the breaker 5, will join the lane ‘D’ and go straight.

c) The vehicles which have to go towards their right side will follow the lane ‘B’, slowing down their speed at the breaker ‘8’ and will switch to the lane ‘I’, and encounter the breaker ‘5’. Then the vehicles will take a U-turn at the point marked as X` and then while switching to the lane ‘F’ will encounter a breaker ‘6’ and go right.

d) The vehicles which have to take a U- turn will follow the ‘step c’ but rather than turning towards left, will continue to go straight and join the lane ‘H’.

CASE-II

Considering the case where the vehicles are commencing from road 2.
a) Now, the vehicles which have to go to their respective left side will follow the lane ’C’, encounter breaker ‘2’ and breaker ‘5’ while turning left and keep following the lane ‘C’.

b) The vehicles which have to go straight will follow the lane ’D’ and will slow down their speed at the breaker ‘2’, take a turn to join the lane ‘I’ and encounter the breaker ‘5’. Then the vehicles will take a U-turn at the point marked as X` and then while switching to the lane ‘F’ will encounter a breaker ‘6’ and go right.

c) The vehicles which have to go towards their right side will follow the ‘step b’ but rather than turning towards left, will continue to go straight and join the lane ‘H’.

d) The vehicles which have to take a U- turn will follow the lane ‘D’, encounter breaker ‘2’, take a U-turn and after crossing the breaker ‘1’ will switch and follow the lane ’B’.

CASE-III

Considering the case where the vehicles are commencing from road 3.
a) Now, the vehicles which have to go to their respective left side will follow the lane ‘E’, encounter breaker ‘6’ and breaker ‘3’ while turning left and keep following the lane ‘E’.

b) The vehicles which have to go straight will follow the lane ‘F’, slow down their speed at the breaker ‘6’and after crossing the breaker 7, will join the lane ‘H’ and go straight.

c) The vehicles which have to go towards their right side will follow the lane ‘F’, slowing down their speed at the breaker ‘6’ and will switch to the lane ‘J’, and encounter the breaker ‘7’. Then the vehicles will take a U-turn at the point marked as X`` and then while switching to the lane ‘B’ will encounter a breaker ‘8’ and go right.

d) The vehicles which have to take a U- turn will follow the ‘step c’ but rather than turning towards left, will continue to go straight and join the lane ‘D’.

CASE-IV
Considering the case where the vehicles are commencing from road 4.

a) Now, the vehicles which have to go to their respective left side will follow the lane ’G’, encounter breaker ‘4’ and breaker ‘7’ while turning left and keep following the lane ‘G’.

b) The vehicles which have to go straight will follow the lane ’H’ and will slow down their speed at the breaker ‘4’, take a turn to join the lane ‘J’ and encounter the breaker ‘7’. Then the vehicles will take a U-turn at the point marked as X`` and then while switching to the lane ‘B’ will encounter a breaker ‘8’ and go right.

c) The vehicles which have to go towards their right side will follow the ‘step b’ but rather than turning towards left, will continue to go straight and join the lane ‘D’.

d) The vehicles which have to take a U- turn will follow the lane ‘H’, encounter breaker ‘4’, take a U-turn and after crossing the breaker ‘3’ will switch and follow the lane ’F’.

6 Conclusion

Using the concept of continuity of topological spaces, we have made a traffic controlling model in which the spaces are made continuous. By modifying the geometry of the traffic controlling, the following advantages can be achieved as:

- No traffic signals required
- No fuel exhaustion when idling.
- Continuity of the vehicles is maintained
- Less requirement of police enforcement
- Less chance of accident due to proper speed breakers.
- Less expenses regarding fuel consumption, traffic installment cost etc.

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