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Proposal of a System for Dynamic Management of Road Traffic Signals

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Abstract: Traffic congestion is one of the biggest problems that metropolitan cities are facing. The degree of the effects heavy traffic congestion can have is not very evident. It can have immense effect not only on one's safety but also on one's personal life. One of the major contributors for this is traffic jams caused by irregular and often longer durations of waiting time at traffic signal junctions. Finding a solution to this problem is imperative. Current technologies use wired and wireless sensors to optimize traffic light control but this method proves to be expensive and incurs high maintenance cost. This paper presents a new cost effective system for adjusting the traffic light waiting time using machine learning. We make use of previous years' traffic data of a city and come up with the appropriate number of seconds of waiting time based on patterns in traffic data.
Keywords: Association rules mining, Apriori algorithm, traffic constraints, rule extraction, intelligent traffic control.

I. INTRODUCTION

Traffic characteristics of a city are an indication of effectiveness of its planning. With the enormous increase in the number of vehicles, traffic congestion is also increasing in huge amount, which, although good with respect to economic growth, causes high fuel consumption, pollution and longer commute duration. In addition, inconsistent driving ability amongst all drivers, lack of adequate infrastructure, and economic forces that allow more people to drive continues to be big challenges.

The existing signal timers have a pre-set waiting time which does not take into account the traffic density at different times of the day.

Due to this, vehicles have to wait unnecessarily for longer intervals even when traffic density is very lean. This not only instigates the drivers to jump signals out of sheer frustration, but also exposes them to pollution for longer durations. Such a system prevents smooth flow of traffic and causes irregular delay in transit. In most junctions, there is no platform for sensing network or feedback on traffic influencing factors. All this leads to more fuel consumption and less efficiency.

The proposed system collects traffic data, i.e., the amount of flow of traffic in the lanes of a city, particularly near traffic signal junctions during different times of the day. Proposed system makes use of such data of previous years and trains the machine learning model in order to find the relation between different traffic constraints at different times of the day and thus come up with efficient and appropriate number of seconds the vehicles in the respective lanes have to wait in the signal under a red light. This approach of customizing the duration of wait time dynamically in traffic signals at particular times of the day not only serves as a better alternative to the currently-in-place constant duration of wait time irrespective of the amount of flow of traffic, it also reduces the duration of time vehicles have to wait in signals where there is a very small amount of traffic.

Proposed system serves as a web application which involves three actors:

1) Administrator
2) Traffic Incharge Officer
3) Public

Administrator is the one who maintains the entire system. He is responsible for appointing Traffic Incharge officers and assigning them to different junctions.

Traffic Incharge officer uploads the necessary traffic data to the server and manages the individual junctions of the city.

Public (visitor) receives service from the application by viewing the predicted result in the form of wait time at the junctions of a particular road at different times of a day.

We aim to find patterns in traffic data using association rule mining.

II. ASSOCIATION RULE MINING: CONCEPTS

Association rule mining is a data mining procedure to discover patterns, relationships and correlations among items in a data set. These relationships are represented as association rules. This method is often used to analyse customer buying behaviour. For example: A customer who buys beer is likely to buy chips (Basket analysis). Other examples include fraud detection in credit card

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transaction, medical diagnosis, network traffic analysis, analysing customer reviews, census data, e-Learning etc.
The rules produced using association rule mining can be divided into two disjoint subsets. In the mathematical form[2],

$$X \rightarrow Y$$

$$\text{where } X \cap Y = \varnothing$$

The expression implies that when *X* occurs, there is a good possibility of *Y* occurring. The extent to which *X* contributes towards the final objective is governed by
'support'.
The probability of occurrence of *Y* given that *X* has already occurred is determined by 'confidence'.

$Support(X) = P(X) = freq(X) / N$

$Confidence(X \rightarrow Y) = P(Y \mid X) = freq(X , Y) / freq(X)$

where *freq(x)* is a function which returns the number of occurrences of x.
In cases of more than one parameter, freq returns the number of co-occurrences of its parameters.
The steps for association rule mining are as follows [3]:

1) Generation of association rules using a suitable algorithm.
2) Fixing threshold values for support and confidence.
3) Selection of rules that meet the threshold requirements.

When the support of an item set is greater than or equal to threshold value, it is called a frequent item set.

III.METHODOLOGY

Apriori algorithm is used for frequent item set mining and association rule mining. It uses a bottom-up approach
where frequent subsets are extended one item at a time by a process known as candidate generation. Groups of such candidates are tested against the data [1][5].
The Apriori Principle: If an item set is frequent, then all of its subsets must also be frequent [2].
We have used Apriori algorithm for our application as it generates accurate patterns for small as well as large datasets. It can also be easily parallelized and implemented.
The procedure for Apriori algorithm that our application uses is:

1) Scan the traffic dataset and determine the support of each 1-itemset.
2) Compare support of 1-itemset and generate frequent 1-itemset.
3) Using join operation, generate the set of candidate k-itemset.
4) Scan the candidate k-itemset and determine the support of each candidate k-itemset.
5) Generate corresponding frequent itemset for the candidate set until candidate itemset, C=NULL.
6) Generate all non-empty subsets for each item in the frequent itemset.
7) Determine the confidence for each non-empty subset. If it is greater than or equal to specified confidence, add to strong association rule.

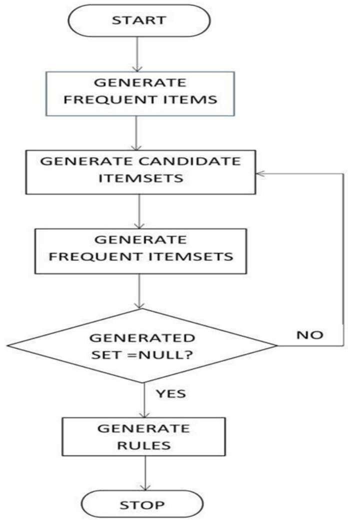

Fig.1 Flowchart of Apriori algorithm [4]

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Association rule mining is useful for discovering hidden relationships among traffic constraints.
The illustration of an example of the above process for our traffic application using Apriori algorithm is described below.

TABLE I
TRAFFIC DATASET

TID	Traffic Constraints
1	{A,C,D}
2	{A,C,E}
3	{A,B,C,E}
4	{B,E}

The above table is a traffic dataset where
A – Wait time
B – Festival day(Y/N)
C – Number of lorries
D – Speed limit
E – Number of 2 wheelers
are the different traffic constraints that we've considered for this example, while it must be noted that the actual implementation may include many more constraints.

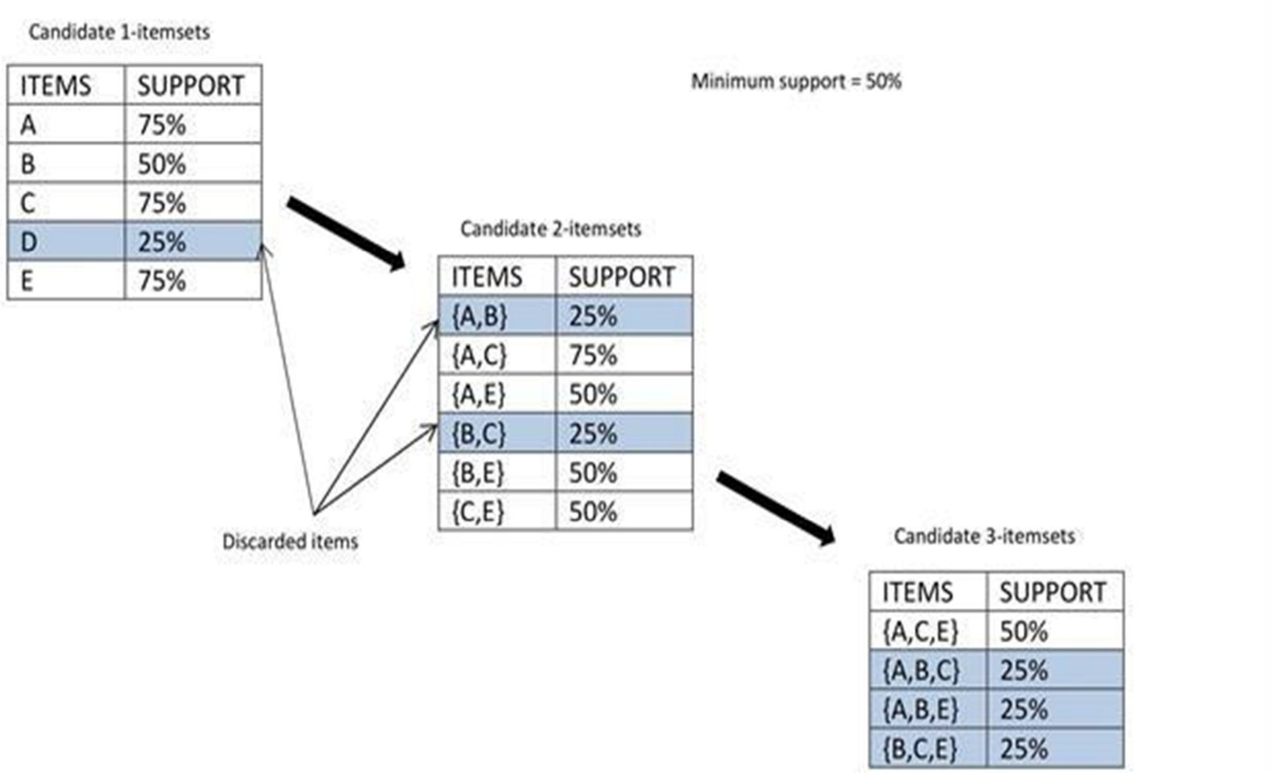

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Fig.2 Illustration of frequent itemset generation

Fig. 2 shows a high level illustration of the frequent itemset generation [2] for the data shown in Table I. The initial step is to calculate the support of these constraints using the equations given above.

We assume that the support threshold is 50%. This means that an item (here {D}) whose support value is less than 50% is discarded. In the next iteration, candidate 2-itemsets are generated using only frequent 1-itemsets. We find that {A,B} and {B,C} are infrequent after computing their support values. The remaining four candidates are used to generate candidate-3 itemsets. Finally the only frequent 3-itemset that we need to keep is {A,C,E}.

After generating all non-empty subsets for the superset of frequent 1-itemsets, frequent 2-itemsets and frequent 3-itemsets, we determine the confidence of each non-empty subset.

The minimum confidence value that we assume is 80%. The rules which have confidence greater than or equal to 80% make strong association rules.

The strong association rules are:

1) $\{B\} \rightarrow \{E\}$
2) $\{C,E\} \rightarrow \{A\}$
3) $\{A,E\} \rightarrow \{C\}$
4) $\{A\} \rightarrow \{C\}$
5) $\{C\} \rightarrow \{A\}$

We extract the rules that contain the constraint – wait time – on its right hand side. In the above example, constraints C and E have major contribution towards determining the value of wait time (A).

The following diagram is a high level view of the system that defines the relationship the system has with other external entities associated with it.

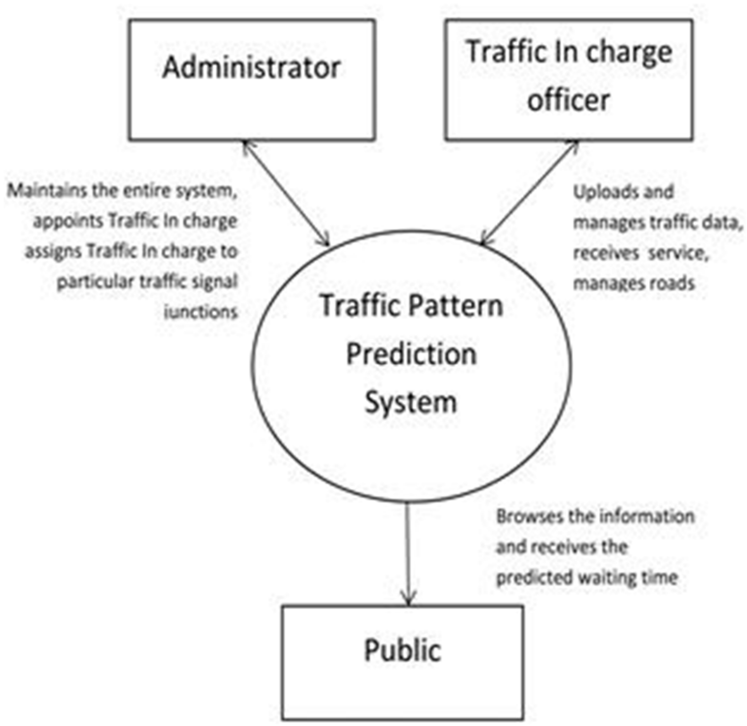

Fig.3 Context flow diagram

IV. FUTURE SCOPE

The System can be incorporated with real time data with previous years' data to make predictions on the fly. The various relationships among traffic constraints can be used for enhancing road infrastructure, signal management, implementing better traffic rules etc. Usage of the system can be expanded to other cities and states to form an intelligent and interconnected traffic network.

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V. CONCLUSION

In the wake of rapid growth of metropolitan cities and population explosion, it is imperative to have an intelligent and cost effective system in place to manage traffic flow. As the wait time information is obtained from the user, he can reroute his way to the destination through an optimal path.

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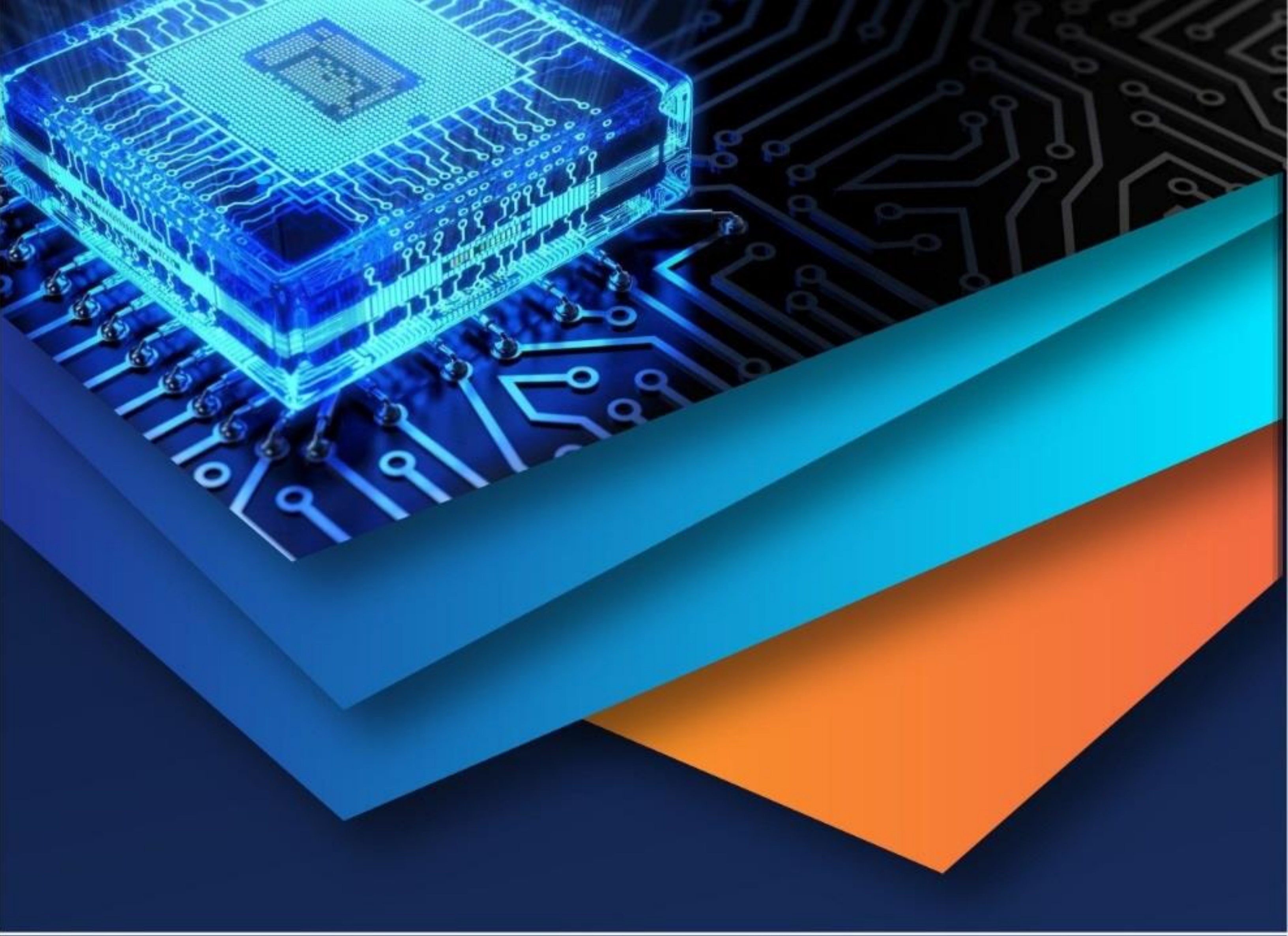

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