Efficient left turn movements at signalized intersections
by applying Floating Car Data (FCD) Technology

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ABSTRACT
The proposed research aims at developing an integrated and efficient travel management model to generate a smart transportation system by minimizing traffic delays and providing the best left turn signal plan at signalized intersections. This study will utilize an emerging data acquiring technique called “Floating Car Data (FCD)” to obtain congestion related information in an arterial segment that can be used for routing decisions and proper signal timing. Even if there were several past studies on using FCD, but those have been limited into obtaining traffic related information parameters (such as speed trajectories only). But this study will focus on using FCD technology to generate most efficient left turn movement at different levels of congestion. Using this performance information during traffic jam, a most effective left turn signal can be regulated providing faster and safer left turning movement where the destinations necessarily to be reached by adopting left turns from an intersection. Left turning movements can also generate a basic relation between the types of left turns and the maximum number of vehicles released during traffic jam. This research will develop an integrated mathematical model based on the first order partial differentiation (PDE) method

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via a “continuum” approach at a signal focusing on left turning traffic movement. The model validation will be carried out using a simulation of traffic data for three different types of left turn protections and its surrounding roadway network. This approach can be applied for congestion relief during peak hour travels as well as in the events of accidents in local roads.

Keywords: FCD, Left turn signal, Continuum approach

1. INTRODUCTION

The purposes of offering efficient mobility and optimum capacity while simultaneously ensuring maximum safety result in competing interests at signalized intersections. The concern of efficiency arises more when it comes to the question of reaching a destination on time. Usually traffic congestion is identified as the most common reason behind delays at arterials. The condition becomes more worsening during the peak hour. Introducing a new inventive technology of acquiring data called floating car data (FCD), this research is planned to obtain congestion related information in an arterial segment that can be used for faster traffic movement. FCD can help mitigating traffic congestion in an arterial study segment. The FCD data is mainly used for traffic signal timing regulation purpose. Depending on the types of left turning protections) the motorists’ speed during turning left and their travel time can be monitored where the signal phase and timing information sometimes may not be available directly from a city’s Traffic Management Center (TMC). Also using infrastructure based approaches for obtaining traffic data, e.g., CCTV and loop detectors can be expensive for both installation and maintenance whereas pure FCD approach can offer relatively lower cost in deployment. The so far application of FCD was in monitoring vehicular speed whereas this research aims at using FCD in obtaining information on left turning vehicles to get informed about delay. Three fundamental left turning
protects are the emphasizes of this study. Secondly this research will also concentrate on developing an algorithm for suggesting the best left turning signal timing offering the most effectual and safe turning maneuvers. The focus of the study is to optimize the left turn protection signal timing based on daily drivers’ left turning movement conveniently and safely. To analyze the overall level of service of signalized intersections by estimating the capacity is also one motivation of this research. This research will develop an integrated mathematical model based on continuum theory focusing on the conservation of left turning cars at signals. The output will be generating method to calculate traffic delays due to left turn movements. The model validation will be conveyed using a simulation of traffic data for three different types of left turn protections and its surrounding roadway network. Driver behavior can also be specifically studied during real-time information relay on congestion through this research.

Figure 1: The proposed system architecture in Astarita et al. (2017)

Labels:  (1) equipped with satellite receiver position system (GNSS)
(2) Central server
(3) Traffic light controller
(4) Traffic lights
(5) Local radio signals emitters
(6) Local radio receiving system
(7) wireless local area data network
(8) local radio receiving system
2. SIGNIFICANCE OF THE STUDY

The main objectives of this research and the associated are to:

- Develop an integrated mathematical model based on deterministic nature of traffic flow during congestion (as delays) at signalized intersections.
- Detect the functional performance of the left turning signals by estimating their duration (phase length) in one direction and drivers’ travel time during turning left (protective only, protective-permissive and permissive only) and establish a good correlation between them by observing driver’s decision to escape through the left turns depending on their types of protection.
- Compare outputs and validate the developed model using a computer simulation at left turn protections.
- Analyze the overall capacity of signalized intersection and level of service by integrating left turning travel time into the capacity estimation.

3. PROPOSED WORKFLOW:

This research is intended to extend the application of floating car data (FCD) technology to a new dimension where effective and best suitable plan of left turning signal phase can be provided or chosen during traffic jam period. This proposed research can significantly contribute on safe left turning movement and travel time comparison between general (non-equipped) and smart cars (equipped with GPS) during congestion period.
Choose signalized intersections with different left turn protections

Collect data on left turning vehicles during various levels of congestion

Count the number of left turning vehicles (for both using GPS and using no GPS)

Evaluate length of green period during turning left

Compare speed as well as travel times of left turning traffic with various types of protections by simulation

Provide the most efficient left turn protection

Figure 2: Proposed research workplan

4. METHODOLOGY

The methodology for this study basically comprises of three key components:

- **Data:** The entire research work will be done based on three different locations with three distinct types of left turning protections. Data on
number of left turning vehicles and speed can be collected for both instrumented and non-instrumented vehicles.

- **Model:** The first step for applying mathematical processes in estimating travel time is to define the relative variables at macro traffic modeling and states to be used in the analysis. Several variables will be used for optimizing travel time of left turning drivers. The primary development of an integrated model will apprehend the sensitivity of car following behavior of roadway users to some extent incorporating floating car data technique of route congestion information. The developed model will also corporate the drivers’ left turning decision during the time of various levels of traffic jam with the type of protection. The method of evolving the model will be a deterministic approach of traffic flow.

- **Analysis:** After the model is established, the subsequent task would be to test the output and validate the developed model by using a computer simulation preferably MATLAB. Model validation will be carried out for routes developed during simulation in identifying critical left turning pockets and can measure the required time length of left turning protections to serve the maximum number of vehicles. As a result, a best plan of left turning signal can be proposed. The validation will involve comparisons of travel time savings (if any) for routes identified using simulation with output from model developed for various congestion levels. The comparisons will help improve and promote the model developed.
5. ANALYSIS & RESULTS:

Three parts in analysis:

– Validation of model

– Use Simulation

– Compare output for different left turn protections

The preliminary results are in terms of graph analysis between speed vs density and flow vs density for both instrumented and non-instrumented vehicles.

![Graph showing speed vs density for general vehicles (with no instrument)](image)

Figure 3: Speed vs Density curve for general vehicles (with no instrument)
Figure 4: Speed vs Density curve for connected vehicles (equipped with instrument)

Both GPS equipped, and non-GPS equipped show no significant differences in the relation between speed and density at microsimulation analysis.

Figure 5: Flow vs density curve for general vehicles (with no instrument)
A significant improvement in vehicular flow can be anticipated from the graphs above for the smart connected vehicles. Preliminary results show significant improvements in travel time savings and delay reductions for light to heavy traffic congestion levels as compared to light or jam conditions as well as left turning signal performances.

6. OVERALL EXPECTED OUTCOME

The expected outcomes of this ongoing research are illustrated as follows:

- A manifest driver’s behavioral system might be understood during the congestion by studying their nature and by applying the technique of FCD.
- Depending on the differences among the types of left turns, the reactions from the drivers can be also be premeditated during real-time traffic data information.
- The developed model may improve the functionality of protective left turning control system by suggesting the best plan of left turn signal protection.
The emission control can be anticipated at an adequate level from the vehicles.

Some advantages of using FCD over loop detector data can be summarized as below:

- Can be inexpensive in terms of non-destruction works (which is costly in cases for installing loop detectors)
- Can offer new algorithms for researchers and engineers
- Can provide best left turn phasing (efficiency)

7. CONCLUSION

The established model can be applied both for peak and non-peak hour congestion mitigation which can clearly identify model inputs and outputs incorporating FCD. It will enhance efficiency in measurement indicating drivers’ behavior during peak hour congestion. Once the general nature of drivers is obtained through modeling the saved time can be calculated from avoiding the congestion propensity to reach the destination. It will also provide fuel economy, reduce air pollution and hence improve environment. Driving behavior can also be carefully studied during real-time information relay on congestion. This research is innovative since it will apply the FCD method to mitigate congestion at signals by collecting and utilizing data and feedback from cars equipped with smartphone (GPS) systems of a roadway users. The overall impact would be to provide cutoff in financial burden for both transportation and environmental agencies.
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