Trajectory analysis at mid-block section using microscopic simulation

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ABSTRACT
With rapid urbanization, traffic has increased in recent years. For a developing nation, mobility is a key concern. Especially, in rapidly expanding urban areas, vehicle accidents are of great concern. Because of this, it is necessary to pay vital attention to transportation and examine the need for greater geometric design and capacity. To assess road user interactions at a mid-block with heterogeneous traffic complexity, innovative trajectory-based data was used. In order to evaluate microscopic traffic flow parameters under various traffic flow conditions a Support Vector Machine (SVM) is used to classify severity grades based on specified indicators which are between generated at two mid-block sections. A vehicle trajectory data for two different mid-block sections using a semi-automated image processing method is generated. The trajectories detected are vehicle ID, vehicle time, speed, longitude, latitude position, flow. From the analysis, microscopic traffic flow parameter like time headway, space headway is estimated by plotting a graph using Linear Regression model. This means that SVM is the best fit model to estimate headway at mid-block section (R² = 0.86, 0.85) studied. From this study, it is concluded that the obtained value of R² and goodness of fit measures using trajectory data base is highly acceptable to estimate the headway at mid-block section.

Keywords: Mid-block section, trajectories, microscopic traffic flow and SVM models.

1. Introduction
Humans have traditionally relied on vehicles as their major mode of transportation and that's why vehicles are regarded to be the most basic kind of transportation available to people. Even in ancient times, travelling was a widespread mode of transportation, and every mode of movement had a start and an end point. Using a vehicle is a good option for both short and long distance travel [1]. As the usage of vehicle is exceeding, the traffic on roads is increasing. Among all the factors considering traffic study, traffic flow is one of the major factors.

Traffic flow studies have concentrated on the interactions between various traffic participants (e.g., vehicles, drivers, pedestrians, and bicyclists) and infrastructure (e.g., highways, signal control devices), with the goal of elucidating the relationship between individual traffic participants and the resulting traffic flow phenomena [2]. Vehicle time headways have been studied in many aspects of traffic flow studies because time headway between any two successive vehicles is regarded as an important parameter affecting a mobility system's capacity, safety, delay, driver behaviour, and level of service [3-5]. As a result, traffic flow studies are empirical in nature, relying primarily on high-quality observations of real-world data [3].

Macroscopic flow characteristics such as speed and density of vehicular motion may be analysed, while microscopic flow parameters such as the routes taken by individual vehicles while travelling can be tracked [1]. Complete vehicle trajectory records are highly valuable for empirical traffic flow research,
but they are challenging to acquire. This is due to the fact that traffic flow is a broad spatial-temporal phenomenon and collecting continuous data from such a broad area is difficult [6, 14, 15]. As we know, there is a system that exists and works in time and space. A model is a system abstraction that may be described as a simplified depiction of a system at a certain moment in time or place that is intended to promote knowledge of the real system. The amount of complexity depends on the individual needs since the model is a simplification of the real situations. In this study, traffic data was collected at mid-block section. The analysis of traffic parameters such as traffic volumes, speed variations, trajectories, vehicle path, headways and safe sight distance were determined.

Simulation is the manipulation of a model in such a manner that it acts on time or space in order to compress it, allowing one to see interactions that would otherwise be invisible due to their separation in time or space. The traffic simulation models span from microscopic to macroscopic models that employ general traffic descriptors such as flow and have applied the phrase nanoscopic model to signify finer depiction of traffic, depending on the desired requirement [10, 11].

Congestion is also becoming a daily issue on several of the country’s major thoroughfares. SimTraffic, VISSIM, and Transyt-7F are popular simulation models used by traffic engineers to analyse traffic signal schemes and alleviate traffic congestion [4]. This article will attempt to shed light on the characteristics and capabilities of VISSIM simulation software under varying situations of trajectories in mid-block section. Future study on the calibration of the chosen software, as well as the evaluation of its effectiveness, should be explored.

The aim of this study is to assess the effectiveness of the developed system, a trajectory database of typical disordered mixed traffic streams was compiled. The results show that the developed system significantly improves the process of collecting trajectory data in such traffic conditions [7-9]. The collected trajectory dataset is then used to examine two crucial aspects of distorted mixed traffic: (i) interaction of different vehicles in the longitudinal and staggered following scenario, and (ii) lateral shift tendency of different vehicles by developing an SVM model.

2. Methodology

Initially literature surveys were conducted on trajectory data on vehicle to vehicle on mid-block sections. Then the study area selected as KPHB-Miyapur section. It has two directions with 5 lanes each and video graphic survey was conducted for 6 hours in each direction. And data collection as carried out from the software which is free source for all traffic related parameters then developing model.

![Fig. 1: Proposed Methodology](image-url)
3. Data collection and Extraction

3.1. Study Area
A literature studies are conducted based on the trajectory data related to vehicle to vehicle interaction at mid-block section. The study area is selected as KPHB mid-block from KPHB to Miyapur, Telangana. Figure 2 represents the study location. The study was conducted for 6 hours i.e., from 9:00 am to 12:00 pm and 4:00pm to 7:00pm in a weekday. As it is feasible for recording video from elevation at the section where the interactions are to be studied, video cameras were fixed at some elevation to capture the appropriate vehicular flow. Data which gets from video- graphic method is extracted using software. As a result of the study, focus on pair-wise interaction, interactions between each vehicle to vehicle were considered. Road users are identified in the video for analysis (frame by frame). In mixed traffic, this can be a challenge, especially if there is no lane discipline in place. A variety of automatic tracking tools is used by the writers to retrieve the data. However, the tracking was not very accurate. If you want to track more than one item, you can use a semi-automated tracking software (i.e., data from sky), which offers a good degree of accuracy in the x, y coordinates which is a free source video processing software in the field of traffic studies, it is commonly used to track vehicles and estimate vehicle speeds.

3.2. Data Extraction

3.2.1. Geometric Parameters

| Parameters                  | KPHB to Miyapur | Miyapur to KPHB |
|-----------------------------|-----------------|-----------------|
| Total Stretch               | 35              | 35              |
| Number of lanes(no's)       | 5               | 5               |
| Approach Width(m)           | 19              | 17.5            |
| Each Lane Width             | 3.5             | 3.5             |
| Traffic Volume (Peak Hours) | 47425           | 59584           |
From the above collected video graphic data, a cumulative frequency distribution is plotted illustrating various percentile speeds as shown in Fig 3, 4 and Table 2.

![Cumulative Frequency Graph for KPHB to Miyapur](image)

**Fig. 3: Cumulative Frequency Graph for KPHB to Miyapur**

![Cumulative Frequency Graph for Miyapur to KPHB](image)

**Fig. 4: Cumulative Frequency Graph for Miyapur to KPHB**

| Percentile Speeds       | KPHB to Miyapur (kmph) | Miyapur to KPHB (kmph) |
|-------------------------|------------------------|------------------------|
| Design speed (98th)     | 86.5                   | 87.5                   |
| Safe speed (85th)       | 69                     | 73.5                   |
| Median speed (50th)     | 54.5                   | 56                     |
| Minimum speed (15th)    | 41.5                   | 45                     |

**Table 2: Percentile speed for traffic flow along both directions.**

The below graph Fig 5 showing the peak hour flow of the selected mid-block section for a 12hours duration starting from morning 8.00am to evening 8.00pm of a week day. From this data, considered only the peak hours of the day as morning peak as 9.00am - 12.00pm and evening peak as 4.00pm - 7.00pm. Microscopic parameters like time and space headways are evaluated from the trajectory data from the above peak time intervals.
### Table 3: PHV and PHF

| Time               | PHV (veh/h) | PHF  |
|--------------------|-------------|------|
| 9:40am to 10:40am  | 15823       | 0.976|
| 5:00pm to 6:00pm   | 15869       | 0.940|

![Graph of Peak Hour Volume of KPHB Mid-block Section]

**Fig. 5:** Peak Hour Volume of KPHB Mid-block Section

#### 3.3. Time and Space Headways

Headway is defined as the time between two consecutive vehicles. Time headway is the time taken from front bumper of leader vehicle to rear bumper of following vehicle. Here all the headways (h) in the time period (t) over which flow has been measured are added together, then

\[
\sum_{i=1}^{n_\text{vehicles}} h_t = t
\]

The flow, on the other hand, is defined as the number of vehicles (n) divided by the time period (t), \(h_{avg}\) is the average headway.

\[
q = \frac{n}{t} \quad h_{avg} = \frac{1}{q}
\]

Space headway is distance between front bumper of leader vehicle to rear bumper of following vehicle. Here all the headways (h) in the distance period (d) over which flow has been measured are added together, then

\[
\sum_{i=1}^{n_\text{vehicles}} h_d = d
\]

The flow, on the other hand, is defined as the number of vehicles (n) divided by the distance period (t), \(h_{avg}\) is the average headway.

\[
q = \frac{n}{d} \quad h_{avg} = \frac{1}{q}
\]
The below table 3,4 gives the appropriate values of the time and space headways and stopping sight distance for each direction also evaluated, speed variation of each vehicle is extracted from the trajectory data.

### Table 3: The descriptive statistics of each direction in the morning flow condition

|                      | KPHB to Miyapur | Miyapur to KPHB |
|----------------------|-----------------|-----------------|
| **Time Headway (s)** |                 |                 |
| MEAN                 | 1.69            | 1.48            |
| S D                  | 1.66            | 1.36            |
| Max                  | 47.93           | 30.4            |
| MIN                  | 0.033           | 0.033           |
| SSD                  | 158.78          | 197.77          |
| Speed                | 63.97           | 72.96           |
| Traffic Flow         | 25531           | 28784           |

### Table 4: The descriptive statistics of each direction in the evening flow condition

|                      | KPHB to Miyapur | Miyapur to KPHB |
|----------------------|-----------------|-----------------|
| **Time Headway (s)** |                 |                 |
| MEAN                 | 1.96            | 1.40            |
| S D                  | 2.01            | 1.41            |
| Max                  | 40.6            | 27              |
| Min                  | 0.033           | 0.033           |
| SSD                  | 133.69          | 192.18          |
| Speed                | 61.02           | 66.8            |
| Traffic Flow         | 21894           | 30800           |

4. Model Formulation

4.1 Support Vector Machine

Support vector machine is one of the easiest and most user-friendly machine learning techniques. Classifications, predictions, and regression must be assessed using learning techniques that are supervised by a teacher. In order to transform nonlinear data to linear data, kernel technology is used. It is possible to employ kernels such as Radial, Linear Polynomial, and Sigmoid. Using test data, the developed model may be validated by separating the data into two sets: train and test data. Train-and-error is used to select the optimum linear kernel with varying cost and Gamma functions.
4.2 R Software

R is a statistical computing and graphics programming language. If you are interested in learning more about statistical approaches, R offers a wide range of options such as nonlinear and linear modelling techniques (classification and clustering), traditional statistical tests, and graphing. R’s best feature is the ease with which charts can be created, including the ease with which mathematical symbols and equations may be created when necessary. Packages make it easy to add new functionality to R. For this research, programmes such as e1071, rpart, and others were used to develop a model on headways.

5. Results and Discussion

5.1 Severity of the mid-block section

Table 4: Severity of the mid-block section at different times and spaces

| Headway (sec) | Space (m) | Severity |
|---------------|-----------|----------|
| 1 < 10 <     | 10 <      | Critical |
| KPHB to Miyapur and | | |
| 1 to 2       | 10 to 30  | Moderate |
| 2 to 4       | 30 to 50  | Minor    |
| > 4          | > 50      | Safe     |

5.2 Support Vector Machine

By considering the both headways in both directions, developed the mathematical models and R values obtained from SVM - R studio.

![Graph showing R² value](image)

Fig. 6: R² value is obtained from support vector machine for KPHB to Miyapur
Fig. 7: $R^2$ value is obtained from support vector machine for Miyapur to KPHB

5.3 Goodness of fit

It was determined that a linear kernel with 1.8 cost and 1 gamma was the most accurate. Table 6 shows the results of the best model's performance measures.

| Goodness of Fit      | Results   |
|----------------------|-----------|
| R-square             | 0.86      |
| MAE                  | 1.47      |
| MAPE                 | 1.18E-08  |
| RMSE                 | 12.39     |
| MSPE                 | 32.90     |
| CHI-SQUARE           | 104475.4  |
| CRITICAL CHI-SQUARE  | 105228    |

It was determined that a linear kernel with 1.8 cost and 1 gamma was the most accurate. Table 7 shows the results of the best model's performance measures.

| Goodness of Fit      | Results   |
|----------------------|-----------|
| R-square             | 0.85      |
| MAE                  | 1.67      |
| MAPE                 | 8.57E-09  |
| RMSE                 | 10.7      |
| MSPE                 | 27.77     |
| CHI-SQUARE           | 141362    |
| CRITICAL CHI-SQUARE  | 159969.8  |
6. Conclusions

Different statistical distributions of time and space headways for varied flow level ranges under mixed traffic conditions are computed using traffic trajectory data gathered from a five-lane road in KPHB. For five-lane road, a vehicle-type specific headway research was conducted, as well as variations in vehicle headway keeping behaviour in the presence of lighting for both types of roads.

1. Severities are evaluated from the trajectory data and severity levels are analysed based on the severities of the mid-block section as shown in the tables 5.
2. Time headway and space headway for both flow direction is estimated then concluded that flow in the Miyapur to KPHB direction is higher than opposite direction. So, it allowing very less headways for vehicle to vehicle compared to KPHB to Miyapur direction and obtained as critical flow.
3. And also compared the SSD for both directions, outcome is SSD for Miyapur to KPHB is very high.
4. Obtained R-square values 0.86, 0.85 and developed mathematical equations are also the best fit for both the directions.
5. From table 6 obtained chi-square value (104475.4) is less than critical chi-square value (105228). And table 7 obtained chi-square value (141362) is less than critical chi-square value (159969.8). So, developed model from the trajectory data is accurate.

Overall, from the points mentioned above can conclude that reduction in speed and less stopping sight distance the criticality is high for KPHB to Miyapur flow than Miyapur to KPHB flow.

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