Capacity of heterogeneous traffic in urban areas: A level of service estimation

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Abstract. A high traffic congestion in metropolitan cities of India is still a problem which affects the capacity of road. The traffic congestion decreases the speed of vehicle and accumulates the vehicles on road. The gradual expansion of urbanization and the rise of megacities, with their massive populations, present considerable obstacles for developing nations. As the world's populace continues to grow, there is a continuous influx of individuals relocating to urban areas. The developing country such as India facing a problem traffic congestion and its affect the infrastructure of road. Thus, in that case Level of Service (LOS) will be beneficial for increasing the capacity of road. Therefore, this study aims to analyse the LOS estimation in peak and non-peak hours. Estimation of LOS in peak and non-peak hours in urban areas will be beneficial for Indian government to take necessary action. Results revealed that During both peak and non-peak hours, the PCU readings for different types of vehicles are calculated. The velocity of vehicles has a notable influence on the capacity of roadways, even when traffic numbers are modest. Increasing the width of the road leads to a corresponding increase in the Passenger Car Unit (PCU) of a certain vehicle. Due to the increased flexibility offered by a broader thoroughfare, it is more advantageous to traverse by vehicle.

Keywords: Level of service, heterogeneous traffic, urban areas, PCU.

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1 Introduction

A high traffic congestion in metropolitan cities of India is still a problem which affects the flow of vehicle on road [1]. The increase in traffic decreases the speed of vehicle and accumulates the vehicles on road. This accumulation of traffic increases the traffic volume. The LOS estimation reflects the quality of traffic [2]. In this direction several studies have been conducted on different areas and countries and determined the LOS [3]. Further, the traffic flow and behaviour of drivers is still complex in heterogeneous conditions. For the estimation of LOS following factors are to be considered [4].

a. Traffic disruptions or limitations, considering the frequency of pauses per km, the delays incurred, and the required adjustments in speed to keep up with the flow of traffic.

b. Speed and timing of the journey, encompassing the average speed and total time required to traverse a specific stretch of road.

c. The traffic greatly influence the comfort of driver and flow of vehicles.

d. The ability to adjust and maintain the optimal operating speeds without restrictions.

e. The economy of the vehicle, taking into account its operational cost.

Due to the complexity of considering these aspects, HCM primarily emphasizes the ratio of service volume to capacity and transit speed [5]. The HCM suggests utilizing operational speeds for highways that often have continuous traffic flow, such as those found in rural regions [6]. Urban areas should utilise the average travel speed as recommended by the HCM [7]. The HCM has provided the operating conditions for the six LOS, with level A being the highest and level F indicating the lowest:

A route characterised by unrestricted traffic flow, minimal traffic volume, and fast travel speeds is classified as Level of Service (LOS) A. The traffic density is currently minimal, and the speed of vehicles is determined by the intended speed restrictions set by drivers and the physical conditions of the route. There are relatively few constraints on maneuverability caused by the presence of other cars on the road, allowing drivers to maintain their chosen speeds with minimal or no interruptions [8]. LOS B A "stable flow zone" refers to an area where traffic operates at speeds that are relatively restricted due to traffic circumstances. Drivers retain a decent degree of autonomy in choosing their speed and lane of travel. A decrease in velocity is not illogical [8]. LOS C remains the area where flow remains consistent, but the speeds and maneuverability remain more strictly regulated due to increased traffic numbers. Many drivers are limited in their ability to independently select their speed, change lanes, or perform overtaking maneuvers. An acceptable level of operating speed may still be achieved with increased service volumes, which may be appropriate for urban design practice [8]. The LOS D exhibits an unstable flow, where the operating speeds are kept within acceptable limits but are significantly influenced by changes in operating circumstances. Variations in volume and temporary limitations on flow can result in significant decreases in operational speeds. Drivers have limited autonomy to navigate, resulting in diminished levels of comfort and convenience. However, these circumstances may be endured for brief durations [8]. It isn't limited to being defined by speed, but rather refers to operations
that occur at even slower speeds than in level D, with quantities that are close to or at the maximum capacity of the route. When operating at maximum capacity, speeds often range about 50 kilometres per hour (KP). The flow is characterised by instability, resulting in occasional temporary stoppages [8]. Forced flow operations refer to the movement of substances at low velocities, specifically when the amounts being transported are below the maximum capacity. Conditions arise due to a buildup of cars queuing up as a result of a restriction farther down the road. The segment under investigation will function as a storage facility for at least some or all of the peak hour. Downstream congestion can significantly decrease speeds and produce intermittent stoppages of varying durations. At the furthest level, both velocity and magnitude can diminish to zero [8].

The impact of public transport service delivery on passengers’ selection of transport modes in Accra, is explained by Ghana [9]. The research seeks to determine the impact of Metro Mass Transit Limited's service delivery on its popularity “among commuter in Accra, Ghana. This study relates service delivery with transit mode choice. To collect both quantitative and qualitative data through standardized questions is the main purpose of survey research. Conducted a comprehensive analysis of traffic characteristics on rural multi-lane roadways [10]. An analysis has been conducted to examine the relationship between ATS and other traffic parameters. Data was empirically gathered from research sites located on the Cairo-Aswan agricultural four-lane divided highway. The analysis first focused on the effects of lane position (median lane and shoulder lane) and average travel speed. By examining key factors study aimed to identify opportunities for improvement within Bengaluru city's midblock areas [11]. Additionally, conducted speed and delay analyses on three distinct occasions, encompassing both peak and non-peak hours, to ascertain the average duration of the voyage. The average delay of all the mid-blocks was obtained by conducting speed and delay trials. A road inventory study was carried out to ascertain the dimensions of the road, including the width, median, and footpath. The capacity estimation was conducted based on spot speed investigations [12][13]. The level of service was assessed by computing the average speed for each mid-block. During periods of high demand, it was noted that the ratio of vehicles to capacity exceeded the permitted limit [14] [15] [16]. The objective was to categorize road segments into clusters and ascertain the speed intervals for different levels of service. Through the cluster approach, study categorised free flow speed of vehicles for different types of urban streets. Further using cluster approach and algorithm, LOS estimation has been done. Based on Indian road conditions, speed ranges were identified for examining the LOS [17], [18], [19]. For mixed traffic conditions, the author examined flow data of traffic based on 4 to 6 lanes, and analysed the speed distribution and capacity of road [20]. The VISSIM microscopic simulation model is employed to replicate real-world data, with the driver behavior parameters adjusted to match the capacity obtained from the field data [21]. The VISSIM traffic simulation technique is employed to provide traffic flow and speed information in demanding scenarios that are difficult to obtain from field study [22,23]. The goal of the advanced car surveillance and tracking device is to track and observe the institution's vehicle in actual time regarding any place A to anywhere B. It depends on an embedded Linux board and a mobile implementation. For Android. The current system might benefit from fresh innovations, such as the Raspberry Pi.
and smartphone Android applications, which depends on embedded Linux. The aforementioned system utilizes the GPS, GPRS, and GSM SIM900A [24]. The algorithm for optimization known as Adaptive Particle Swarm (APSO) classifies different types of faults through the use of a rules-based association mining relying challenge categorization technique [25]. The probability vectors of relevant time-based trends are used to calculate the similarities among two different sequences [26,27].

2 Research Methodology

A study is being conducted to assess the LOS, traffic volume of the specified stretch. A traffic assessment will then be undertaken on a specific section of the highway to identify its Level of Service. Subsequently, zoning will be carried out to assess the operating conditions across the six Levels of Service identified within the Highway Capacity Manual (HCM). Level A denotes the greatest level, while level F denotes the lowest level [28]. The first step is to establish the sort of urban roadway, such as whether it is an arterial or downtown street. Additionally, the selection of urban street type will be determined based on functional and design characteristics. Functional characteristics aid in determining if an urban roadway is a primary arterial or a minor arterial. Design factors provide insight into the classification of urban streets as high-speed, intermediate, suburban, or urban. The free flow speed will be calculated in the middle section of the route when there is a very low density of cars. Urban street classes (I, II, III, and IV) can be formed based on functional and design factors, as well as FFS (Functional Street) classification. The Floating Car approach will be employed to ascertain the duration of trip, the duration of delays, and consequently calculate the average speed of vehicles [29]. The segment's average travel speed may be computed by considering factors such as Free Flow Speed (FFS), Urban street class, and Level of Service (LOS).

The site is in Jaipur city along the NH-21 motorway. The overall distance from Jaipur to Mahua is 109 km, but the survey will merely encompass the portion from Jaipur, which is 60 kilometres long as by show in Fig. 1. The roadway consists of four lanes. Four corridors are being chosen, with each corridor being 500 metres in length. The corridor is going to be devoid of pedestrian traffic and bus stops [30-33].
3 Speed distribution in peak and non-peak hours

The PCU factor exhibits a clear correlation with the average speed values of various vehicle classes. This is determined by dividing the average velocity of passenger cars by the average velocity of any vehicle category. The distance between the entry and exit points is determined based on the site characteristics. Chronometers were synchronized and employed to accurately measure the timings of every vehicle traversing the specified route. The spot speed is determined by analyzing the extracted footage. Space mean speeds are recorded at 5-minute intervals. The average velocity is displayed in Table 1.

**Table 1.** Speed statistics of individual vehicles

<table>
<thead>
<tr>
<th>S. no</th>
<th>Type of vehicle</th>
<th>Peak hours</th>
<th>Non-peak hours</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Mean speed (Km/h)</td>
<td>Mean speed (Km/h)</td>
</tr>
<tr>
<td>1</td>
<td>Car</td>
<td>53.41</td>
<td>52.56</td>
</tr>
<tr>
<td>2</td>
<td>Truck</td>
<td>45.12</td>
<td>41.52</td>
</tr>
<tr>
<td>3</td>
<td>Bus</td>
<td>40.10</td>
<td>41.89</td>
</tr>
<tr>
<td>4</td>
<td>2-wheeler</td>
<td>38.71</td>
<td>35.12</td>
</tr>
<tr>
<td>5</td>
<td>3-wheeler</td>
<td>39.12</td>
<td>36.58</td>
</tr>
<tr>
<td>6</td>
<td>Trailer</td>
<td>37.58</td>
<td>35.03</td>
</tr>
<tr>
<td>7</td>
<td>LCV</td>
<td>38.63</td>
<td>38.46</td>
</tr>
</tbody>
</table>
According to the data, trucks and trailers slow down during peak hours because of large loads or traffic, whereas vehicles maintain a constant speed. In non-peak hours, buses exhibit a greater mean speed, whereas in peak hours, two-wheelers and LCVs exhibit a lower mean speed.

4 Results and discussion

This analysis examines traffic volume, vehicle composition, and Level of Service (LOS) for urban street roads during peak and non-peak hours. It reveals a consistent increase in traffic during peak hours due to work commutes, while non-peak hours show a decrease. Variations in Passenger Car Units reveal a higher prevalence of three-wheelers and two-wheelers, while trailers contribute to traffic jams. The LOS estimation shifts from 'D' during peak hours to 'C' during non-peak hours, suggesting smoother traffic flow and faster travel times.

4.1 Traffic Volume

The traffic volume is analysed and vehicle count was done by considering 5 min intervals and converted into vehicle per hour. The vehicle count has been done by analysing the recorder video.

![Vehicle/hr vs Time](image)

**Fig. 2.** Variation of vehicle per hour vs time for peak and non-peak hour

This difference in traffic volume between peak and non-peak hours is a consistent phenomenon observed in transportation studies and traffic studies in cities. Commuter arrivals and departures there, daily commute increases traffic on highways, arterial roads and highways, resulting in congestion and slower travel speeds. Additionally, in the course of peak hours, there is probably extended business sports, along with deliveries or provider vehicles, in addition contributing to the overall site visitors extent. Fig. 2, presumably a graphical illustration or facts
visualization illustrating traffic patterns, affords visual proof helping the aforementioned trend. The depicted graph probable indicates a distinct top for the duration of height hours, with a major decline in site visitors quantity for the duration of non-peak hours. This decline can be attributed to different factors, which include fewer commuters on the roads, decreased business sports, and a shift in tour patterns toward off-height times.

**Fig. 3.** Variation of PCU per hour for peak and non-peak hour

Passenger Car Units (PCU) for different vehicles are compared in the Fig. 3 between peak and off-peak times. Three-wheelers and two-wheelers are prevalent, although trailers cause greater traffic jams. Bicycles barely make a difference. Figure 3 presents the distribution of passenger vehicle units (PCUs) for vehicles during peak and peak hours. PCU is a common methodology in traffic engineering to classify the impact of vehicles on traffic, where PCU usually represents the traffic impact of passenger vehicles. Figure 3 provides an insight at it is valuable in terms of traffic composition and impact of vehicle types in congestion. Understanding these dynamics can inform transportation policies and management strategies aimed at reducing congestion, creating more efficient use of roadways, and promoting sustainable transportation modes always encouraged.

### 4.2 Estimation of LOS

LOS for an urban street road has been estimated by considering the flow speed of vehicle. The average travel speed is calculated by measuring the stretch length and time of vehicle in crossing the stretch. Table 2 demonstrates that the level of service L.O.S for urban streets in peak hours.

Table 2 displays average speeds for different vehicle kinds according to their design and application. The greatest average speed belongs to cars, a sign of their efficiency and quicker travel. Because of their size, weight, and frequent stops, larger vehicles—such as trucks and buses—move at slower rates. The operating situations of motorcycles, scooters, and three-wheelers in crowded urban areas result in slower
speeds for these vehicles. Because of the goods and traffic, light commercial trucks and trailers move at moderate speeds.

Table 2. Speed statistics of individual vehicles in peak hours

<table>
<thead>
<tr>
<th>S. no</th>
<th>Type of vehicle</th>
<th>Mean speed (Km/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Car</td>
<td>50.11</td>
</tr>
<tr>
<td>2</td>
<td>Truck</td>
<td>41.62</td>
</tr>
<tr>
<td>3</td>
<td>Bus</td>
<td>39.21</td>
</tr>
<tr>
<td>4</td>
<td>2-wheeler</td>
<td>36.46</td>
</tr>
<tr>
<td>5</td>
<td>3-wheeler</td>
<td>32.33</td>
</tr>
<tr>
<td>6</td>
<td>Trailer</td>
<td>35.78</td>
</tr>
<tr>
<td>7</td>
<td>LCV</td>
<td>36.23</td>
</tr>
</tbody>
</table>

Understanding the dynamic speeds of the vehicles shown in Table 2 is important for transport strategists, policy makers and road users This enables informed decisions about traffic management, infrastructure implementation and promotion of efficient and sustainable transport. Knowing the specific performance characteristics of vehicles, efforts can be directed towards smoother traffic, improving road safety, and improving overall mobility in cities and towns.

Table 3: LOS in peak and non-peak hours

<table>
<thead>
<tr>
<th>LOS</th>
<th>Peak hours</th>
<th>Non-peak hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>D</td>
<td></td>
<td>C</td>
</tr>
</tbody>
</table>

The Level of Service (LOS) during peak and off-peak hours appears in Table 3. A "D" LOS at peak hours denotes crowded conditions with slower moving traffic, less comfort, and longer travel times. The "C" LOS for non-peak hours denotes superior travel circumstances, including faster speeds, shorter travel times, and more comfortable travel. The effect of different traffic volumes on driving quality is seen in this table. The comparison of level of service (LOS) between peak and peak hours in Table 3 reveals the significant impact of different traffic volumes on driving quality Increased traffic volume during peak hours results in poorer LOS, characterized by crashes and slower travel speeds The results improve LOS, with faster travel times and greater comfort for drivers who understand these differences in The internal LOS is important for transport planners and planners to develop strategies to manage traffic, deal with congestion, and maximize the overall driving experience of the S when deployed authorities can work to promote development Ensuring LOS and efficient and enjoyable transportation for road users.
4.3 Vehicle composition

Fig. 4: Percentage of individual vehicle for peak hour

Fig. 4 shows that car constitute 5%, truck constitute 8%, bus constitute 7%, 2w constitute 11%, 3w constitute 7%, trailer constitute 33%, LCV constitute 14% and bicycle constitute 4% of traffic volume for peak hours. Fig. 5 shows that car constitute 2%, truck constitute 15%, bus constitute 9%, 2w constitute 10%, 3w constitute 7%, trailer constitute 35%, LCV constitute 10% and bicycle constitute 2% of traffic volume for non-peak hours. These statistics provide a detailed description of the distribution of vehicle types in peak and non-peak traffic areas. Understanding these parameters is important for traffic planners and policy makers to formulate effective route options that managed traffic, improved road systems and solved congestion problems at various times of the day.

Fig. 5: Percentage of individual vehicle for non-peak hour

According to the pie graph in Fig. 5, trailers make up 35% of all traffic during non-peak hours, dominating the traffic mix. Light commercial vehicles and buses make
up a moderate portion, while trucks and two-wheelers account for 15% and 12% respectively. Bicycles have the least impact, whereas vehicles and three-wheelers are less common. Overall, the pie graph in Figure 5 shows the pattern of off-peak traffic patterns, revealing the dominance of passenger cars, followed by light commercial vehicles, a mixture of buses, trucks, and bicycles. Bicycles are rare, while cars and three-wheelers are rare in the traffic mix. Understanding these transport dynamics is important for transport planners to design strategies for better traffic management, infrastructure development and promotion of sustainable transport modes.

5 Conclusion

A comprehensive range of automobiles often encountered in Jaipur, India, were included in the field research. During both peak and non-peak hours, the PCU readings for different types of vehicles are calculated. The velocity of vehicles has a notable influence on the capacity of roadways, even when traffic numbers are modest. Increasing the width of the road leads to a corresponding increase in the Passenger Car Unit (PCU) of a certain vehicle. Due to the increased flexibility offered by a broader thoroughfare, it is more advantageous to traverse by vehicle.

a. Vehicle velocity significantly impacts roadway capacity, even with minimal traffic. Wider roads increase PCU of vehicles. Vehicles traverse more easily due to broader thoroughfares. Speed gain depends on vehicle size and acceleration rate.


References


