

Evidence-Based Traffic Operations Optimisation and Multicriteria Engineering Design of an Urban Road Junction: Capacity, Safety, Accessibility and Sustainable Mobility at Narsapur X Road, Hyderabad, India

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Abstract: This study evaluates traffic operations at the Narsapur X Road junction, which serves movements from Shobana Theatre, KPHB, Old Airport Road, and the Medak–Hyderabad Road. Junction design aims to provide safe, comfortable, and efficient movement for all road users, including cars, buses, trucks, two-wheelers, and pedestrians. Under India’s heterogeneous, non-lane-based traffic conditions, vehicle volumes are commonly expressed in Passenger Car Units (PCU) per hour by converting each vehicle type to an equivalent passenger-car value. A classified traffic-volume survey was conducted from 8:00 a.m. to 6:00 p.m. using the manual indirect counting method. Hourly data were recorded for buses, cars, three-wheelers, two-wheelers, and light commercial vehicles, and peak-hour volumes were converted to PCU using the equivalency factors specified in IRC SP:41. Rotary capacity was assessed using the weaving-section method, considering weaving width, average entry width, weaving length, and the proportion of weaving traffic. The calculated weaving-section capacity was approximately 5,121 vehicles per hour, exceeding the recommended practical maximum of about 3,000 vehicles per hour for rotary intersections. The findings indicate that a conventional rotary is unlikely to perform satisfactorily in the long term. Signal control, geometric improvements, enhanced pedestrian facilities, and demand-management measures are therefore recommended.

Keywords: Traffic volume study, Passenger Car Unit, rotary intersection, weaving section, capacity analysis, heterogeneous traffic, junction improvement.

I. INTRODUCTION

Traffic Volume and PCU. Transportation systems play a central role in urban growth and development. Traffic volume

is a fundamental input for the planning, design, and operation of these systems, just as structural loads are essential to structural design. It is defined as the number of vehicles passing a specified road section during a given period. However, a simple vehicle count does not adequately represent traffic streams containing vehicles of different sizes and operating speeds. To provide a consistent basis for analysis, vehicle classes are therefore converted into equivalent passenger cars and expressed as Passenger Car Units (PCU) per hour.

Junction Context and Existing Conditions. The Narsapur X Road junction connects Shobana Theatre, KPHB, Balnagar, Old Airport Road, and the Medak–Hyderabad Road. It carries substantial traffic during both peak and off-peak periods, resulting in delays, long queues, and reduced levels of service. Inadequate traffic management and poor junction geometry further intensify congestion and increase journey times.

Traffic-Flow Characteristics. Traffic-flow analysis examines the interaction among road users, vehicles, roadway infrastructure, traffic signs, and control devices. Its principal parameters are speed, density, and flow. At low traffic densities, vehicles generally move under stable, uninterrupted conditions. As density increases, however, flow becomes unstable, and minor disturbances can trigger repeated stop-and-go movements. At the Narsapur X Road junction, these effects are compounded by diverse turning movements, heterogeneous traffic, and intensive roadside activity.

II. LITERATURE REVIEW

Understanding Traffic Congestion. Traffic congestion arises when demand for road space approaches or exceeds available capacity, leading to lower speeds, longer journey times, and queue formation. Previous studies have modelled regional congestion delay as a function of traffic volume and capacity,

quantified congestion through operational performance measures, and assessed the role of Intelligent Transportation Systems in incident management and road safety.

Congestion Assessment and Mitigation. Research on congestion quantification has established congestion as a measurable indicator of level of service. Related studies have examined congestion duration, incident-related delay, accident prediction, black-spot identification, and the application of Geographic Information Systems to map and analyse transport data. Collectively, this work indicates that effective congestion mitigation requires an integrated approach combining geometric improvements, traffic control, demand management, and safety-focused planning.

GIS integrates database operations, statistical analysis, and geographic visualization. It can combine roadway, traffic, land-use, and utility data as thematic layers. In the present study, GIS-related concepts are relevant for identifying geometric, traffic, roadside, and utility characteristics that influence junction performance.

The identified risk criteria can be grouped into four categories: geometric characteristics, traffic characteristics, land-use or roadside characteristics, and utility characteristics. Geometric characteristics include roadway width, carriageway width, stopping sight distance, number of curves, and pavement condition. Traffic characteristics include headway, volume-to-capacity ratio, speed, delay, and parking intensity. Land-use characteristics include access points and commercial, residential, semi-residential, and industrial areas along the link. Utility characteristics include overlap size and trip intensity.

III. STUDY AREA AND METHODOLOGY

The study area is the Shobana Theatre - Narsapur X Road section at Balnagar, which connects KPHB, Balnagar, Old Airport Road, and the Medak - Hyderabad Road. The junction carries a highly heterogeneous mixture of buses, cars, three-wheelers, two-wheelers, and light commercial vehicles. Traffic volume data were collected through a classified traffic volume count survey conducted between 8:00 AM and 6:00 PM.



Fig.1. Location of project

Two principal methods are available for traffic volume counting: manual counting and automatic counting. Manual counting may be direct, using tally sheets or mechanical/electronic counters, or indirect, using video recording followed by data extraction. Automatic counting uses contact-based systems, such as pneumatic tubes, or contactless systems, such as video image processing, infrared, radar, and microwave detectors.

In this study, the manual indirect method was adopted. Video-based observation permits repeated checking of vehicle classification, turning movements, and directional flows. It is particularly suitable for non-lane-based heterogeneous traffic, although it requires a suitable elevated camera position and subsequent manual transcription.



Fig.2. Traffic volume survey, Shobana Theatre to Narsapur 'X' Road

A. Traffic Volume Study

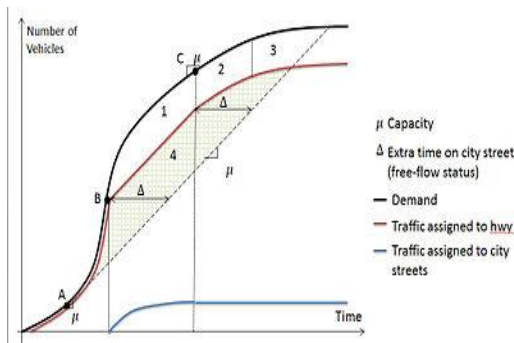
Traffic volume study determines the number, movement, and classification of roadway vehicles at a given location and time. It provides magnitude, composition, directional split, hourly

variation, and peak-period characteristics of traffic. These data are essential for junction design, signal timing, capacity estimation, and identification of improvement measures.



Fig.3. Traffic conjunction during 6 pm

The principal uses of traffic volume studies are to determine vehicle flows by class and direction, identify hourly and seasonal variations, estimate annual average daily traffic from short-period counts, evaluate demand on individual approaches, and support planning of new or improved facilities.



Graph-1. User equilibrium traffic model

B. Passenger Car Units

Because Indian urban roads carry mixed traffic, vehicle volumes were converted into PCU using the equivalency factors given in IRC SP:41. The PCU values used in this study are presented in Table I.

TABLE I. PCU VALUES USED IN THE STUDY

Vehicle type	PCU value
Car	1.0
Auto-rickshaw / three-wheeler	0.5
Motorcycle / two-wheeler	1.0
Tempo	1.0
Light commercial vehicle	1.5
Bus / truck	3.0

C. Rotary Capacity Method

A rotary intersection converts major crossing conflicts into merging, diverging, and weaving manoeuvres. Vehicles entering the rotary move in one direction around a central island and weave out toward their desired exit. The capacity of a rotary is governed mainly by the capacity of its weaving sections.

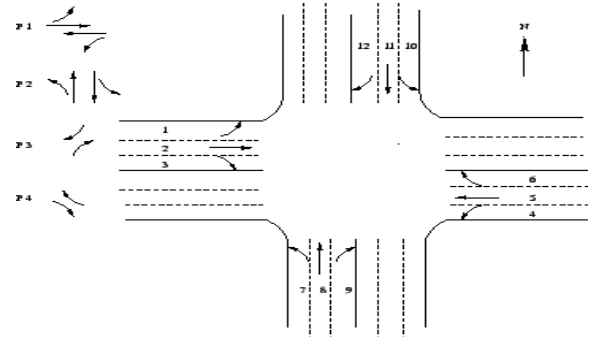
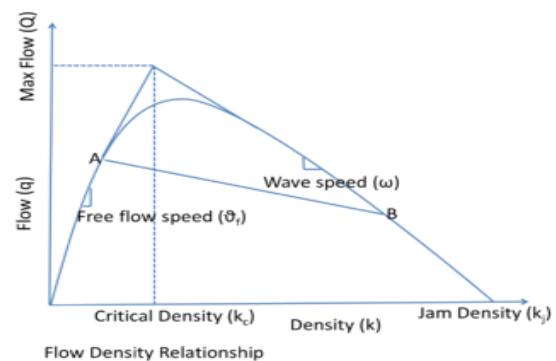


Fig. 4. Intersection Movements

The weaving-section capacity was calculated using the following empirical relationship:

$$Q_w = 280 w (1 + e/w)(1 - p/3) / (1 + w/l)$$

where Q_w is the weaving-section capacity in vehicles per hour, w is the width of the weaving section, e is the average entry width, l is the weaving length, and p is the proportion of weaving traffic. The parameters used were $w = 18$ m, $e = 14.5$ m, $l = 72$ m, $e/w = 0.80$, $w/l = 0.24$, and $p = 0.90$.



Graph-2. Flow density relationship

IV. RESULTS AND ANALYSIS

Traffic counts were recorded separately for the Shobana Theatre approach and the Narsapur X Road approach. The observed hourly traffic volumes show that two-wheelers form the largest vehicle group, followed by cars and three-wheelers. Traffic increases substantially during the morning and evening peak periods.



Fig.4 Traffic survey- Narsapur 'X' Road

A. Traffic Flow from Shobana Theatre, Balnagar

TABLE II. HOURLY CLASSIFIED TRAFFIC FLOW FROM SHOBANA THEATRE, BALNAGAR

Time	Bus	Car	3W	2W	LCV
8:00-9:00	650	2,900	1,000	4,700	388
9:00-10:00	630	2,736	970	4,446	376
10:00-11:00	610	2,577	956	4,270	359
11:00-12:00	500	2,068	876	3,758	332
2:00-3:00	397	1,437	675	3,169	286
3:00-4:00	420	1,705	737	3,893	343
4:00-5:00	573	3,145	897	4,576	378
5:00-6:00	726	3,198	938	5,226	414
Total	4,506	19,766	7,049	34,038	2,876

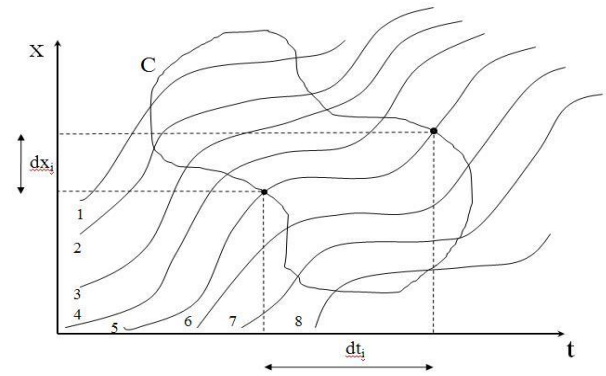
B. Traffic Flow from Narsapur X Road

TABLE III. HOURLY CLASSIFIED TRAFFIC FLOW FROM NARSAPUR X ROAD

Time	Bus	Car	3W	2W	LCV
8:00-9:00	707	3,203	1,033	5,300	436
9:00-10:00	817	3,122	1,056	4,761	411
10:00-11:00	756	2,810	981	4,715	398
11:00-12:00	615	2,189	921	4,162	381
2:00-3:00	497	1,751	719	3,961	309
3:00-4:00	539	1,902	778	4,112	401
4:00-5:00	774	3,974	921	4,991	462
5:00-6:00	752	3,843	1,031	5,756	614
Total	5,457	22,794	7,440	37,758	3,412

C. Peak-Hour Traffic and PCU Conversion

The peak-hour traffic was considered for capacity evaluation. For the Shobana Theatre approach, the recorded peak-hour composition was 630 buses, 1,893 cars, 3,025 three-wheelers, 9,700 two-wheelers, and 402 light commercial vehicles. For the Narsapur X Road approach, the corresponding composition was 930 buses, 2,737 cars, 4,075 three-wheelers, 10,472 two-wheelers, and 674 light commercial vehicles.



Graph-3. Time-speed flow

TABLE IV. PEAK-HOUR PCU CONVERSION

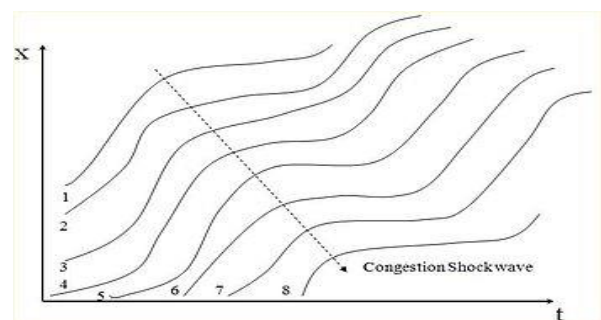
Approach	Bus	Car	3W	2W	LCV
Shobana Theatre - vehicles	630	1,893	3,025	9,700	402
Shobana Theatre - PCU	2,652	4,171	2,422	4,512	1,239
Narsapur X Road - vehicles	930	2,737	4,075	10,472	674
Narsapur X Road - PCU	4,029	5,853	2,230	4,794	389
Total vehicles	1,560	4,630	7,100	20,172	1,076
Total PCU	6,681	10,024	4,652	9,306	1,628

D. Rotary Weaving-Section Capacity

The rotary geometry was represented by an average entry width of 14.5 m, weaving-section width of 18 m, weaving length of 72 m, and weaving proportion of 0.90. Substituting these values in the empirical capacity formula gives:

$$Q_w = 280 \times 18 \times (1 + 0.80) \times (1 - 0.30) / (1 + 0.24) = 5121 \text{ vehicles/hour}$$

The calculated capacity of approximately 5,121 vehicles per hour exceeds the practical upper limit of about 3,000 vehicles per hour, generally considered suitable for rotary operation. This indicates that the existing weaving section is subjected to traffic demand beyond the desirable operating range for a conventional rotary.

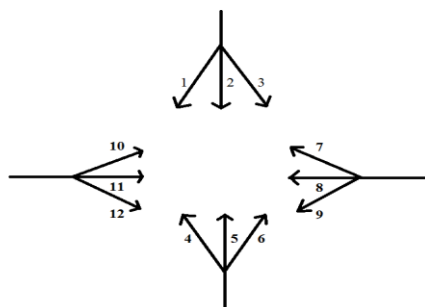


Graph-4. Congestion Shockwave

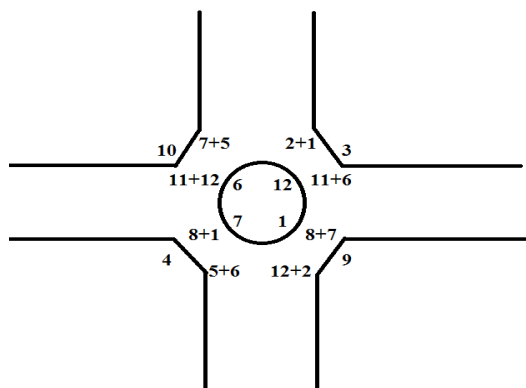
Under such conditions, weaving conflicts, queue formation, and delay are likely to increase, particularly during peak hours.

V. DISCUSSION

The traffic survey confirms that the junction carries a high proportion of two-wheelers and three-wheelers, which are highly maneuverable but contribute to non-lane-based movement. The high PCU loading from buses and light commercial vehicles further reduces the effective capacity of the weaving area. The calculated rotary capacity indicates that a rotary alone cannot efficiently accommodate the present and future traffic demand without complementary measures.



Inter-sectioning point at Narsapur 'X' Road



Rotary at Narsapur 'X' Road

The analysis also shows that traffic flow varies considerably by hour. The morning and evening periods produce the highest volumes, while midday volumes are comparatively lower. Therefore, junction control should be designed for peak-hour demand while considering off-peak operation and pedestrian movement.

VI. CONCLUSION AND RECOMMENDATIONS

A classified traffic volume study was conducted at the Narsapur X Road junction to evaluate traffic composition, peak-hour demand, and rotary capacity. The study found that heterogeneous traffic, high peak-hour volumes, and inadequate weaving capacity are the principal causes of congestion at the junction. The calculated weaving-section capacity of about 5,121 vehicles per hour is above the desirable rotary operating range, suggesting that the present rotary configuration is not fully suitable for the observed demand.

Based on the analysis, the following improvements are recommended:

1. Provide signalized control or adaptive signal control if peak-hour demand continues to exceed rotary capacity.
2. Improve channelization through properly designed traffic islands, lane markings, and separate turning lanes.
3. Widen or redesign the weaving section only after detailed geometric and land-availability analysis.
4. Provide marked pedestrian crossings, refuge islands, and pedestrian phases where pedestrian movement is significant.
5. Restrict roadside parking and encroachments near the junction to preserve effective carriageway width.
6. Conduct periodic traffic counts and update PCU-based capacity analysis to account for traffic growth.
7. Use intelligent transportation measures, such as coordinated signals and real-time traffic monitoring, to reduce recurrent congestion.

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