International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 13 Issue: 07 | Jul 2026 www.irjet.net p-ISSN: 2395-0072

DEVELOPMENT OF A GRADE SEPARATED INFRASTRUCTURE SYSTEM TO ACHIEVE SIGNAL – FREE OPERATIONS AT AN URBAN INTERSECTION

Anushka Umesh Shirsat[1], Dr. Tarapada Mandal[2]

[1]*Research Scholar, M.Tech, Transportation Engineering, GHRU Amravati, Maharashtra, India*
[2]*Assistant Professor, Department of Civil Engineering, GHRU Amravati, Maharashtra, India*

Abstract - *Rapid urbanization within western Hyderabad's IT corridor has generated severe structural bottlenecks at key nodes such as the IIIT Junction along the Gachibowli-Lingampally arterial road. Currently operating as a staggered, at-grade signalized intersection, the node experiences failing Levels of Service (LOS), excessive vehicle idling, and heavy delays due to intense peak-hour commuter rushes between major business districts including DLF Cyber City, the Financial District, and the Indian School of Business (ISB). This research paper presents a comprehensive feasibility and design study aimed at transforming the IIIT Junction into a completely signal-free multi-level corridor. Utilizing extensive field investigations including classified traffic volume counts, turning movement surveys, and geotechnical testing—the total daily traffic was quantified at over 2.27 lakh Passenger Car Units (PCUs), with peak-hour volumes reaching 14,266 PCU/hr. Six distinct alternative proposals combining underpasses, Level 1 flyovers, and Level 2 unidirectional flyovers were evaluated based on construction cost, land acquisition impact, and conflict reduction. The finalized scheme (Alternative VI) integrates a 6-lane divided underpass for Gachibowli-Lingampally through traffic, a 4-lane divided flyover for ISB-DLF movements, and dual 3-lane unidirectional flyovers for right-turn movements utilizing an optimized S-curve alignment. This configuration successfully eliminates 6 out of 8 major conflict points, secures 90.75% conflict-free traffic movement, and minimizes land acquisition to 24,199.80 sqm, establishing a sustainable, high-capacity urban mobility framework.*

Key Words: Grade-Separated Infrastructure, Signal-Free Operation, Flyover Design, Traffic Volume Count, Geometric Design, Level of Service

1. INTRODUCTION

Urban intersections act as the primary operational and structural bottlenecks within metropolitan road networks, directly dictating travel delay profiles, fuel consumption rates, emission indices, and macroscopic safety. As the administrative and commercial capital of Telangana and a major national Information Technology (IT) hub, Hyderabad has experienced exponential population and commercial growth, with the Hyderabad Metropolitan Area (HMA) accommodating over 7.7 million residents. The western IT corridor centered on the Gachibowli-Lingampally arterial road serves as a crucial lifeline connecting major institutional, residential, and corporate landmarks such as IIIT-Hyderabad, the Gachibowli Sports Complex, and corporate campuses of TCS, Wipro, Microsoft, and DLF.

The IIIT Junction is a complex, staggered four-armed intersection where the high-volume Gachibowli-Lingampally arterial road intersects heavy traffic streams from the ISB and DLF arms. Because conventional at-grade signalized control systems are completely overwhelmed by a heterogeneous mix of private cars, corporate shuttle buses, auto-rickshaws, and two-wheelers, the intersection suffers from severe peak-hour gridlock and operates at a failing Level of Service (LOS). To resolve these deficiencies, this research develops a multi-level grade-separated infrastructure system designed to achieve total signal-free operations, eliminate major vehicular conflict points, and future-proof the urban transport network.

1.1 Salient Features of the Project Corridor

The project corridor spans the Gachibowli-Lingampally and ISB-DLF axes. Existing right-of-way (ROW) widths are 65.00 m along the Gachibowli-Lingampally road (as per the development plan) and 35.5 m to 36.00 m along the ISB-DLF corridor. Topographically, Hyderabad sits on the Deccan Plateau at an average elevation of 550 m above mean sea level, with the IIIT Junction located near a structural ridge point flanked by rolling gradients ranging between 0.40% and 3.42%. Major utilities intersecting the corridor include overhead high-tension (H.T.) and low-tension (L.T.) electrical lines, a 32kV switching station near the junction, underground RCC utility ducts, and storm water drainage networks.

1.2 Objectives of the Study

- To analyze current traffic patterns, turning movements, and peak-hour volume bottlenecks at the IIIT Junction.
- To evaluate the inadequacy of existing at-grade infrastructure through rigorous lane capacity and Level of Service (LOS) analyses.
- To formulate, design, and compare multiple structural alternatives (including underpasses and multi-tier flyovers) in compliance with Indian Roads Congress (IRC) standards and other relevant codes.
- To minimize land acquisition impacts and construction-period disruptions while ensuring

International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 13 Issue: 07 | Jul 2026 www.irjet.net p-ISSN: 2395-0072

maximum conflict-free traffic movement and long-term economic feasibility.

Fig -1: Key map of IIIT Junction Corridor

2. SURVEY AND FIELD INVESTIGATIONS

Comprehensive field investigations, including reconnaissance surveys, topographical surveys via high-precision Total Stations and GPS, geotechnical explorations, and classified turning movement traffic surveys, were executed to establish a reliable baseline database.

2.1 Traffic Survey and Analysis Methodology

Classified Traffic Volume Counts (CTVC) and turning movement surveys were conducted continuously over 2-day periods across all intersection approaches. Vehicles were categorized into fast and slow modes, and raw traffic counts were converted into Passenger Car Units (PCUs) using standard conversion factors stipulated in IRC: 106-1990 for urban roads. The total daily traffic entering the IIIT Junction was recorded at 227,286 PCU/day (2.27 lakh PCU/day). Peak-hour traffic conditions occurred during the evening rush between 6:00 PM and 7:00 PM, registering a massive volume of 14,266 PCU/hr. Modal split analysis revealed that two-wheelers comprise 49.74%, passenger cars represent 39.61%, auto-rickshaws account for 8.11%, and buses/heavy vehicles constitute the remaining 2.54%.

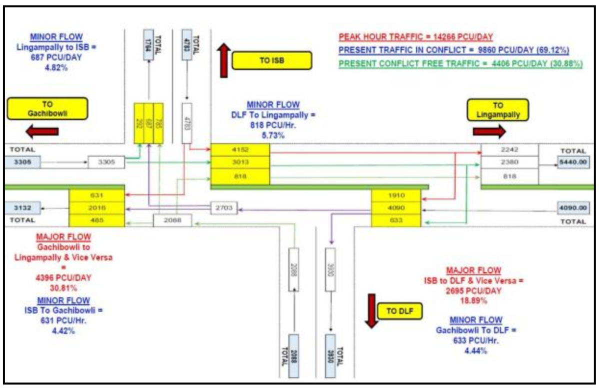

Fig -2: Peak Hour Traffic Flow Chart at Junction

Table -1: Summary of Direction wise traffic in PCU

Directional Movement	Average Daily Traffic (PCU/Day)	Peak Hour Traffic (PCU/Hr - Evening)
Lingampally ↔ Gachibowli (Major Flow)	75,173 (33.07%)	4,396
ISB ↔ DLF (Major Flow)	35,547 (15.64%)	2,695
Lingampally ↔ ISB Road	18,793 (8.27%)	687
DLF ↔ Lingampally	18,427 (8.11%)	818
ISB Road ↔ Gachibowli	9,877 (4.35%)	631
Gachibowli ↔ DLF	9,491 (4.18%)	633
Total Junction Volume	**227,286**	**14,266**

2.2 Justification for Grade Separation

According to IRC: 92-1985 (Clause 3.1), the implementation of a grade separator at an urban intersection is officially warranted when peak-hour traffic exceeds 10,000 PCU/hr. With the observed peak-hour volume reaching 14,266 PCU/hr alongside severe queuing and delay profiles, structural grade separation is conclusively justified. Furthermore, lane capacity analysis conducted under IRC:106-1990 indicates that existing at-grade configurations violate Level of Service (LOS) C thresholds, necessitating dedicated multi-tier structural interventions.

2.3 Geotechnical Investigations

Subsurface explorations comprising multiple boreholes across the junction revealed a multi-layered geotechnical profile consisting of 1.0 m to 2.0 m of top filling soil and murum, followed by soft disintegrated rock layers extending to depths between 6.0 m and 14.0 m, underlain by hard rock strata. This bearing stratum confirms that the site is fully suitable for open foundations or R.C.C. bored piles depending on structural loads.

3. ALTERNATIVE PROPOSALS & COMPARATIVE EVALUATION

To address the severe geometric and topographical constraints of the staggered junction while adhering to the statutory Revised Development Plan (RDP), six distinct structural alternatives were engineered and evaluated:

- Alternative I: Features a 6-lane divided underpass (470 m length) along the Gachibowli-Lingampally axis combined with a 4-lane divided flyover (745 m length) along the ISB-DLF axis. In plan view, these configurations cross perpendicularly at grade level with independent elevated approaches, achieving an 80.59% conflict-free traffic movement efficiency.

- Alternative II: Incorporates a similar structural pairing of a 6-lane divided underpass along the Gachibowli-Lingampally corridor and a 4-lane divided flyover along the ISB-DLF axis, but extends the overall structural length to 1,250.00 m with modified approach ramps to test localized spatial constraints, securing an 80.59% conflict-free rating.

- Alternative III: Introduces an intermediate multi-level configuration where a 3-lane underpass and a 3-lane flyover handle the main Gachibowli-Lingampally movements, paired with stacked viaduct elements for the intersecting arms. This layout spans a total structural length of 2,971.30 m and raises conflict-free traffic efficiency to 85.01%.

- Alternative IV: Expands upon Alternative III by refining the multi-level stacking layout, deploying a 3-lane underpass and 3-lane flyover for the main axis alongside a 4-lane flyover at Level 2 and a 2-lane turning flyover at Level 1 for ISB/DLF connectivity. This configuration increases the total length to 3,044.73 m and yields an 85.41% conflict-free efficiency.

- Alternative V: Represents a comprehensive multi-tiered scheme following a standard linear alignment layout. It resolves 6 out of 8 directional conflicts through a 6-lane divided underpass (Level 0), a 4-lane divided flyover (Level 1), and dual 3-lane unidirectional right-turn flyovers (Level 2), achieving 90.75% conflict-free movement across a total length of 3,367.90 m.

- Alternative VI: Builds upon the multi-tiered framework of Alternative V (achieving the same 90.75% conflict-free efficiency via a 6-lane underpass, 4-lane Level 1 flyover, and dual 3-lane Level 2 right-turn flyovers) but strategically optimizes the viaducts using a smooth S-curve alignment in plan view. This geometrical refinement compresses the total structural length to 3,305.20 m and successfully minimizes land acquisition impacts.

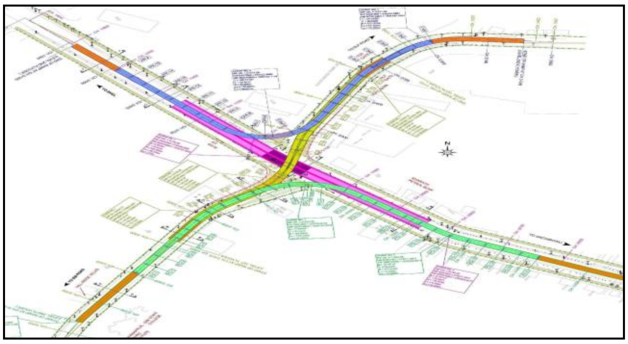

Fig -3: Plan Layout of Alternative VI S-Curve Alignment

Table -2: Summary of comparative evaluation parameters across all six alternative proposals

Alternative Option	Conflict-Free Traffic (%)	Total Length (m)	Land Acqui-sition (sqm)	Base Cost Excl. GST (INR Cr.)	Total Cost Incl. GST (INR Cr.)
Alternative I	80.59 %	1215	24,619.10	123.11	149.98
Alternative II	80.59 %	1250	22,054.12	125.78	152.87
Alternative III	85.01 %	2,971.30	24,619.10	187.62	228.04
Alternative IV	85.41 %	3,044.73	24,619.10	189.35	230.14
Alternative V	90.75 %	3,367.90	24,619.10	265.35	322.51
Alternative VI	**90.75 %**	**3,305.2**	**24,199.80**	**267.41**	**325.02**

3.1 Analytical Discussion: Performance Rationale of Alternative VI

A critical cost-benefit and spatial evaluation of the formulated options reveals distinct operational trade-offs. While Alternatives I and II require lower capital outlays, their structural capacity is severely restricted, achieving only 80.59% conflict-free traffic movement and leaving major turning bottlenecks unresolved under future traffic growth projections.

Stepping up to Alternatives III and IV, traffic efficiency improves to 85.01% and 85.41% respectively through intermediate stacked configurations. However, these options require significantly longer structural lengths (~2,971 m to ~3,044 m) and higher capital investments without fully capturing the comprehensive turning distributions required for the heavy right-turn movements between the ISB and Lingampally corridors, making them sub-optimal for long-term urban efficiency.

Conversely, Alternatives V and VI achieve the maximum operational efficiency of 90.75% conflict-free movement by successfully integrating multi-tiered interventions for all dominant turning streams, though they differ significantly in spatial footprint and constructability. Alternative V strictly adheres to a standard linear alignment layout, resulting in an extended structural length and a heavy land acquisition footprint of 24,619.10 sqm within a densely built urban corridor.

By introducing an optimized S-curve geometry for the Level 1 and Level 2 flyovers in plan view, Alternative VI strategically bypasses primary structural obstructions and property boundaries. This spatial adjustment reduces the required land acquisition footprint down to 24,199.80 sqm saving approximately 419.30 sqm of high-value urban real estate compared to Alternative V. Although Alternative VI carries a marginally higher initial capital requirement, the long-term economic savings derived from reduced land acquisition compensation, lower social displacement friction, and minimized utility relocation delays strongly outweigh the marginal cost variance. Consequently, Alternative VI delivers the most optimal balance between fiscal expenditure, spatial efficiency, and long-term corridor capacity.

4. CONCLUSIONS & RECOMMENDATIONS

Based on rigorous technical, economic, and spatial evaluations, Alternative VI is conclusively recommended as the optimal infrastructure intervention for the IIIT Junction upgrade.

4.1Selected Infrastructure Components (Alternative VI)

- Grade Separator (Underpass): 3+3 lane bidirectional configuration along the Gachibowli to Lingampally axis, spanning 520.00 meters with an 80.00 m closed box obligatory span
- Level 1 Flyover: 2+2 lane bidirectional configuration for ISB to DLF traffic, spanning 635.00 meters
- Level 2 Flyovers: Dual 3-lane unidirectional flyovers for ISB to Gachibowli (1,205.00 m) and DLF to Lingampally (945.00 m) movements, providing a minimum vertical clearance of 5.5 meters over crossing structures

4.2 Key Benefits

Alternative VI achieves 90.75% conflict-free traffic movement (clearing 6 out of 8 directional conflict points), ensures a design speed of 50 km/h across all tiers, substantially mitigates peak-hour tailbacks, reduces vehicular emissions through uninterrupted idling reduction, and minimizes land acquisition requirements to 24,199.80 sqm via its optimized S-curve geometry. The total project cost, inclusive of utility relocations and environmental integration, is estimated at Rs. 325.02 Crores, delivering a highly resilient, future-ready transportation network for western Hyderabad

ACKNOWLEDGEMENT

The author expresses sincere gratitude to the faculty and institution for their continuous guidance and support throughout this M. Tech thesis work. Special thanks are also extended to all individuals and authorities who assisted with the field traffic data collection and technical coordination.

REFERENCES

[1] Yu, X., & Prevedouros, P. D. (2013). Left-turn prohibition and partial grade separation for signalized intersections: Planning-level assessment. Journal of Transportation Engineering, 139(4), 393–401.

[2] Amanamba, E. C. (2016). Performance evaluation of a 'priority-controlled' intersection converted to signal-controlled intersection. International Journal of Civil, Environmental, Structural, Construction and Architectural Engineering, 10(7), 890–895.

[3] Boontaveeyuwat, S., & Wongwai, N. (2025). Scenario-based evaluation of phase optimization, coordinated signal control, and flyover alternative with integrated economic and environmental appraisal: A multi-intersection corridor study in Eastern Thailand. Transportation Research Interdisciplinary Perspectives, 34, 101751.

[4] Leisch, J. P. (1993). Grade-separated intersections. Transportation Research Record, 1385, 48–57.

[5] Harris, A. (2018). Engineering formality: Flyover and skywalk construction in Mumbai. International Journal of Urban and Regional Research, 42(2), 295–314.

[6] Salatoom, N., & Taneerananon, P. (2015). A study of the flyover-bridge intersection – Improved junction. Engineering Journal, 19(1), 1–13.

[7] Pachpande, T.M., Bansode, S. (2025). Impact Assessment of Grade Separator on Travel Time Delays: Case Study Pune. In: Kashyap, A., Goyal, R., Li, R.Y.M., Mahesh, G., Deepak, M.D. (eds) Advances in Construction Management. ICCRIP 2023. Lecture Notes in Civil Engineering, vol 601. Springer, Singapore.

[8] Prajapati, M., Advani, M., & Parida, P. (2018). Identifying the most suitable road crossing infrastructure based on estimated delay to pedestrians and vehicle users. Transportation Letters, 10(2), 113–127.