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Feasibility Study of an Alternative for Right Turn Movement at Angadippuram City Area

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***Abstract:** Traffic congestion has become a critical issue in many developing towns, and Angadippuram is of no exception. The growing number of vehicles, mixed traffic conditions, and limited road space have led to significant delays, especially at intersections where right-turn movements frequently disrupt the flow of through traffic. Conventional signalized intersections, though widely used, are often inefficient under these conditions due to multiple signal phases, long waiting times, and safety conflicts between turning and through movements. As a result, there is a pressing need to explore alternative intersection designs that can enhance operational efficiency while maintaining safety and minimizing costs. Increasing urbanization and growth in vehicular traffic have resulted in severe congestion and delay issues, particularly at intersections where right-turn movements create significant traffic conflicts. This study focuses on conducting a feasibility analysis for developing an alternative design for right-turn movement at the Angadippuram city area, which currently experiences high traffic delays and operational inefficiencies Initially geometrical survey was conducted to obtain measurements of the existing road layout and intersection geometry. such as road width, lane configuration, turning radius dimensions of the right-turn section. With this data a base map of the study area was created. which served as a reference for analysing the existing conditions and developing suitable design alternatives for the right-turn movement. Additionally, data were collected using the floating car method and camera recordings. The floating car method was employed to measure travel time, speed, and delay characteristics of vehicles during different time periods, providing realistic insights into prevailing traffic conditions. Camera recordings were used to capture vehicle counts, turning movements, and lane utilization patterns. The collected data were analysed to determine the peak hour flow and average delay. Based on these results, various alternative design options for right-turn movement were proposed, such as channelization, and geometric redesign.*

***Keywords:** Angadippuram; right-turn management; median U-turn; intersection delay; heterogeneous traffic; PCU; floating car method; channelization; geometric deficiency*

Urban intersections in fast-growing towns commonly experience recurrent congestion due to heterogeneous traffic composition, roadside friction, limited right-of-way, and inadequate intersection geometry. In the Angadippuram city area along the Perinthalmanna–Angadippuram corridor, direct right-turn movements at busy junctions were observed to interrupt the dominant through stream and generate queues, delays, and safety conflicts. This thesis evaluates the operational feasibility of an alternative right-turn management strategy in which direct right turns are restricted at critical junction locations and are served indirectly through designated U-turn facilities, supported by basic channelization and traffic control improvements. The study is based on field observations, a detailed geometrical survey, video-based traffic volume counts (7:00 AM to 7:00 PM over four consecutive days), conversion of classified volumes into Passenger Car Units (PCU), and a floating car (probe vehicle) survey to identify travel time and delay patterns along the corridor. The findings indicate that the existing carriageway widths and intersection layouts in the study area are insufficient to accommodate present demand under mixed traffic conditions, and that right-turn waiting behavior is a primary contributor to intersection blockage and variability in travel time. A U-turn-based alternative is shown to be a practical, low-to-moderate cost approach for reducing conflict points at the main junction and improving progression of through traffic, provided that suitable median opening locations, turning radii, lane discipline measures, signage/markings, and parking management are implemented. The thesis concludes with context-specific recommendations for staged implementation, safety considerations for pedestrians near high-activity land uses (temples, bus stops, and commercial areas), and scope for future performance evaluation using before–after studies.

***Keywords:** Angadippuram; right-turn management; median U-turn; intersection delay; heterogeneous traffic; PCU; floating car method; channelization; geometric deficiency*

I. INTRODUCTION

A. Background

Intersection performance is a key determinant of corridor mobility in urban and peri-urban road networks. When traffic demand increases faster than geometric capacity upgrades, congestion concentrates at junctions where multiple movements compete for limited space. This problem is intensified in many Indian towns by heterogeneous vehicle mixes (two-wheelers to heavy vehicles), limited lane discipline, frequent pedestrian crossings, on-street parking, bus stop dwell activity, and access movements associated with commercial frontage. Under such conditions, even a single disruptive turning stream can reduce effective capacity for all approaches and create unstable queues that propagate upstream. Traffic congestion at urban intersections has become a major operational and safety issue in many developing towns due to rapid motorization and constraints in right-of-way expansion. The Angadippuram city area represents a typical context where increasing traffic volume, heterogeneous traffic behavior, roadside commercial activity, pedestrian movement, and insufficient carriageway width collectively degrade intersection performance. A recurring operational difficulty reported and observed in this study is the right-turn movement at busy junctions. Right-turning vehicles often occupy the effective running lane while waiting for an acceptable gap in the conflicting stream; this interrupts the dominant through movement and triggers queue formation, stop-and-go driving, increased travel time variability, additional fuel consumption, and elevated crash exposure for both vehicles and pedestrians. The Perinthalmanna–Angadippuram corridor functions as an important connector in the regional road network, supporting both local access trips and inter-town movement toward Valanchery, Kottakkal, Kozhikode, and Malappuram. The traffic stream includes cars, buses, trucks, auto-rickshaws, and a high proportion of two-wheelers operating under mixed traffic conditions. In addition to through demand, the corridor experiences significant roadside friction due to commercial establishments, temples, bus stops, pedestrian crossings, informal vending, and on-street parking. At critical junction locations, right-turning vehicles commonly wait within the carriageway because of the absence of exclusive turning bays or channelization. This behavior reduces the effective width available to the through stream and produces localized bottlenecks that influence corridor-level travel time and reliability.

Accordingly, this thesis conducts a feasibility study to identify and assess a practical alternative for improving right-turn movement at the Angadippuram city area. The work evaluates existing geometric conditions, traffic characteristics, and delay patterns and then examines traffic management alternatives with an emphasis on restricting direct right turns and serving the movement indirectly through designated U-turn facilities. Supporting measures such as basic channelization, signage/markings, geometric refinements, and parking/pedestrian management are also considered. The expected contribution is a context-appropriate, economically feasible improvement strategy that can reduce congestion and conflict at the main junction while maintaining accessibility for local users.

B. Problem Statement

The operational problem addressed in this study is the recurring blockage and delay at junctions within the Angadippuram city area caused primarily by direct right-turn maneuvers under mixed traffic conditions and limited geometric capacity. In the absence of exclusive turning lanes and with frequent roadside friction, right-turning vehicles are forced to wait within the through lane, thereby reducing discharge flow for the major movement and creating unsafe interactions with pedestrians and two-wheelers. The research problem is to determine whether an alternative right-turn treatment—specifically, restricting direct right turns and accommodating the movement via controlled U-turns at appropriate downstream locations—can be feasible and beneficial for the study corridor given existing right-of-way constraints.

C. Need and Significance of the Study

Conventional capacity expansion (widening, grade separation, or major land acquisition) is often difficult to implement in built-up town centers due to cost, encroachments, and social impacts. Therefore, low-cost operational treatments that reorganize movements and reduce severe conflict points offer an important pathway to improve mobility and safety. Alternative intersection forms that relocate turning conflicts away from the primary junction—such as median U-turn and restricted crossing U-turn concepts—have been used internationally to reduce the number of crossing conflicts and simplify control. Informational guides and safety evaluations by the Federal Highway Administration describe how median U-turn and RCUT treatments can reduce conflict points and improve operations when applied with appropriate geometric design and access management.

D. Objectives of the Study

- To analyze the existing traffic and roadway operating conditions at the Angadippuram city area.
- To examine congestion mechanisms and delay attributable to direct right-turn movements at major junction locations.

- To conduct geometric and traffic surveys (including classified volume counts) at selected junctions and along the study corridor.
- To identify geometric deficiencies and roadside friction elements that reduce effective capacity and contribute to conflicts.
- To evaluate alternative right-turn management measures, with emphasis on restricting direct right turns and serving the movement through designated U-turn facilities.
- To develop context-appropriate recommendations for improving traffic flow and safety through feasible geometric and operational measures.

E. Scope, Assumptions, and Limitations

The scope of this thesis is limited to the operational and geometric assessment of right-turn-related congestion at key junctions within the Angadippuram city area along the Perinthalmanna–Angadippuram corridor. Field data were collected during the study period through daytime video counts (7:00 AM to 7:00 PM for four days) and probe-vehicle runs for travel time and delay. The analysis is intended to support feasibility-level recommendations and does not include detailed micro-simulation calibration, detailed pavement/structural design, land acquisition planning, or signal timing optimization beyond conceptual considerations. The feasibility of a U-turn alternative is discussed with respect to expected operational benefits, safety rationale (conflict reduction), and implementability under right-of-way constraints; a full before–after crash study would be required following implementation to quantify safety benefits.

F. Study Area Description

The study area includes the Angadippuram junction and the Pariyapuram Road junction located along the Perinthalmanna–Angadippuram route. These junctions experience sustained traffic demand across the day due to the combination of local access trips, public transport activity, and regional movements connecting surrounding towns. Land-use features such as temples, commercial centers, roadside shops, and bus stop activity introduce frequent pedestrian crossings and short-duration stopping behavior, which increases internal friction and reduces intersection discharge efficiency. In this context, the right-turn movement becomes particularly disruptive because it requires gap acceptance within a high and continuous through stream.

Field measurements indicate that several road sections in the study area do not satisfy desirable urban road cross-section provisions. In constrained segments, the available carriageway is approximately 6–8 m, which becomes a bottleneck during peak periods when buses, trucks, and two-wheelers simultaneously compete for space. The absence of exclusive turning lanes, limited shoulder/verge width, and inadequate channelization further reduce the effective width and increase side friction. These observations are consistent with the need for geometric and cross-section improvements outlined in the Indian Roads Congress guidance for geometric design of urban roads and streets.

II. LITERATURE REVIEW

A. Intersection Congestion Under Heterogeneous Traffic

Urban intersections operating under heterogeneous traffic frequently exhibit lower effective capacity than suggested by lane-based theory because vehicles do not maintain strict lateral discipline and because roadside activity introduces continuous friction. Turning movements can be disproportionately disruptive when they lack storage space, since turning vehicles occupy running lanes and trigger shockwaves that reduce saturation discharge for multiple movements. Therefore, many studies emphasize geometric channelization, access management, and movement reorganization as feasible approaches where widening is constrained.

B. Alternative Intersection Designs for Managing Turning Movements

Alternative intersection designs seek to improve safety and operations by reducing the number of high-severity crossing conflicts at the main intersection and by simplifying control (fewer signal phases or fewer competing priority movements). Among these, the median U-turn (MUT) concept relocates certain turning movements to downstream median openings, thereby reducing turning conflicts at the primary junction. The Federal Highway Administration’s informational guide on MUT intersections documents operational improvements through separation of turning and through movements and provides planning/design considerations for implementing such treatments.

Similarly, restricted crossing U-turn (RCUT) / reduced conflict intersection concepts prohibit certain minor-road crossing and left-turn movements at the main intersection and reroute them through downstream U-turn crossovers. Safety evaluations highlight that the reduction in conflict points is a central mechanism by which these treatments can reduce crash potential, in addition to offering smoother progression for the major-road through traffic under appropriate site conditions.

C. Travel Time and Delay Studies Using Probe Vehicles

Travel time and delay studies provide performance measures that are understandable for users and useful for identifying corridor bottlenecks. The floating car (probe vehicle) method is widely used for such studies: the driver attempts to travel in a representative manner within the stream while an observer records run times and delay occurrences between control points. Educational notes describing travel time and delay measurement on road sections discuss how the method can capture congestion delay and operational delay caused by turning movements, pedestrian interference, and roadside activities.

III. METHODOLOGY

This chapter describes the data collection program and analytical approach adopted to (i) diagnose right-turn-related congestion and (ii) evaluate the feasibility of a U-turn-based alternative. The methodology was designed to be implementable with field-oriented surveys and to produce corridor-relevant measures such as peak-hour volumes, vehicle composition, and travel time/delay patterns.

A. Preliminary (Reconnaissance) Survey

A reconnaissance visit was conducted to understand the nature of congestion, identify the dominant traffic movements, and shortlist junction locations where right-turn maneuvers were observed to interrupt through flow. Notes were recorded on queue formation, pedestrian crossing behavior, bus stopping locations, roadside parking/encroachments, and physical constraints that may influence the selection of feasible improvement alternatives.

B. Geometrical Survey

A detailed geometric survey was carried out at the selected junctions and along critical road sections to document the physical features that affect turning operations and effective capacity. The following measurements/observations were collected:

- Carriageway (paved) width and effective usable width
- Shoulder/verge availability and constraints
- Median presence and median-opening availability (where applicable)
- Junction layout, corner radii/turning space, and approach alignment
- Presence/absence of exclusive turning lanes or storage bays
- Locations of bus stops, pedestrian desire lines, parking/encroachments, and other friction elements

The survey indicated multiple geometric deficiencies, notably inadequate effective carriageway width, lack of turning storage space, and constrained turning paths for larger vehicles. These constraints informed the selection of improvement alternatives and the feasibility discussion in later chapters.

C. Traffic Volume Survey (Classified Counts)

Classified traffic volume data were collected using video recording at the study junctions from 7:00 AM to 7:00 PM for four consecutive days. Vehicles were classified by category (e.g., two-wheelers, cars, auto-rickshaws, buses, trucks) and, where feasible, were coded by turning movement (through/left/right) to understand movement-specific interference. The extracted counts were converted into Passenger Car Units (PCU) to obtain equivalent homogeneous demand measures for comparison across time periods and vehicle mixes. A summary of the observed volumes and peak-hour compositions should be reported in tabular form (Table 3.1) once the extracted counts are finalized.

Table: 1 Observation of vehicle flow at morning.

Trip	Direction	Journey time	Delay (Stop)	No of vehicle overtaking	No of vehicle over taken	Opposite vehicle count
1	Perinthalmanna to Valanchery	1.39	0	0	11	45
2	Valanchery to Perinthalmanna	1.38	0	1	2	45
3	Perinthalmanna to Valanchery	1.37	0	0	5	39
4	Valanchery to Perinthalmanna	1.49	0	0	2	50
5	Perinthalmanna to Valanchery	2.25	0	0	7	49
6	Valanchery to Perinthalmanna	1.39	0	0	5	68

Table: 2 Observation of vehicle flow at noon

Trip	Direction	Journey time	Delay stops	No of vehicle overtaking	No of vehicle over taken	Opposite vehicle count
1	Perinthalmanna to Valanchery	1.26	0	0	0	44
2	Valanchery to Perinthalmanna	1.42	0	0	5	38
3	Perinthalmanna to Valanchery	1.39	0	0	3	27
4	Valanchery to Perinthalmanna	1.46	0	1	5	34
5	Perinthalmanna to Valanchery	2.01	0	1	7	64
6	Valanchery to Perinthalmanna	1.45	0	0	4	44

Table: 3 Observation of vehicle flow at evening

Trip	Direction	Journey time	Delay stops	No of vehicle overtaking	No of vehicle over taken	Opposite vehicle count
1	Perinthalmanna to Valanchery	1.44	0	0	1	71
2	Valanchery to Perinthalmanna	2.28	0.09	0	0	68
3	Perinthalmanna to Valanchery	2.05	0.07	0	2	80
4	Valanchery to Perinthalmanna	1.34	0	0	3	63
5	Perinthalmanna to Valanchery	1.47	0	0	0	49
6	Valanchery to Perinthalmanna	1.41	0	0	0	43

Table: 4 Observation of vehicle flow at morning

Trip	Direction	Journey time	Delay stops	No of vehicle overtaking	No of vehicle over taken	Opposite vehicle count
1	Perinthalmanna to Malappuram	6057	0	1	26	331
2	Malappuram to Perinthalmanna	5.95	0	0	30	252
3	Perinthalmanna to Malappuram	6.57	0	0	31	389
4	Malappuram to Perinthalmanna	7.09	0	0	33	322
5	Perinthalmanna to Malappuram	6.57	0	0	20	346
6	Malappuram to Perinthalmanna	6.51	0	0	27	270

Table: 5 Observation of vehicle flow at noon

Trip	Direction	Journey time	Delay stops	No of vehicle overtaking	No of vehicle over taken	Opposite vehicle count
1	Perinthalmanna to Malappuram	6.35	0.05	0	21	296
2	Malappuram to Perinthalmanna	5.5	0	1	14	220
3	Perinthalmanna to Malappuram	7.07	0.17	0	26	282
4	Malappuram to Perinthalmanna	6.45	0.08	0	19	317
5	Perinthalmanna to Malappuram	6.13	0	1	26	265
6	Malappuram to Perinthalmanna	6.23	0	0	18	290

Table: 6 Observation of vehicle flow at evening

Trip	Direction	Journey time	Delay stops	No of vehicle overtaking	No of vehicle over taken	Opposite vehicle count
1	Perinthalmanna to Malappuram	5.58	0	1	33	324
2	Malappuram to Perinthalmanna	6.45	0	2	24	332
3	Perinthalmanna to Malappuram	6.41	0	3	32	252
4	Malappuram to Perinthalmanna	7.45	0.18	0	29	343
5	Perinthalmanna to Malappuram	6.05	0	0	17	353
6	Malappuram to Perinthalmanna	6.38	0	0	31	312

D. Travel Time and Delay Study (Floating Car / Probe Vehicle Method)

A floating car (probe vehicle) survey was conducted to estimate travel time, running speed, and delay characteristics along the study stretch during peak and off-peak periods. The test vehicle was driven to represent the general traffic stream while control-point times and delay causes were recorded (e.g., right-turn waiting, pedestrian interference near activity centers, bus stopping/merging, roadside parking friction). This approach follows standard travel time and delay study practices discussed in transportation engineering notes on measurement along a length of road.

Table: 7 Peak hour and peak hour flows

Date	Angadippuram junction		Pariyapuram junction	
	Peak hour flow in PCU	Peak hour	Peak hour flow in PCU	Peak hour
12.01.2026	5923	17.15 – 18.15	5016	17.15 – 18.15
13.01.2026	5680	08.45 – 09.45	5341	08.45 – 09.45
14.01.2026	5946	17.00 – 18.00	5622	17.00 – 18.00
15.01.2026	5493	09.00 – 10.00	5228	09.00 – 10.00

Table: 8 Delay- Perinthalmanna - Valanchery road (morning)

	Perinthalmanna to Valanchery (morning)	Valanchery to Perinthalmanna (morning)
Design speed	40-50 km/h	40-50 km/h
Distance traveled	0.8 km	0.8 km
Time free flow (distance travelled/design speed)	57.6 s	57.6 s
Actual time taken	1.28 min	1.24 min
Delay (actual time taken - free flow time)	38 s	28 s

Table: 9 Delay- Perinthalmanna - Malappuram road (morning)

	Perinthalmanna to Malappuram (morning)	Malappuram to Perinthalmanna (morning)
Design speed	80 km/h	80 km/h
Distance traveled	2.5 km	2.5 km
Time free flow (distance travelled/design speed)	2 min 27 s	2 min 27 s
Actual time taken	5.58 min	5.49 min
Delay (actual time taken - free flow time)	3 min 6 s	3 min 62 s

Table: 10 Delay- Perinthalmanna - Valanchery road (noon)

	Perinthalmanna to Valanchery (noon)	Valanchery to Perinthalmanna (noon)
Design speed	40-50 km/h	40-50 km/h
Distance traveled	0.8 km	0.8 km
Time free flow (distance travelled/design speed)	57.6 s	57.6 s
Actual time taken	0.32 min	1.17 min
Delay (actual time taken - free flow time)	36 sec	21 sec

Table: 11 Delay- Perinthalmanna - Malappuram road (noon)

	Perinthalmanna to Malappuram (noon)	Malappuram to Perinthalmanna (noon)
Design speed	80 km/h	80 km/h
Distance traveled	2.5 km	2.5 km
Time free flow (distance travelled/design speed)	2 min 27 s	2 min 27 s
Actual time taken	5.3 min	4.46 min
Delay (actual time taken - free flow time)	3 min 43 s	2 min 59 s

Table: 12 Delay- Perinthalmanna - Valanchery road (evening)

	Perinthalmanna to Valanchery (evening)	Valanchery to Perinthalmanna (evening)
Design speed	40-50 km/h	40-50 km/h
Distance traveled	0.8 km	0.8 km
Time free flow (distance travelled/design speed)	57.6 s	57.6 s
Actual time taken	1.57 min	1.59 min
Delay (actual time taken - free flow time)	1 min 1 s	1 min 3 s

Table: 6.15 Delay- Perinthalmanna – Malappuram road (evening)

	Perinthalmanna to Malappuram (evening)	Malappuram to Perinthalmanna (evening)
Design speed	80 km/h	80km/h
Distance traveled	2.5 km	2.5 km
Time free flow (distance travelled/design speed)	2 min 27 s	2 min 27 s
Actual time taken	5.07 min	5.66 min
Delay (actual time taken - free flow time)	3 min 2 s	4 min 17 s

From these data we can see a delay of about 6 minutes is experienced by the vehicles moving in the NH. As these data were collected during Fasting Month of Muslims, it would have largely a biased data. Due to time constraints, we couldn't do the Floating car experiment in a period which do not have any influence. Detailed study during a time period free from any local effects is needed to get a good data.

E. *Data Processing and Analysis*

The collected geometry, traffic volume, and probe-vehicle data were processed to derive performance indicators relevant to right-turn interference and corridor operation. The main analytical outputs include:

- Identification of peak hours and peak-period equivalent flows (PCU/h)
- Vehicle composition and dominance of slow/large vehicles affecting discharge behavior
- Qualitative and quantitative indicators of queue formation and blockage related to right-turn waiting
- Travel time, running time, and delay components from probe-vehicle runs (peak vs. off-peak)
- Diagnosis of high-friction points associated with parking, bus stops, and pedestrian crossings

The analysis helped in identifying the need for alternative traffic control measures at the junctions.

IV. RESULTS AND DISCUSSION

A. *Geometrical Survey Findings*

The geometric survey confirmed that the effective roadway cross-section at multiple locations is constrained relative to the observed traffic demand. Key deficiencies influencing right-turn operation and intersection performance are summarized below.

1) Approach widths near Angadippuram junction were observed to be as low as approximately 6–7 m on certain legs, creating a single effective running lane under mixed traffic conditions.
2) Some corridor segments were observed at approximately 8–9 m width, which becomes inadequate when buses/trucks interact with two-wheelers and roadside activity.
3) Absence of exclusive turning lanes/storage bays forces turning vehicles to wait within the running stream, directly reducing through capacity.
4) Limited shoulder/verge space and localized encroachments reduce the effective carriageway and limit opportunities for short-term stopping without disruption.

5) High pedestrian activity near temples, commercial establishments, and bus stops increases crossing conflicts and reduces discharge flow at junction influence areas.

B. Traffic Survey Results and Operational Diagnosis

The classified volume surveys and field observations indicate pronounced peak periods in the morning and evening with mixed traffic composition (two-wheelers, cars, auto-rickshaws, buses, and trucks). Even when total volumes are within what might appear manageable on a purely lane-based basis, the combination of constrained width and side friction leads to unstable flow at the junction influence area.

1) Right-turn interference: Right-turn movements were observed to generate the maximum localized delay because vehicles wait for acceptable gaps while occupying effective running space.
2) Queue formation: Queues formed repeatedly during peak periods, with spillback risk when bus stops/parking friction occurred near the junction.
3) Through-flow disruption: The through stream experienced repeated interruptions due to turning vehicles, pedestrian crossings, and merging maneuvers.
4) Heavy-vehicle effects: Buses and trucks faced constrained turning paths and required larger turning radii, increasing blockage duration when turning or maneuvering near the junction.
5) Travel time reliability: Probe-vehicle runs indicated noticeable travel time variability, with delays attributable to congestion, roadside parking, pedestrian movement, and turning conflicts.

C. Feasibility Assessment of U-Turn-Based Right-Turn Alternative

Based on the observed operational bottleneck mechanisms, this study examined a right-turn management strategy that restricts direct right turns at the most congested junction locations and serves the movement indirectly using designated U-turn facilities. The core rationale is to remove right-turn waiting from the immediate junction influence area so that the dominant through stream can discharge with fewer interruptions and fewer severe conflicts.

1) Feasibility Criteria Considered

- Geometric feasibility: availability of adequate roadway width/median space to accommodate U-turn maneuvers and provide basic channelization without creating new bottlenecks.
- Operational feasibility: ability to reduce right-turn blockage at the main junction and to maintain acceptable progression for the major through movement.
- Safety feasibility: potential reduction in severe crossing conflicts at the main junction by relocating turning conflicts to controlled locations, consistent with alternative intersection principles.
- Pedestrian feasibility: ability to provide safer, more predictable pedestrian crossing opportunities near high-activity land uses (temples, bus stops, commercial frontages).
- Implementation feasibility: extent of civil works required (markings, signs, minor median/opening works) relative to widening/grade separation.

2) Concept of Operation (How the Alternative Works)

Under the proposed concept, a vehicle intending to make a right turn at the congested junction is guided to proceed through the junction (or make a controlled left/through movement as applicable) and then complete the desired directional change at a designated U-turn location where turning space and merging control can be better managed. This reduces the tendency of vehicles to wait within the junction area and lowers the number of direct conflicts at the main intersection.

- Restrict direct right-turn movements at the identified critical junction approach(es) using regulatory signs and physical guidance (as feasible).
- Provide/identify a downstream U-turn location(s) with adequate turning radius and visibility.
- Channelize the approach to reduce weaving and to guide vehicles toward the U-turn path.
- Provide clear lane markings and advance direction signs so drivers can understand the indirect movement.
- Manage roadside friction near the main junction (parking control, bus stop management) to protect the operational gains.

3) Design and Management Considerations

To be effective in the Angadippuram context, the U-turn alternative should be supported by geometric and operational measures that match urban-road cross-section constraints and pedestrian activity. Key considerations include ensuring adequate turning space for buses/trucks, locating U-turns where approach sight distance is adequate, providing channelization/markings to reduce random lateral movement, and improving pedestrian facilities near activity generators. The Indian Roads Congress guidance on urban road geometric design provides relevant cross-section and geometric design considerations that should be consulted during detailed design.

V. CONCLUSIONS AND RECOMMENDATIONS

A. Conclusions

The field-based assessment indicates that congestion in the Angadippuram city area is strongly linked to constrained roadway geometry, significant roadside friction, and disruptive right-turn maneuvers at critical junction locations. The geometric survey found limited effective carriageway widths and inadequate turning/storage space, which increases the probability that right-turning vehicles will block the through stream. The traffic surveys and operational observations showed recurrent queue formation and travel time variability during peak periods, with right-turn waiting, bus stop activity, pedestrian crossings, and roadside parking acting as recurring delay sources. Based on the feasibility assessment, restricting direct right turns at the most critical junction approach(es) and accommodating the movement through designated U-turn facilities is a practical operational alternative under right-of-way constraints. The expected benefits include improved continuity of through flow, reduced junction blockage, and reduced severity of conflicts at the main intersection, provided that the treatment is supported by channelization, clear signs/markings, and management of roadside friction.

B. Recommendations

1) Implement basic channelization and geometric improvements at the immediate junction influence area to organize approach paths and reduce random lateral movements.
2) Restrict direct right-turn movements at the most congested approach locations where right-turn waiting blocks the through stream; provide clear regulatory signs and advance guidance.
3) Introduce designated U-turn facilities at suitable downstream locations with adequate turning space for heavy vehicles and safe merging/entry behavior.
4) Improve effective road width where feasible through removal/relocation of encroachments and by enforcing parking restrictions near junctions and bus stops.
5) Provide proper lane markings, stop lines, and directional arrows to communicate the indirect turning path to drivers.
6) Strengthen pedestrian management near temples and commercial frontages using defined crossing locations and warning signage; consider guardrails or channelized crossings where warranted.
7) During peak and festival seasons, apply traffic management support (manual regulation and temporary barriers) to maintain the intended movement pattern.
8) Conduct a staged implementation with monitoring; refine U-turn locations, signage, and enforcement based on observed user behavior after deployment.

C. Scope for Future Work

Future work may include (i) detailed selection and design of U-turn locations using turning path templates and sight-distance checks, (ii) micro-simulation or video-based trajectory analysis to quantify delay and conflict changes under alternative designs, and (iii) a structured before–after evaluation (travel time, queue length, and crash analysis) following any field implementation. Additional scope includes integrating bus stop relocation/indents and pedestrian facility design to reduce roadside friction near junctions.

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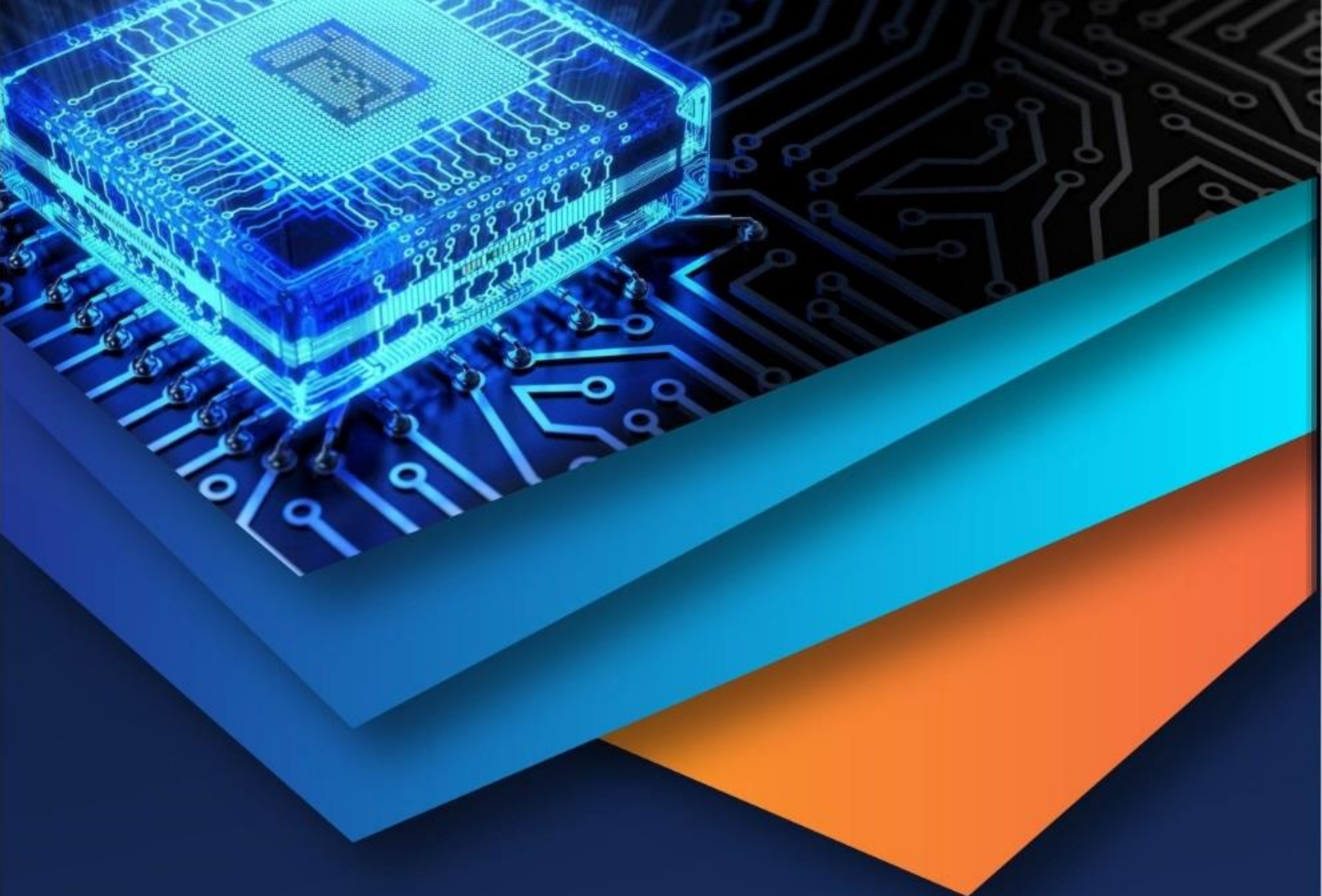

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