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Conflict-Free Intersection Design and PTV VISSIM Calibration for Mixed Traffic under MTHL Dispersal Influx: A Case Study of Airoli Junction

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Abstract-*This research evaluates the operational performance and geometric optimization of Airoli Junction under intense, heterogeneous, non-lane-based traffic conditions resulting from the Mumbai Trans Harbour Link (MTHL) dispersal influx. Primary traffic data, including Classified Turning Movement Counts (CTMC) and travel time surveys, were acquired during peak operating hours. A microscopic simulation model was constructed, calibrated, and validated in PTV VISSIM, adjusting Wiedemann-74 and Wiedemann-99 psychophysical car-following parameters to accurately reflect Indian driving behaviors such as lateral creeping and seepage. The validated model successfully achieved GEH values under 5.0 for over 85% of observed turning movements. Four distinct scenarios were simulated and comparatively evaluated using Measures of Effectiveness (MOEs): Scenario 1 (At-grade signalized junction), Scenario 2 (Roundabout with slip-lane), Scenario 3 (Existing Mumbai-Thane grade separator with signalized at-grade remainder), and Scenario 4 (Cloverleaf interchange). Results demonstrate that temporal signal optimization alone is inadequate, leaving the base node at Level of Service (LOS) F. In contrast, the Cloverleaf Interchange (Scenario 4) completely eliminates at-grade crossing conflicts, reducing average vehicle delay to 5.29 s/veh and upgrading intersection performance to LOS A, thereby providing a robust, scientifically backed framework for regional traffic dispersal.*

Key Words: PTV VISSIM Calibration, GEH Statistic, Heterogeneous Traffic, MTHL Dispersal, Cloverleaf Interchange, Level of Service.

1. INTRODUCTION

Rapid urbanization and industrial expansion across the Mumbai Metropolitan Region (MMR) have generated severe transportation demands on existing highway corridors. The recent commissioning of the Mumbai Trans Harbour Link (MTHL) successfully links Mumbai to the mainland, but abruptly discharges high-speed passenger and freight traffic into saturated arterial networks in Navi Mumbai, Airoli, and Thane. These mainland corridors accommodate heavy local mixed traffic and industrial freight from regional ports, converging at critical at-grade urban intersections.

The Airoli Junction serves as a primary dispersal node within this network, experiencing severe operational friction due to its four-arm configuration, 32 major conflict points, and a highly heterogeneous traffic mix comprising motorized two-wheelers (MTWs), auto-rickshaws, passenger cars, and multi-axle trucks. Operating under non-lane-based 'seepage' and aggressive gap-acceptance behaviors, the existing junction suffers from chronic gridlock, projecting an unacceptable Level of Service (LOS) F. Traditional deterministic capacity methods fail under these stochastic conditions. This research aims to develop a high-fidelity, calibrated PTV VISSIM micro-simulation model of Airoli Junction and systematically evaluate 'conflict-free' geometric and temporal alternatives to optimize regional traffic dispersal.

1.1 Problem Statement

The existing at-grade configuration contains numerous major conflict points. Inadequate turning radii, limited channelization, obstruction of free-left movements and static signal phasing intensify traffic friction. These conditions may neutralize regional travel-time benefits and push the junction towards LOS F. A calibrated micro-simulation framework is therefore required to reproduce non-lane-based traffic behaviour and compare conflict-minimized geometric alternatives before implementation.

1.2 Objectives

The study aims to collect and analyze classified turning movement data; develop a high-fidelity PTV VISSIM model; calibrate mixed-traffic driving behaviour; validate the model using GEH and travel-time measures; identify bottlenecks through delay, queue and LOS indicators; simulate alternative junction configurations; and recommend the most effective geometric solution based on Measures of Effectiveness (MOEs).

2. LITERATURE REVIEW

Heterogeneous Indian traffic is characterized by diverse vehicle dimensions, acceleration capabilities and aggressive gap-acceptance behaviour. Conventional PCU-based analytical methods are useful for aggregate capacity assessment but may not reproduce stochastic queue formation and lateral seepage. Microscopic simulation evaluates individual vehicle behaviour and permits alternative geometries to be tested prior to construction.
Default Wiedemann car-following parameters were developed primarily for lane-disciplined traffic. Previous studies indicate that standstill distance, headway, lateral

clearance and same-lane overtaking behaviour require calibration for Indian mixed traffic. The literature also identifies a research gap in applying calibrated models to rapid regional dispersal zones where high-speed passenger traffic interacts with heavy industrial freight. This study addresses that gap by jointly examining temporal control and spatial/geometric segregation.

3. METHODOLOGY

3.1 Study Area and Data Collection

Airoli Junction was selected based on high traffic volume, documented congestion, strategic MTHL dispersal function and complex non-lane-based traffic. A 24-hour videography survey captured classified traffic and turning movements. Counts were processed at 15-minute intervals. The Floating Car Method was used for travel-time observations, while video review supported estimation of queue lengths, headways and lateral clearances.

Table -1: Summary of observed traffic

Measure	Value
Total traffic	186,085 veh/day
Total traffic	185,936 PCU/day
Critical peak-hour volume	13,931 veh/h
Critical peak-hour flow	11,719 PCU/h

3.2 VISSIM Model Development

The baseline network was coded using links and connectors representing all approaches, exits and turning movements. Vehicle classes included motorized two-wheelers, auto-rickshaws, cars, LCVs, buses and trucks. Effective roadway width was modeled after considering side friction. Wide-link/no-lane-discipline coding and reduced lateral clearance were used to reproduce seepage and filtering.

Table -2: Selected calibrated driving-behaviour parameters

Parameter	W-99 Free-flow	W-74 Dense
Look ahead distance (max)	250 m	100 m
Standstill distance	1.00 m	0.50 m
CC1 gap time	0.50 s	—
Accepted deceleration (own)	-2.00 m/s²	-8.00 m/s²
Min. front/rear clearance	0.50 m	0.20 m
Min. lateral distance, standstill	0.20 m	0.20 m
Reaction time	1.20 s	1.00 s

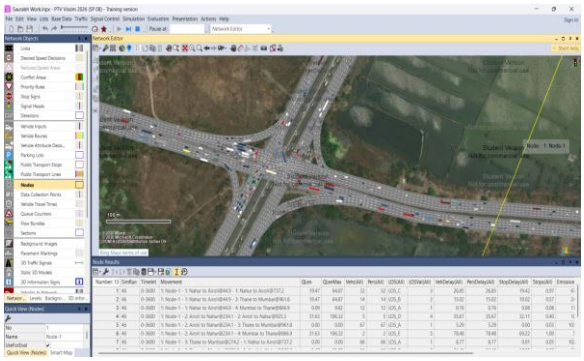

Fig -1: Representative study/model figure extracted from the thesis

4. MODEL CALIBRATION AND VALIDATION

Wiedemann-74 was used for Scenarios 1–3 because these alternatives contain dense, signalized and spatially constrained urban traffic. Wiedemann-99 was applied to the cloverleaf interchange to represent higher-speed free-flow merging and diverging. Calibration focused on close following, aggressive accepted deceleration and reduced lateral clearance.

Validation was undertaken using the GEH statistic for throughput and travel-time comparison for corridor-level performance. The model acceptance criterion was GEH below 5.0 for at least 85% of observed movements. All four validation arms reported GEH values well below 5.0.

Table -3: GEH validation of model throughput

Arm	Observed PCU/h	Simulated PCU/h	GEH	Status
Thane	1200	1250	1.43	Valid
Airoli	4325	4210	1.76	Valid
Mumbai	1850	1820	0.70	Valid
Nahur	1905	1805	2.32	Valid

Table -4: Travel-time validation

Corridor section	Observed (s)	Simulated (s)	Difference	Status
Nahur–Airoli	115	110	4.34%	Valid
Airoli–Nahur	122	120	2.53%	Valid
Mumbai–Thane	124	114	2.58%	Valid
Thane–Mumbai	120	110	3.50%	Valid

5. OPTIMIZATION SCENARIOS

Four scenarios were coded and evaluated with calibrated driving parameters. Scenario 1 retained an at-grade signalized junction and relied on temporal separation. Scenario 2 introduced a roundabout with dedicated slip lanes to reduce central-node friction. Scenario 3 used the existing Mumbai–Thane grade separator for primary through movements while controlling remaining movements at grade. Scenario 4 introduced a cloverleaf interchange to eliminate at-grade crossing conflicts and provide continuous movements through loop and directional ramps.

5.1 Evaluation Measures

Operational performance was assessed using average vehicular delay, average travel speed, maximum queue length and Level of Service. VISSIM node evaluation and queue-counter outputs were used to identify the most critical approaches and spatial bottlenecks. Feasibility was additionally considered in terms of Right-of-Way, structural requirements, utility relocation and implementation cost.

6. RESULTS AND DISCUSSION

The base configuration exhibited substantial friction at right-turn crossing zones and where free-left traffic was blocked by through queues. The comparison of alternatives showed that signal control alone cannot adequately address the conflict matrix of a heavily trafficked regional dispersal junction. Channelization and grade separation provide progressively stronger operational benefits because they physically segregate incompatible traffic streams.

Among the evaluated alternatives, Scenario 4 the cloverleaf interchange provided the highest operational efficiency. Its grade-separated configuration removes critical at-grade crossing movements and transforms the predominant interaction into lower-risk merging and diverging operations. The resulting flow is smoother, with reduced vehicular interaction and improved junction performance. The result supports a combined geometric and operational approach rather than isolated signal-timing optimization.

7. CONCLUSIONS

The study developed and validated a PTV VISSIM micro-simulation model for Airoli Junction under heterogeneous, non-lane-based traffic conditions. Site-specific traffic volumes, turning movements and travel-time observations were used to reproduce prevailing traffic behaviour. Calibration of close-following and lateral seepage parameters enabled the model to represent dense Indian traffic, while GEH and travel-time checks confirmed acceptable validation.

Comparative assessment of four junction configurations established that comprehensive geometric intervention is necessary at this high-conflict dispersal node. The cloverleaf interchange is recommended as the preferred long-term alternative because it spatially segregates major traffic streams and eliminates critical at-grade crossing conflicts. Implementation should be subject to detailed engineering design, Right-of-Way and land assessment, structural feasibility, drainage, utility relocation, environmental assessment and economic evaluation.

Future research should incorporate projected traffic growth and dynamic origin–destination matrices for a 10–20 year horizon, public transport operations, pedestrian and non-motorized traffic, and environmental indicators such as fuel consumption and vehicular emissions.

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