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Intersection Performance in the Kathmandu Valley: A Systematic Review of Capacity, Level of Service, and Intervention Effectiveness

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Abstract

Urban intersections in rapidly motorising South Asian cities routinely operate beyond design capacity, yet the severity of failure and the comparative effectiveness of remedial interventions remain poorly characterised for heterogeneous, motorcycle-dominated traffic streams. This systematic review synthesises quantitative findings from 32 peer-reviewed intersection performance studies and six contextual studies examining capacity, level of service (LOS), and intervention effectiveness across 25 intersections in the Kathmandu Valley, Nepal, spanning 2014–2026. Five principal findings emerge. LOS F prevails at most of studied signalised intersections while DOS among LOS F intersections ranges from approximately 1.3 to 17.37. The absence of a unified motorcycle PCU standard produces a 22–48% divergence in estimated traffic demand, shifting LOS classifications by up to two tiers from the same field data; a parallel inconsistency in simulation calibration — with VISSIM and SIDRA parameters routinely applied without reference to prior site-specific derivations — compounds cross-study incomparability. Intervention effectiveness is strongly DOS-stratified: signal optimisation yields meaningful delay reduction only below DOS ~2.5; grade separation achieves LOS C with 87–90% delay reductions in all modelled flyover scenarios; and a 50% modal shift from motorcycles to public transport produces a 74% corridor delay reduction without infrastructure investment. Signal coordination is spacing-dependent: beneficial at 180 m (Shital Nivas–Kanti, −75% and −50% delay reductions) and counterproductive at 1,130 m (Satdobato–Gwarko, +4.7% network queue increase). Across all 32 studies, only one provides genuine before-after field measurement of a recommended intervention; five independent studies at New Baneshwor remain unvalidated following implementation, confirming that the primary barrier to performance improvement is institutional rather than technical. These findings collectively identify PCU and calibration parameter standardisation, simulation-to-field validation protocols, and cumulative knowledge production as the three priorities for advancing intersection management in the Valley.

Keywords: Level of service; intersection capacity; signal optimisation; degree of saturation; PCU; heterogeneous traffic; Kathmandu Valley; SIDRA; VISSIM; signal coordination; systematic review

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1. Introduction

Rapid motorization in the developing world has repeatedly outpaced the capacity of urban infrastructure and institutions to manage vehicular growth. In Kathmandu, Nepal's capital and dominant economic centre, centralised policies on employment, education, and healthcare have driven sustained rural-to-urban migration, compounding pressure on a road network not designed for its current demand [1]. Cumulative vehicle registrations in Nepal surpassed 5.5 million by mid-2024, up from approximately 2 million in 2014/15, with motorcycles accounting for more than 4.47 million of that total [2]. This growth represents not merely a quantitative shift but a structural mismatch between the pace of motorization and the institutional capacity to regulate it. Intersections are the primary locus of the resulting congestion: as nodes where conflicting vehicle streams, pedestrians, and informal transport modes compete for space, they disproportionately govern network-level performance [3]. When demand approaches or exceeds capacity, delay, queue spillback, and network-wide travel time deterioration compound rapidly [4]. These dynamics are further amplified in Kathmandu by heterogeneous, non-lane-based traffic conditions in which motorcycles dominate vehicle composition and lane discipline is inconsistently observed, rendering standard western analytical frameworks inadequate for local operating conditions [3].

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The inadequacy of those frameworks is not merely a modelling inconvenience but carries direct policy consequences. Nepal's own road standard, NRS 2070, designates a minimum design level of service (LOS) of B, corresponding to approximately 45% of capacity under mixed traffic conditions, yet the research record documents a wholesale departure from this benchmark [5], [6], [7]. Despite substantial accumulation of technical knowledge on saturation flows, passenger car unit (PCU) factors, and locally calibrated intervention recommendations, these findings have not translated into systematic implementation of improved signal timings, coordinated intersection management, or measurable reductions in vehicle delay [8]. Studies conducted at the same locations proceed with limited acknowledgement of prior work, and peer-reviewed recommendations remain largely unimplemented. Whether this gap between knowledge production and operational application is tractable requires systematic synthesis across the available literature — which the present review provides.

This systematic review consolidates findings from 32 peer-reviewed intersection performance studies in the Kathmandu Valley, supplemented by six contextual studies cited for methodological and corridor-level context. Its objectives are to: (a) catalogue published assessments of intersection capacity, LOS, and signal optimisation; (b) critically evaluate methodological diversity across PCU standards, simulation tools, and calibration approaches; (c) synthesise quantitative performance findings across intersections, intervention types, and time periods; (d) expose the consequences of PCU non-standardisation in high-motorcycle-share environments; and (e) identify research gaps and propose a standardised methodological framework for future work. The full study-level details supporting each finding are documented in Table A1 of the Appendix.

2. Methods

2.1 Search Strategy

The literature search was conducted in two stages. First, structured keyword queries in Google Scholar employed combinations including: ("signalized intersection" OR "intersection") AND "level of service" AND ("Kathmandu" OR "Nepal"); "degree of saturation" AND "PCU" AND "Nepal"; and ("SIDRA" OR "VISSIM") AND "intersection" AND ("Nepal" OR "Kathmandu"). Second, backward citation tracking was applied to all identified studies, and forward citation searches were conducted on the most frequently cited anchor papers. From an initial pool of 890 records, 91 were identified as potentially relevant following title and abstract screening.

2.2 Inclusion Criteria, and Data Extraction Strategy

A full-text review retained 32 studies meeting the inclusion criteria. Studies were included if they: (a) examined at least one named intersection within the Kathmandu Valley; (b) reported at least one quantitative performance metric — traffic volume, PCU flow, saturation flow, delay, DOS, LOS, queue length, headway, or travel time; (c) employed a recognised analytical method (HCM, SIDRA Intersection, VISSIM, Indo-HCM, or field measurement); and (d) were published in a peer-reviewed journal, conference proceeding, or institutional repository. Studies were excluded if they reported only qualitative assessments, could not be geolocated to a named intersection, focused solely on pedestrian behaviour without intersection-level metrics, or constituted unpublished grey literature. Six additional studies examining highway sections, non-valley sites, or road segments without intersection-level performance metrics were retained in the reference list for methodological or contextual citation but excluded from the reviewed count.

For each included study, a standardised set of variables was extracted: intersection name and district; data collection year and season; software and version; PCU standard and motorcycle PCU value; existing and post-intervention delay, DOS, and LOS; calibration and validation methods and thresholds; vehicle composition; a COVID-19 flag where applicable; and the presence or absence of before-after field validation. Substantial methodological heterogeneity across the dataset — arising from incompatible PCU standards, varied calibration practices, and inconsistent data collection periods — precluded formal meta-analysis. Findings are therefore synthesised through a qualitative narrative approach, organised by intersection cluster and intervention type. The complete extracted dataset is provided in Table A1 of the Appendix, with software and calibration details in Tables A2 and A3.

3. Results

3.1 Study Characteristics and Overview

The 32 included studies were published between 2014 and 2026. Data collection years are explicitly stated in 16 of these studies, spanning 2016 to 2024, with a pronounced concentration in 2022 to 2024; the remaining 16 studies do not report survey timing — a gap that itself constitutes a methodological limitation. Examined locations span all three valley districts, covering 25 distinct named intersections. In Kathmandu district, studied sites include Narayan Gopal Chowk/Maharajgunj, New Baneshwor, Keshar Mahal, Khanibhivag, Narayanhiti, Thapathali, Durbar Marg, Padmodaya Chowk, Singhadurbar, Jay Nepal, New Plaza, Pepsicola, Shital Nivas Chowk, Kanti Children's Hospital, and Jorpati. In Lalitpur district, sites include Satdobato, Gwarko, Ekantakuna, and Jawalakhel Roundabout. In Bhaktapur district, covered sites include Gatthaghar, Naya Thimi, and Kamalbinayak Chowk.

Among the 25 locations, the degree of research attention varies considerably. New Baneshwor is the most extensively studied, with five independent studies spanning 2017 to 2024, while intersections such as Pepsicola, Padmodaya Chowk, and Jorpati appear in only a single study each. Keshar Mahal is the only location documented across the transition from an unsignalised baseline to coordinated signalised operation [6], [9], [10], making it the sole site where before-and-after institutional change can be partially reconstructed from independent sequential studies.

3.2 Methodological Characteristics

3.2.1. Software, Calibration, and PCU Practices

SIDRA Intersection was the primary analytical tool in 13 of the 32 studies and VISSIM in 11; the remainder applied field-based regression, HCM manual methods, or Indo-HCM worksheets. Among SIDRA-based studies, seven explicitly report version 8.0, one reports version 8.1, and one study [1] uses version 9.1; four do not report the version used. Among VISSIM-based studies, three report explicit versions (VISSIM 10, 2022, 2023 SP06); eight do not specify the version. This pattern of incomplete version reporting is consequential: SIDRA versions 8.0 and 9.1 differ in default parameters, and version-unspecified results cannot be fully replicated or compared.

Three distinct PCU standards appear in the reviewed literature. NRS 2070 assigns a motorcycle PCU of 0.50 and is the most frequently applied (12 of 32 studies). KVITSP assigns 0.25, reflecting observed interstitial gap-filling behaviour specific to Kathmandu traffic, and is applied in seven studies. Indo-HCM assigns 0.40 and appears in three studies. Dynamic, locally derived PCU models are employed in three additional studies, and eight studies do not specify a standard. These choices are not methodologically neutral. At the 52–78% motorcycle shares observed across the dataset, the difference between PCU values of 0.25 and 0.50 produces a 22–48% divergence in estimated total demand, shifting LOS classifications by up to two full tiers from identical field data. This consequence is most directly demonstrated at New Baneshwor by Paudel et al. [7], where NRS 2070 and Indo-HCM frameworks applied to the same field observations yielded a peak DOS 23% higher under NRS 2070 than under Indo-HCM (11.341 versus 9.203), both nevertheless yielding LOS F.

The most rigorously field-derived PCU relationship in the dataset is Shrestha & Marsini [3] regression model at Koteshwor, Tinkune, and Jadibuti, which yielded two-wheeler PCU = 0.25 and saturation flow $S = 525.88W$ ($R^2 = 0.956$). S. Pokhrel & Shrestha [11] replicated this approach at New Baneshwor, Maharajgunj, and Jawalakhel Rotary, obtaining two-wheeler PCU = 0.243 at four-legged signalised intersections and 0.312 at the rotary, with $S = 551.1W + 1{,}975$ PCU/hr ($R^2 = 0.707$). The higher rotary PCU estimate suggests that motorcycle space-filling efficiency declines under roundabout queuing conditions. Calibration quality varied markedly: S. Tiwari et al. [1], using field-measured saturation flows of 1,203–1,937 veh/hr/lane at Satdobato, stands in direct methodological contrast to Dhakal et al. [12], who adopted the program default of 1,900 veh/hr/lane without field measurement — producing a ~7% difference in estimated delay attributable entirely to calibration choice. Among VISSIM-based studies, calibration approaches ranged from volume-based GEH comparisons to the bi-level genetic algorithm framework of Manandhar & Pradhananga [13], which achieved mean absolute percentage error below 7% for volume and below 15% for queue length, with GEH below 5 throughout, making it the most rigorous VISSIM calibration in the dataset.

Two anomalies warrant particular attention. Thakuri et al. [14], calibrating VISSIM under COVID-19 conditions at Ekantakuna, recorded GEH exceeding 5 for motorcycles and a calibrated standstill distance of 0.15 m — substantially below the 0.30 m established by Acharya & Marsani [15] under normal demand at the same intersection — without discussing this divergence. S. Kafle & Shrestha [16] reported a validation R^2 of 1.0 at Ekantakuna, a statistically implausible result indicating overfitting to a small validation sample, compounded by the direct transfer of Acharya & Marsani [15] behavioural parameters without site-specific recalibration. These cases confirm that VISSIM behavioural parameters are not stable across demand regimes and must not be transferred between studies without independent re-validation.

Table 1. Existing-condition performance metrics across reviewed intersections

Intersection	**Type**	**Year**	**Software**	**PCU Std**	**Avg Delay (sec/veh)**	**DOS**	**LOS**	**Study**
Satdobato	4-leg Sig.	2022	SIDRA 9.1	KVITSP	226.5	~1.97	F	(S. Tiwari et al., 2024)[1]
Satdobato	4-leg Sig.	~2022	SIDRA 8.0	N.S.	243 (demand-wtd.)	~1.6	F	(Dhakal et al., 2023)[12]
Satdobato	4-leg Sig.	2024	SIDRA 8.1	KVITSP	238.2	1.320	F	(Amgain, Shrestha, et al., 2025)[17]
New Baneshwor	4-leg Sig.	2023	HCM manual	NRS + Indo-HCM	n.r.	11.341 (NRS)	F	(Paudel et al., 2024)[7]
Gwarko	4-leg Sig.	2022	SIDRA 9.1	KVITSP	201.1	n.r.	F	(S. Tiwari et al., 2024) [1]
Gwarko	4-leg Sig.	2020	Indo-HCM	Indo-HCM	7,576 (worst approach)	17.37 (worst)	F	(Shrestha et al., 2024)[18]
Jawalakhel RBT	Roundabout	2022	SIDRA 8.0	KVITSP	750.3 (AM avg.)	4.478 (Lagankhel)	F	(Karkee et al., 2023)[19]
Narayan Gopal Chowk	4-leg Sig.	2024	SIDRA 8.0	NRS	216	1.394 (worst)	F	(S. R. Kafle et al., 2025)[20]
Thapathali	4-leg Sig.	2022	SIDRA	KVITSP	99.6 (wd) / 35.1 (we)	2.215 / 1.353	F/D	(Maharjan & Marsani, 2023)[21]
Padmodaya Chowk	T-Sig.	2024	SIDRA 8	Indo-HCM	49.3	n.r.	D	(Amgain, Silwal, Karmacharya, et al., 2025)[22]
Pepsicola	T-Unsig.	2023	VISSIM 2023	N.S.	18.62	n.r.	C	(Budhathoki & Shrestha, 2024)[23]
Shital Nivas Chowk	3-leg Sig.	2022	SIDRA 8	N.S.	106.0	n.r.	F	(H. Tiwari et al., 2023)[24]
Kanti Children's Hosp.	3-leg Sig.	2022	SIDRA 8	N.S.	43.1	n.r.	D	(H. Tiwari et al., 2023) [24]
Jorpati	3-leg Unsig.	~2024	SIDRA	KVITSP	22.2 avg; 97.2 worst	0.65 (worst)	C	(Sharma et al., 2025)[25]
Jay Nepal	3-leg Sig.	n.r.	SIDRA 8.0	N.S.	119.3 (AM) / 92.3 (PM)	2.385 / 1.783	F	(A. Pokhrel et al., 2023)[26]
New Plaza	3-leg Sig.	n.r.	SIDRA 8.0	NRS 2070	251[a]	n.r.	F	(Amgain, Silwal, Shrestha, et al., 2025)[27]

Note: N.S. = not stated; n.r. = not reported; wd = weekday; we = weekend; RBT = roundabout; T-Sig. = T-junction signalised; T-Unsig. = T-junction unsignalised. Narayan Gopal Chowk and Maharajgunj refer to the same intersection. [a]*Amgain, Silwal, Shrestha, et al. (2025)* [27]*: source body text reports 301.9 sec/veh; Table 8 of that paper reports 251 sec/veh; the table figure is used here*

3.4. The Satdobato–Gwarko Corridor

The Satdobato–Gwarko corridor on Lalitpur's Ring Road is the most densely studied sub-network in the dataset, with four independent studies of Satdobato and two of Gwarko spanning 2020 to 2024. At an inter-intersection spacing of 1,130 m, it is the only location where an explicit network-level interaction test has been conducted, making it the sole empirical basis for assessing coordination feasibility at mid-range spacings. Table 2 presents the Satdobato longitudinal record

Table 2. Longitudinal performance record: Satdobato intersection, 2020–2024

Study	**Year**	**Software**	**PCU Std**	**Avg Delay (sec/veh)**	**DOS**	**Best Improvement**	**LOS After**
(Prajapati et al., 2022)[28]	Sep 2020	VISSIM	N.S.	213,986 (corridor total stopped delay)[a]	2.22 V/C[b]	50% MC→bus: −74% corridor stopped delay	n/a
(Dhakal et al., 2023)[12]	~2022	SIDRA 8.0	N.S.	243 (demand-wtd.)	~1.6	Left turn signal control + opt. cycle: −26%	F
(S. Tiwari et al., 2024)[1]	Aug 2022	SIDRA 9.1	KVITSP	226.5	~1.97	Lead RT + 4-phase 100 s cycle: −77%	D
(Amgain, Shrestha, et al., 2025)[17]	Jun 2024	SIDRA 8.1	KVITSP	238.2	1.320	Flyover (Mahalaxmisthan–Gwarko): −87%	C

Note: N.S. = not stated. [a]*Prajapati et al. (2022)* [28]*: corridor-level total stopped delay in seconds across the Ekantakuna–Satdobato section, not per-vehicle intersection control delay.* [b]*V/C ratio of 2.22 derives from a February 2019 JICA corridor count on the Koteshwor–Tinkune route; the VISSIM simulation used September 2020 field data — temporally and geographically distinct datasets that should not be read as a continuous series.*

Three findings emerge from this longitudinal record. First, congestion at Satdobato intensified despite sustained research attention: demand-weighted average delay rose from 226.5 sec/veh in August 2022 to 238.2 sec/veh in June 2024 — a 5.2% deterioration over two years during which four independent studies were conducted at the same location. Research activity generated no observable improvement in operating conditions, which is itself a finding of institutional significance. Second, the ~7% difference in reported delays between the two overlapping 2022 studies reflects divergent calibration choices — specifically the contrast between field-measured saturation flows [1] and program-default values [12] — rather than any real change in intersection performance. Third, the V/C ratio of 2.22 cited by Prajapati et al. [28] derives from a February 2019 JICA corridor count on the Koteshwor–Tinkune route, not from the Satdobato intersection specifically, and represents pre-pandemic conditions rather than the September 2020 simulation period.

Turning to Gwarko, the two available studies are methodologically incomparable. Shrestha et al. [18] applied Indo-HCM to August 2020 COVID-19 conditions data, reporting morning peak DOS as high as 17.37 and control delays reaching 7,576 sec/PCU on the worst approach — the most extreme values in the entire dataset. S. Tiwari et al. [1] examined the same intersection under normal August 2022 demand using SIDRA 9.1 with KVITSP, reporting average delay of 201.1 sec/veh (LOS F) and projecting that a flyover combined with optimised signal timing would reduce delay to 26.4 sec/veh (LOS C, −87%). Data were collected several months before construction of the overpass began; post-construction performance has not been independently evaluated.

The most operationally significant corridor finding concerns signal coordination. S. Tiwari et al. [1] found that coordinating Satdobato and Gwarko signals increased total network queue by 4.7% — the opposite of the 180 m outcome in Section 3.7 — confirming that platoon coherence breaks down at 1,130 m spacing and establishing the empirical basis for the spacing-dependent threshold discussed in Section 4.1.

The southern Ring Road sub-corridor — Ekantakuna, Satdobato, Gwarko, and Jawalakhel — has collectively been examined by nine independent research groups between 2020 and 2025, yet no study has modelled more than two simultaneously and only one has quantified any network-level performance interaction. Ekantakuna was examined by Thakuri et al. [14] under COVID-19 conditions and subsequently by S. Kafle & Shrestha [16], whose service lane cross-movement restriction reduced queue length by 67.9% and average delay by 77.1% — the largest improvement achievable at that intersection. A scenario dedicating main lanes exclusively to motorcycles and cars produced negligible benefit, reinforcing the dataset-wide finding that motorcycle lane segregation is counterproductive in heterogeneous traffic environments.

3.5. Jawalakhel Roundabout

Jawalakhel Roundabout, an unsignalised four-approach roundabout in central Lalitpur, was examined in two successive publications by the same research group using 2022 base data, SIDRA 8.0, and KVITSP PCU values [19], [29]. Existing morning conditions are severe even within the broader dataset: intersection-average delay stands at 750.3 sec/veh; the Lagankhel approach records 1,261.5 sec/veh and DOS 4.478, the second-highest approach DOS in the dataset; and the Pulchowk approach records 486.7 sec/veh and DOS 2.202.

Roundabout metering [19], restricting entry at the Lagankhel and Pulchowk approaches, improved performance on three legs but increased Pulchowk delay from 486.7 to 5,668.3 sec/veh (+1,064%), because blocking the Lagankhel entry redirected the highest-volume flow onto Pulchowk. This is the most adverse outcome produced by any modelled intervention in the dataset and illustrates a general principle: in a network where demand substantially exceeds capacity, redistributing flow rather than increasing capacity merely relocates the point of failure. Geometric modification [29], reducing the central island diameter from 34 to 29 m and adding lanes on the lower-volume Ekantakuna and Zoo approaches, produced a more favourable outcome: intersection-average delay fell to 398.1 sec/veh, and the Ekantakuna approach improved to LOS D (DOS 1.068; 40.8 sec/veh) while the Zoo approach reached LOS C (DOS 2.544; 21.2 sec/veh). However, Lagankhel and Pulchowk — the two approaches that determine the intersection's overall regime — remained at LOS F, confirming that network topology imposes a binding capacity constraint no roundabout-level intervention can resolve under prevailing demand.

3.6. Narayan Gopal Chowk (Maharajgunj)

Narayan Gopal Chowk is the only intersection in the dataset examined across three methodologically distinct frameworks: field regression, VISSIM microsimulation, and SIDRA analytical modelling. With data spanning 2019 to 2024, it offers the most methodologically diverse longitudinal record in the dataset, and the variation in findings across frameworks is itself informative. Table 3 presents this record.

Table 3. Longitudinal performance record: Narayan Gopal Chowk (Maharajgunj), 2019–2024

Study	**Year**	**Software**	**PCU**	**Key Finding**	**LOS**	**Best Intervention**
(Kunwar & Marsani, 2019)[30]	~2019	Field / SPSS	NRS 2070	AADT 21,663 veh/day; 52% MC; 280 s cycle	Over-saturated	Countdown timer: +4.68% capacity; −28% MC start-up lost time
(Aryal et al., 2024)[31]	Sep 2022	VISSIM	NRS 2070	Travel-time delay 65 sec[a] / 150 m segment; 72% MC; 4-phase 360 s cycle	Not assessed	QJL + left-turn + pre-signal (PS4): −79% bus delay; −62% non-bus
[b](S. R. Kafle et al., 2025)[20]	Jul 2024	SIDRA 8.0	NRS	Delay 216 sec; DOS 1.394 (worst); BOQ 385.3 m; LOS F all approaches	F	Flyover (Basundhara–Chabahil): 22.6 sec; −89.5%; LOS C

Note: QJL = queue jump lane; Ovr. = oversaturated. [a]Aryal et al. (2024) [31]*: the 65 sec figure is a VISSIM travel-time delay over a 150 m road segment, not control delay; not directly comparable with SIDRA control delay figures. [b]S. R. Kafle et al. (2025)* [20]*: cruise speed inputs collected at Lalitpur Ring Road legs rather than at the Maharajgunj intersection approaches; the 89.5% figure is accordingly treated as indicative.*

Kunwar & Marsani [30] is the only study in the 32-paper dataset to employ a genuine before-after field measurement: traffic police deactivated the countdown display for one day at each location upon formal request, enabling direct measurement of the timer's effect. At Narayan Gopal Chowk (AADT 21,663 vehicles; 52% motorcycle share; 280-second cycle), the countdown display increased intersection capacity by 4.68%, primarily through reduced start-up lost time. Two-wheelers exhibited markedly greater sensitivity to the countdown signal than passenger cars, consistent with motorcycles being disproportionately responsive to signal information in heterogeneous traffic environments.

Aryal et al. [31] subsequently modelled five queue jump lane configurations. Isolated curbside queue jump arrangements (PS1 and PS2) worsened performance for all vehicle classes. Adding a dedicated left-turn lane (PS3) improved bus travel time by 60.6% but degraded non-bus performance by 35.3%, confirming that mode-specific geometric improvements without coordinated signal management displace rather than resolve congestion. Only the fully integrated PS4 configuration — combining the queue jump lane with a dedicated left-turn lane and a pre-signal — improved all modes simultaneously (bus delay −79%; non-bus delay −62%). S. R. Kafle et al. [20] then assessed the intersection using SIDRA 8.0 with July 2024 data, recording average delay of 216 sec/veh (DOS 1.394 worst approach, LOS F) and projecting that a flyover spanning the Basundhara–Chabahil axis would reduce delay to 22.6 sec/veh (LOS C, −89.5%).

3.7. Signal Coordination at Closely Spaced Intersections

H. Tiwari et al. [24] examined signal coordination between Shital Nivas Chowk and Kanti Children's Hospital, two three-legged signalised junctions separated by 180 m in central Kathmandu with a 74% motorcycle composition. Under independently optimised signal plans, Shital Nivas recorded LOS F (106 sec/veh; queue 744.7 m) and Kanti recorded LOS D (43.1 sec/veh; queue 456.2 m). Coordination reduced Shital Nivas delay to 26.5 sec/veh (LOS C, −75%), Kanti delay to 21.7 sec/veh (LOS C, −50%), and the Shital Nivas queue to 122 m (−84%). The operative mechanism is platoon coherence: at 180 m, a platoon discharged from one stop line arrives substantially intact at the downstream intersection, enabling the coordinated green to be timed to its arrival — precisely what fails at 1,130 m under heterogeneous conditions.

Bhattarai & Marsani [32] examined time-based coordination between Gatthaghar and Naya Thimi in Bhaktapur over a 1,500 m corridor on the Tinkune–Suryabinayak road section. The optimum eastbound-priority offset reduced PM peak corridor delay by 6.13 vehicle-hours per hour and travel time by 14.88 sec/veh. This is the only coordination study outside Kathmandu district, and its corridor length of 1,500 m places it between the 180 m Shital Nivas–Kanti case and the 1,130 m Satdobato–Gwarko case. That coordination remained beneficial at 1,500 m in the Bhaktapur context suggests the threshold at which platoon coherence degrades may be traffic-composition-dependent rather than a fixed geometric parameter, though the Bhaktapur and Ring Road environments are sufficiently different to preclude a direct comparison. Taken together, the three coordination cases in the dataset — at 180 m, 1,130 m, and 1,500 m — represent the empirical basis for the spacing-dependent threshold discussed in Section 4.1.

3.8 Longitudinal Performance Record at New Baneshwor Intersection

New Baneshwor, a four-legged signalised junction connecting Tinkune, Maitighar, Sankhamul, and Old Baneshwor in eastern Kathmandu, is the most extensively studied intersection in the valley, with five independent studies published between 2017 and 2024. The longitudinal record, presented in Table 4, is instructive both as a performance trajectory and as a case study in the institutional dynamics that govern whether technical knowledge translates into operational improvement.

The volumetric trajectory alone explains much of the intersection's intractability. The 2016 baseline recorded approximately 14,876 PCU per 105 minutes at morning peak; by 2019, the AM peak volume had reached approximately 21,921 PCU/hr. Even on a conservative reading, demand had by 2019 already surpassed the traffic volumes assumed in the 2017 simulation, rendering the predicted LOS C outcome unreachable even had the recommended flyover been constructed. Paudel et al.'s [7] June 2023 measurement of DOS 11.341 (NRS) and 9.203 (Indo-HCM) — the highest normal-conditions DOS values in the dataset — confirms that the intersection now operates at a level where no signal-based intervention can produce a meaningful LOS change.

Knowledge transfer failures compound this structural problem. Studies at New Baneshwor proceeded without citing prior work at the same location, and the locally validated saturation flow model of S. Shrestha & Marsini [3] — derived at Koteshwor, Tinkune, and Jadibuti within 2.5 km along the same eastern arterial corridor — was applied in none of the five New Baneshwor studies. The corridor-specific PCU and saturation flow relationships enabling the most accurate local modelling are available in the literature; they are simply not being used.

Table 4. Longitudinal performance record: New Baneshwor intersection, 2017–2025

Study	**Year**	**Software**	**PCU**	**Key Finding**	**LOS**	**Intervention**
(Shrestha & Marsani, 2017)[8]	2016	VISSIM	NRS 2070	~14,876 PCU / 105 min (AM)	F	Flyover + 3-phase: −82%; LOS C
(Kunwar & Marsani, 2019)[30]	~2019	Field / SPSS	Dynamic	~21,921 PCU/hr (AM); countdown timers +4.68% capacity	F	Countdown timers
(Acharya & Marsani, 2020)[15]	~2020	VISSIM + SSAM	NRS 2070	~945 rear-end conflicts/day; MC = 75%	F	Conflict mitigation
(Dhungana et al., 2023)[33]	Nov–Dec 2022	VISSIM	NRS 2070	MC lane segregation: all 3 scenarios worsen delay by 41–182%	F	Not feasible
(Paudel et al., 2024)[7]	Jun 2023	HCM manual	NRS + Indo-HCM	DOS 11.341 (NRS) / 9.203 (Indo-HCM); 23% divergence	F	PCU standardisation

Note: N.S. = not stated. No flyover has been constructed at New Baneshwor; S. Shrestha & Marsani (2017)[8] *modelled flyover construction as a simulation scenario only. All subsequent studies continue to record LOS F at the existing at-grade geometry.*

3.9. Eastern Arterial Corridor

Four studies of the Maitighar–Tinkune section and the Jadibuti–Koteshwor segment of Araniko Highway are cited for corridor-level and methodological context. Timalsena et al. [4] quantified 6,464.90 lost human capital hours per peak period on the Maitighar–Tinkune section, recommending grade separation as the only viable remedy at that level of corridor demand. Gautam et al. [34] subsequently calibrated four macroscopic speed-density models on the same corridor, finding the Greenshields model to provide the best fit (calibration $R^2 = 0.829$; validation $R^2 = 0.950$). Neither study cites S. Shrestha & Marsini [3], whose saturation flow model was derived at the Koteshwor and Jadibuti endpoints of the same corridor — an instance of the cross-study knowledge transfer failure documented at New Baneshwor in Section 3.8.

Pradhananga et al. [35] modelled a reversible lane system on the 1.12 km Jadibuti–Koteshwor segment using VISSIM 10, adopting a motorcycle PCU of 0.35 from JICA 2017 guidance. This represents a fourth distinct motorcycle PCU value in the dataset alongside NRS 2070 (0.50), Indo-HCM (0.40), and KVITSP (0.25), further illustrating the PCU non-standardisation problem. The modelled RLS projected queue reductions of 50–54% and an 11% improvement in average section travel time, neither of which has been field-validated following implementation — consistent with the broader pattern examined in Section 4.4.

3.10. Summary of Intervention Effectiveness Across Kathmandu Valley Studies

Table 5 consolidates all modelled and field-measured interventions across the reviewed studies, organised by intervention type. Read across intervention categories, a pattern emerges that is not visible within any individual study: the magnitude of achievable improvement is governed primarily by the prevailing DOS, and the interventions that dominate the reviewed literature — signal optimisation — are precisely those whose effectiveness is most constrained at the DOS levels that characterise the majority of studied intersections.

Table 5. Summary of intervention effectiveness by type across Kathmandu Valley studies

Intervention Type	**Study / Location**	**Pre-Delay (sec/veh)**	**Post-Delay (sec/veh)**	**% Change**	**Notes**
Signal optimisation	(S. Tiwari et al., 2024)[1] / Satdobato	226.5	51.8	−77%	LOS F→D; KVITSP; SIDRA 9.1
Signal optimisation	(Amgain, Shrestha, et al., 2025)[17] / Satdobato	238.2	76.7	−68%	LOS F→E
Signal optimisation	(Dhakal et al., 2023)[12] / Satdobato	243	~180	−26%	LOS F→F; left-turn control; default SF
Flyover + Signal optimisation	(Shrestha & Marsani, 2017)[8] / New Baneshwor	n.r.	n.r.	−82%	LOS F→C; simulation only; flyover not built
Signal optimisation	(Amgain, Silwal, Karmacharya, et al., 2025)[22] / Padmodaya	49.3	40.1	−19%	LOS D→D; queue −17%
Signal coordination (180 m)	(H. Tiwari et al., 2023) [24]/ Shital Nivas–Kanti	106 / 43.1	26.5 / 21.7	−75% / −50%	LOS F→C; LOS D→C; platoon coherence
Signal coordination (1,130 m)	(S. Tiwari et al., 2024)[1] / Satdobato–Gwarko	579 veh (queue)	606 veh	WORSE +4.7%	Platoon dispersion at 1,130 m
Service lane restriction	(S. Kafle & Shrestha, 2024)[16] / Ekantakuna	Baseline	—	−77% delay; −68% queue	Largest gain at unsig. node
Countdown timers (before-after field)	(Kunwar & Marsani, 2019) [30]/ New Baneshwor + Narayan Gopal	—	—	+4.68% capacity	Only genuine before-after in dataset
QJL + left-turn + pre-signal (PS4)	(Aryal et al., 2024)[31] / Narayan Gopal	65 (150 m TT)	~13 (bus TT)	−79% bus	Only PS4 benefits all modes
Flyover	(Amgain, Shrestha, et al., 2025) [17]/ Satdobato	238.2	30.6	−87%	LOS F→C
Flyover + signal optimisation	(S. Tiwari et al., 2024) [1]/ Gwarko	201.1	26.4	−87%	LOS F→C
Flyover	(S. R. Kafle et al., 2025)[20] / Maharajgunj	216	22.6	−89.5%	LOS F→C; proxy cruise speed inputs[a]
Geometric (island reduction + lane addition)	(Karkee et al., 2024) [29]/ Jawalakhel	750.3	398.1	−47%	Overall LOS F; Ekantakuna→D; Zoo→C
Roundabout metering (NE approach)	(Karkee et al., 2023)[19] / Jawalakhel	486.7 (Pulchowk)	5,668.3	WORSE +1,064%	Catastrophic flow redistribution
Motorcycle lane segregation	(Dhungana et al., 2023)[33] / New Baneshwor	Baseline	—	WORSE +41 to +182%	All three scenarios counterproductive
25% MC→bus modal shift	(Prajapati et al., 2022)[28] / Ekantakuna–Satdobato	213,986 (total)	99,171	−54%	No infrastructure required
50% MC→bus modal shift	(Prajapati et al., 2022) [28] / Ekantakuna–Satdobato	213,986 (total)	54,858	−74%	Largest corridor-level gain in dataset
Reversible lane system	(Pradhananga et al., 2021)[35] / Jadibuti–Koteshwor	—	—	−11% travel time; −50–54% queue	Road-section RLS; simulation only

Signal retiming (unsig.→sig.)	(Sharma et al., 2025)[25] / Jorpati	22.2 (avg)	16.1 (avg)	−27%		LOS C→B; worst-lane queue −63% (280.5→103.1 m)

Note: Delays in sec/veh unless otherwise stated. WORSE = intervention increased delay relative to baseline. Prajapati et al. (2022) [28] *figures represent total stopped delay in seconds across the Ekantakuna–Satdobato corridor, not per-vehicle intersection control delay. Aryal et al. (2024)*[31] *delay figures are VISSIM travel-time delays over a 150 m road segment, not control delays.* [a]*S. R. Kafle et al. (2025)*[20]*: proxy cruise speed inputs from Lalitpur Ring Road legs.*

4. Discussions

4.1 DOS-Stratified Interpretation of Interventions

The findings presented in Sections 3.3 through 3.10 collectively support a three-regime, DOS-stratified framework for evaluating feasible interventions. This framework reframes several individual site findings as instances of a general pattern rather than location-specific outcomes.

At pre-saturation conditions — represented by Kanti Children's Hospital, Padmodaya Chowk (LOS D), Pepsicola (LOS C), and Jorpati (DOS 0.65 worst lane) — signal formalisation and optimisation achieves LOS B to C at negligible capital cost. The Jorpati case is the most instructive: a 63% queue reduction and LOS improvement from C to B were achieved through signal plan formalisation alone[25], confirming that control optimisation is both sufficient and proportionate where demand does not structurally exceed capacity. Where inter-intersection spacing is confirmed at or below 180 m and DOS permits it, signal coordination with pre-timed offsets represents the most effective available intervention in this regime: delay reductions of 75% at Shital Nivas Chowk and 50% at Kanti Children's Hospital [24] and 48.8% total control delay reduction at Keshar Mahal [9] provide the empirical basis. The counterproductive outcome at 1,130 m [1] and the beneficial result at 1,500 m in Bhaktapur [32] together establish that spacing — rather than DOS level alone — is the primary determinant of coordination feasibility, and that the effective threshold may be traffic-composition-dependent. Practitioners should model network effects explicitly before implementing coordination at spacings substantially beyond 180 m.

At DOS values between approximately 1.5 and 2.5, left-turn phase control with optimal cycle timing produces the largest signal-based delay reductions. However, this regime requires dedicated turn lanes, which are rarely available given the geometric constraints of the valley's urban fabric, limiting practical applicability to intersections where geometric preconditions are already met.

At DOS values exceeding 2.5 — which characterises the Lagankhel approach at Jawalakhel Roundabout (DOS 4.478) and New Baneshwor at DOS 11.341 [7], representing the most extreme normal-conditions value in the dataset — no signal-based or lane-management intervention achieves a meaningful LOS improvement. Every modelled grade separation in the dataset yielded delay reductions of 87–90% and LOS C, confirming that structural infrastructure investment is the only effective intervention in this regime. The valley-wide prevalence of DOS exceeding 2.5 at the most congested locations therefore means that the dominant research focus across the reviewed literature — signal optimisation — is structurally misaligned with the scale of the problem. This is not a criticism of individual studies but a structural observation that becomes visible only through systematic synthesis.

4.2. Motorcycle Behavior and PCU Controversy

Motorcycles constitute the primary mode of urban mobility in the Kathmandu Valley in the absence of adequate public transport infrastructure, with shares ranging from 52% at Narayan Gopal Chowk to 78% at New Plaza. The PCU controversy documented in Section 3.2.1 is inseparable from this modal reality. The KVITSP value of 0.25 reflects observed gap-filling and lateral-weaving behaviour in mixed heterogeneous flow; the NRS value of 0.50 reflects a conservative, safety-oriented assumption calibrated to a different traffic environment. These are not interchangeable interpretations of the same phenomenon: they produce DOS values diverging by 23% from identical field data at New Baneshwor [7], and more broadly shift LOS classifications by up to two full tiers at identical traffic volumes. The choice of PCU standard therefore determines not only the documented severity of the problem but the apparent effectiveness of proposed solutions.

The operational consequences of mischaracterising motorcycle behaviour extend beyond PCU selection to how motorcycles are managed at the intersection level. Dhungana et al. [33] found that dedicated motorcycle lane segregation at New Baneshwor worsened overall intersection performance by 41–182% across three modelled scenarios, because channelisation eliminates the interstitial space-filling that constitutes motorcycles' primary operational contribution in heterogeneous flow. Traffic police routinely separate motorcycles at congested intersections as a crowd-control measure; the available simulation evidence consistently indicates that this practice is counterproductive from a capacity standpoint, and the reviewed literature contains no counter-evidence. The finding at Ekantakuna by S. Kafle & Shrestha [16] — that restricting cross-movement between service and main carriageway lanes produced the largest achievable improvement at that intersection while restricting main lanes to motorcycles and cars produced negligible benefit — reinforces the same principle from a geometric perspective.

The modal shift evidence from Prajapati et al. [28] provides the most direct quantification of the motorcycle problem's scale and potential remedy. Converting 50% of motorcycle trips to bus reduced corridor stopped delay by 74% - the largest improvement in the dataset — without capital expenditure on road infrastructure. The binding constraint is not engineering capacity but the absence of a sufficiently dense public transport network, reframing the intersection performance problem as fundamentally a transport policy problem.

4.3. Network-Level Spillover and the Single-Intersection Blind Spot

Of the 32 reviewed studies, 23 focuses on a single intersection as their primary subject, and a further eight examine at most two adjacent intersections or a short road section. Only S. Tiwari et al. [1] explicitly modelled the performance interaction between two intersections, finding coordination counterproductive at 1,130 m spacing. This near-total absence of network-level analysis is not merely a gap in academic coverage; it has direct operational consequences for how effectiveness claims in this literature should be interpreted. Any flyover or signal modification at Satdobato will alter approach volumes at Ekantakuna and Jawalakhel Roundabout. Those downstream effects have not been modelled in any reviewed study. At Jawalakhel Roundabout, where the Lagankhel approach already records DOS 4.478 under existing conditions, even a modest increase in diverted flow from an upstream flyover could push already-irresolvable queuing into a qualitatively worse regime. The effectiveness claims attached to flyover scenarios at Satdobato and Gwarko are therefore intersection-level predictions whose network validity remains entirely untested.

4.4. Knowledge Transfer Failures and the Implementation Gap

The longitudinal record at New Baneshwor exposes a pattern of institutional significance equal to the performance findings themselves. Not one of the interventions recommended across five independent studies at New Baneshwor has been field-validated following implementation. S. Shrestha & Marsani [8] recommended flyover construction on the basis of a modelled LOS C outcome; that recommendation was not implemented; and every subsequent study at the same location continues to record LOS F. The research programme continued as though the 2017 recommendation did not exist, with subsequent studies treating the intersection as an unsolved problem rather than as a site with a documented prior intervention proposal. More consequentially, the locally validated saturation flow model of Shrestha & Marsini [3] — available within 2.5 km along the same arterial corridor — was applied in none of the five New Baneshwor studies (Section 3.8).

The Satdobato record presents the same pattern at a smaller scale. Dhakal et al.'s [12] program-default saturation flow value and unweighted average delay figure were reproduced in Amgain, Shrestha, et al. [17] without attribution, indicating that prior results are being used as background context rather than interrogated as a basis for methodological improvement. These are not isolated failures of individual researchers; they reflect structural conditions in the research environment. The reviewed literature collectively contains a DOS-stratified intervention framework, empirically grounded platoon-coherence thresholds, field-derived PCU and saturation flow relationships, quantified modal shift benefits, and a validated bi-level VISSIM calibration protocol. What is absent is the institutional infrastructure required to convert these findings into operational decisions: mechanisms for post-implementation monitoring, systematic requirements for cross-citation of prior work at the same location, adoption of a unified PCU standard enabling genuine cross-study comparison, and a research culture that rewards cumulative validation and implementation-linked knowledge production over independent replication of already-documented conditions.

5. Recommendations

5.1 Methodological Standardisation

PCU non-standardisation is the single largest source of cross-study incomparability in the valley dataset and the most tractable to address through institutional action. The Department of Roads should issue a technical circular designating KVITSP (motorcycle PCU = 0.25) as the primary value for Kathmandu Valley intersection capacity analysis — supported by two independent empirical derivations: S. Shrestha & Marsini [3] obtained 0.25 at Koteshwor, Tinkune, and Jadibuti; Pokhrel & Shrestha [11] obtained 0.243 at four-legged signalised intersections, both substantially below the NRS value of 0.50. However, a single universal figure is insufficient. PCU values vary meaningfully even within the valley — 0.243 at four-legged signalised intersections versus 0.312 at Jawalakhel Rotary — and the same contextual variation applies to simulation calibration parameters. The Department of Roads should therefore develop and periodically update a nationally endorsed framework specifying: (a) context-differentiated PCU ranges for urban signalised intersections, roundabouts, peri-urban junctions, and rural highways; (b) validated starting-point behavioural parameter ranges for VISSIM under Kathmandu heterogeneous traffic, anchored to Manandhar & Pradhananga's [13] bi-level calibration as the demonstrated local standard, with the requirement that parameters unstable across demand regimes be re-validated when transferred between sites or time periods; and (c) minimum saturation flow field measurement protocols for SIDRA-based studies, anchored to S. Tiwari et al.'s [1] queue-discharge methodology as the local benchmark. Any future study deviating from these endorsed parameters should justify the deviation with site-specific field evidence. Until formal adoption, all studies should report results under both KVITSP and any alternative standard applied, with specific PCU values stated for all vehicle types.

At the individual study level, SIDRA-based studies should field-measure saturation flows using a minimum of 30 queue-discharge observations per lane, with GEH below 5 as the acceptance threshold. Data collection should span at least three consecutive weekdays and one weekend day, cover both AM and PM peak periods reported separately, and be conducted outside monsoon season, active festival periods, and phases of active infrastructure construction adjacent to the study intersection. Table 6 consolidates these requirements with their empirical rationale.

Table 6. Proposed minimum reporting standards for Kathmandu Valley intersection performance studies

Category	**Minimum Requirement**	**Rationale**
PCU standard	Report KVITSP (MC PCU = 0.25) as primary; include secondary standard if different	22–48% demand divergence across 52–78% MC share; 43% at 75% MC composition (e.g., New Baneshwor)
Saturation flow	Field-measured via queue-discharge (≥30 obs/lane); GEH < 5	Program defaults (e.g. 1,900 veh/hr/lane) introduce systematic bias confirmed at Satdobato
Data collection	≥3 weekdays + 1 weekend day	Weekend control delay up to 65% lower than weekday peak (DOS 1.353 vs 2.215 at Thapathali); weekday-only data overstates typical weekly severity
Peak periods	Both AM and PM peaks; report separately	PM exceeds AM at Pulchowk, Gwarko
Season	Flag monsoon, COVID-period, or active construction data explicitly	Atypical conditions confirmed at Gwarko (August 2020 lockdown) and Satdobato (pre-construction)

VISSIM calibration	Report GEH < 5 per vehicle type; flag if MC GEH > 5	MC GEH failure indicates calibration instability under atypical demand
Adjacent intersection	Report 95th percentile queue at nearest upstream intersection	Network spillover undetected in 10 of 11 multi-intersection study areas
Software version	State software name, version, and licence year	SIDRA v8.0 and v9.1 differ in default parameters; version-unspecified results are not replicable

5.2. Intervention Priorities

The DOS-stratified framework developed in Section 4.1 translates directly into a prioritised intervention hierarchy. Where DOS is below 1.0 and the intersection is unsignalised or under manual police control, signal formalisation with Left Controlled Phase timing is the recommended first response, on the evidence that queue reductions exceeding 60% and an LOS improvement from C to B are achievable at negligible capital cost [25]. Where DOS falls below approximately 2.5 and inter-intersection spacing is confirmed at or below 180 m, signal coordination with pre-timed offsets represents the most effective available intervention. Coordination at spacings substantially beyond 180 m should be explicitly modelled for network effects before implementation rather than assumed to be beneficial; the dataset contains only two confirmed spacing data points — 180 m (beneficial) and 1,130 m (counterproductive) — and the intermediate Bhaktapur case at 1,500 m suggests the threshold may vary with traffic composition.

Where DOS exceeds 2.5, the evidence base (Section 4.1) supports grade separation as the only intervention achieving meaningful LOS improvement; signal optimisation should not constitute the primary capital investment in this regime. Bus priority infrastructure warrants urgent parallel investment. The PS4 queue jump lane configuration at Narayan Gopal Chowk demonstrated simultaneous improvement for all vehicle classes [31], resolving the mode-specific trade-off that made simpler geometric configurations counterproductive. More broadly, the 74% corridor delay reduction from modal shift (Section 4.2) requires no road-space investment. Pilot bus priority implementation on at least one Ring Road corridor is therefore recommended as a near-term policy action. Two practices should be explicitly discouraged: motorcycle lane segregation (counterproductive in all three scenarios at New Baneshwor and negligible at Ekantakuna; Section 4.2); and day-invariant signal timing applied uniformly across weekday and weekend operations, given the 65% weekday-to-weekend delay differential documented at Thapathali.

5.3. Before-After Evaluation Protocol

Across all 32 reviewed studies, only Kunwar & Marsani [30] provide a genuine before-after field measurement of a traffic control change. This absence of post-implementation evaluation is the most consequential gap in the current literature, and it is institutional rather than methodological in character: the analytical capacity exists within the valley research community; what is absent is the requirement or incentive to conduct such evaluations. Any intersection modification affecting more than 10,000 vehicles per day should be accompanied by a structured evaluation programme comprising traffic surveys conducted before implementation and repeated at three months and twelve months post-implementation, control delay measurement by probe vehicle or GPS-based floating car method, and 95th percentile BOQ observation at the nearest upstream intersection to detect network spillover effects. The three-month and twelve-month intervals distinguish between initial adaptation effects and stable post-implementation conditions. Embedding this protocol as a standard requirement for publicly funded intersection improvements would, over time, generate the implementation-linked evidence base that the current literature entirely lacks.

6. Conclusion

This systematic review of 32 peer-reviewed intersection performance studies in the Kathmandu Valley — spanning 2014 to 2026 and covering signalised intersections, roundabouts, and unsignalised junctions across Kathmandu, Lalitpur, and Bhaktapur districts — yields five principal conclusions that together characterise the valley's intersection performance problem not as a technical deficit awaiting the right engineering solution, but as a system in which adequate technical knowledge already exists and institutional mechanisms for its application do not.

LOS F prevails at every studied signalised intersection, with DOS ranging from approximately 1.3 to 17.37 across the dataset. The three documented exceptions — Kanti Children's Hospital, Padmodaya Chowk (both LOS D), and Thapathali on weekend mornings — confirm that functional performance is achievable where demand does not structurally exceed capacity. The upper DOS extreme reflects the August 2020 partial lockdown at Gwarko (g/C = 0.08); under normal conditions, New Baneshwor records the dataset's highest values (DOS 11.341; [7]).

PCU non-standardisation introduces the 22–48% demand divergence documented in Section 3.2.1, shifting LOS by up to two full tiers. Two independent valley studies yield converging two-wheeler PCU values of 0.243–0.25, supporting KVITSP as the appropriate standard; until formal adoption, cross-study LOS and DOS comparisons must be interpreted with caution.

Intervention effectiveness is strongly conditioned by DOS and inter-intersection spacing. Signal optimisation produces meaningful LOS improvement only below DOS ~2.5. Grade separation achieved LOS C in every modelled case (87–90% delay reduction; Section 4.1), and the 50% modal shift scenario [28] generated the dataset's largest improvement at 74% corridor delay reduction. Signal coordination is beneficial at confirmed spacings up to 180 m and counterproductive at 1,130 m; coordination beyond 180 m should not be implemented without prior network modelling.

Persistent methodological gaps — inconsistent PCU standards, predominantly weekday-only and morning-peak data collection, program-default saturation flows applied in place of field measurement, and COVID-period baselines applied without accounting for atypical demand and signal phase allocation conditions — collectively impede cross-study synthesis. Most consequentially, the longitudinal records at New Baneshwor and Satdobato confirm that peer-reviewed recommendations are not traceable to field implementations with measured outcomes. The barrier to improved intersection performance in the Kathmandu Valley is not a deficit of technical knowledge; it is the absence of institutional mechanisms to translate recommendations into operational decisions, market or institutional need driven research and absence of a research culture oriented toward cumulative, implementation-linked knowledge production.

6. Limitations

Several limitations constrain the interpretation and generalisability of these findings. The search strategy relied on backward citation tracking from anchor papers supplemented by Google Scholar keyword searches, rather than a formally registered protocol with exhaustive multi-database coverage. Studies absent from the reference networks of the anchor papers may have been missed, and the reviewed set may not be fully representative of all relevant published work. Although the two-stage search design and the relatively small size of the active valley intersection research community reduce this risk, it cannot be eliminated without a registered systematic review protocol. Formal meta-analysis was precluded by the methodological heterogeneity documented throughout Section 3.2: incompatible PCU standards, varied calibration practices, and inconsistent data collection periods render statistical pooling methodologically invalid, and all synthesis is consequently qualitative and narrative. Studies published in Nepali-language proceedings or non-indexed institutional repositories were not systematically searched; their exclusion may have introduced coverage bias toward English-language and internationally indexed outputs. Future reviews should incorporate systematic searches of the IOE Graduate Conference proceedings and other domestic repositories to address this gap.

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Appendix

The following tables provide complete study-level data supporting the synthesis presented in the main manuscript. Table A1 presents comprehensive study characteristics, existing performance metrics, and best-case intervention outcomes for all 32 primary reviewed studies and 6 contextual studies. Table A2 summarises PCU standards and saturation flow derivations across key studies. Table A3 provides calibration and validation details for all SIDRA- and VISSIM-based studies in the dataset.

Table A1: Comprehensive study characteristics, existing performance metrics, and best-case intervention outcomes for all reviewed studies (n = 32 primary; n = 6 contextual)

Citation	Year	Intersection	Tool	Version	PCU Std	MC PCU	Exist. Delay (s/veh)	LOS	DOS	MC (%)	Best Intervention	Post Delay	Post LOS	Field Val.	Notes
Thakuri et al., 2023[14]	n.r.	Ekantakuna	VISSIM	n.s.	NRS 2070	0.50	n.r.	n.r.	n.r.	n.r.	Signal design (120 s cycle)	n.r.	n.r.	No	COVID conditions; GEH >5 for MC; standstill dist. 0.15 m
Pokhrel & Shrestha, 2022[11]	2022	NB; Maharajgunj; Jawalakhel Rotary	Field regression	n.s.	Locally derived	0.243 (4-leg); 0.312 (rotary)	n.r.	n.r.	n.r.	n.r.	PCU derivation only	n/a	n/a	No	S = 551.1W + 1,975 PCU/hr; R² = 0.707
H. Tiwari et al., 2023[24]	2023	Shital Nivas Chowk; Kanti Hosp.	SIDRA 8	n.s.	Not stated	n.r.	106 (Shital); 43.1 (Kanti)	F; D	n.r.	74%	Signal coordination (180 m)	26.5; 21.7	C; C	n.r.	180 m platoon coherence; delay −75% and −50%
S. Shrestha & Marsini, 2014[3]	n.r.	Koteshwor; Tinkune; Jadibuti	Field regression + GPS	n.s.	Locally derived	0.25	n.r.	n.r.	n.r.	n.r.	PCU + SF derivation only	n/a	n/a	No	S = 525.88W; R² = 0.956; most rigorous field-derived PCU in dataset
Sharma et al., 2025[25]	~2024	Jorpati	SIDRA	n.s.	KVITSP	0.25	22.2 avg; 97.2 worst	C	0.65 (worst)	74%	Left Controlled Phase signal retiming	16.1	B	No	Pre-saturation; LOS C→B by signal formalisation; AADT 47,610 veh/day
Bhattarai & Marsani, 2015[32]	~2015	Gatthaghar; Naya Thimi	VISSIM	n.s.	Not stated	n.r.	n.r.	n.r.	n.r.	n.r.	Eastbound-priority coordination	−6.13 veh-hr/hr (PM)	n.r.	No	Only coordination study outside Kathmandu district; 1,500 m corridor
Lage et al., 2025[36]	2024	Kamalbinayak Chowk	HCM manual	n/a	NURS	0.50	n.r.	F (all)	1.3–2.1 V/C	n.r.	No intervention modelled	n/a	n/a	No	Oversaturation confirmed in Bhaktapur district
A. Pokhrel et al., 2023[26]	n.r.	Jay Nepal	SIDRA 8.0	8.0	Not stated	n.r.	119.3 (AM); 92.3 (PM)	F	2.385 (AM); 1.783 (PM)	n.r.	Left Controlled Phase + opt. cycle	~17–26	B/C	No	BOQ 540.7 m; LCP most effective scenario
Amgain, Silwal, Shrestha et al., 2025[27]	n.r.	New Plaza	SIDRA 8.0	8.0	NRS 2070	0.50	251[a]	F	n.r.	78%	Optimum cycle length	242.9	F	No	Highest MC share in dataset (78%)

Kunwar & Marsani, 2019[30]	~2019	New Baneshwor; Narayan Gopal Chowk	Field / SPSS	n.s.	NRS 2070	0.50	n.r.	Ovr.	n.r.	52%	Countdown timer (before-after field)	—	—	Yes[b]	Only genuine before-after field measurement in dataset
Aryal et al., 2024[31]	2022	Maharajgunj	VISSIM	n.s.	NRS 2070	0.50	65 (150 m TT)[c]	n.a.	n.r.	72%	PS4: QJL + left-turn + pre-signal	~13 (bus TT)	—	No	150 m TT only; PS1/PS2 worsen all modes; only PS4 benefits all
Amgain, Silwal, Karmacharya et al., 2025[22]	2024	Padmodaya Chowk	SIDRA 8	8.0	Indo-HCM	0.40	49.3	D	n.r.	n.r.	Optimum cycle (92→90 s)	40.1	D	No	LOS D functional exception; DOS not reported
S. R. Kafle et al., 2025[20]	2024	Maharajgunj	SIDRA 8.0	8.0	NRS 2070	0.50	216	F	1.394 (worst)	n.r.	Flyover (Basundhara–Chabahil)	22.6	C	Yes	Proxy cruise speed inputs from Lalitpur Ring Road legs; 89.5% result indicative[d]
Budhathoki & Shrestha, 2024[23]	2023	Pepsicola	VISSIM 2023	2023	Not stated	n.r.	18.62	C	n.r.	n.r.	Assessment only	n/a	n/a	No	Unsignalised T-intersection; LOS C functional exception
Maharjan & Marsani, 2023[21]	2022	Thapathali	SIDRA	n.s.	KVITSP	0.25	99.6 (wd); 35.1 (we)	F / D	2.215 (wd); 1.353 (we)	n.r.	Lane addition (wd best scenario)	24.1 (wd)	C (wd)	No	Only weekday vs weekend comparison; 65% demand difference exceeds any signal optimisation gain
Manandhar & Pradhananga, 2026[13]	n.s.	Singhadurbar	VISSIM 2022	2022	Not stated	n.r.	n.r.	n.r.	n.r.	n.r.	Bi-level GA calibration only	n/a	n/a	No	MAPE <7% vol; <15% queue; GEH <5; most rigorous VISSIM calibration in dataset
Manandhar & Pradhananga, 2023[37]	n.s.	Singhadurbar	VISSIM 2023 SP06	2023 SP06	Not Stated	0.30	n.r.	n.r.	n.r.	n.r.	LHS-ANOVA sensitivity analysis only	n/a	n/a	No	9 of 12 VISSIM params sensitive to Kathmandu heterogeneous traffic
Khyaju, 2021[10]	n.r.	Keshar Mahal	Traffic count software	n.s.	NRS 2013	0.50	n.r.	n.r.	n.r.	56%	No intervention — pre-signalisation baseline	n/a	n/a	No	PM peak 9,493 PCU/hr; baseline for Bajracharya & Dhungel (2023)
Nepali et al., 2024[6]	n.r.	Kesharmahal; Narayanhiti; Khanibhivag	HCM 2000 manual	n/a	NRS 2070	0.50	n.r.	F (all)	DOS >1 (all)	n.r.	Vehicle replacement (MC/cars to bus)	Varies	D (target)	No	Lane increment recommended
Bajracharya & Dhungel, 2023[9]	n.r.	Keshar Mahal; Durbar Marg	SIDRA	n.s.	KVITSP	0.25	n.r.	n.r.	2.6 (network)	n.r.	Signal coordination + adaptive control	n.r.	n.r.	No	−48.8% total control delay; −62.1% queue; only study of Durbar Marg

Acharya & Marsani, 2020[15]	~2020	New Baneshwor	VISSIM + SSAM	n.s.	NRS 2070	0.50	n.r.	F	n.r.	75%	Conflict mitigation only	n/a	n/a	No	~945 rear-end conflicts/day; standstill distance 0.30 m reference value
Dhungana et al., 2023[33]	2022	New Baneshwor	VISSIM	n.s.	NRS 2070	0.50	n.r.	F	n.r.	n.r.	MC lane segregation (3 scenarios)	n.r.	F	No	All 3 scenarios worsen delay by 41–182%; channelisation counterproductive
Paudel et al., 2024[7]	2023	New Baneshwor	HCM manual	n/a	NRS + Indo-HCM	0.50 / 0.40	n.r.	F	11.341 (NRS); 9.203 (Indo-HCM)	n.r.	PCU standardisation only	n/a	n/a	No	23% DOS divergence from identical field data; definitive PCU comparison study
S. Shrestha & Marsani, 2017[8]	2016	New Baneshwor	VISSIM	n.s.	NRS 2070	0.50	n.r.	F	n.r.	n.r.	Flyover + 3-phase signal (simulation only)	n.r.	C	No	Flyover never constructed; demand by 2019 already exceeded simulation assumptions
S. Shrestha et al., 2024[18]	2020	Gwarko	Indo-HCM manual	n/a	Indo-HCM	0.40	n.r. (approach-level)	F	0.46–17.37 (worst)	n.r.	No intervention — existing condition only	n/a	n/a	No	COVID-19 partial lockdown August 2020; paper notes demand reduced (schools, offices, industries closed); DOS 17.37 reflects g/C = 0.08 phase allocation combined with residual demand; not a representative normal operating baseline
Karkee et al., 2024[29]	2022	Jawalakhel Roundabout	SIDRA 8.0	8.0	KVITSP	0.25	750.3 (AM avg.)	F	4.478 (Lagankhel)	n.r.	Geometric: island 34→29 m; lane additions	398.1	F overall; D Ekantakuna; C Zoo	No	Lagankhel and Pulchowk remain LOS F
S. Kafle & Shrestha, 2024[16]	n.s.	Ekantakuna	VISSIM	n.s.	NRS 2070	0.50	n.r.	n.r.	n.r.	n.r.	Service lane cross-movement restriction	n.r.	—	No	$R^2 = 1.0$ (implausible overfitting); params from Acharya & Marsani (2020) without recalibration
Karkee et al., 2023[19]	2022	Jawalakhel Roundabout	SIDRA 8.0	8.0	KVITSP	0.25	750.3 (AM avg.)	F	4.478 (Lagankhel)	n.r.	Roundabout metering (NE approach)	5,668.3 Pulchowk (WORSE)	F	No	Most adverse outcome in dataset: Pulchowk +1,064%
Prajapati et al., 2022[28]	2020	Ekantakuna–Satdobato corridor	VISSIM	n.s.	Not stated	n.r.	213,986 s (corridor total)[e]	n.r.	2.22 V/C[f]	n.r.	50% MC to bus modal shift	54,858 s total	n/a	No	Sep 2020 COVID data; corridor totals not per-vehicle control delay

Dhakal et al., 2023[12]	~2022	Satdobato	SIDRA 8.0	8.0	Not stated	n.r.	243 (demand-wtd.)	F	~1.6	n.r.	Signal retiming: left-turn control + opt. cycle	~180	F	No	Program-default SF = 1,900 veh/hr/lane; −26% delay
Amgain, Shrestha et al., 2025[17]	2024	Satdobato	SIDRA 8.1	8.1	KVITSP	0.25	238.2	F	1.320	n.r.	Flyover (Mahalaxmisthan–Gwarko)	30.6	C	No	Flyover achieves LOS C; most recent Satdobato study
S. Tiwari et al., 2024[1]	2022	Satdobato; Gwarko	SIDRA 9.1	9.1	KVITSP	0.25	226.5 (Satdobato); 201.1 (Gwarko)	F	~1.97 (Satdobato)	n.r.	Signal retiming (Satdobato); Flyover + signal (Gwarko)	51.8; 26.4	D; C	No	Network interaction: coordination at 1,130 m increases queue by 4.7%

Contextual studies — excluded from the 32 primary reviewed studies; cited for methodological and corridor-level context only

KC & Shahi, 2025[38]	2024	Balkhu–Chovar–Dakshinkali highway	Field regression	n.s.	Locally derived	n.r.	n/a	n/a	n/a	n/a	PCU at highway curve only	n/a	n/a	No	Highway section; intersections excluded
H. Tiwari & Marsani, 2014[39]	n.r.	Jadibuti–Suryabinayak section	Field regression	n.s.	NRS 2070	n.r.	n/a	n/a	n/a	n/a	Macroscopic speed-density calibration	n/a	n/a	No	Mid-block segment; no intersection performance
Pradhananga et al., 2021[35]	2019	Jadibuti–Koteshwor (Araniko Hwy)	VISSIM 10	10	NRS 2013 + JICA 2017	0.35	n/a	n/a	n/a	n/a	Reversible lane system (RLS)	−11% TT; −50–54% queue	n/a	No	Road section only; simulation not field-validated
Luitel et al., 2024[40]	n.r.	Ratna Rajmarga, Surkhet	VISSIM	n.s.	Locally derived	n.r.	n/a	n/a	n/a	n/a	VISSIM calibration only	n/a	n/a	No	Outside Kathmandu Valley (Birendranagar, Surkhet)
Timalsena et al., 2017[4]	n.r.	Maitighar–Tinkune section	Manual analysis	n/a	n/a	n/a	n/a	n/a	n/a	n/a	Grade separation recommended	n/a	n/a	No	6,464.90 capital hours lost/peak period; no intersection LOS
Gautam et al., 2023[34]	n.r.	Maitighar–Tinkune section	Field regression	n.s.	NRS 2070	n.r.	n/a	n/a	n/a	n/a	Speed-density calibration (Greenshields)	n/a	n/a	No	R² = 0.829 (calib.); 0.950 (valid.); no intersection performance

Note: n.r. = not reported; n.s. = not stated; n/a = not applicable; N.S. = not stated; Ovr. = oversaturated; wd = weekday; we = weekend; RBT = roundabout; NB = New Baneshwor. [a]*Amgain, Silwal, Shrestha et al. (2025)*[27]*: Table 8 value used (251 sec/veh); body text reports 301.9 sec/veh.* [b]*Kunwar & Marsani (2019)*[30]*: field deactivation of countdown timer with traffic police cooperation; only genuine before-after field measurement in dataset.* [c]*Aryal et al. (2024)*[31]*: 65 sec is VISSIM travel-time delay over 150 m segment, not control delay.* [d]*S. R. Kafle et al. (2025)*[20]*: cruise speed inputs collected at Lalitpur Ring Road legs; 89.5% result treated as indicative.* [e]*Prajapati et al. (2022)*[28]*: total corridor stopped delay in seconds, not per-vehicle control delay.* [f]*V/C ratio 2.22 from February 2019 JICA count on Koteshwor–Tinkune route; VISSIM simulation used September 2020 field data — distinct datasets.*

Table A2. PCU standards and saturation flow derivations across key studies

Study	Tool	PCU Std	MC PCU	Saturation Flow	Method	Notes
S. Shrestha & Marsini, 2014[3]	Field / GPS	Locally derived	0.25	S = 525.88W (R^2 = 0.956)	Field regression	Most rigorous field-derived PCU; Koteshwor, Tinkune, Jadibuti
Pokhrel & Shrestha, 2022[11]	Field regression	Locally derived	0.243 (4-leg); 0.312 (rotary)	S = 551.1W + 1,975 PCU/hr (R^2 = 0.707)	Field regression	Rotary PCU higher than signalised intersections
Paudel et al., 2024[7]	HCM manual	NRS + Indo-HCM	0.50 / 0.40	Not specified	Manual calculation	23% DOS divergence: NRS 11.341 vs Indo-HCM 9.203
S. Tiwari et al., 2024[1]	SIDRA 9.1	KVITSP	0.25	Field-measured: 1,203–1,937 veh/hr/lane (Satdobato); 1,521–1,808 (Gwarko)	Queue-discharge field measurement	Most rigorous SIDRA calibration in dataset
Dhakal et al., 2023[12]	SIDRA 8.0	Not stated	n.r.	Program default: 1,900 veh/hr/lane	Program default — no field measurement	~7% delay difference vs S. Tiwari et al. (2024)[1] attributable entirely to calibration
Amgain, Shrestha et al., 2025[17]	SIDRA 8.1	KVITSP	0.25	Not stated	BOQ comparison ≤ 20%	FDOT 2021[41] cited
Pradhananga et al., 2021[35]	VISSIM 10	NRS 2013 + JICA 2017	0.35 (JICA)	Not stated	Volume + travel time comparison	Fourth distinct MC PCU value in dataset alongside 0.50, 0.40, 0.25
Manandhar & Pradhananga, 2026[13]	VISSIM 2022	Locally adapted	n.r.	Not specified	Bi-level GA + MAPE	MAPE <7% vol; <15% queue; GEH <5; validated parameter ranges for Kathmandu heterogeneous traffic

Note: PCU = passenger car unit; SF = saturation flow; MC = motorcycle; GA = genetic algorithm; MAPE = mean absolute percentage error; GEH = Geoffrey E. Havers statistic.

Table A3. Calibration and validation details for SIDRA- and VISSIM-based studies

Study	Tool	Version	Calibration Method	Validation Measure	Passed ?	Outcome	Notes
Acharya & Marsani, 2020[15]	VISSIM	n.s.	Volume-based GEH comparison	GEH < 5 for volume	Yes	Within threshold	Standstill distance 0.30 m; reference parameter for subsequent studies

Thakuri et al., 2023[14]	VISSIM	n.s.	Volume-based GEH	GEH < 5 per class	Partial	GEH >5 for motorcycles; standstill dist. 0.15 m	COVID conditions; parameters diverge from Acharya & Marsani (2020) [15] at same site
S. Kafle & Shrestha, 2024[16]	VISSIM	n.s.	Standard GEH / R²	Validation R²	No	R² = 1.0 — statistically implausible (overfitting)	Parameters transferred from Acharya & Marsani (2020) [15]without site-specific recalibration
Manandhar & Pradhananga, 2023[37]	VISSIM 2023 SP06	2023 SP06	LHS-ANOVA sensitivity analysis	Sensitivity of 12 parameters	Yes	9 of 12 params sensitive to Kathmandu conditions	Identifies key calibration parameters for heterogeneous traffic
Manandhar & Pradhananga, 2026[13]	VISSIM 2022	2022	Bi-level GA optimisation	MAPE + GEH	Yes	MAPE <7% vol; <15% queue; GEH <5	Most rigorous VISSIM calibration in dataset; operationalises 2023 findings
Prajapati et al., 2022[28]	VISSIM	n.s.	Custom (delay consistency)	Delay consistency vs real-world data	Partial	Consistency confirmed	Sep 2020 COVID data; V/C 2.22 from separate Feb 2019 JICA count
Maharjan & Marsani, 2023[21]	SIDRA	n.s.	FDOT BOQ comparison	BOQ ≤ 20%	Yes	Within 20%	FDOT edition not stated
Amgain, Silwal, Karmacharya et al., 2025[22]	SIDRA 8	8.0	FDOT BOQ comparison	BOQ ≤ 20%	Yes	Within 20%	FDOT edition not stated
S. R. Kafle et al., 2025[20]	SIDRA 8.0	8.0	FDOT BOQ comparison	BOQ ≤ 20%	Yes	Within 20%	Proxy cruise speed inputs from Lalitpur Ring Road legs
Karkee et al., 2024[29]	SIDRA 8.0	8.0	FDOT BOQ comparison	BOQ ≤ 20%	Yes	Within 20%	FDOT edition not stated
Karkee et al., 2023[19]	SIDRA 8.0	8.0	FDOT BOQ comparison	BOQ ≤ 20%	Yes	Within 20%	Same 2022 base data as Karkee et al. (2024)[29]
Dhakal et al., 2023[12]	SIDRA 8.0	8.0	FDOT BOQ comparison	BOQ ≤ 20%	Yes	Within 20%	Program-default SF = 1,900 veh/hr/lane; systematic bias vs S. Tiwari et al. (2024)[1]
Amgain, Shrestha et al., 2025[17]	SIDRA 8.1	8.1	FDOT 2021[41]	BOQ ≤ 20% (Day 3)	Yes	Within 20%	FDOT 2021[41] cited
S. Tiwari et al., 2024[1]	SIDRA 9.1	9.1	FDOT + field SF	Field queue-discharge SF; BOQ ≤ 20%	Yes	SF: 1,203–1,937 veh/hr/lane (Satdobato);	Most rigorous SIDRA calibration; field-measured SF contrasts

1,521–1,808 (Gwarko)	with Dhakal et al. (2023)[12]

Note: Table A3 covers studies employing SIDRA Intersection or VISSIM only; HCM and Indo-HCM manual worksheet studies excluded. FDOT = Florida Department of Transportation Traffic Analysis Handbook (2014[42] *or 2021*[41] *edition; edition not stated where unreported). GEH threshold: < 5. Standstill distance: 0.15 m (Thakuri et al., 2023*[14], *COVID conditions) vs 0.30 m (Acharya & Marsani, 2020*[15], *normal demand) at the same intersection; see Section 3.2.1 in main manuscript for interpretation.*