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DYNAMIC TRAFFIC MANAGEMENT AND SAFETY IN URBAN ROAD WORK ZONES: EVIDENCE AND IMPLEMENTATION PRIORITIES

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Abstract: At a signalized urban work zone, a lane closure may change turning capacity, pedestrian access, and queues at the next junction at the same time. The selected studies seldom assess these changes together. This critical narrative review examines 18 Chinese and international publications from 2018 to 2026, distinguishing observed traffic behavior from model-based predictions and safety-related indicators. A Toronto field study measured 1,766 signal cycles and found substantial variation in saturation flow across closure arrangements; an urban island-work-zone signal model reported queues 15.6% shorter and delay 17.2% lower in its evaluated comparison. More recent simulations include conflict-related objectives, while longitudinal site records reveal difficulties in maintaining traffic-management arrangements during construction. The available findings are informative about capacity, delays, and driver responses, but offer much less direct evidence on injury prevention or the experience of pedestrians, cyclists, transit users, and workers. The review develops a stage-based monitoring-response matrix linking site conditions to authorized actions, fallback arrangements, and follow-up checks. Field testing will need to capture traffic diverted to nearby streets, exposure along temporary routes, and the reliability of controls installed on site.
Keywords: Urban road work zones; Signalized intersections; Temporary traffic control; Traffic operations; Surrogate safety measures; Multimodal access

1 INTRODUCTION

At a signalized junction, the effects of a construction barrier do not stop at the barrier. Removing a turn lane can alter the usable green time; a displaced bus stop changes passenger movements; and a narrowed crossing may sit directly beside an unfamiliar merge. On a corridor with short blocks, queues soon affect the next signal. These are connected operating problems, although they are commonly measured separately.

The research literature reflects that separation. Broad reviews cover work-zone hazards [1], pedestrian accommodation [2], and the prospects for smart work-zone systems [3]. Urban field studies, by contrast, have concentrated on measurable traffic behavior, including intersection discharge and lane-specific speeds [4-5]. Signal-control experiments investigate options that could not easily be tested on a live street [6-7]. An improvement in one of these outcomes is not necessarily an improvement in the others: the traffic entering a junction, for instance, is not the same population as the people using a temporary crossing.

The purpose of this review is to compare what these studies actually establish and identify the decisions for which that evidence is useful. We focus on construction-stage changes, urban junction capacity, responsive traffic control, and safety-related exposure across the affected network. The review uses these comparisons to specify what a stage-based monitoring-response matrix would need to address on an operating urban street.

2 REVIEW APPROACH AND EVIDENCE BASE

2.1 Selection and Scope

The 18 publications, dated 2018–2026, were selected for their relevance to urban road construction, signalized junctions, temporary capacity, work sequencing, traffic monitoring, conflict indicators, or access for non-motorized users. Original investigations were preferred where the site or simulated scenario, design, and outcome were identifiable. Reviews and guidance supply the broader safety context [1-3, 8-9]; a limited number of freeway investigations are retained specifically to examine the transfer of control methods to city streets [10-11]. Bibliographic details and the reported numerical results were checked against available journal, publisher, and indexing records in October 2026.

This is a critical narrative review. No prespecified systematic search, screening log, or quantitative synthesis was conducted, and the selection cannot establish how frequent a method or finding is across the entire field. That limitation matters particularly when discussing gaps in pedestrian and worker safety research: the comparisons below describe the evidence represented by the selected publications, not an exhaustive census of all work-zone studies.

2.2 Reading Observations and Modeled Results Together

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The same phrase, “work-zone capacity,” can refer to different quantities depending on how it was obtained. Dehman and Farooq observed headways during actual construction-stage configurations at a Toronto intersection [4]. Zhu and colleagues, working with three Chengdu sites, used field observations to calibrate a model from which traffic movements under other layouts could be explored [12]. A close match between modeled and observed speeds is valuable, but it does not turn every subsequently simulated layout into an observed outcome. The distinction is even sharper for proposed controllers, whose percentage improvements depend on the baseline policy, demand, and geometric assumptions used in the comparison [6-7].

Safety-related findings require a separate reading. Liu and colleagues controlled equipment position and lighting in a simulator with 26 drivers [13], whereas site supervision records document whether traffic-management measures remained in place during actual construction [14]. Neither observation has the same endpoint as a police-reported injury crash. Similarly, a freeway merge experiment can help identify a responsive-control mechanism without specifying the signal phases, turning conflicts, or pedestrian clearances required at an urban junction [10]. These distinctions are used below where they change the practical interpretation of a result, rather than treated as a hierarchy in which one study design automatically supersedes another.

3 HOW CONSTRUCTION STAGES CHANGE TRAFFIC AND EXPOSURE

3.1 Staging Decisions and Queue Spillback

In Yang and colleagues’ bilevel scheduling model, construction sequence and crew allocation influenced both project duration and road-user travel cost [15]. Adding crews shortened the modeled works but increased the travel cost borne by users in the numerical example. The result exposes a tension in project scheduling: a faster construction program can impose a more disruptive daily traffic arrangement. The numerical exercise thus captures travel-cost consequences of staging decisions; it did not evaluate an implemented traffic plan or record safety outcomes. Decisions about when a barrier moves or a road section reopens consequently merit assessment against the traffic pattern expected during that particular stage, not just the project completion date.

Queue propagation makes stage boundaries especially consequential on streets with closely spaced signals. If a work area reduces discharge from one approach, the resulting queue may obstruct a crossing or turning bay before the queue at the worksite itself looks exceptional. Traffic diverted from that approach can also raise pressure on nearby streets. These are plausible network mechanisms rather than effects directly measured by the scheduling model [15]. They explain why a stage plan assessed only at the fenced section may appear successful after delay has simply moved elsewhere.

3.2 Geometry, Discharge, and Driver Response

Evidence from Toronto shows the scale of variation that a generic capacity value can conceal. Across five long-term configurations at a single signalized intersection, more than 140 hours of video yielded 1,766 signal cycles and 22,057 headways. Saturation flow ranged from 1,318.7 to 1,767.3 passenger-car equivalents per hour per lane; the Highway Capacity Manual work-zone model overestimated capacity for the studied arrangements [4]. The comparison is anchored in actual traffic, but its range belongs to those configurations and prevailing conditions. A later stage at the same site, or another city, may require fresh headway estimates.

The Chengdu analysis addresses a related problem from the modeling side. Zhu and colleagues calibrated and validated a social-force traffic-flow model with observations from three urban work zones that straddled intersections and adjacent road sections [12]. Mean absolute relative errors for traffic volume, average speed, and traversal time were reported below 10%. In the subsequent simulations, location relative to the median, heavy-vehicle proportion, and turning composition affected the traffic patterns. Together with the Toronto measurements, this suggests that the position and operating context of a closure matter as much as the nominal number of open lanes. The reported errors measure how well the model reproduced traffic operations; collision prediction was outside its validation target.

Equipment placement adds a behavioral dimension not captured by discharge rates. In Liu and colleagues’ driving-simulator study, 26 participants approached urban work areas under different equipment layouts and lighting conditions [13]. Placing heavy equipment near the middle of the work zone, rather than at its beginning, was associated with a 14.6% longer merging distance and higher passing speeds in the experiment. Lighting also affected driver responses in the experiment. These observed differences justify studying equipment placement on actual streets, where traffic interactions are more varied than in the simulator.

3.3 Users Outside the Vehicle Queue

The most detailed operational data concern motor vehicles, although a temporary traffic plan also determines where people can walk, cycle, wait for a bus, or work beside live traffic. Shaw and Oneyear located nine eligible pedestrian-accommodation studies in the literature covered by their review through mid-2021; none quantitatively tested the effectiveness of the design measures examined [2]. This is a finding about that review’s coverage and date, but it highlights a problem still visible in the selected urban control studies: temporary-route quality and exposure often remain outside the principal outcomes. For example, a diversion that eases vehicle queues may require cyclists to use a narrower receiving street or move a bus stop farther from an accessible crossing. Those consequences cannot be

recovered from intersection delay alone. Work-zone guidance and safety reviews address provision and protection [1, 8], but site-level evaluations need observations of who uses the altered routes and how.

4 TRAFFIC CONTROL UNDER CHANGING SITE CONDITIONS

4.1 What Can Be Decided Before a Stage Opens?

A construction-stage model is useful when it distinguishes feasible layouts rather than merely predicting congestion. In Delhi, Singh and colleagues calibrated a cellular-automata model using mixed-traffic observations around a metro construction area; simulated queues increased as the work-zone segment lengthened [16]. Khamphay and colleagues also modeled delay associated with urban road works [17]. These studies make the cost of geometric decisions more explicit, but the simulated queue is conditional on the chosen demand and behavioral assumptions. A stage comparison should therefore specify which turning paths, crossing arrangements, and loading or equipment movements are physically possible before selecting the arrangement with the smallest modeled delay.

Signal retiming may recover some of the capacity lost to an intersection closure, although only within the movements that the temporary geometry permits. At an island work zone, Yang and colleagues calibrated and evaluated traffic and signal-control models using real intersection data [7]. In the evaluated comparison, the proposed control scheme reduced modeled queue length by approximately 15.6% and delay by 17.2%. The size of the modeled gain is consequently tied to that island-work-zone geometry and its comparator. When an approach is reconfigured, the critical question is whether the available turning lanes, crossing phases, and clearance intervals still correspond to the assumptions used to obtain that result.

4.2 Queue-Responsive Control and Displaced Traffic

Duan and colleagues compared fixed and dynamic signal-control strategies with early and late merging in a freeway cellular-automata experiment [10]. Under the studied conditions, dynamic control yielded roughly 10% less simulated delay and 20% fewer aggressive lane changes, with the reported advantage concentrated at lower traffic densities. The study demonstrates how a queue-responsive strategy may work within a controlled merging environment. At an urban intersection, however, the signal cannot simply maximize release from the narrowed approach: pedestrians need crossing time, and vehicles released upstream must be able to enter the next block.

Afriyie and colleagues incorporated merge-conflict risk, stop-and-go instability, and spillback into the objective of a deep Q-network signal controller [6]. In its SUMO-based shockwave comparison against an adaptive-control baseline, maximum queue length decreased by 39.1% and maximum spillback distance by 45.8%. These are meaningful model outcomes precisely because the comparator is specified. The percentages describe the largest queue and furthest spillback in the tested scenario, not the full spatiotemporal pattern of congestion or observed changes in injury crashes. Whether the controller's conflict indicators correspond to improved safety on a busy city street would require trajectories and exposure information from field conditions, including the movements not represented in the tested closure.

A signal adjustment may also be paired with a diversion. Qi and colleagues used VISSIM and MOVES to test alternatives informed by the Wenhui Road construction project in Jinan [18]. Among the modeled cases, signal-timing changes combined with a 10% diversion performed favorably for delay and vehicle emissions. This modeled result identifies an alternative worth testing, provided that receiving-street conditions are assessed at the same time. If diverted vehicles encounter a short block, turning queue, or heavily used pedestrian crossing, the original work-zone approach may improve while disruption accumulates elsewhere. Such displacement has to be measured across the network, not inferred from a single simulated approach.

4.3 What Continuous Video Reveals—And What It Does Not

Pi and colleagues estimated lane-specific speeds from 21 days of urban work-zone video using computer vision [5]. Their reported speed-estimation errors ranged from 0 to 6.4 km/h. In the observed setting, traffic-control barrels in the median work zone were associated with an average speed approximately 15 km/h lower, and the lane beside the work area showed greater speed variation. Construction activity was associated with different speeds when traffic was slow, whereas a statistically significant difference was not found under faster-flow conditions. That contrast is more informative for on-site monitoring than a single site-wide mean: an approaching queue, for example, changes both the range of speeds and the opportunity for drivers to respond to the temporary layout. A causal estimate of barrier effects would require stronger control of changes in demand and layout across the observation period.

Table 1 retains the study-specific comparisons behind these findings. The purpose is not to rank methods, but to show which figures were measured at a site and which were produced in a particular model or experimental scenario.

Table 1 Selected Work-Zone Studies: Designs, Reported Outcomes, and Interpretation

Study and setting	Data and study design	Main result	Scope of interpretation
Yang et al. [15]; urban network, China	Bilevel scheduling with cumulative-prospect-theory user equilibrium; numerical example	Crew allocation and sequence affected modeled construction time and travel cost.	Scheduling trade-offs from a numerical model; safety unmeasured.

Study and setting	Data and study design	Main result	Scope of interpretation
Singh et al. [16]; Delhi	Cellular-automata model calibrated with mixed-traffic observations	Longer modeled work-zone sections produced longer queues.	Scenario-dependent queues; no field intervention test.
Zhu et al. [12]; three Chengdu sites	Field-calibrated and validated social-force traffic-flow model	Mean absolute relative error below 10% for volume, speed, and traversal time.	Operational model fit, not collision prediction.
Dehman and Farooq [4]; Toronto junction	Five configurations; >140 h video; 1,766 signal cycles and 22,057 headways	Saturation flow: 1,318.7–1,767.3 pc/h/ln; generic model overestimated capacity.	One junction across construction stages; other networks need calibration.
Pi et al. [5]; urban work zone	21-day video study with computer-vision speed estimates	Speed error 0–6.4 km/h; median barrels associated with ~15 km/h lower mean speed.	Observational association; layout and demand may confound.
Duan et al. [10]; freeway work zone	Cellular-automata comparison of merging and signal-control strategies	~10% less modeled delay; ~20% fewer aggressive lane changes.	Freeway simulation; urban movements not represented.
Xu et al. [11]; expressway model	Simulation of conflict-based dynamic assessment and response	Risk appraisal completed in ~20 min under moderate modeled traffic.	Computational feasibility, not urban field effectiveness.
Yang et al. [7]; island work zone	Urban intersection data informing signal-control model assessment	~15.6% shorter modeled queues; ~17.2% less modeled delay.	Modeled comparison; pedestrian and injury outcomes not evaluated.
Liu et al. [13]; urban simulator	26 drivers; equipment layouts and lighting conditions	Mid-zone equipment associated with 14.6% longer merging distance and higher speed.	Controlled driver response; field transfer untested.
Qi et al. [18]; Jinan	VISSIM and MOVES scenarios informed by an urban construction site	Signal adjustment and 10% diversion favored modeled emissions and delay.	Simulation estimate; receiving-street conditions require study.
Afriyie et al. [6]; intersection near work zone	SUMO simulation of deep Q-network control with safety-related objectives	Maximum queue 39.1% shorter; maximum spillback 45.8% shorter versus adaptive control.	Shockwave comparator in simulation; no observed injury endpoint.
Sanchez Corredor et al. [14]; urban project	288 supervised days over 16 months; compliance and incident records	Non-compliance fell from 27/144 (18.8%) to 10/144 (6.9%) days.	Temporal association with changing site conditions; causality unclear.

Note: Outcomes and percentages are tied to the settings and comparison strategies shown. pc/h/ln = passenger-car equivalents per hour per lane. Operational and conflict-related outcomes are not interchangeable with recorded crashes or injuries.

5 INTERPRETING SAFETY EVIDENCE

5.1 The Outcome and the Population at Risk

For a temporary road layout, a shorter vehicle queue says little about how risk is distributed among the people using the street. Delay and discharge characterize vehicle movement; crossing volumes, cyclist passages, and time spent by workers beside moving traffic describe the amount of exposure. Severe braking, time to collision, post-encroachment time, and incursions may indicate hazardous interactions, while recorded crashes and injuries measure realized harm. Their relationship is neither fixed nor direct. Reviews of surrogate indicators show that interpretation depends on the conflict definition, road context, trajectory data, and measurement error [9]; evidence drawn mainly from unsignalized intersections cannot automatically validate the same thresholds for a signalized work zone.

The choice of denominator can reverse a seemingly favorable result. If cyclists avoid a narrow temporary lane, conflicts counted at that point may fall even though the diversion has moved them onto a less protected route. A comparison should therefore relate conflicts to relevant crossings or passages, identify diverted users, and distinguish changes in traffic volume from changes in the risk of each encounter. Injury crashes are usually too infrequent during a brief stage for a single-site before-and-after count to be decisive. Conflict observation can help diagnose a hazardous movement sooner, provided it is reported as such rather than as an estimated number of prevented injuries.

5.2 Dynamic Risk Assessment at the Site

Xu and colleagues demonstrated an iterative risk-assessment process in a simulation based on the S20 expressway in Shanghai [11]. Under moderate modeled traffic, an assessment could be completed in approximately 20 minutes. This establishes a computational precedent for repeated conflict assessment, but an urban operator also has to contend with pedestrian phases, buses obscuring a camera's field of view, and barriers moved between inspections. The interval over which a hazard changes may be shorter than the time needed to detect, approve, and implement a response. The time needed to act on a warning is therefore as consequential as the speed of the risk calculation.

The minimum protection of people using the site must be set independently of the control system's delay objective. A closed accessible crossing cannot be compensated for by a shorter vehicle queue; nor does lower mean speed establish that workers are separated from an entering heavy vehicle. Route continuity, sightlines, crossing clearance, bus-stop access, and construction-vehicle entry require direct inspection as well as sensors. Technical guidance describes

available countermeasures [8], while individual traffic-management plans still need thresholds and inspection practices suited to the stage and the street.

6 FROM DETECTION TO A FIELD DECISION

6.1 Authority, Compliance, and the Operating Plan

Traffic-management plans are often judged by the design they prescribe, whereas the actual risk depends on what remains installed and functioning each day. Sanchez Corredor and colleagues analyzed 288 supervised workdays over 16 months on an urban infrastructure project [14]. Traffic-management-plan non-compliance declined from 27 of the first 144 days (18.8%) to 10 of the next 144 (6.9%; $p = 0.0028$), with seven traffic incidents recorded over the study. Changing work conditions, staff arrangements, and repeated signal theft complicate any causal interpretation of that reduction. The contribution of the records is more direct: they show that maintaining the specified temporary controls is itself a changing operational task.

An adaptive signal or warning system needs to fit within that task. Before each major stage, the site team can establish usable pedestrian and cycling paths, emergency access, approved changes to signal operation, and the locations where displaced queues will be checked. During the works, a detected change becomes an action only if someone has authority to make it and the revised layout is safe to use. For hazards such as an open worker-traffic interface or failed crossing separation, the field response takes priority over attempts to improve progression. Automation can flag a problem; the site operator remains responsible for authorizing the corrective arrangement.

6.2 A Proposed Monitoring-Response Matrix

Table 2 converts these requirements into site-level examples. It pairs an observable condition with the person responsible for a response and specifies what should be checked after the change. The actions are proposals for local adaptation and testing; no trigger value or response time has been validated by this review.

Table 2 Proposed Monitoring-Response Matrix for Urban Road Work Zones

Observed condition	Response and decision-maker	Safeguard or fallback	What to check afterwards
Queue approaches crossing or next signal	Network operator reviews coordination, metering, or an approved diversion.	Keep crossings and emergency access clear; reverse if spillback worsens.	Queues at both junctions, crossing obstruction, bus delay.
Speeds become more variable beside a temporary route	Site supervisor inspects channelization; operator reviews permitted warnings or controls.	Check sightlines and physical separation, not mean speed alone.	Lane-level speeds, near-conflicts, route condition.
Pedestrians or cyclists avoid the designated detour	Site safety lead repairs protection, accessibility, and wayfinding.	Maintain a usable route before changing vehicle progression.	Route use, accessibility, crossings, observed deviations.
Worker or equipment enters moving traffic	Construction supervisor stops unsafe activity and restores controlled access.	Apply site emergency procedures ahead of signal optimization.	Incursions, barriers, incident and corrective-action records.
Diversion overloads a receiving street	Network operator reviews turn controls, signs, or signal offsets.	Preserve transit and emergency access; check for displaced conflict.	Turn movements, side-street delay, bus movements, conflicts.
Sensors fail or detection becomes unreliable	Control operator selects approved fallback and requests inspection.	Suspend unsupported automation; record recovery conditions.	Data gaps, safe operating state, rollback and response log.

Note: This matrix has not been validated prospectively. Site-specific trigger values, decision authority, and criteria for suspension, fallback, and resumption should be approved in the traffic-management plan before use.

6.3 Testing a Response, Including When It Fails

A relocated camera, missing sign, communication outage, or new construction stage can undermine the conditions on which automated control was approved. At that point, maintaining unverified automation becomes less defensible than returning to a conservative, inspected traffic arrangement. The action log needs to capture the alert, authorization, change made, reason for stopping or reversing it, and time required to restore acceptable operation. Otherwise a system may look effective in model outputs while routine equipment and staffing problems remain invisible.

Field evaluation should be planned around the intervention actually delivered. Counts and queues from the worksite should be paired with those from receiving streets, while pedestrian crossings, cyclist movements, transit access, and worker encounters define safety-related exposure. Repeated stage measurements and a credible comparison site or period are more informative than a single before-and-after snapshot. An interrupted time series may suit a sustained control change; a difference-in-differences analysis requires a defensible comparison group and assessment of its pre-intervention trends. Neither method rescues poor outcome measurement. Reports should include missing sensor periods, operator non-adherence, adverse responses and uncertainty in conflict rates, rather than quoting only the most favorable simulated percentage.

7 PRIORITIES FOR FURTHER FIELD RESEARCH

Reliable transfer across urban layouts requires stage-specific replication at more than one site. Toronto's measured saturation flows [4], Chengdu's calibrated representation of straddling work zones [12], and the island-intersection signal results concern distinct configurations [7]. A useful multisite study would record exactly when a stage changes the number of usable lanes, turning paths, pedestrian phases, bus movements, and construction-vehicle access. Short utility repairs and prolonged intersection reconstruction are unlikely to share a stable response to the same control setting. Without these details, differences across sites can be mistaken for differences between algorithms.

Network outcomes also need to be connected to the exposure of road users omitted from vehicle-queue statistics. The limited quantitative pedestrian evidence identified through mid-2021 contrasts with detailed measurements and simulations of vehicle discharge [2, 4], lane speeds [5], and adaptive control [6]. Temporary cycling routes, crossing use, bus-stop relocation and site-entry conflicts should therefore be observed before and after a control change, including where users have been diverted. Evaluating safety-related indicators requires reporting their denominators and detection quality, and longer or pooled studies would be needed to examine changes in injury crashes.

Finally, field trials can answer a question that simulations usually leave open: whether the intended arrangement remains operational across staff changes, sensor failures, equipment movements, and changing demand. The supervision records make day-to-day plan maintenance part of the intervention itself [14]. A comparison between an advanced controller and a well-maintained conventional traffic-management plan should report installation effort, response time, override frequency, operator workload, and conditions that forced a return to manual control. These observations may explain more about deployment than a small improvement in average modeled delay.

8 CONCLUSIONS

Urban work-zone geometry can alter intersection discharge sufficiently that a single capacity assumption is unreliable across construction stages. Field-informed models offer ways to compare alternative controls, but the size of a predicted improvement is inseparable from the layout and comparison policy. The 15.6% queue reduction reported for an island-intersection scheme and the 39.1% reduction in maximum queue length reported for a safety-aware controller arise from different scenarios and reference controls [6-7]; each has to be interpreted within its own comparison. The studies also leave substantial uncertainty about how traffic changes alter the exposure of pedestrians, cyclists, transit passengers, and workers.

For practice, the useful connection is between a changing physical layout, an authorized operational response, and observation of its consequences beyond the worksite. The monitoring-response matrix offered here makes that connection explicit without claiming an independently validated safety benefit. Future urban field studies will be most informative when they measure what actually changed at the site, where delay or conflicts moved, whether temporary protections remained in place, and which outcomes improved for the people using the street.

COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

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