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TRAFFIC CONFLICT RISKS AND LOCAL STREET NETWORK MANAGEMENT DURING ARRIVAL AND DISMISSAL PEAKS AROUND URBAN PRIMARY AND SECONDARY SCHOOLS: A NARRATIVE REVIEW

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Abstract: School arrival and dismissal concentrate pedestrians, cyclists and vehicles on streets with little room for stopping, waiting or crossing. Conflicts can arise at the entrance, but also at pick-up points, junctions and streets used to bypass congestion. This narrative review draws on Chinese school-access studies, video-based traffic-conflict research, evaluations of timed vehicle restrictions and relevant design guidance to examine how local street circulation affects these interactions. The evidence measures different outcomes: video records reveal potentially hazardous encounters; collision-risk models estimate risk under specified assumptions; crash data document past injuries; and intervention studies largely measure traffic volumes or travel choices. Video observations at one primary school identified 43 potential conflicts using time-to-collision, post-encroachment time and braking criteria. Controlled evaluations of School Streets, by contrast, reported differing changes in active school travel. Monitoring around two restricted school streets also found traffic redistribution and altered parking activity alongside lower total vehicle volumes across the monitored roads. These findings make a gate-only assessment inadequate. The review relates crossing design, pick-up arrangements, turning restrictions and route continuity to their respective conflict mechanisms, then sets out measures for comparing safety, traffic operation and access across the surrounding streets. Whether such interventions reduce pupil–vehicle conflicts or injury crashes over time remains less certain.
Keywords: School-zone safety; Traffic conflicts; School arrival and dismissal; Local street network; Pick-up and drop-off management; Traffic circulation

1 INTRODUCTION

At the start and end of the school day, pupils walking or cycling share short stretches of urban street with private cars, motorised two-wheelers and school buses. A car stopping beside the entrance can block a cycle lane; a cyclist avoiding it may move onto the footpath; and vehicles waiting near a crossing can conceal children from approaching drivers. When the queue reaches an adjacent junction, its effects extend beyond families travelling to the school. These connected movements make school-peak traffic more complex than a simple increase in vehicle demand.

School-related journeys have a measurable effect on urban traffic. Using a triple-difference design, Sun et al. estimated that school runs increased the probability of congestion on the Beijing roads studied by 4.5 percentage points, with a larger contribution during morning drop-off [1]. In Foshan, Zhao et al. described overlapping peak periods, substantial private-car pick-up demand, limited parking and gaps in local street connectivity [2]. A systematic review by Katoch et al. likewise found that school-zone safety research spans road design, road-user behaviour and traffic conditions [3]. Taken together, these studies describe a problem that varies with both travel demand and the surrounding street layout.

An intervention that clears vehicles from the gate may leave the main pedestrian crossing unchanged or shift waiting cars to the next block. The central question is therefore where pupils encounter traffic before and after a change to local circulation. This review considers the entrance, stopping areas, connecting junctions and alternative routes as parts of one school-access network, while keeping safety, traffic performance and accessibility distinct.

2 REVIEW SCOPE AND ANALYTICAL BOUNDARIES

2.1 Evidence Considered

The evidence discussed here includes Chinese investigations of school travel and street conditions, studies using video or crash data to examine traffic risk, and international evaluations of restrictions around schools. Systematic reviews provide context for the wider literature [3-4]. A two-school field-monitoring report by Sustrans adds observations of traffic on roads beyond the restricted school frontage [5]. The synthesis focuses on the movements and outcomes documented in each source, particularly where research on congestion, travel behaviour and safety addresses different aspects of the same street.

In this article, local street network management refers to changes in access, stopping, pedestrian crossings, turning movements and route choice around a school. A timed one-way street is one possible measure, not a complete description of the approach. The relevant area usually extends from the entrance to the routes pupils follow, the

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locations where caregivers wait, the nearest junctions and streets that may receive diverted traffic. Its boundary is set by those movements, not by a fixed distance from the gate.

2.2 What Constitutes a Safety Outcome?

Road crashes, traffic conflicts and traffic conditions describe related but different aspects of safety. Recorded crashes document harm, although the short observation periods typical of a school-site intervention may contain very few injuries. A traffic conflict is a potentially hazardous encounter between road users, often identified from their trajectories or evasive actions. Time to collision (TTC) is the time remaining to a collision if relevant positions and movements continue unchanged; post-encroachment time (PET) describes the interval between successive road users occupying the same conflict area. Values depend on the trajectories observed and the thresholds chosen by investigators [3,6-7].

This distinction matters when comparing studies. Crash records reveal where injuries have occurred [8-9], while video can identify brief encounters that did not result in contact [7]. School Street evaluations often report traffic volumes, perceived safety or travel modes [10-11]. None of these outcomes is interchangeable with another. In particular, a change in car use is not itself a measured change in pupil–vehicle conflict risk.

3 HOW ARRIVAL AND DISMISSAL PEAKS PRODUCE CONFLICT

3.1 Temporal Concentration and Household Travel Schedules

School arrival is often tightly concentrated before the morning bell; dismissal may be spread across different class times and after-school activities. Sun et al. estimated a stronger congestion contribution from morning drop-off than afternoon pick-up in Beijing [1]. He and Guo found that the timing of parents' work and children's school schedules was associated with school travel mode in Kunming [12]. An access restriction may consequently meet a different pattern of travel demand at a school with staggered departures than at one where most pupils leave together.

School trips also reflect distance from home, public and school transport options, children's ages, weather and parents' work schedules. These factors shape how many vehicles reach the neighbourhood and when they arrive. Moving a queue away from the entrance changes its location, but not necessarily the underlying demand. It is therefore useful to separate vehicles passing through the area from those collecting or delivering pupils: the former may have alternative routes, whereas the latter still require a place to stop and a practicable walking connection.

3.2 Kerbside Interruptions and Mixed-Mode Movements

The kerbside is often where conflicting movements begin. A vehicle stopped in a running lane may prompt following traffic to change course, push cyclists towards pedestrians and obscure a crossing. Caregivers waiting opposite the gate create additional pedestrian movements across the road. Electric bicycles and other two-wheelers further complicate access when they share narrow approaches with children. Serious interactions are possible even at low speeds, particularly near obstructed corners and on streets with no dedicated stopping space.

The Chinese case studies help explain how these pressures differ by location. Zhao et al. described a mismatch between concentrated school travel demand and the road and stopping space available in Foshan [2]. From drone video at a Kunming primary school, Ji et al. reported that mean traffic density during arrival was about 2.5 times the dismissal value, although dismissal showed sharper local accumulation at certain moments [13]. Average density and short-lived queues capture different features of the peak. Neither, by itself, identifies the pedestrian or cyclist interactions that occur within the crowding.

3.3 Why Adjacent Junctions Matter

The nearest junction may receive the consequences of stopping outside the school. Queues can block pedestrian crossings, reduce turning visibility or force children to cross between stationary vehicles. Restricting movements on the frontage changes where some drivers turn or rejoin the wider network. Crash-hotspot analysis in Seoul by Chun et al. and spatial crash-risk research in Shenzhen by Wu et al. show that relevant safety patterns extend beyond an administrative school-zone boundary [8,14]. Their findings concern observed spatial patterns, rather than the measured effect of a particular circulation change.

4 IDENTIFYING SAFETY RISKS BEFORE SELECTING A CONTROL MEASURE

4.1 Field Observation and Conflict Mapping

A gate-side vehicle count captures only part of the exposure created by school trips. Children may cross the road at a bus stop, walk around a vehicle queue or encounter turning traffic at the next junction. Video-based work is especially useful here because the same movements can be reviewed for vehicle paths, pedestrian decisions and the location of evasive manoeuvres. Interpretation still depends on which approaches were visible to the camera and whether morning and afternoon periods were covered. A conflict hotspot outside the field of view will be absent from the record, however crowded the entrance appears.

Renard et al. used unmanned aerial vehicle footage around a primary school to identify 43 potential conflicts through TTC, PET and heavy-braking criteria [7]. These were observed surrogate safety events, not injury crashes, and the results came from one school environment. Hu et al. took a different approach, combining surrogate indicators with extreme-value modelling to estimate collision risk on roads near schools during the morning peak [6]. The former study illustrates the location and character of observed interactions; the latter estimates risk under a statistical model. Their outcomes can inform the same local assessment, but they are not estimates of the same event rate.

4.2 Combining Event Data with Street-Environment Assessment

Longer-term crash records provide a different perspective on the locations identified through short video surveys. Zhang et al. examined serious pedestrian-injury crash hotspots in Seoul in relation to the surrounding street environment [9]. In Beijing, Wang et al. assessed whether facilities around a primary school offered usable routes for children [15]. The first concerns where severe harm has occurred; the second examines the practical suitability of school-access facilities. Considered alongside direct observations, they help distinguish a busy location from one where the street environment may expose children to particular hazards.

Table 1 sets out how selected studies differ in their design, measured outcomes and implications for managing streets around schools.

Table 1 Selected Studies Informing School-Peak Conflicts and Local Street Organisation

Study or source	Design and focus	Observed or estimated outcome	Implications for local streets
Sun et al. [1]	Triple-difference analysis; Beijing	Congestion probability (+4.5 percentage points)	School-trip demand adds to congestion
Hu et al. [6]	Risk modelling; morning peak	Estimated vehicle collision risk	Modelled risk, not direct pupil conflicts
Renard et al. [7]	Drone-video conflicts; primary school	43 potential TTC/PET/braking conflicts	Locates conflicts at one school
Ji et al. [13]	Video traffic density; Kunming	Traffic density and peak accumulation	Arrival and dismissal differ
Wu et al. [8]	Spatial crash analysis; Shenzhen	Road environment and child crash risk	Locates historical crash patterns
Dowling et al. [10]	Natural experiment; Bradford	Lower gate flow; some active travel declines	Reduced flow need not change travel mode
Patterson et al. [11]	Controlled natural experiment; UK	Change in travel-mode proportions	Travel mode, not conflict frequency
Belcourt-Weir et al. [5]	Two-school field study; Birmingham	Nearby traffic, parking and speed	Identifies diversion and stopping changes
Zhao et al. [2]	School-access case study; Foshan	Demand and management options	Connects stopping space and road layout

Note: TTC = time to collision; PET = post-encroachment time. Findings from the field-monitoring report are identified separately from peer-reviewed studies.

5 LOCAL STREET NETWORK MANAGEMENT: MATCHING MEASURES TO RISKS

5.1 A Protected School-Gate Approach

The approach to a school is a route, not merely the space immediately in front of its gate. Continuous footpaths, visible crossings and sufficient waiting space determine where pupils walk and where drivers encounter them. Xia et al. described child-oriented school routes in terms of connected sections and successive traffic nodes [16]. China's GA/T 1215-2025 standard also addresses the arrangement of traffic facilities and road operations around primary and secondary schools [17]. In practice, the position of a crossing or barrier matters as much as its presence: a protected entrance is of limited value if it directs children towards an exposed crossing nearby.

Protection can also create a new concentration point. A barrier may keep vehicles off the footpath but bring waiting pedestrians together at its end, especially where the nearest safe crossing is some distance away. Similarly, space cleared for pupils must still accommodate through pedestrians and essential vehicle access. The design problem is continuity between the surrounding streets and the gate, rather than the appearance of an uncluttered frontage.

5.2 Managing Pick-Up and Drop-Off at the Kerb

Stopping arrangements depend on the different rhythms of arrival and collection. Morning drop-off generally involves short unloading stops; afternoon collection can involve longer waits while caregivers look for pupils. A bay that allows children to step directly onto the footpath avoids an additional road crossing. Where such space cannot be provided at the entrance, remote pick-up and drop-off become options only when the walk to school is accessible and does not introduce an unsafe crossing. The greater morning congestion effect reported by Sun et al. also cautions against treating the two peak periods as operationally identical [1].

Relocating parked or waiting cars changes the geography of the problem. The Birmingham monitoring report observed increased parking-related interactions near some restriction barriers, despite no observed increase in the severity of those interactions [5]. A remote collection point may ease the queue outside the school, yet produce a new cluster of

pedestrians and vehicles farther along the route. For this reason, the experience of pupils at the new stopping point is part of the effect of the relocation, not a separate issue.

5.3 Timed One-Way Circulation and Junction-Level Controls

A timed one-way street removes opposing traffic from one section of road, but the same school-bound vehicles still need to reach the entrance and leave the area. Some turns disappear while others are transferred to adjoining junctions. The consequences differ between a connected street grid with several exit choices and a narrow access road with few alternatives. Circulation design therefore hinges on where drivers turn, wait and re-enter through traffic, rather than on the direction of movement outside the gate alone.

Observed turning movements and the position of nearby crossings offer a firmer basis for a circulation plan than the entrance queue alone. A restriction timed to the school peak is also different from a permanent change to the street network. Where modelling is used, its usefulness depends on credible assumptions about stopping duration, cycle movements and pedestrian crossings. A model that reproduces vehicle queues but omits these interactions cannot answer the safety question at the centre of this review. Signs, barriers and staff arrangements are part of how a proposed layout operates on the street; their effects remain matters for field observation.

5.4 Crossing Control, Cycling and Alternative School Travel

Children's routes rarely end at the protected frontage. Farther along the journey, an uncontrolled crossing, missing footpath link or poorly placed cycle merge may present the more difficult interaction. Crossing time, approach speed and waiting space thus matter alongside vehicle circulation. Wang et al. showed that the presence of school-route facilities and children's ability to use them are not necessarily the same [15]. A local improvement is more meaningful when pupils can reach it without negotiating a hazardous gap in the route.

Street controls also interact with how families organise the school journey. Staggered opening times, school transport and supervised walking arrangements address the concentration or mode of travel rather than the geometry of a junction. He and Guo's analysis links travel choice with parental time constraints [12], a factor that can limit how readily households respond to a restriction. Measures directed at travel demand and measures directed at traffic movements consequently affect different stages of the same trip.

5.5 Adjusting Controls as Travel Patterns Change

Peak-period conditions need not remain stable once a restriction is introduced. Drivers may start waiting just beyond a barrier, cyclists may choose a different approach or a queue may form at a previously quiet turn. Short-term forecasts of traffic accumulation, such as those developed by Ji et al. near a Kunming primary school [13], can help anticipate when pressure is greatest. They cannot, however, reveal whether the altered pattern produces new pupil–vehicle conflicts. That requires observations of the movements and stopping behaviour after the change.

6 INTERVENTION EVIDENCE AND THE RISK OF DISPLACEMENT

6.1 What Timed Access Restrictions Have Shown

School Streets usually restrict general motor-vehicle access to the road beside a school for short periods around arrival or dismissal. Their aim overlaps with Chinese school-area controls, although a timed closure is not the same intervention as a neighbourhood one-way loop or remote pick-up scheme. In a controlled natural experiment covering 166 intervention schools and 332 matched controls in England and Scotland, Patterson et al. reported a 5.9-percentage-point increase in active school travel and a 5.3-percentage-point decrease in private motor-vehicle travel relative to controls [11]. A quasi-experimental evaluation of London School Streets by Thomas found more modest travel-mode changes [18]. Both studies chiefly inform the effect on how children travel; neither provides a direct estimate of the change in observed conflicts or injury crashes.

The Bradford findings were less favourable. Dowling et al. reported declines in some self-reported active travel measures relative to control schools, without clear improvement in children's satisfaction with the street or perceived crossing safety [10]. Vehicle flow on the restricted school roads nevertheless fell substantially. The contrast matters: fewer cars at the gate and more walking to school are separate outcomes, and one does not guarantee the other. Differences in catchment distances, pre-existing travel habits and the way restrictions are implemented may contribute to variation between sites. Yuan and Ermagun's review similarly identified uneven evaluation practices across Safe Routes to School programmes [4].

6.2 Traffic Changes beyond the School Frontage

Traffic does not necessarily disappear when access beside a school is restricted; some of it changes route or stopping location. A Sustrans report followed traffic volumes, speeds and parking interactions before and after School Street restrictions at two Birmingham primary schools, including streets outside the barriers [5]. Some traffic moved to neighbouring locations, but the total volume across monitored roads fell during restriction periods. Parking interactions increased near certain barriers without an observed increase in interaction severity, and average car speed rose slightly

at one site. These findings give a more nuanced picture than either assuming that displaced traffic creates danger or treating the cleared gate as evidence of wider safety improvement. The observations describe two sites, not an area-wide change in crash incidence.

The relevant question is where the displaced movements go. A queue that shifts to a junction used by pupils may create an obstructed crossing, whereas a redistribution of vehicles on streets with suitable capacity may have different consequences. The spatial crash patterns reported for Seoul and Shenzhen identify locations of existing concern [8-9,14], but changes attributable to a particular traffic arrangement require observations before and after it begins. Looking only at the restricted road would miss both improvements and newly concentrated interactions elsewhere.

7 A PRACTICAL EVALUATION FRAMEWORK FOR SCHOOL-PEAK MANAGEMENT

The unit of evaluation follows the journey from the street where a pupil approaches to the point of school entry. This calls for observations at comparable school times before and after a traffic change, with differences in weather, attendance and enforcement taken into account. When an unaffected comparison street or school is available, it may help distinguish a local intervention from broader changes in travel. Even a smaller site evaluation is informative if it records the actual movements altered by the scheme, rather than relying solely on vehicle counts at the entrance.

The choice of measure depends on the question. Counts of pedestrian–vehicle and cyclist–vehicle encounters describe who interacts with whom; TTC or PET adds information about the timing of particular encounters. Queue spillback, dwell time and blocked footpaths capture disruption to traffic and walking space. Walking distance and the quality of crossings on the way to a remote pick-up area describe access. A clearer gate queue, for example, would be an incomplete result if pupils now cross a busier side street. Table 2 links common traffic measures to these different observations.

Table 2 Suggested Measures for Evaluating School-Area Circulation Changes

Management action	Expected operational mechanism	Measures to examine	Possible trade-off or relocated risk
Protected school approach and crossing	Define pedestrian routes and improve visibility at crossing points	Mode-specific conflicts; approach speed; crossing delay	Interactions may concentrate near barrier ends or adjacent crossings
Remote pick-up and short-stay kerbside bay	Shift prolonged stopping away from the entrance	Vehicle dwell time; illegal stopping; conflicts along the walking route	Waiting and conflicts may move to the remote bay or its crossing
Timed one-way loop or turn restriction	Change opposing and turning movements near the entrance	Queue spillback; turning conflicts; traffic on adjacent links	Longer access trips or traffic diverted to neighbouring streets
Continuous walking and cycle routes	Limit interruptions and unnecessary interaction between modes	Footpath obstruction; cycle interactions; gaps in route continuity	New merging points or constrained space for cyclists
Staggered school times or school transport	Spread peak arrivals or reduce demand for private-car trips	Arrival profiles; mode shares; waiting times	Schedules or transfer arrangements may disadvantage some families

Note: The matrix offers a practical set of comparisons for local evaluations; it is not a validated scoring instrument.

Conflict counts also depend on exposure. Ten conflicts among a small number of encounters convey something different from ten conflicts among hundreds of pedestrians and vehicles. Results expressed per observation hour and per 1,000 relevant encounters answer different questions, especially when access restrictions change traffic volumes. TTC and PET reports are most interpretable when travel modes, trajectory assumptions, thresholds and missing observations are described. Counts and severity distributions together offer more information than either alone.

Changes in access deserve the same attention as changes in vehicle movement. Moving collection away from the main entrance may shorten the immediate queue while lengthening a pupil's walk or adding another road crossing. A timed restriction may be straightforward for families living nearby but less convenient for pupils travelling longer distances or requiring accessible drop-off. The judgement about a scheme therefore depends on what has changed along the whole journey, not simply at the point where the intervention was installed.

8 LIMITATIONS OF CURRENT EVIDENCE AND RESEARCH PRIORITIES

The literature leaves a central gap between what is commonly measured and what school-area traffic management is meant to improve. Video studies identify potential conflicts at particular sites, while crash analyses describe longer-term injury patterns; intervention evaluations more often measure vehicle flows or school travel modes [3,7,10-11]. These findings cannot yet establish whether a quieter school frontage produces fewer hazardous encounters at nearby junctions or relocated collection points. Much of the available intervention research also concerns primary schools, leaving less direct evidence on the travel patterns and responses of secondary-school pupils.

An evaluation capable of answering this question would follow the same pupil routes before and after a targeted change. It would cover the entrance, the most-used crossing, nearby turns and any relocated pick-up point, with morning and afternoon analysed separately. Where feasible, comparison streets and longer follow-up would distinguish persistent travel patterns from an initial adjustment. Pupils' and caregivers' accounts would identify difficult crossings or access barriers that traffic counts might miss.

9 CONCLUSION

School-peak traffic management concerns a connected set of approaches, crossings, collection points and junctions. Intervention studies currently document changes in vehicle flow and children's travel modes more clearly than changes in pupil–vehicle conflicts or injuries. Video observations can locate hazardous encounters, but they cannot establish the long-term safety effects of a circulation change on their own. A clear school entrance is therefore an incomplete measure of success. The stronger test is whether pupils can reach the gate without encountering newly concentrated hazards after parking, turning and through traffic have been redistributed to nearby streets.

COMPETING INTERESTS

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

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