



International Journal of Highway and Transportation Engineering

Journal homepage: <https://trpub.org/journal.php?id=WZtiKJ4WZ4>

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IJHTE

International Journal of
Highway and
Transportation
Engineering

Vol. 1 Issue 1 2026

Methodology Article

Open Access

Converting a Signalised Urban Corridor to Bus Priority in a Mid-Sized City: A Proposed Planning and Evaluation Procedure

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Article Info

Volume 1, Issue 1, 2026

doi: [10.62715/ijhte.2026.v1.i1.pp8-13](https://doi.org/10.62715/ijhte.2026.v1.i1.pp8-13)

Received: 05 December 2025

Accepted: 06 February 2026

Published: 24 March 2026

Abstract

Guidance on bus priority has been written largely with metropolitan corridors in mind, where buses arrive every few minutes and a reserved lane is easy to justify. Mid-sized cities face a different problem: moderate frequencies, a handful of congested junctions, signal equipment of mixed age, and strong local attachment to kerbside parking. This article proposes a seven-step procedure for converting an existing signalised arterial to bus priority under those conditions. The steps are to diagnose where buses lose time using archived vehicle location data, to set objectives expressed in person-based measures, to match treatments to individual segments instead of applying one design throughout, to design signal priority and stop layout together, to plan kerbside access and enforcement, to stage the opening, and to evaluate the result with a before-and-after design that includes a comparison corridor. For each step the article states its purpose, the information it needs and the output it should produce, drawing on published manuals and research on transit preferential treatments. The procedure is a proposal. It has not been applied to a corridor or validated here, and the article sets out what a first application would need to show.

Keywords: *Bus priority, Transit signal priority, Bus lanes, Arterial corridors, Before-and-after evaluation, Mid-sized cities*

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1. Introduction

A bus on a signalised arterial spends its time in four ways: moving, waiting at signals, standing at stops, and rejoining traffic. Only the first is productive, and on a congested corridor it can be the smaller part of the journey. Bus priority is the collective name for measures that reduce the other three, from reserved lanes and signal priority to stop relocation and faster boarding. The measures are well documented, and their effects on speed and reliability are described in the standard manuals (Kittelson & Associates *et al.*, 2013; Danaher, 2010).

Much of that documentation derives from large cities and from bus rapid transit, where high frequencies and heavy loads make a continuous busway defensible (Levinson *et al.*, 2003; Wright and

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Hook, 2007; Deng and Nelson, 2011). A mid-sized city, with a bus every ten or fifteen minutes on its main corridor, cannot simply scale such designs down. A reserved lane that carries few buses an hour looks empty to motorists, the signal controllers may not support priority requests, and the traders along the street will count every parking space. The question for such a city is which treatments to use where, and how to show afterwards that they worked.

This article proposes a procedure for answering that question. It is a method assembled from published guidance and research and is offered for discussion and trial. It does not describe a completed project and reports no measurements.

2. Background

Three bodies of knowledge underlie the procedure: the range of preferential treatments, the particular behaviour of signal priority, and the methods of evaluating a change on a street.

2.1. Preferential treatments

Treatments fall into those applied along the link and those applied at the junction. Link treatments are bus lanes in their several forms, kerbside, offset from the kerb outside a parking lane, or in the median, operating full-time or in peak periods only (NACTO, 2016). Where bus flows are too low to justify a permanent lane, intermittent bus lanes that are cleared of other traffic only as a bus approaches have been proposed and analysed (Viegas and Lu, 2004; Eichler and Daganzo, 2006). Junction treatments include queue jump lanes, which let a bus bypass the queue on a short approach lane and leave ahead of it on a special signal phase, and signal priority itself. Stop-related measures, such as wider stop spacing, kerb extensions and boarding through all doors, attack dwell time and the delay in re-entering traffic (Kittelson & Associates et al., 2007).

2.2. Signal priority

Transit signal priority alters signal timing in favour of an approaching bus, most often by extending a green or truncating a red. It differs from pre-emption in that the controller stays in coordination (Smith et al., 2005). Its benefit depends on detail. Priority is most effective where the stop is on the far side of the junction, because the arrival time of the bus at the stop line is then predictable. It imposes least cost on cross traffic when it is conditional, that is, granted only to buses running behind schedule, a strategy shown by Furth and Muller (2000) to improve punctuality with little disturbance. Skabardonis (2000) sets out the range of passive and active strategies and the circumstances that favour each.

2.3. Evaluation

Traffic on a corridor changes for many reasons unrelated to a scheme, so a simple comparison of bus speeds before and after is weak evidence. The stronger quasi-experimental designs add a comparison group and a series of observations on either side of the change (Shadish et al., 2002). Transit agencies are well placed to use them, since automatic vehicle location and passenger counting systems archive the running time of every trip and the load on every bus, and methods for turning those archives into measures of speed and reliability are established (Furth et al., 2006).

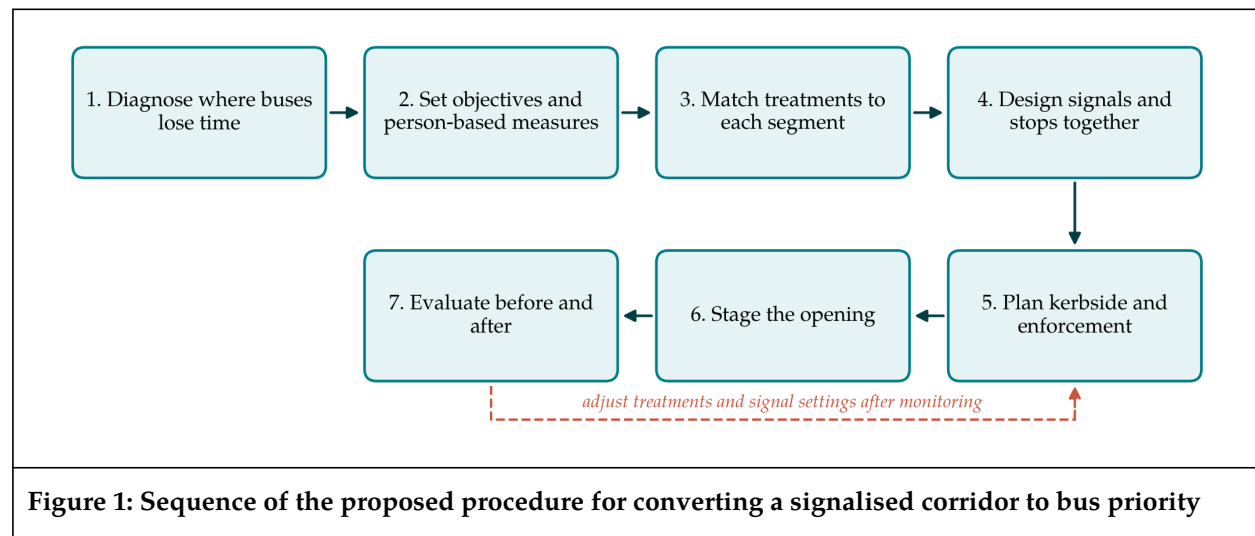
3. The Proposed Procedure

The procedure has seven steps, shown in sequence in Figure 1. Each is described below with its purpose and its output. The loop in the figure reflects the expectation that signal settings and some physical details will need adjusting once the corridor is operating.

3.1. Step 1: Diagnose where buses lose time

The first task is to divide observed bus travel time into its components by location. Archived location data, at stop level or finer, allow running time between stops, dwell time and, with care, signal delay to be separated for each segment and time of day (Furth et al., 2006). The variability of each component should be extracted along with its average, because passengers and schedulers are affected by unreliable trips at

least as much as by slow ones. The output is a delay profile of the corridor: a table or strip map showing, for each junction and stop, how much time is lost and how consistently.



3.2. Step 2: Set objectives and person-based measures

Objectives should be agreed before treatments are discussed. The procedure recommends stating them in terms of people and not vehicles: person-delay across all modes at each junction, bus running time and its spread, and schedule adherence. Vehicle-based level of service, as computed by conventional capacity analysis (Transportation Research Board, 2016), remains a necessary check on general traffic but gives a bus with forty passengers the same weight as a car with one. Fixing the measures at this stage also fixes what must be collected for the evaluation in Step 7.

3.3. Step 3: Match treatments to each segment

With the delay profile and objectives in hand, each segment is assigned the lightest treatment that addresses its dominant source of delay. Table 1 sets out the pairing proposed here. The underlying principle, consistent with the published guidance (Danaher, 2010), is that a mid-frequency corridor seldom needs a continuous lane. Delay is usually concentrated at a few junctions, and a queue jump or a short length of lane on the approach captures most of the benefit at a fraction of the kerbside cost. A reserved lane over a longer length is kept for segments where queues regularly extend back through upstream junctions.

Table 1: Proposed matching of bus priority treatments to the dominant source of delay on a segment

Dominant source of delay	Treatment proposed	Main condition or cost
Signal delay at an uncongested junction	Conditional signal priority with far-side stop	Controller and detection must support priority requests
Queue at an isolated congested junction	Queue jump lane with advance bus phase	Space for a short approach lane; turning traffic
Queues spanning several junctions	Reserved bus lane, peak periods or full-time	Loss of a traffic or parking lane; enforcement
Low bus flow on a constrained link	Intermittent bus lane or priority at the bottleneck only	Driver compliance; signing and detection
Long or variable dwell times	All-door boarding, level boarding, wider stop spacing	Fare system; longer walks for some passengers
Delay rejoining traffic	In-lane stops with kerb extensions	Following vehicles wait behind the stopped bus

3.4. Step 4: Design signals and stops together

Signal priority and stop position should be settled in one exercise. Moving a stop to the far side, consolidating two closely spaced stops, and choosing between green extension and early green all interact, and treating them separately tends to produce priority requests that arrive at the wrong time. The mid-sized city has one advantage here. Because buses are not frequent, successive priority calls rarely conflict, and cross-street delay from an occasional extension is small. The design should set a limit on the extension, define the lateness threshold for conditional priority, and record the assumptions so that they can be revised in service.

3.5. Step 5: Plan kerbside access and enforcement

Most objections to bus priority on a commercial street concern the kerb: parking, loading and access to premises. The procedure treats these as design inputs. Parking and loading activity should be surveyed by block and time of day, alternatives identified on side streets or in off-peak windows, and the rules for the bus lane (hours, permitted users, turning vehicles) written with enforcement in mind. A lane that is routinely blocked delivers little, and the means of enforcement, whether patrols or cameras where the law allows them, belong in the scheme from the start (NACTO, 2016).

3.6. Step 6: Stage the opening

Opening the corridor in stages serves both engineering and politics. Signal priority and stop changes can precede lane reallocation, since they require no road space, and a lane can be introduced with paint and signs before permanent works are committed. Each stage gives operating data against which the next can be adjusted. Staging does carry a risk, which is that an early, partial stage yields a modest gain and weakens support for the rest; the sequence should therefore begin with the junctions where Step 1 found the largest delays.

3.7. Step 7: Evaluate before and after

The evaluation uses the measures fixed in Step 2 and the same archived data sources as Step 1. The design proposed is an interrupted series with a comparison corridor: bus running times, their variability and passenger loads are extracted for a substantial period on either side of each stage, for the treated corridor and for a similar corridor left unchanged. Differences in the change between the two give a more credible estimate of effect than the raw change alone (Shadish et al., 2002). General traffic should be measured as well, and ridership interpreted cautiously, since patronage responds slowly and to many influences beyond travel time (Currie and Delbosc, 2011).

4. Fitting the Procedure to a Mid-Sized City

Several features of the procedure are concessions to scale. It relies on data the operator already holds and avoids special surveys where possible. It prefers spot treatments to continuous infrastructure, which suits both the budget and the bus flows. It expects signal equipment to be uneven and allows priority to be introduced junction by junction as controllers are renewed. And it assumes a small technical team, so the outputs of each step are deliberately simple: a delay profile, a list of measures, a segment table, a timing record, a kerbside plan, a staging plan and an evaluation report.

The procedure also takes a position on ambition. Comparative work on bus rapid transit shows that systems vary widely in cost and specification (Hensher and Golob, 2008), and classic transit planning holds that the degree of separation from other traffic is the main determinant of performance (Vuchic, 2005). A mid-sized city may reasonably start with partial separation, provided the design does not foreclose a fuller busway if demand grows.

5. Limitations and What Remains to Be Shown

The procedure is proposed and has not been validated in this article. A first application would need to establish whether the delay profile of Step 1 can be produced reliably from the location data that smaller operators archive, which are often recorded only at timing points; whether the segment-by-segment

matching of Step 3 yields a scheme that the public can understand as a coherent corridor; and whether a suitable comparison corridor exists in a city with few arterials. Where none does, the evaluation falls back on a longer before-and-after series and its conclusions are weaker.

The procedure is also silent on matters that may decide a scheme in practice, among them the treatment of cyclists in or beside bus lanes, the effect on traffic diverted to parallel streets, and the legal basis for enforcement, all of which vary by jurisdiction.

6. Conclusion

For a mid-sized city the conversion of a signalised corridor to bus priority is less a matter of building a busway than of finding the few places where buses lose time and treating each appropriately. The seven steps proposed here organise that work from diagnosis to evaluation, lean on data the operator already collects, and keep person-based measures in view throughout. Their usefulness can only be judged by application, and the article has indicated what such a trial should test.

Conflict of interest

To be declared by the author(s) before publication.

Funding

To be declared by the author(s) before publication.

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