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Beyond the Harbor Transitway: Evaluating Freeway-Based Bus Service Opportunities

A comprehensive project submitted in partial satisfaction of the requirements for the degree Master of Urban & Regional Planning

Ivan Emilio Sanchez III • 2026

Client: California Department of Transportation, District 7

Faculty Advisor: Juan Matute, Ph.D.



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Disclaimer

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Executive Summary

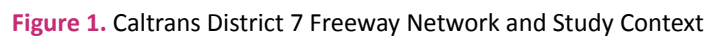
Caltrans District 7 (Los Angeles and Ventura Counties) freeway corridors require evaluation to determine their capacity to support effective regional bus-based trunk service. While District 7's freeways already function as the region's primary mobility backbone, transit performance within freeway environments is uneven and often constrained by access, operating conditions, and institutional fragmentation. This research identifies the core factors allowing freeway corridors to support reliable, legible, and scalable all-day trunk bus service, and applies these variables to early-stage corridor screening in District 7.

A comparative case study methodology examines U.S. freeway-based corridors and international high-capacity busway reference systems through a consistent unit of comparison: Type 1 all-day trunk services. Quantitative performance indicators (where available) are paired with qualitative agency documentation to identify recurring drivers of corridor outcomes. Results converge on five core factors that consistently govern performance: right-of-way continuity, trunk consolidation versus fragmented route layering, station interface and throughput capacity, governance coordination, and downstream/terminal capacity constraints. The synthesis clarifies their hierarchy: right-of-way continuity sets the operating envelope; station interface often becomes the first binding constraint as frequency and demand increase; governance functions as an enabling condition for sustained corridor legibility and disciplined service roles.

An applied District 7 freeway screening framework evaluates freeway segments across two dimensions: Market Potential and Implementation Feasibility. Subsequent planning and policy implications address institutional readiness, phased implementation, equity and access mitigation, and long-term scalability.



Existing facilities, such as the Harbor Transitway (I-110) and El Monte Busway (I-10), demonstrate that freeway-based transit is physically feasible. Yet, these corridors also highlight persistent friction between high-speed vehicle throughput and the needs of passenger access (Banerjee et al., 2001; LA Metro, 2025). Evaluation is required to determine whether District 7's freeway infrastructure can be adapted to function as high-capacity transit under contemporary equity and climate objectives.



Regional Mobility Challenges in District 7

Rail investments have improved connectivity along specific axes, yet many high-demand freeway corridors lack frequent, all-day regional bus service. Research on transit ridership consistently demonstrates that frequency, reliability, and directness are underlying drivers of sustained demand (Taylor & Fink, 2013; Deng & Nelson, 2011). Where freeway corridors lack these characteristics, transit-dependent populations may face indirect routing, longer travel times, or multiple transfers to reach regional destinations (Lucas, 2012).

The central mobility challenge is whether existing freeway infrastructure can be adapted to support high-capacity regional bus service without acquiring new right-of-way.

Research Question

The core research question is:

Under what structural conditions can freeway corridors support effective, equitable, and feasible regional bus service, and how can those conditions inform early-stage corridor screening in Caltrans District 7?

Contribution of the Study

The following analysis clarifies a functional definition of freeway-based bus service, synthesizes case studies to identify core factors of performance, and operationalizes those findings into a corridor screening framework tailored to District 7.

Integrating comparative research with agency-oriented evaluation demonstrates how legacy freeway infrastructure can be systematically assessed as part of broader multimodal planning strategies.



Literature and Conceptual Foundations

Defining Freeway-Based Bus Transit

Agencies inconsistently use terms such as express bus, busway, freeway BRT, and managed-lane transit to describe different combinations of infrastructure and service planning. Therefore, this definition relies on operating patterns and station types. Legal facility classifications and single design standards do not dictate this categorization (Levinson et al., 2003; Miller, 2009; ITDP, 2024).

Freeway-based bus transit refers to bus routes that operate on limited-access highway facilities for a substantial portion of their trip. These alignments include service operating in managed lanes (HOV/HOT), dedicated busways, or general-purpose freeway lanes where permitted. Many regional freeway services operate partially on local streets. They collect riders at on-street stops or transit centers before transitioning onto the freeway for longer-distance travel. This pattern uses freeway infrastructure to support faster regional travel (Cervero, 2013; Deng & Nelson, 2011).

Freeway-running service exists on a spectrum, from low-cost managed-lane operations to higher-investment grade-separated busway facilities incorporating BRT elements (Levinson et al., 2003; Deng & Nelson, 2011). Because facility design and operating practices vary substantially, this analysis evaluates the operational characteristics shaping performance and usability. This entails where service runs, how stations are accessed, and whether buses remain in managed or exclusive lanes when serving stops. A universal “freeway BRT” label is therefore avoided (Miller, 2009; ITDP, 2024).

Regional Mobility and Trunk-Feeder Models

High-capacity transit requires integration into a connected network. Isolated corridor investments underperform by comparison. Transit and land use integration drives sustained regional benefits, particularly where employment and housing are distributed across multiple centers (Suzuki, Cervero, & Iuchi, 2013). For bus rapid transit, speed and reliability are necessary baseline conditions. Services must connect cleanly to local routes, feeder services, and activity centers to convert line-haul performance into actual accessibility gains (Deng & Nelson, 2011; Cervero, 2013).

Service structure dictates network function, primarily through the distinction between trunk and feeder routes. Trunk services provide the scheduled all-day backbone: bidirectional service, legible routing, and frequency supporting diverse trip purposes. Overlay commuter routes and hybrid local–freeway services add coverage or peak capacity. They do not provide the same baseline regional accessibility independently (Levinson et al., 2003; Deng & Nelson, 2011). Consequently, frequent regional trunk services serve as the primary reference type for cross-case comparison and screening framework development.



Operational Determinants of Busway Performance

Historical freeway-based transit research focuses on operational performance: speed, reliability, throughput, and cost-efficiency (Deng & Nelson, 2011). Early U.S. freeway-running services emerged as operational adaptations, utilizing shoulders, reversible lanes, and limited-stop patterns (Levinson et al., 2003). These evolved into purpose-built facilities including in-line median stations, bus-only ramps, and managed-lane integration (Cervero, 2013).

Several recurring core factors shape corridor performance:

Right-of-way exclusivity

Systems operating in fully exclusive or managed lanes demonstrate higher reliability. General-purpose traffic lanes degrade schedule adherence (Deng & Nelson, 2011). International systems such as Bogotá demonstrate that uninterrupted median running combined with passing lanes supports extremely high passenger throughput

Station spacing and stop penalty

Station spacing between 1.5 and 2 miles balances speed and accessibility for freeway corridors (ITDP, 2024). Where buses exit managed lanes to serve stops, merge delay and re-entry friction significantly reduce reliability (Miller, 2009).

Service frequency and span

Frequent, all-day service drives sustained demand. Peak-only operations fail to capture equivalent ridership markets (Taylor & Fink, 2013; Deng & Nelson, 2011). Minimum peak frequencies near 8 buses per hour, paired with consistent off-peak service, establish the threshold for high-capacity rapid transit function (ITDP, 2024).

Critical-link constraints

Bottleneck segments dictate fleet sizing and headway stability. Average corridor conditions do not accurately reflect operational limits. Planning frameworks size operations around the “critical link” where congestion, weaving, or lane restrictions constrain throughput (ITDP, 2017; 2024).

Station Access and Governance Considerations

Station access and user experience

Freeway stations typically occupy environments optimized for vehicle throughput. These locations rarely prioritize pedestrian circulation. Case evidence from Los Angeles demonstrates that excessive noise exposure, long vertical circulation times, and limited visibility reduce walk-up demand, even with high service frequency (Banerjee et al., 2001). Contemporary evaluation models elevate comfort, safety, and environmental quality to co-equal performance dimensions. They are no longer treated as secondary design features (Huo et al., 2020).

Performance thresholds identified in the literature include:



- Platform crowding below 4–5 passengers per square meter (ITDP, 2024)
- Peak headways under 7.5 minutes (ITDP, 2024)
- Vertical access times under 90–120 seconds (eBRT2030 Consortium, 2023)
- Ambient platform noise below 70 dBA (Banerjee et al., 2001)

Where ramps or noise barriers isolate stations, freeway running speeds fail to produce regional mobility gains.

Land use integration and equity

Surrounding land use conditions directly determine transit effectiveness. Integrating transit and land use improves accessibility and long-term ridership stability (Suzuki, Cervero, & Iuchi, 2013). Without integration, freeway-based systems function as isolated transport infrastructure. They fail to operate as comprehensive regional accessibility tools.

Permanent, high-quality transit infrastructure increases adjacent property values, supporting reinvestment strategies when paired with land use policy (Perk & Catalá, 2009). However, freeway environments reinforce spatial inequities if station access prioritizes auto-oriented park-and-ride. Facilities must accommodate walk-in access for transit-dependent populations to mitigate this risk (Lucas, 2012).

Governance and coordination

Freeway corridors involve multiple agencies, operators, and funding sources. Coordination dictates branding, fare integration, service hierarchy, and role clarity between trunk and overlay routes (Deng & Nelson, 2011). Fragmented governance produces inconsistent service planning and diluted network legibility.



Research Design and Comparative Methodology

Overall Research Strategy

A cross-case review evaluates U.S. and international freeway based systems. Standardized performance, access, and contextual indicators facilitate comparison across corridors with divergent physical designs, governance structures, and market conditions. This methodology supports Caltrans' objective of early-stage feasibility screening. It does not replace project-level design or environmental analysis.

SCREENING-LEVEL FRAMEWORK

Market Potential



Feasibility



Goal: All of District 7's Freeways to be evaluated at a segment level.

Figure 2. Conceptual Screening Framework: Market Potential and Implementation Feasibility

Case Selection Logic (U.S. + International)

Case studies reflect a spectrum of freeway- and busway-based transit typologies relevant to Southern California freeway conditions. This selection evaluates how different structural configurations perform under varied physical, institutional, and market contexts. It does not attempt to isolate a single best-practice model. U.S. cases represent freeway-based bus services operating within limited-access highway environments.

Typologies include median and in-line freeway stations, managed lane operations (HOV/HOT), grade-separated busways within freeway corridors, and hybrid systems combining freeway operation with arterial segments. Corridors in Los Angeles (Harbor Transitway, El Monte Busway), San Diego (I-15 Rapid), Seattle, Minneapolis–St.

Paul, and Pittsburgh reflect variations in service structure, station configuration, and governance arrangements directly relevant to District 7.

Three criteria guided case selection: relevance to Los Angeles, data availability, and comparable infrastructure. A standardized template organizes each case review to enable cross-case synthesis.

Data Sources

Quantitative indicators originate from publicly available agency dashboards, National Transit Database (NTD) reports, published annual reports, and internal agency correspondence. Key metrics capture:

- Ridership productivity (e.g., average weekday boardings)
- Reliability (e.g., on-time performance)
- Financial efficiency (e.g., subsidy per boarding, annual operating cost)
- Capital investment scale (order-of-magnitude estimates, adjusted to approximate current dollars where feasible)

For U.S. systems, comparison focuses on Type 1 regional all-day trunk services. Conservative annualized estimates replace missing full-year data. Qualitative evidence from agency reports, planning documents, and practitioner consultation contextualizes these performance outcomes and identifies the underlying drivers behind the observed data.

Standardized performance data remained inconsistent for international cases. Consequently, this methodology omits quantitative aggregation across international systems. Available ridership, capacity, and investment figures illustratively bound expectations. They do not construct direct cost-efficiency comparisons.

Unit of Comparison: Type 1 Trunk Services

The Type 1 Regional All-Day Trunk Service serves as the primary unit of comparison.

Type 1 trunk services operate bi-directionally with consistent frequency throughout the day. These services function as the core regional backbone within freeway corridors. They provide legible, high-capacity bus transit comparable in span and frequency to urban BRT. However, their alignments rely primarily on freeway facilities. Surface street operations are minimized.

These services typically:

- Operate every 5–15 minutes for much of the day
- Use freeway median stations or direct-access ramps
- Maintain long daily service spans
- Support a wide range of trip purposes
- Serve as the backbone onto which commuter overlays or hybrid routes are layered



Examples include Metro's J Line (Harbor Transitway), SDMTS Route 235 (I-15 Rapid), and Minneapolis Metro Transit's Orange Line. The trunk service provides the structural foundation for corridor performance. Additional routes operate as supplements.

Isolating the trunk service focuses the analysis on the operational layer most directly tied to corridor-level accessibility and screening relevance. This establishes a consistent structural baseline to evaluate performance, access conditions, and governance arrangements across systems with disparate service mixes.

Cross-Case Synthesis Approach

The synthesis identifies recurring core factors documented in agency reporting and comparative research. These include:

- The performance advantages of consolidated trunk corridors
- The role of uninterrupted right-of-way in sustaining speed and reliability
- Station design as a capacity and usability constraint
- Corridor-level governance in multi-operator systems
- Scalability and terminal capacity limitations

The cross-case synthesis addresses four comparative questions:

- Under what structural conditions do freeway- or busway-based trunk services achieve sustained ridership?
- How do station access conditions modify otherwise strong operational performance?
- How does right-of-way form influence achievable reliability?
- What governance arrangements repeatedly appear in higher-performing corridors?



U.S. Case Study Findings

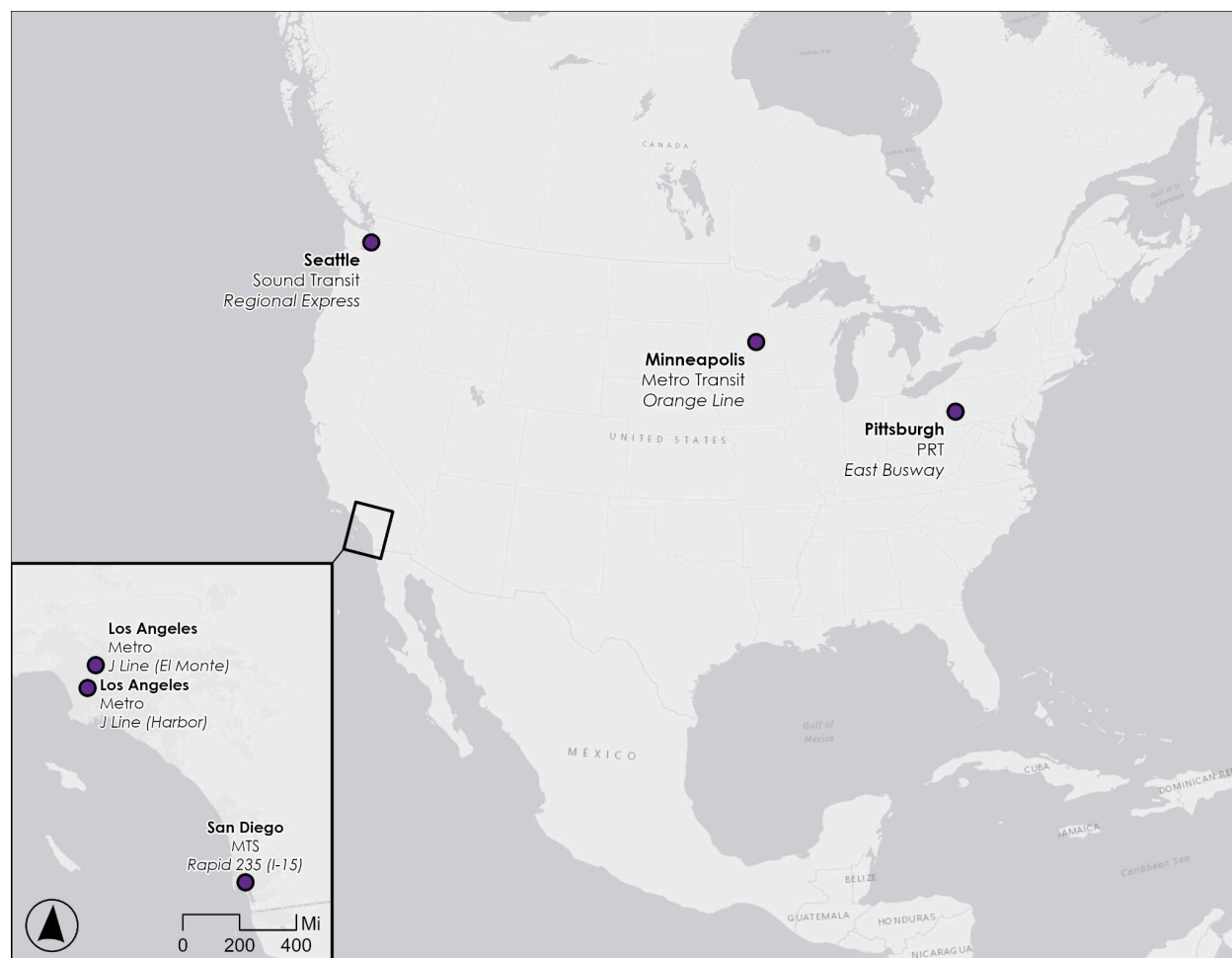


Figure 3. U.S. Freeway and Busway Based Case Study Corridors

Structural Determinants of Performance

The cross-case synthesis identifies five recurring underlying drivers.

First, differentiating between trunk services and overlays dictates corridor function.

In Los Angeles (Harbor Transitway and El Monte Busway), San Diego (I-15 Rapid), and Minneapolis (Orange and Red Lines), corridors supporting a frequent, all-day trunk service alongside peak-period commuter overlays demonstrate clear service roles (Los Angeles County Metropolitan Transportation Authority, 2025; San Diego Metropolitan Transit System, 2025; Metropolitan Council, 2024). Facilities treating all routes equivalently lack this definition. Trunk services operate continuously along the freeway facility. Overlay services use the infrastructure selectively. This distinction drives both reliability and network legibility.

Second, the station–freeway interface directly dictates speed and usability.

Freeway-median and centerline stations keep trunk buses within managed or exclusive lanes, preserving line-haul performance. However, these configurations introduce vertical circulation, arterial crossings, and access constraints that degrade the rider experience. The ability of buses to remain in-lane when serving stations consistently differentiates corridor performance. Station configuration dictates operating speed, accessibility, and passenger usability.

Third, right-of-way control imposes distinct performance constraints.

San Diego’s I-15 Rapid illustrates trunk service operating in priced managed lanes (San Diego Association of Governments, 2018). Enforcement, pricing, and lane-management policies dictate performance. Transit-exclusive control does not apply here. Pittsburgh’s grade-separated busways utilize fully exclusive rights-of-way (Pittsburgh Regional Transit, 2025). Here, station spacing and operational design drive performance. Right-of-way control serves as the primary factor dictating achievable reliability and speed. Branding and vehicle type have minimal impact.

Fourth, multi-operator delivery requires explicit role definition.

Los Angeles, Seattle, and Minneapolis involve multiple operators sharing freeway or freeway-adjacent infrastructure. Clearly defined service roles and branding produce layered systems anchored by a primary trunk. Weaker coordination generates a disparate collection of routes. It fails to create a coherent facility. Governance structure dictates how effectively shared infrastructure functions as a unified corridor.

Fifth, station access conditions vary within corridors and require site-specific evaluation.

Station access varies even within a single facility. In Los Angeles and San Diego, freeway-median stations rely on vertical circulation and protected pedestrian access from adjacent arterials. In Pittsburgh, grade-separated busways depend on bridges, stairways, and constrained paths shaped by corridor geometry. Local design and context dictate access quality. Facility type alone does not guarantee usability. Evaluating station-level access early in the process is essential during corridor screening.

Trunk vs. Overlay Service Organization

Freeway-based bus service typically assumes a layered form: a frequent all-day trunk supplemented by commuter overlays and hybrid local–freeway routes. Separating these service types determines whether shared freeway infrastructure behaves like a coherent corridor or a disjointed collection of routes.





Figure 4. Harbor Transitway Layered Service Structure: Trunk, Overlay, and Hybrid Routes

Explicitly distinguishing the trunk role from overlays clarifies corridor function. A continuous all-day trunk operating along the facility, paired with overlays using the infrastructure selectively, clarifies service roles. The shared infrastructure does not need to function as a single uniform service. Treating all routes as equivalent degrades legibility. The corridor behaves like a bundle of overlapping services. It fails to function as a single understandable network element.

This analysis uses Type 1 trunks as the primary comparison set. Trunk services maintain broadly similar all-day frequency and service spans. With a comparable baseline, meaningful differences shift from headways to corridor organization. Specifically, this involves the presence of a stable trunk backbone and the structure of its overlays.

Station–Freeway Interface Effects

Station configuration directly dictates both operating speed and rider usability (Levinson et al., 2003; eBRT Consortium, 2023). Station typology determines whether buses retain their speed advantage within freeway facilities. It also dictates how easily passengers access platforms from surrounding networks.

This review identifies four recurring station configurations:



Figure 5. Recurring Freeway Station Typologies Observed in U.S. Cases

Freeway median (in-line) stations: Located within the right-of-way, these preserve line-haul speed by keeping buses in managed lanes. However, they demand extensive vertical circulation (bridges, elevators) and isolate passengers from surrounding land uses.

Direct-access stations: Dedicated ramps allow buses to serve platforms without leaving managed lanes. This eliminates operational friction but demands significantly higher infrastructure investment.

Flyer (ramp) stops: Buses exit the freeway to board passengers before re-entering. Short segments of mixed-traffic deviation introduce delay and degrade reliability.

Freeway-adjacent transit centers: Located off the freeway, these facilities prioritize auto access and local transit transfers. They require the greatest deviation from the trunk corridor.

The central distinction among these typologies involves lane retention. In-line or direct-access configurations allow trunk services to maintain uninterrupted movement. Exiting into mixed traffic ties performance to ramp geometry, signalization, and surrounding roadway conditions.

U.S. corridors illustrate these trade-offs. Freeway-median stations in Los Angeles and on the El Monte Busway support high-speed trunk operations. They require additional access treatments to match the rider experience of off-freeway stops (Banerjee et al., 2001). San Diego's centerline stations provide similar line-haul speed benefits. They mandate vertical access from arterial overpasses (San Diego Association of Governments, 2015). In Minneapolis, constrained or indirect access paths degraded service outcomes and forced subsequent capital adjustments (Moore, 2023).



Station design dictates four core performance dimensions:

- Speed, achieved by maintaining uninterrupted movement.
- Lane retention, defined by keeping buses in managed or exclusive facilities during stops.
- Vertical access requirements, encompassing bridges, elevators, and stairways.
- Usability, determined by the directness of platform access and surrounding network transfers.

Managed Lanes vs. Exclusive Right-of-Way

Right-of-way control dictates achievable speed and reliability. Managed-lane facilities and fully exclusive transit rights-of-way impose distinct performance constraints, regardless of service frequency.

In managed-lane environments, trunk services operate within shared freeway facilities. Pricing and enforcement policies govern these alignments. San Diego's I-15 Rapid illustrates this condition. Buses operate in express lanes designed to maintain flow. However, the facility lacks transit exclusivity. Tolling policy, enforcement consistency, and active lane management dictate reliability. Transit performance remains tied to general traffic behavior.

Fully exclusive rights-of-way rely on transit-controlled factors. Pricing and enforcement do not dictate performance. Pittsburgh's grade-separated busways provide a reference case. These busways operate in dedicated corridors isolated from general-purpose traffic. Station spacing, operational design, and internal corridor management dictate reliability. Buses bypass pricing policies and mixed-flow congestion entirely (Wohlwill, 2022; U.S. Department of Transportation, 2003).

Right-of-way control acts as the dominant underlying driver of corridor performance. Managed lanes provide substantial transit priority. However, traffic policy and enforcement establish their performance ceiling. Exclusive rights-of-way guarantee operational certainty. They demand higher capital investment and long-term infrastructure commitments.

Governance and Multi-Operator Implications

Multiple operators typically deliver freeway-based bus corridors. These alignments require multiple agencies to share freeway or freeway-adjacent infrastructure. Operator coordination dictates network legibility. Strong coordination produces a coherent system. Weak coordination results in a collection of independent routes.

Los Angeles, Seattle, and Minneapolis feature multiple operators using shared freeway facilities (LADOT, 2025; Sound Transit, 2025; Metropolitan Council, 2024). These arrangements demand explicit coordination regarding service roles, branding, fare integration, and operating practices. Clearly defined roles, anchored by a primary trunk service, produce layered systems with recognizable structures. Weak coordination generates overlapping routes lacking a unified identity.

Governance models dictate corridor perception and management. A single agency may oversee branding and service design despite multi-operator service delivery. Alternatively, separate agencies deliver service without a



unified corridor framework. Seattle's network-based freeway express system illustrates this complexity. Multiple all-day freeway express trunks operate across different corridors. They do not operate under a single branded facility. Coordination occurs at the network level. It does not exist at the corridor-brand level (Sound Transit, 2025).

Delivery models dictate service role communication, fare policy alignment, and operating practice standardization. Without defined governance, well-designed facilities lack rider legibility.



International Case Study Findings

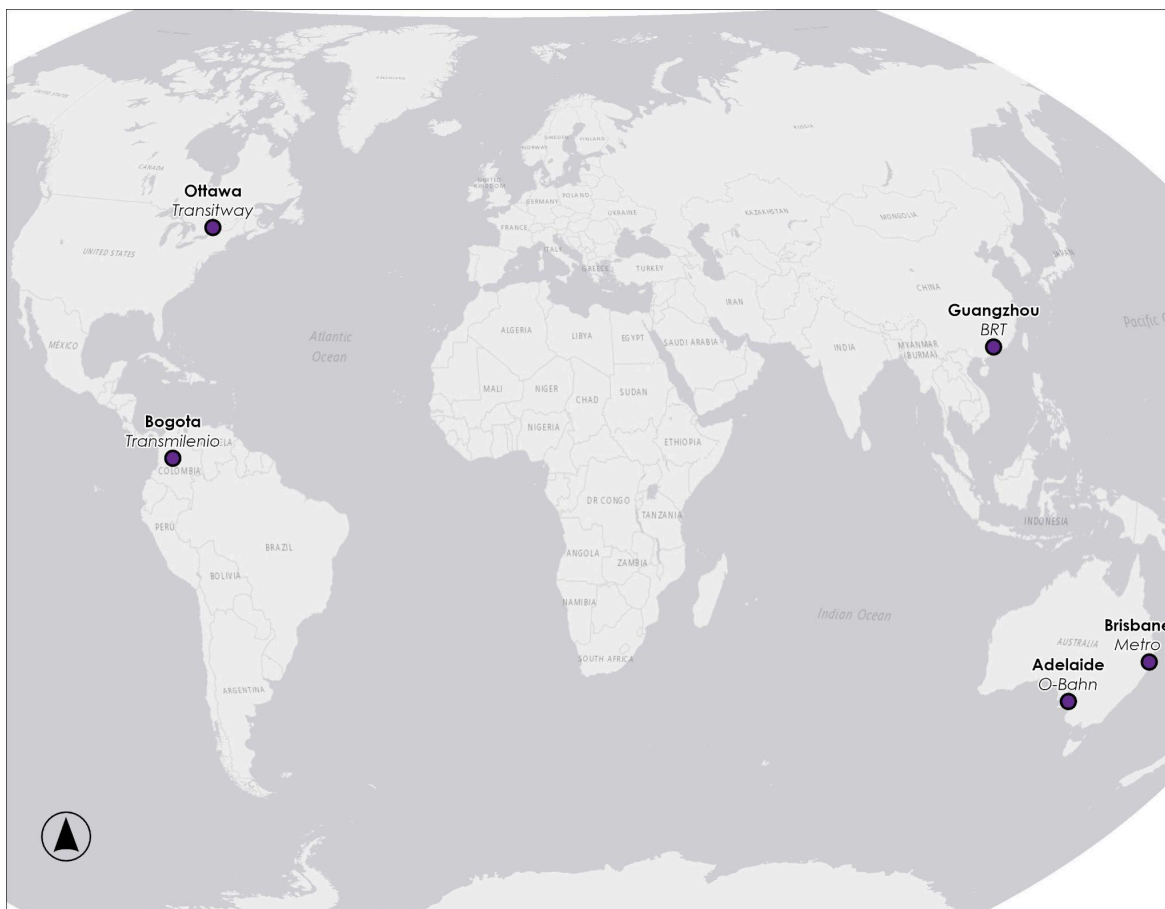


Figure 6. U.S. Freeway- and Busway-Based Case Study Corridors

Continuous Trunk Capacity

Ottawa, Brisbane, and Bogotá demonstrate this model. In Ottawa, selected segments utilize highway bus-only shoulders and grade-separated stations. Other portions function on standalone guideways (Levinson et al., 2003). This configuration proves consolidated trunk performance extends beyond strict freeway classifications.

Local services deliver riders to trunk stations. The main corridor sustains continuous, high-volume line-haul movement. This separation maintains trunk frequency and capacity. It eliminates operational friction from complex route merging.

Unconsolidated routes sharing a corridor require strict scheduling discipline. Adelaide and Guangzhou demonstrate that overlapping, decentralized services generate bus-on-bus congestion (Government of South Australia, n.d.; Zhu, 2013).

Station Design as Capacity Constraint

High-capacity systems in Bogotá and Guangzhou utilize large, multi-berth stations with passing lanes (Cain et al., 2006; Zhu, 2013). These configurations accommodate simultaneous boarding and overtaking. Lacking these features, vehicle dwell times compound and corridor throughput drops. Station scale directly dictates maximum corridor volume.

Pedestrian access and vertical circulation impose practical limits, even on dedicated running ways. Ottawa and Brisbane report access challenges at highway-adjacent stations (Brisbane City Council, 2018). Grade separation and constrained rights-of-way obstruct passenger movement. Adelaide demonstrates that indirect or slow station connections generate transfer friction, eroding operational time savings (Public Transport South Australia, 2025).

Governance Scaling

Brisbane consolidated routes to improve legibility and eliminate internal capacity competition (Brisbane City Council, 2018). This restructuring proves service consolidation and governance reform increase effective corridor capacity. Right-of-way expansion is not required. Bogotá and Guangzhou operate large, multi-operator systems under unified control (TransMilenio S.A., 2023; Velazquez et al, 2017). This maintains coordinated scheduling and service roles across the trunk. Centralized governance produces a single operational system.

Limits of Surface Operations

Ottawa's busway saturated downtown surface streets with high passenger volumes. This forced a transition to rail (OC Transpo, 2025). Peak intensity demanded nearly two hundred buses per hour for downtown service. Terminal and surface street capacity establish binding constraints, even with uncongested trunk running ways.

Bogotá and Guangzhou experience persistent crowding and financial pressure at extreme demand levels (TransMilenio S.A., 2023; Fjellstrom, 2019). Surface street capacity, terminal design, and lifecycle cost pressures dictate long-term scalability limits. Adelaide exposes lifecycle and community interface challenges caused by specialized infrastructure within constrained corridors (Public Transport South Australia, 2025).



Cross-Case Structural Synthesis

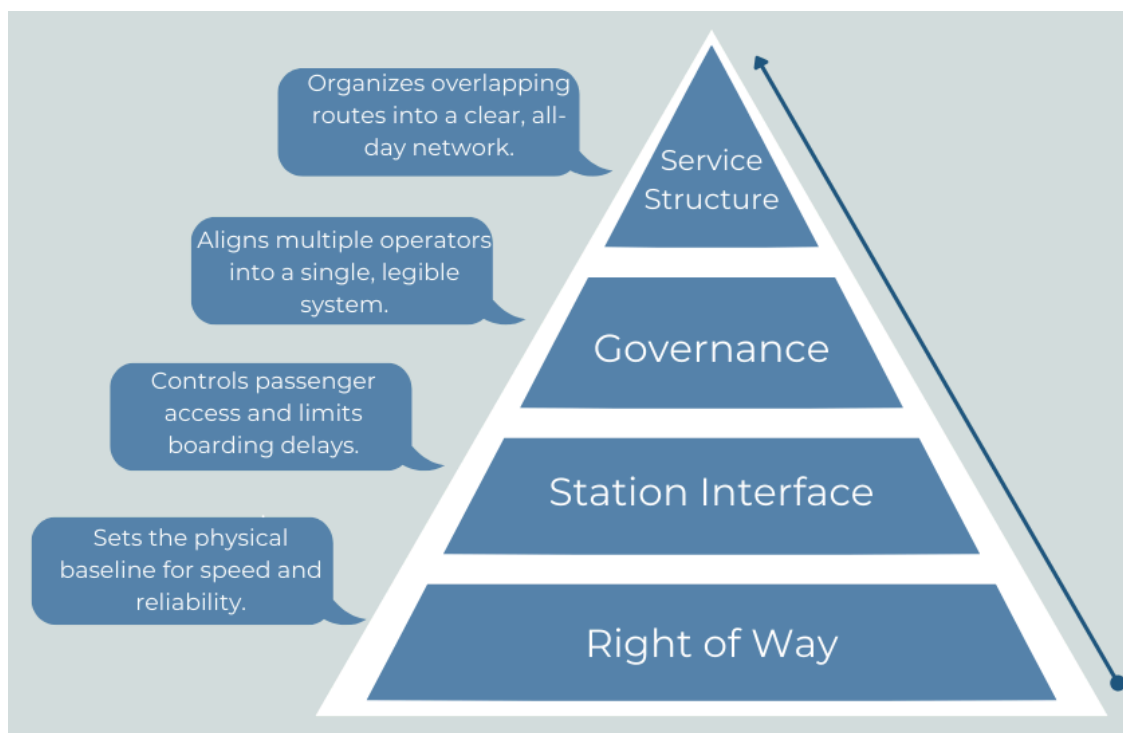


Figure 7. Hierarchy of Structural Determinants Influencing Corridor Performance

Recurring Determinants Across Contexts

The U.S. and international cases reveal five consistent underlying drivers. The cross-case synthesis demonstrates a clear operational hierarchy (Figure 7). Right-of-way continuity acts as the primary baseline, establishing the maximum performance envelope. Station interface acts as the secondary bottleneck, restricting throughput as frequency and demand scale. Governance functions as an enabling condition that sustains the corridor, while trunk consolidation and terminal capacity operate as contextual dependencies.

Right-of-Way Continuity as Primary Variable

Right-of-way continuity functions as the dominant core factor driving corridor performance. Uninterrupted operating environments consistently correlate with higher reliability and sustained line-haul speed.

Where buses remain insulated from mixed traffic, intersection delay, and policy-driven variability, performance becomes primarily a function of transit-controlled factors such as scheduling and station operations. Where right-of-way continuity is partial, subject to pricing policy, enforcement variability, intersection control, or ramp friction, transit performance remains partially contingent on external traffic conditions.



Station Access as Performance Constraint

Station design consistently emerges as the binding constraint as ridership and frequency increase. Station interface affects usability through transfer friction and pedestrian access, while station geometry governs total throughput. Platform length, berth count, overtaking capability, and passenger circulation capacity determine how many vehicles and passengers can be processed without dwell-induced delay (ITDP, 2024).

Station constraints can emerge even when running ways remain uncongested. Downtown saturation, terminal queuing, and insufficient berth capacity illustrate how nodes limit corridor performance. Links alone do not dictate these constraints.

Governance as Enabling Condition

In multi-operator environments, defined service roles, schedule integration, unified branding, and consistent operating standards are necessary to prevent internal fragmentation. Consolidated trunk models require centralized oversight to maintain frequency discipline and avoid route competition for shared capacity. As corridors move toward higher frequency and higher passenger volumes, governance complexity increases.



Application: District 7 Freeway Screening Framework

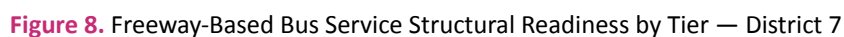
The following screening-level framework applies these structural findings to Caltrans District 7. This product evaluates whether the necessary structural conditions for freeway-based bus service appear to be present within specific freeway segments.

Because freeway corridors serve different travel markets and exhibit varying physical and operational conditions along their length, evaluation occurs at a segment level. Corridor-wide scale obscures these local variations. The framework is therefore designed to support an initial ordering of segments by relative structural readiness. Subsequent planning phases require more detailed engineering, operational, and financial analysis.

This approach evaluates two foundational dimensions derived from the cross-case synthesis:

- Travel market viability, which reflects the potential for consolidated trunk service to succeed, and
- Implementation feasibility, which reflects right-of-way conditions, infrastructure context, and corridor characteristics that influence deliverability.





Interregional Connectivity captures corridors carrying substantial long-distance regional or statewide travel. The case studies indicate that limited-stop or express trunk services are most viable where sustained long-haul demand exists.

Frequent Transit Overlays serve as an indicator of latent demand and transfer markets. High-frequency bus or rail routes intersecting or paralleling a freeway suggest concentrated travel activity that could feed a trunk facility (Los Angeles County Metropolitan Transportation Authority, 2025; Foothill Transit, 2025).

Equity & Community Access is acknowledged as a critical future analysis dimension. While not formally scored at this screening level, corridors serving communities with high transit reliance may warrant additional evaluation in subsequent phases.

Collectively, these indicators assess whether a segment exhibits the demand-side conditions necessary to support consolidated trunk service.

Implementation Feasibility

Existing Bus Transit Facilities serve as a proxy for implementation readiness. Corridors with express bus service, managed lanes, or on-freeway transit stations may offer opportunities for phased or incremental improvements (Los Angeles County Metropolitan Transportation Authority, 2025; Caltrans District 11, 2023). Full facility reconstruction is not an absolute prerequisite.

Deliverability & Physical Feasibility acknowledge the central importance of right-of-way continuity identified in Section 6. However, detailed right of way analysis is beyond the scope of this screening-level study, so this factor is also not formally scored at this screening level.

In corridors where high-capacity rail already occupies the freeway right-of-way, additional freeway-based bus service may provide limited incremental structural benefit. For this reason, the screening matrix scores such corridors differently than those without existing service.

Corridor Segmentation Logic

Segment boundaries are defined at major functional breaks, including:

- Transitions between urban core and suburban or rural conditions
- Shifts in dominant travel market (local vs. interregional)
- Changes in airport access relevance
- Major interchanges or geographic constraints
- District boundary transitions

Corridors such as I-5, US-101, I-10, I-405, I-110, and I-210 exhibit materially different structural conditions along their length (travel market composition, operational context etc). Each corridor is divided into discrete segments that reflect these functional distinctions.

Scoring at the segment level therefore ensures that each portion of the freeway network is evaluated against its own structural conditions.



Criteria applied across network

1. Market & Key Destinations
2. Airport Access
3. Interregional Connectivity
4. Frequent Transit Overlays
5. Existing Bus Transit Facilities



Segment gets scored

Score	Interpretation
0	Not applicable
1	Low potential
2	Limited supportive conditions
3	Moderate conditions
4	Strong supportive conditions
5	High potential

Figure 9. Segment Scoring Rubric and Interpretation

Screening Matrix Development

The scale captures the relative strength of observable conditions:

- 0 (N/A): Indicator not applicable to the segment.
- 1 (Low): Minimal supporting conditions or substantial constraints.
- 2 (Modest): Limited or inconsistent supporting conditions.
- 3 (Moderate): Mixed conditions; supportive but not exceptional.
- 4 (Strong): Multiple favorable indicators present.
- 5 (High): Strong structural alignment with trunk viability and feasibility conditions.



Table 1. Prioritization Matrix for Evaluating Freeway Based Bus Service Potential on District 7 Freeway Segments

Corridor / Segment	Market & Key Destinations	Airport Access	Inter-Regional Connectivity	Frequent Transit Overlays	Existing Transit Facilities	Total Score
I-110: South → Downtown Los Angeles	4	1	3	5	5	18
I-10: Downtown Los Angeles → San Bernardino County line	4	2	5	3	3	17
I-405: Orange County line → LAX	5	5	4	3	0	17
I-10: Santa Monica → Downtown Los Angeles	5	1	5	5	0	16
I-405: LAX → San Fernando Valley	5	4	4	3	0	16
I-105: LAX → Norwalk	3	5	2	5	0	15
I-5: Downtown Los Angeles → Santa Clarita Valley	4	3	5	3	0	15
US-101: Downtown Los Angeles → Woodland Hills	4	1	5	4	0	14
I-5: Orange County line → Downtown Los Angeles	3	1	5	3	0	12
SR-134: Pasadena → Burbank	4	3	3	4	0	12
SR-110: Downtown Los Angeles → Pasadena	4	1	3	3	0	11
US-101: Woodland Hills → Ventura County line	3	1	5	1	0	10
I-5: San Fernando Valley → Kern County line	2	1	5	1	0	9



Corridor / Segment	Market & Key Destinations	Airport Access	Inter-Regional Connectivity	Frequent Transit Overlays	Existing Transit Facilities	Total Score
SR-60: East Los Angeles → Diamond Bar	3	1	3	2	0	9
I-210: Pasadena → San Bernardino County line	3	1	4	1	0	9
SR-170: Universal City → I-5 Interchange	3	1	3	2	0	9
SR-14: Santa Clarita → Lancaster	2	1	4	1	0	8
I-210: I-5 → Pasadena	2	1	3	1	0	7
I-605: Long Beach → Duarte	3	1	2	1	0	7
I-710: Port of Los Angeles → East Los Angeles	3	1	1	2	0	7
SR-118: San Fernando Valley → Simi Valley	2	1	2	1	0	6
SR-2: Downtown Los Angeles → Glendale	2	1	2	1	0	6
SR-91: Gardena → Artesia	1	1	3	1	0	5
SR-23: Thousand Oaks → Moorpark	1	1	2	1	0	4



Table 2. Tier Assignment Based on Prioritization Criteria for District 7 Freeways

Tier	Corridor / Segment
1 – High Priority <i>Strong market demand, existing transit overlays, and key destinations</i>	I-110: South Los Angeles → Downtown Los Angeles I-10: Downtown Los Angeles → San Bernardino County line I-405: Orange County line → LAX I-10: Santa Monica → Downtown Los Angeles I-405: LAX → San Fernando Valley I-5: Downtown Los Angeles → Santa Clarita Valley I-105: LAX → Norwalk US-101: Downtown Los Angeles → Woodland Hills
2 – Moderate Priority <i>Strong in specific categories (like Airport Access or Regional Connectivity) but lacking in others.</i>	I-5: Orange County line → Downtown Los Angeles SR-134: Pasadena → Burbank SR-110: Downtown Los Angeles → Pasadena US-101: Woodland Hills → Ventura County line I-5: Santa Clarita Valley → Kern County line SR-60: East Los Angeles → Diamond Bar I-210: Pasadena → San Bernardino County line SR-170: Universal City → I-5 Interchange
3 – Lower Priority <i>Significant constraints or low current demand indicators.</i>	SR-14: Santa Clarita → Palmdale I-210: I-5 → Pasadena I-605: Long Beach → San Gabriel Valley I-710: Port of Los Angeles → East Los Angeles SR-118: San Fernando Valley → Simi Valley SR-2: Downtown Los Angeles → Glendale SR-91: Gardena → Artesia SR-23: Thousand Oaks → Moorpark

The resulting matrix and tier assignments provide a visual ordering of segments based on structural alignment with the underlying drivers identified in Sections 4 through 6. Tier 1 segments are not necessarily immediately actionable, and Tier 3 segments are not permanently unsuitable. The matrix functions as a structured filter to identify where further technical analysis may be most warranted.

Limitations of Screening-Level Analysis

First, the framework relies on qualitative indicators. It does not utilize corridor-specific modeling. Travel demand, operational performance, and capital cost implications would require detailed technical study beyond the scope of this assessment.



Second, right-of-way availability, geometric constraints, and interchange complexity are not evaluated at an engineering level. Because right-of-way continuity is a primary core factor driving performance, this limitation is significant and would require formal corridor-level feasibility analysis in subsequent phases.

Third, demographic and equity analysis is acknowledged but not formally scored. A comprehensive equity assessment would require spatial demographic mapping and agency coordination.

Fourth, institutional considerations, such as governance structure, interagency agreements, and funding availability, are not embedded in the scoring framework. These factors materially influence implementation timelines and would need validation through discussions with District 7, Metro, and municipal operators.



Planning and Policy Implications

Institutional Readiness

Establish Multi-Operator Service Models

- Pair continuous all-day trunk services with commuter overlays.
- Clearly define trunk vs. overlay roles prior to launch.
- Manage the corridor as a singular, integrated transit asset.

Formalize Interagency Coordination Early

- Develop agreements covering scheduling integration, fare policy, maintenance standards, and branding.
- Secure corridor-level governance structures before construction.
- Implement integrated interagency operational standards.

Centralize Corridor Branding

- Use unified corridor identity regardless of operator count.
- Maintain legibility across agencies.
- Avoid competing brand layers that obscure trunk hierarchy (Deng & Nelson, 2011).

Filter for Governance Capacity

- Advance corridors only where institutional capacity exists to manage trunk consolidation.
- Treat governance readiness as co-equal to infrastructure readiness.

Implementation Phasing

Utilize Existing Managed Lanes First

- Utilize HOV/HOT/express lanes to reduce capital costs.
- Advance managed-lane trunk operations before constructing fully exclusive guideways.
- Budget for enforcement protocols and lane management agreements.

Prioritize In-Line and Median Stations

- Design stations that allow buses to remain within managed or exclusive lanes.
- Minimize ramp weaving and off-corridor deviations (Miller, 2009).
- Pair median stations with direct access ramps where feasible.

Integrate with Strong Transfer Hubs

- Align trunk corridors with major multimodal nodes.
- Prioritize segments that connect to high-volume rail or bus hubs.
- Reinforce trunk-feeder structure at intermodal junctions.



Deploy High-Capacity Vehicles

- Evaluate high-capacity vehicle configurations for Tier 1 corridors.
- Increase throughput without excessive headway compression.
- Improve productivity per operator hour.

Mandate Operational Standards at Opening

- Off-board fare collection and all-door boarding.
- Ramp and signal priority treatments (ITDP, 2024).
- Real-time passenger information systems.
- Grade-separated pedestrian access at median stations.

Equity and Accessibility Considerations

Address the Freeway Barrier Effect

- Fund pedestrian bridges, elevators, and protected approaches as core infrastructure. This ensures vertical access does not limit corridor usability.
- Treat vertical access as a performance determinant, not an amenity (Lucas, 2012).

Balance Auto Access with TOD Potential

- Avoid exclusive dependence on park-and-ride access.
- Site stations where pedestrian and development integration is feasible (Suzuki, Cervero, & Iuchi, 2013).
- Support land-use coordination where freeway geometry allows.

Prioritize Reliability Over Coverage

- Concentrate high-frequency trunk service where sustained demand exists (Taylor & Fink, 2013).
- Avoid extending trunks into low-demand segments that degrade reliability.
- Use overlays or feeder services to maintain equity coverage.

Require Multimodal Access Infrastructure

- Include bike facilities and seamless transfer terminals.
- Expand effective catchment areas beyond freeway ramps.

Long-Term Scalability

International reference cases demonstrate that performance ceilings shift over time.

Adopt Trunk–Feeder Integration

- Funnel multiple feeder routes into a consolidated high-frequency spine.
- Avoid unmanaged route layering that produces bus-on-bus congestion (Fjellstrom, 2010).



- Preserve corridor capacity through disciplined service design.

Plan for High-Capacity Stations

- Model station berth capacity under high-frequency conditions.
- Incorporate passing lanes at high-demand stations.
- Identify secondary terminals before saturation occurs.

Preserve Right-of-Way for Future Conversion

- Protect alignments that may support future rail transition.
- Avoid infrastructure specialization that constrains fleet flexibility.
- Evaluate lifecycle scalability before committing to permanent design elements.

Adopt Trunk–Feeder Integration

- Funnel multiple feeder routes into a consolidated high-frequency spine.
- Avoid unmanaged route layering that produces bus-on-bus congestion (Fjellstrom, 2010).
- Preserve corridor capacity through disciplined service design.

Balance Specialization with Flexibility

- Favor open-standard busway designs where possible.
- Avoid guided systems that restrict vehicle procurement options (Levinson et al., 2003).
- Ensure near-term BRT investments do not preclude future capacity expansion.



Conclusion

Evaluating freeway-based bus corridors across U.S. and international contexts identifies the structural conditions driving reliable bus-based trunk service at a corridor scale.

These underlying drivers form the basis of a screening-level framework applied to Caltrans District 7. The framework evaluates whether the foundational structural conditions necessary for freeway-based trunk service appear to be present within specific freeway segments.

Guidance for Applying the Screening Matrix

Potential next steps include:

Develop Segment Snapshots

Prepare detailed profiles for Tier 1 segments incorporating AADT, land use density, managed lane configurations, and existing transit infrastructure.

Validate Transfer and Access Assumptions

Coordinate with Metro and municipal operators to assess feasibility of potential transfer locations, ramp treatments, and service integration concepts.

Conduct Structured Scoring Workshops

Review qualitative scores with District 7 divisions to ensure internal alignment and refine assumptions regarding right-of-way constraints and operational feasibility.

Identify Pilot Segments

Select two to three segments for deeper operational feasibility analysis or concept-level development.

These actions establish a transparent, adaptable structure for identifying where freeway-based bus service warrants further study.

Freeway-based bus service application varies across District 7. Where core factors align, including sustained travel markets, right-of-way continuity, station feasibility, and institutional coordination, corridor-scale trunk service offers a viable strategy for improving regional mobility within existing freeway environments.



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Appendix A: Standardized Case Study Profiles (U.S. and International Systems)

U.S. Reference Cases

This appendix provides standardized profiles of selected U.S. and international freeway- and busway-based transit systems. Metrics are drawn from agency reporting, prior evaluations, and direct practitioner outreach. Where full-year ridership data were unavailable, annualized estimates are documented in Appendix B.

Los Angeles — Harbor Transitway (I-110)

District 7's primary freeway-median bus facility; serves as the baseline U.S. reference for managed-lane trunk service within a Los Angeles freeway corridor.

System Specifications

Metric	Detail
Facility Context	Freeway-median transitway within I-110 corridor
Stations	8 (In-line median & off-freeway access combinations)
Service Roles	Type 1 Trunk (J Line) + Peak Overlays (LADOT, Torrance)
Governance	Multi-operator (Metro, LADOT, Torrance Transit)

Performance Baseline (FY2025)

Metric	Detail
Annual Boardings	6.2 million (Corridor total, all operators)
Peak Headways	4–10 minutes (Combined trunk)
Commercial Speed	~25.5 mph (Includes CBD street-running)
On-Time Performance	Metro J Line: 88%
Financials (J Line)	Operating Cost: \$26.8M Subsidy / Passenger: \$4.63 Farebox Recovery: 14.4%
Capital Cost	\$548M (\$1988) ~\$1.4–1.5B (\$2025)

Structural Determinants

- **Right-of-Way:** Operates primarily within managed freeway median lanes; performance remains partially contingent on mixed-traffic downstream segments.
- **Trunk Consolidation:** Clear Type 1 trunk backbone (J Line) with overlays layered selectively based on span and extent of freeway use.
- **Station Interface:** Mixed typology; in-line median stations preserve lane retention, but vertical circulation and arterial interfaces dictate access quality.
- **Governance:** Shared facility use requires a defined trunk–overlay hierarchy and coordinated operating practices.
- **Terminal Constraints:** Street-running in CBD segments acts as the primary bottleneck for commercial speed and reliability.

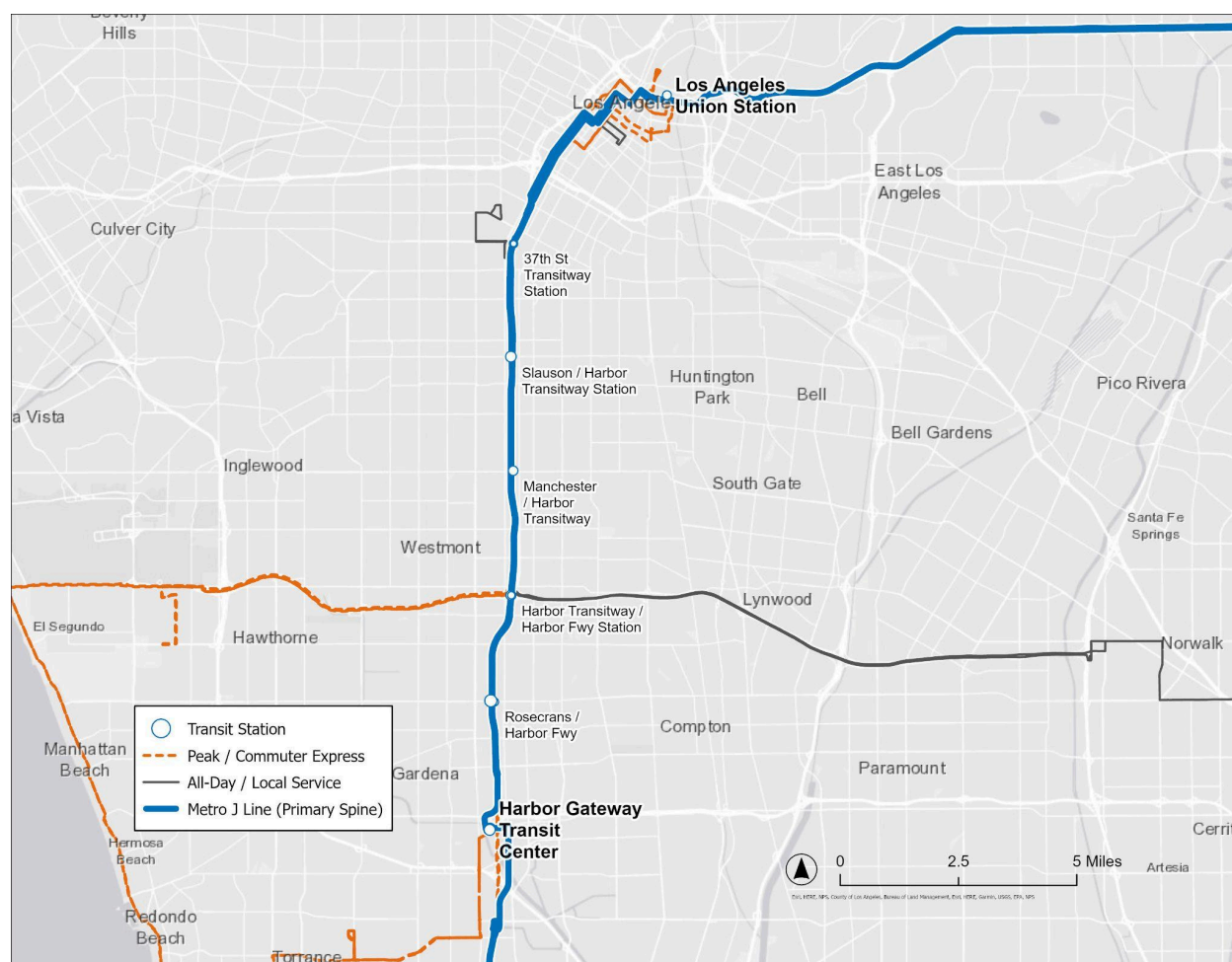


Figure 9. Harbor Transitway (I-110) Corridor Alignment and Station Locations



Figure 10. Freeway-Median In-Line Station Platform and Vertical Access — Harbor Transitway

Data Sources: Metro FY25 Dashboard; LADOT & Torrance Internal Data (2025); Banerjee et al. (2001)



Los Angeles — El Monte Busway (I-10)

District 7's primary east–west freeway bus trunk corridor; illustrates a shared multi-operator trunk structure within a managed-lane environment.

System Specifications

Metric	Detail
Facility Context	Dedicated freeway busway (I-10); HOT ExpressLanes operation
Stations	3 primary stations (Centerline and off freeway station)
Service Roles	Combined Trunk (J Line + Silver Streak) + Peak Overlays
Governance	Multi-operator (Metro, Foothill Transit)

Performance Baseline (FY2025)

Metric	Detail
Annual Boardings	6.2 million (Corridor total, all operators)
Peak Headways	4–10 minutes (Combined trunk)
Commercial Speed	20–30 mph (Includes surface street segments)
On-Time Performance	Metro J Line: 88% Foothill Silver Streak: 82%
Vehicle Capacity	60-ft articulated (~100 max) & Double-deck (~80 seated)
Capital Cost	~\$93M (Historic), ~\$550–650M (\$2025)

Structural Determinants

- **Right-of-Way:** Operates within managed HOV/HOT lanes; reliability is directly influenced by ExpressLanes tolling policy and traffic enforcement.
- **Trunk Consolidation:** Functions as a shared trunk with two frequent all-day services operating continuously, alongside selective commuter overlays.
- **Station Interface:** Median stations preserve speed, while off-freeway and park-and-ride interfaces dictate transfer geometry and access conditions.
- **Governance:** Corridor performance relies entirely on schedule and service hierarchy coordination between Metro and Foothill Transit.



- Terminal Constraints: Surface-running segments in Downtown Los Angeles and eastern corridor approaches limit achievable commercial speeds.

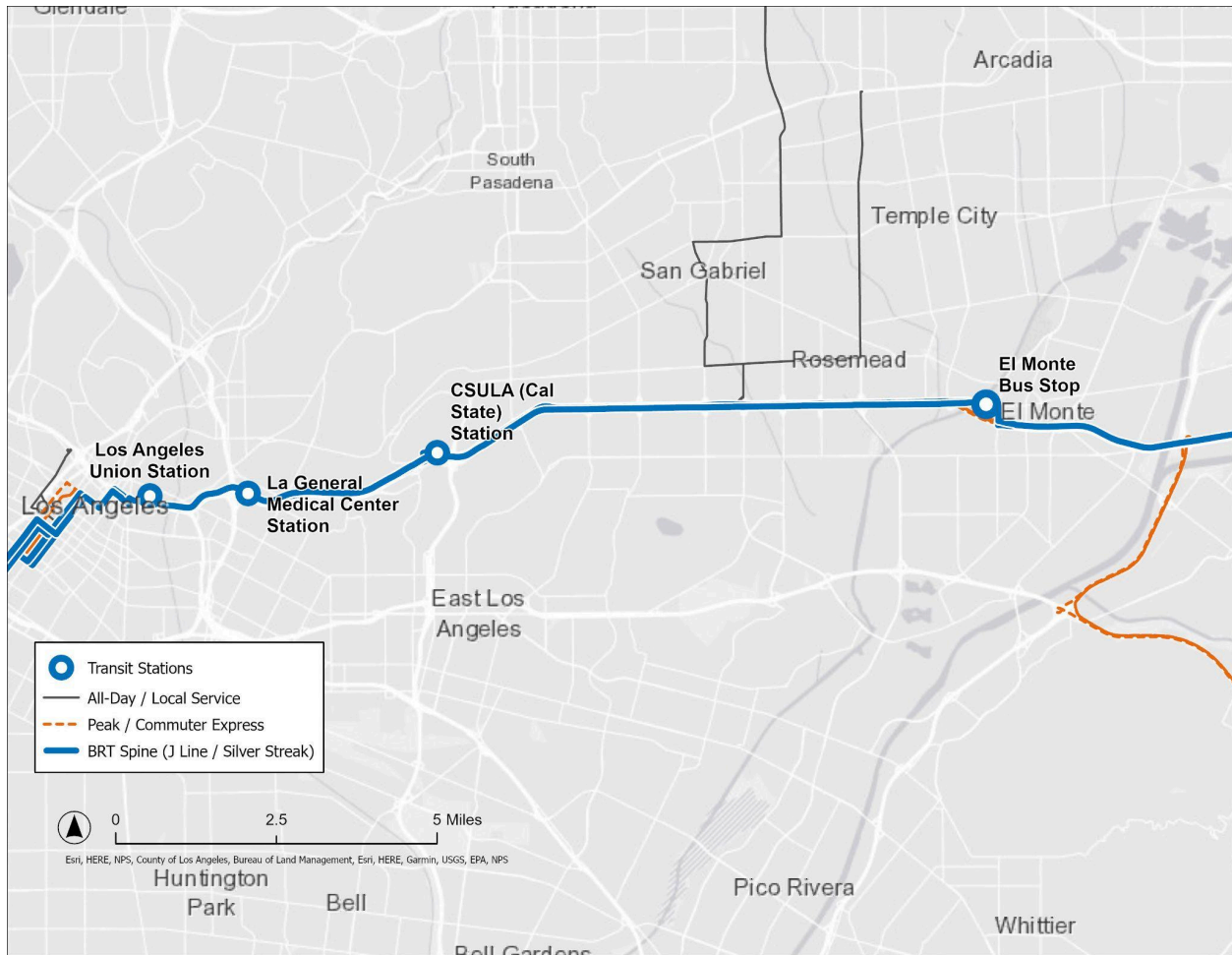


Figure 11. El Monte Busway (I-10) Corridor Alignment and Station Locations



Figure 12. Freeway-Median Station Platform — El Monte Busway

Data Sources: LA Metro FY25 Ridership Dashboard, Foothill Transit Internal Data (2025), Metro Motion 2015-0612 (Silver Line Development), LACMTA Wassell Presentation (2025)



San Diego — I-15 Rapid (SR-15 / I-15 Express Lanes)

Managed-lane trunk example illustrating how freeway-based bus service operates within a congestion-pricing program rather than a transit-exclusive facility.

System Specifications

Metric	Detail
Facility Context	Priced managed lanes (I-15 Express Lanes)
Stations	6 primary (Centerline stations & Direct Access Ramps)
Service Roles	Type 1 Trunk (MTS Route 235) + Peak Overlays (Routes 280, 290)
Governance	Infrastructure: SANDAG/Caltrans Operations: San Diego MTS

Performance Baseline (FY2023–2024)

Metric	Detail
Annual Boardings	1.3 million (Corridor total, all Rapid services)
Peak Headways	13–17 minutes (Route 235 trunk)
Commercial Speed	30–35 mph (Enabled by DARs minimizing street-running)
On-Time Performance	Route 235: 89%
Financials (Route 235)	Subsidy / Passenger: \$7.41 Farebox Recovery: 13–14%
Capital Cost	Program: ~\$1.4B (2018\$) BRT Centerline Stations: ~\$65M

Structural Determinants

- **Right-of-Way:** Trunk operates within priced managed lanes; reliability is shaped by tolling policy, enforcement, and lane management rather than transit-exclusive control.
- **Trunk Consolidation:** Single all-day trunk (Route 235) with overlays layered selectively, anchoring corridor legibility.
- **Station Interface:** Centerline stations with DARs preserve in-lane operation; vertical access from arterial overpasses defines transfer geometry.
- **Governance:** Infrastructure is delivered through a regional managed-lane program (SANDAG), requiring tight alignment between pricing policy and transit operations (MTS).



- Terminal Constraints: Surface-running segments in Downtown San Diego dictate achievable commercial speeds relative to the express-lane segments.



Figure 13. I-15 Express Lanes Corridor with Centerline Stations and Direct Access Ramps



Figure 14. Centerline Freeway Station Platform and Vertical Access — I-15 Centerline Station

Data Sources: MTS FY24 Annual Service Performance Report, SANDAG I-15 Centerline Studies, Correspondence with MTS Service Planning (2025)



Seattle — Freeway Express Bus Network (I-5 / I-405 / SR-520)

A multi-corridor, route-based freeway express network that illustrates how trunk-like all-day services operate without a single corridor-branded transitway.

System Specifications

Metric	Detail
Facility Context	Freeways with HOV/express lanes (I-5, I-405, SR-520)
Stations	16 (Inline, flyer stops, transit centers, park-and-rides)
Service Roles	Corridor-based all-day express trunks + Peak Overlays
Governance	Multi-agency (Sound Transit, King County Metro, Community Transit)

Performance Baseline (FY2024–2025)

Metric	Detail
Annual Boardings	~5 million (Network total)
Average Weekday Riders	SR-520: ~10,100 I-5: ~4,400 I-405: ~2,500
Peak Headways	6–15 minutes (All-day express routes)
On-Time Performance	87% (Network average)
Financials (Route 235)	Subsidy / Passenger: ~\$10–14 (Varies by operator and corridor)

Structural Determinants

- **Right-of-Way:** Operates primarily in HOV/express lanes; performance is highly contingent on corridor-specific managed-lane policies and congestion conditions.
- **Trunk Consolidation:** Functions as parallel corridor-based trunks rather than a single consolidated facility; route-based structure defines service identity more than infrastructure branding.
- **Station Interface:** Mixed typologies (inline, flyer stops, transit centers) preserve freeway running but introduce variability in access geometry and transfer friction.
- **Governance:** Shared freeway network delivered by multiple agencies; corridor performance depends on schedule integration rather than unified facility governance.
- **Terminal Constraints:** Extensive street-running at corridor ends heavily influences reliability and effective network performance.



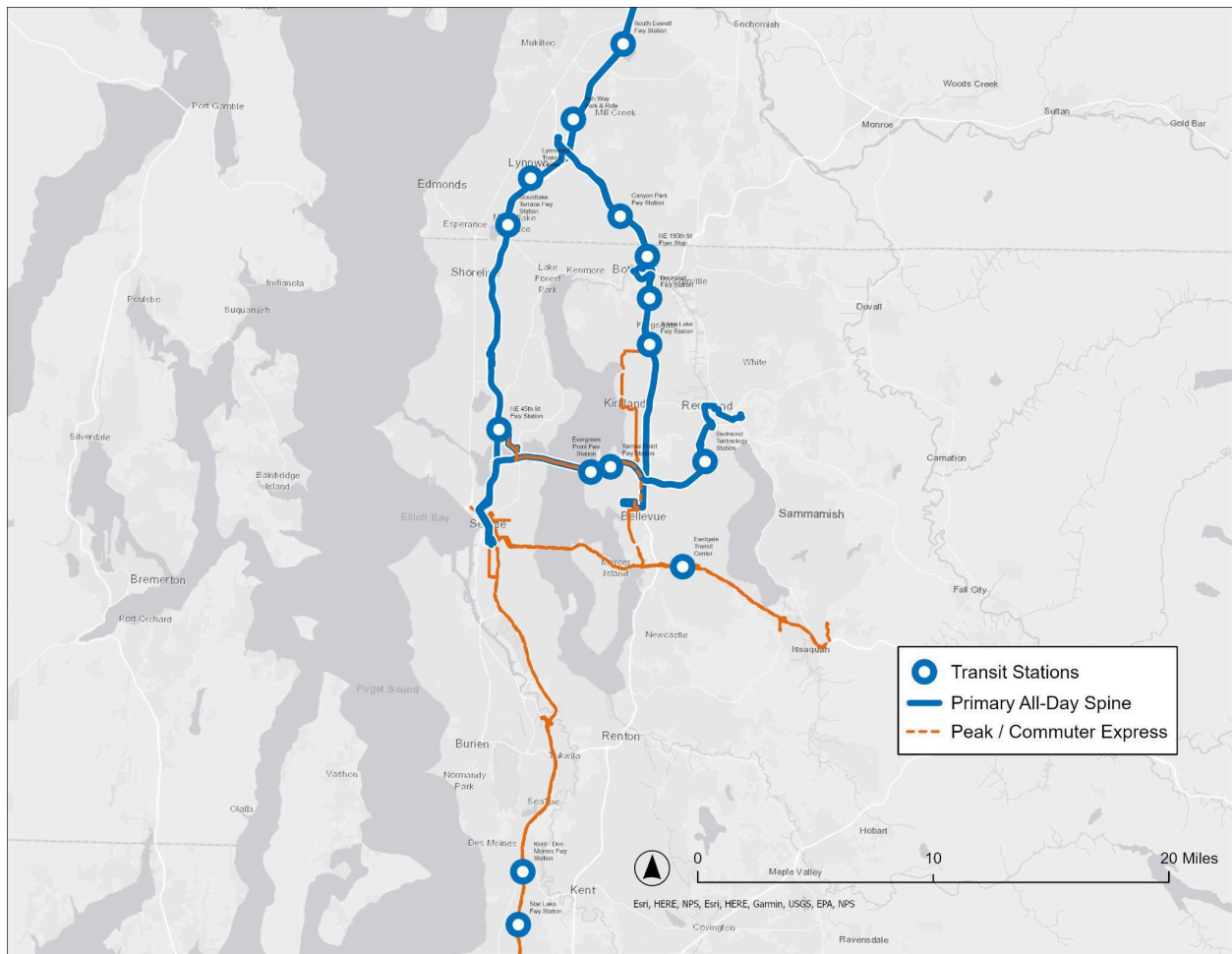


Figure 15. Seattle Regional Freeway Express Corridors (I-5, I-405, SR-520)



Figure 16. Inline Freeway Station Configuration — Seattle Region

Data Sources: Sound Transit System Performance Tracker (2025), King County Metro Internal Data (2025), Community Transit Internal Data (2025)

Minneapolis–St Paul — Orange Line / Red Line (I-35W / Cedar Avenue)

A Twin Cities comparison case illustrating the performance differences between freeway-median trunk service and freeway-adjacent bus operations within the same regional governance context.

System Specifications

Metric	Detail
Facility Context	Freeway-median with DARs (Orange) vs. Arterial/Adjacent (Red)
Stations	Median platforms (Orange) vs. Arterial stations (Red)
Service Roles	Type 1 Trunk (Orange) vs. Hybrid/Adjacent (Red) + Peak Overlays
Governance	Metro Transit, MVTA, and MnDOT



Performance Baseline (FY2023–2024)

Metric	Orange Line (Median Trunk)	Red Line (Freeway-Adjacent)
Average Weekday Riders	~1,500	~400
Peak Headways	7–10 minutes	~25 minutes
On-Time Performance	90%	Not separately reported
Subsidy per Passenger	\$14.10	\$17.70
Capital Cost (2025\$)	~\$180.2M (Bundled with I-35W project)	~\$176.7M

Structural Determinants

- **Right-of-Way:** The Orange Line maintains freeway-median continuity via DARs, whereas the Red Line operates with limited freeway integration, severely constraining speed and reliability.
- **Trunk Consolidation:** The Orange Line functions as a defined freeway trunk; MVTA overlays supplement rather than define the corridor structure.
- **Station Interface:** Median station retention on I-35W supports lane continuity; the Red Line illustrates performance sensitivity to indirect or constrained station access.
- **Governance:** Bundling the Orange Line infrastructure with MnDOT highway reconstruction reduced delivery risk, while the Red Line required greater post-opening coordination adjustments.
- **Terminal Constraints:** Performance is influenced by street-running segments at corridor ends, heavily impacting the Red Line.



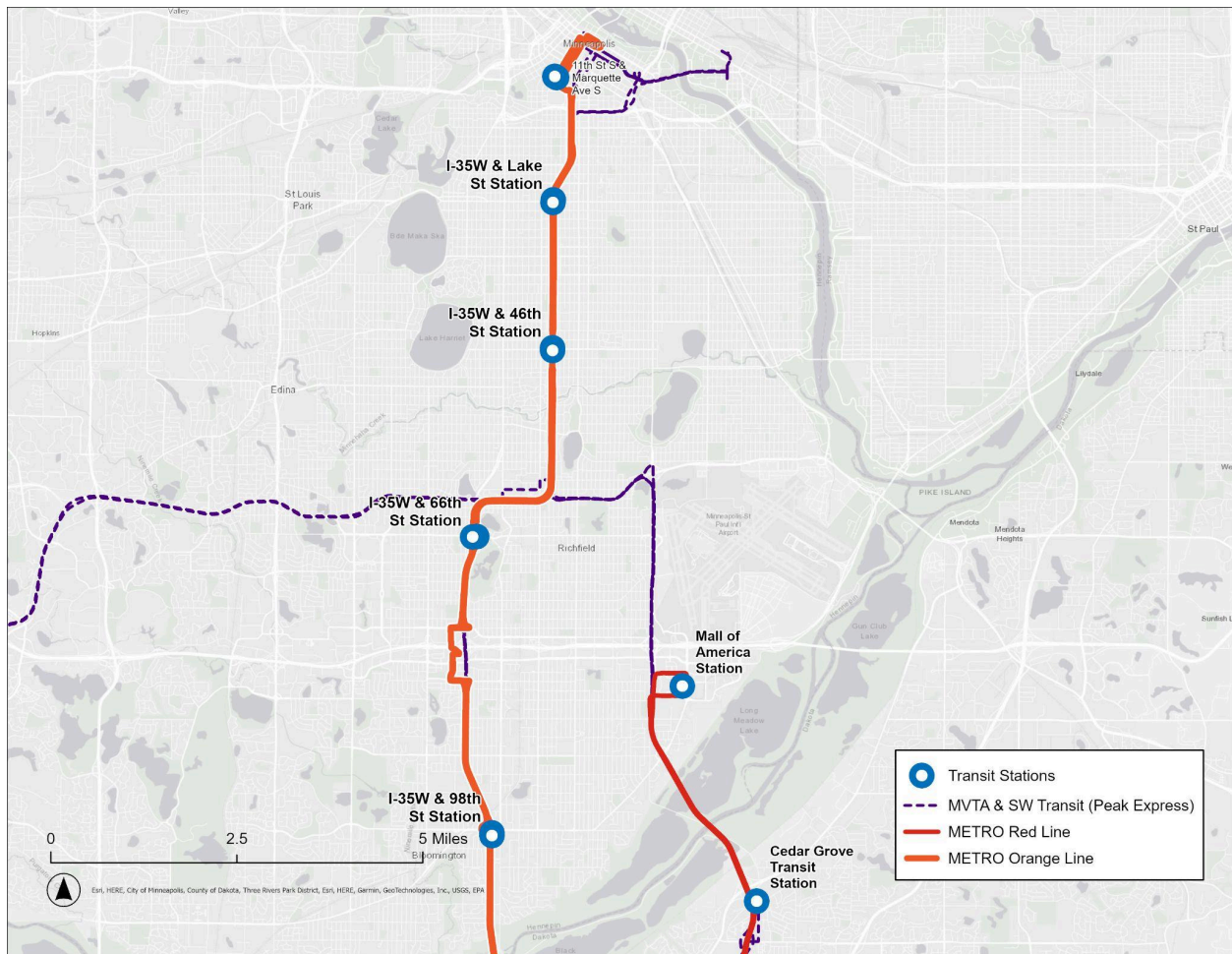


Figure 17. I-35W and Cedar Avenue Corridor Alignment — Orange and Red Lines



Figure 18. Freeway-Median and Arterial Station Conditions — Orange and Red Line

Data Sources: Metropolitan Council Regional Route Performance Analysis (2023–2024), Metro Transit Orange Line Lessons Learned (2022), Star Tribune Red Line Reporting (2023)



Pittsburgh — Grade-Separated Busways (Reference Case)

An exclusive, grade-separated busway network used as a non-freeway benchmark to isolate the performance effects of full right-of-way separation from general traffic.

System Specifications

Metric	Detail
Facility Context	Fully grade-separated busways in former rail/industrial ROW
Stations	25 (Busway stations with pull-offs and passing segments)
Service Roles	Type 1 Trunk (East Busway) + Lower-frequency trunks
Governance	Pittsburgh Regional Transit (PRT)

Performance Baseline (FY2025)

Metric	Detail
Annual Boardings	4.3 million (All busways combined)
Peak Headways	5–10 minutes (Range across corridors)
Average Weekday Riders	East: ~4,800 West: ~1,400 South: ~1,000
On-Time Performance	East: 84% West: 82% South: 72%
Subsidy per Passenger	East: \$3.84 West: \$9.25 South: \$15.41
Capital Cost (~2025\$)	East & Ext: ~\$305M West: ~\$475M South: ~\$47M

Structural Determinants

- **Right-of-Way:** Extreme bus volumes eventually fall victim to intersection delay, capping commercial speeds despite the exclusive median lanes.
- **Station Interface:** Represents the absolute physical limit of bus throughput, relying on massive multi-berth passing configurations to prevent gridlock.
- **Governance:** Unifies over 40 distinct routes operated by different companies under a single centralized ITS and fare collection umbrella to prevent fragmentation.



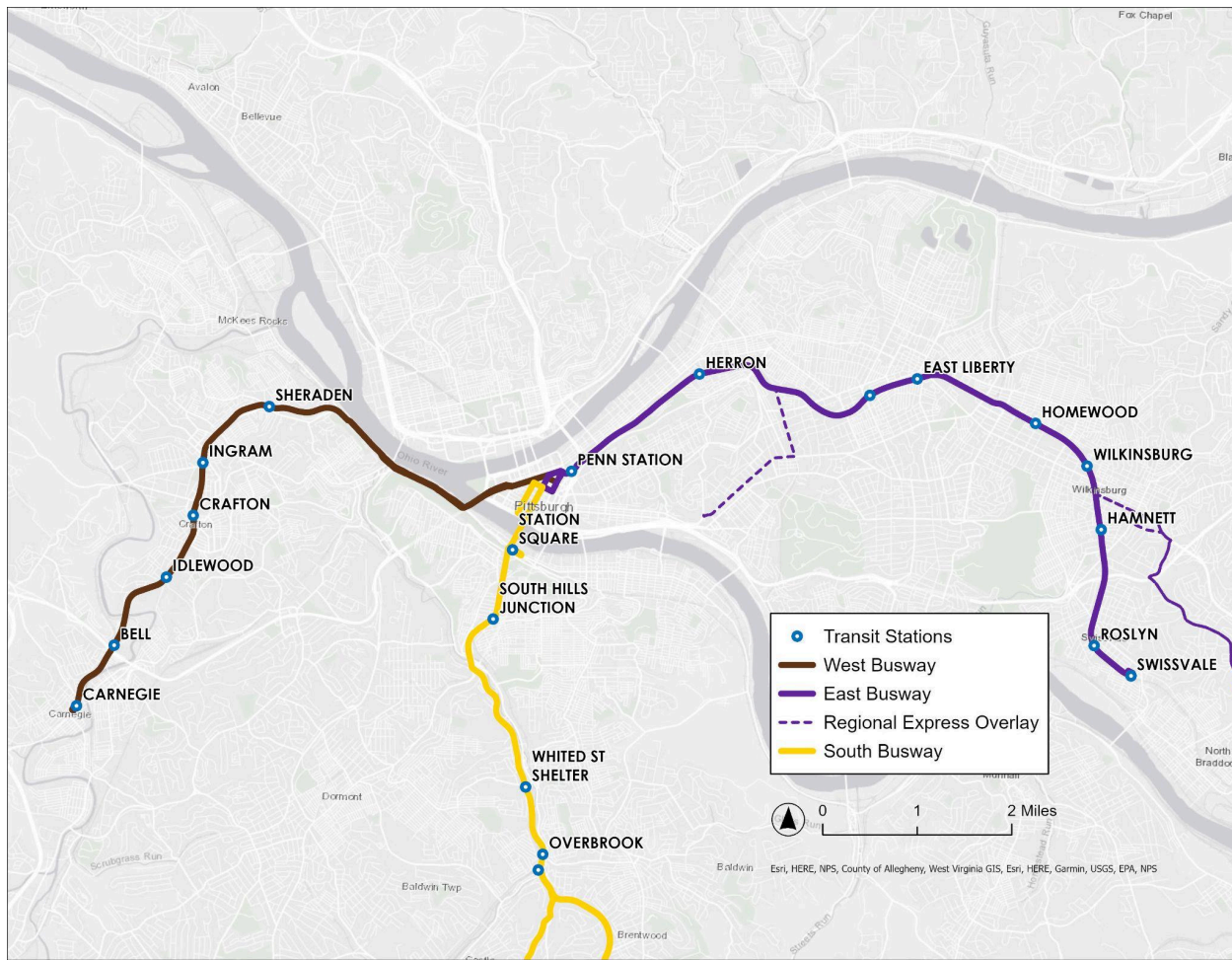


Figure 19. East, West, and South Busway Corridors — Pittsburgh





Figure 20. Grade-Separated Busway Station — East Busway

Data Sources: Pittsburgh Regional Transit FY24 Annual Service Report, PRT Performance Metrics Dashboard. Perk & Catalá (2009), Wohlwill (2022)

International Reference Cases

These international systems operate on urban expressways or purpose-built busways rather than California-style limited-access freeways. They serve as functional reference cases to examine trunk consolidation, right-of-way continuity, station throughput, and governance under extreme capacity conditions.

Ottawa — Transitway (Highway-adjacent trunk reference)

A high-capacity bus-only trunk system operating partly within highway rights-of-way, serving as a historical reference for capacity ceilings and trunk-feeder integration prior to rail conversion.



System Specifications

Metric	Detail
Facility Context	Bus-only guideway & shoulder-running (Highway 174/417)
Stations	Grade-separated & highway-adjacent platforms
Service Roles	Continuous Trunk + Consolidated Feeders
Governance	OC Transpo (Systemwide planning and operations)
Note	Metrics reflect pre-rail conversion operations. Operating/maintenance costs were not disaggregated from system budgets.

Performance Baseline (Early 2000s - Busway Era)

Metric	Detail
Peak Headways	~5–10 minutes
Commercial Speed	28–37 mph (45–60 km/h)
Vehicle Capacity	~90–110 (Double-deck & articulated fleet)
Farebox Recovery	~30%
Capital Cost	~C\$435M (~US\$650–700M in 2025\$)

Structural Determinants

- **Right-of-Way:** Dedicated bus-only lanes within the highway envelope preserved uninterrupted trunk flow.
- **Trunk Consolidation:** A continuous trunk supported by coordinated suburban feeders; corridor performance was directly tied to feeder consolidation.
- **Station Interface:** Highway-adjacent stations enabled fast trunk travel but introduced access friction, including indirect pedestrian approaches and separated directional platforms.
- **Terminal Constraints:** Peak bus volumes approaching ~200 buses/hour through the downtown core created a system-level bottleneck, ultimately forcing the conversion to rail.



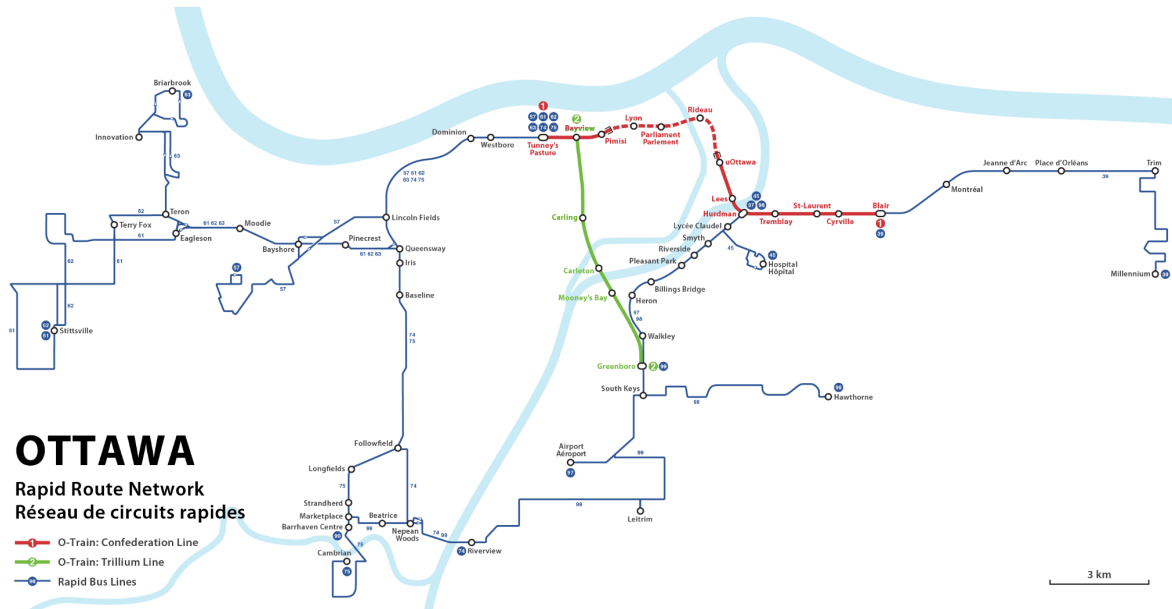


Figure 21. OC Transpo Transitway Busway Network



Figure 22. Highway-Adjacent Busway Station and Platform Configuration — Ottawa Transitway

Data Sources: OC Transpo Transitway Ridership Extract (Winter 2025), TCRP Report 90, OC Transpo Operating Cost Correspondence

Brisbane — Metro (Trunk consolidation reference)

Illustrates trunk consolidation and governance restructuring on an established busway network to increase corridor capacity and legibility.

System Specifications

Metric	Detail
Facility Context	Grade-separated continuous busway network
Stations	18 (Upgraded for high-capacity vehicle interfaces)
Service Roles	Type 1 Trunk (M1/M2) + Truncated Feeders
Governance	Brisbane City Council (Ops) & Translink (Coordination)

Performance Baseline (2025 Launch Year)

Metric	Detail
1st Year Ridership	~3–4 million trips (Cumulative estimate)
Peak Headways	28–37 mph (45–60 km/h)
Peak Throughput	~20–30 buses/hour (Metro trunk routes only)
Commercial Speed	~25–35 mph (40–55 km/h)
Vehicle Capacity	~150–170 passengers (Bi-articulated fleet)
Capital Cost	~A\$944M (~US\$620–650M in 2025\$)
Note	Unit of analysis reflects Metro trunk routes; underlying busways carry additional routes not included here

Structural Determinants

- **Trunk Consolidation:** Multiple overlapping suburban routes were restructured into two high-frequency trunk services, increasing corridor legibility without constructing new right-of-way.
- **Governance:** Centralized trunk operations required the coordinated truncation of direct CBD routes and a strict redefinition of feeder relationships.
- **Right-of-Way:** Performance is driven by continuous bus-only guideways, demonstrating that right-of-way continuity must precede branding.



- Station Interface: Restructuring concentrated demand onto higher-capacity trunk vehicles to reduce CBD bus congestion, requiring extensive legacy station modifications.

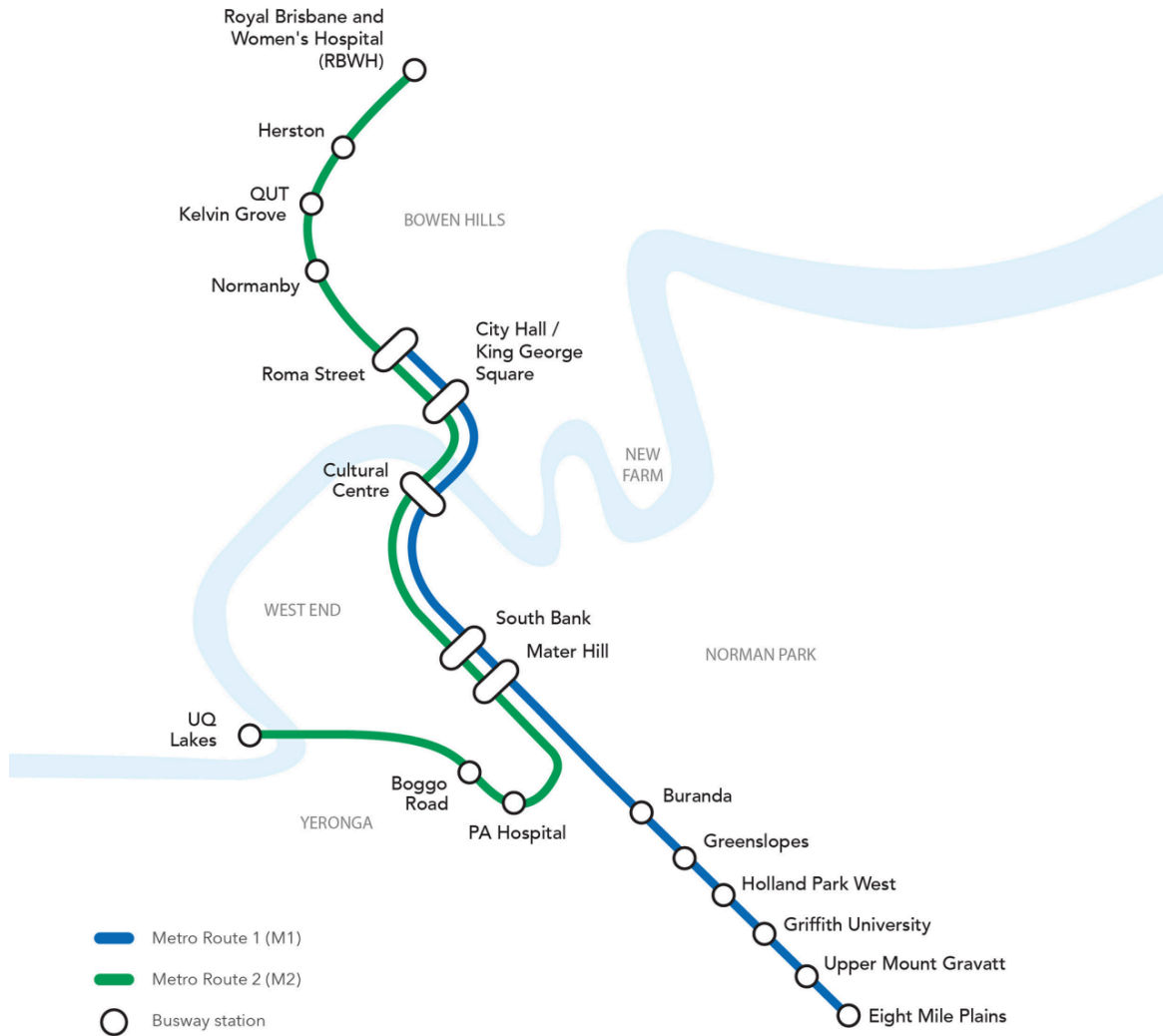


Figure 23. Brisbane Metro Trunk Corridors and Busway Network



Figure 24. High-Capacity Metro Vehicle at Grade-Separated Busway Station — Brisbane

Data Sources: Queensland Department of Transport Annual Report 2024–25, Brisbane City Council Project Evaluation (2018), Translink / Brisbane Metro Correspondence (2025)



Adelaide — O-Bahn (Specialized guideway reference)

Illustrates operational tradeoffs of a purpose-built guided busway supporting very high trunk frequencies under exclusive right-of-way control.

System Specifications

Metric	Detail
Facility Context	Purpose-built concrete guided busway
Stations	3 primary grade-separated interchanges
Service Roles	Core Trunks (M44, J1/J2) + Frequent BRT + Peak Express
Governance	Adelaide Metro

Performance Baseline (2025)

Metric	Detail
Daily Ridership	~35,000
Peak Headways	~1 minute (Combined)
Peak Throughput	~90 buses/hour
Commercial Speed	~37 mph (60 km/h avg)
Vehicle Capacity	~60–100 passengers
Capital Cost	~A\$100M (Historic), ~US\$250–300M (2025\$)

Structural Determinants

- **Right-of-Way:** Fully separated from general traffic; reliability and speed are governed entirely by transit-controlled operations rather than pricing or mixed-flow congestion.
- **Passing Capacity:** Pull-off lanes and passing segments enable simultaneous express and local operations, increasing corridor throughput without rail-style overtaking constraints.
- **Trunk Consolidation:** The East Busway functions as a consolidated trunk spine, while the West and South busways demonstrate performance variations under lower demand.
- **ROW Reuse:** Development within former rail corridors reduced land acquisition needs but imposed geometric and lateral-access constraints on station siting.



- Station Interface: Grade separation and terrain limit direct pedestrian access at several locations, affecting usability despite the exclusive ROW.

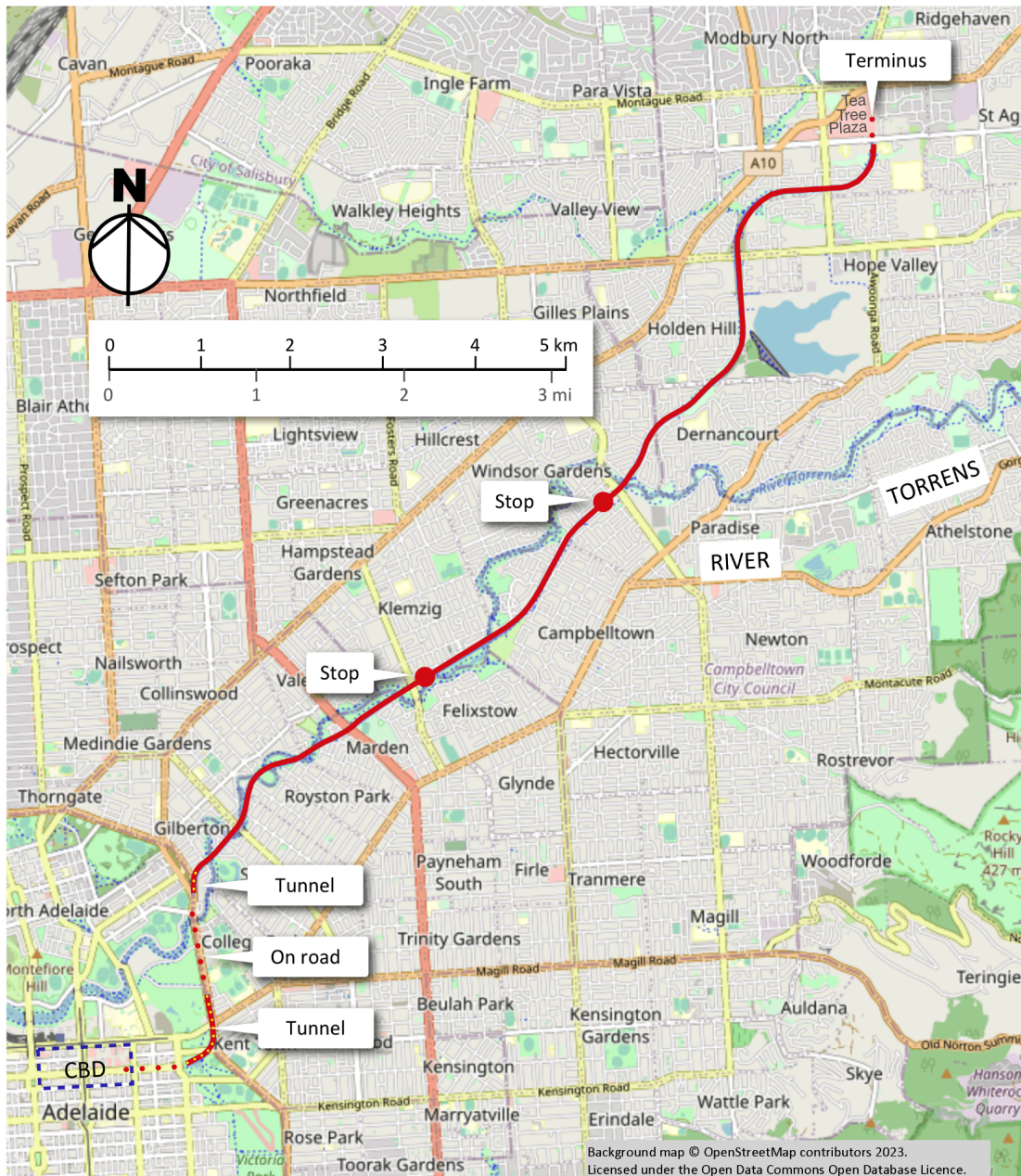


Figure 25. Adelaide O-Bahn Guided Busway Corridor and Interchanges



Figure 26. Guided Busway Guide-Rail and Interchange Station Configuration — O-Bahn

Data Sources: Public Transport South Australia (PTSA) Patronage Data (2025), Adelaide Metro Service Contracts



Bogotá — TransMilenio (High-demand BRT reference)

Illustrates a high upper performance of median-running trunk-and-feeder BRT under sustained high demand.

System Specifications

Metric	Detail
Facility Context	Exclusive median arterial busways (Dual lanes)
Stations	143 enclosed stations + 9 portals
Service Roles	Type 1 Trunk (Exclusive BRT) + Zonal Feeders
Governance	TransMilenio S.A.
Note	Ridership, cost, and farebox data are reported systemwide; corridor-level financial data are not publicly disaggregated.

Performance Baseline (2023)

Metric	Detail
Daily Boardings	~2.0 million (Systemwide)
Peak Headways	2–3 minutes
Peak Throughput	~250–300 buses/hour (Corridor maxima)
Commercial Speed	~16–20 mph
Vehicle Capacity	~160–250 passengers (Bi-articulated fleet)
Financials	Farebox Recovery: ~48% Annual Operating Cost: ~\$1.35–1.40B

Structural Determinants

- **Throughput Driver:** Dual median lanes, passing capability, multi-berth enclosed stations, and off-board fare payment enable high bus volumes per corridor.
- **Service Structure:** Clear trunk–feeder separation; trunk corridors are protected from route merging and local service interference.
- **Constraint:** Under extreme demand, capacity bottlenecks shift from running lanes to station dwell, platform crowding, and terminal circulation.
- **Vehicle Scaling:** Use of bi-articulated buses maximizes passenger throughput per vehicle slot.
- **Governance Model:** High-capacity trunk sustained under partial farebox recovery with public subsidy.





Figure 27. TransMilenio Trunk Corridor Network (Median-Running BRT System)



Figure 28. Enclosed Median Station with Passing Lanes — TransMilenio

Data Sources: TransMilenio S.A. Informe de Gestión (2023), World Bank PPP Knowledge Lab, FTA Report No. FL-26-7104

Guangzhou — GBRT (Extreme throughput upper bound)

Illustrates the performance limits of a single, continuous median BRT corridor operating under extreme demand.

System Specifications

Metric	Detail
Facility Context	Separated median busway (Zhongshan Avenue)
Stations	27 (Extended enclosed multi-berth)
Service Roles	Type 1 Trunk (Overlapping routes)
Governance	Municipal oversight coordinating multiple private operators



Performance Baseline (Historic)

Metric	Detail
Daily Boardings	~800,000 trips
Peak Throughput	~350 buses/hour (~10-second headways)
Commercial Speed	~11–12 mph
Vehicle Capacity	~80–160 passengers (Mixed fleet)
Note	Peak capacity and bus throughput reflect reported corridor maxima from external studies, not system averages

Structural Determinants

- **Throughput Driver:** Large station footprint, multi-berth passing design, centralized control, and active enforcement enable extreme corridor-level throughput.
- **Governance Scaling:** Over 40 routes share infrastructure under unified fare and dispatch management, preventing corridor fragmentation.
- **Constraints:** Intersection delay, limited signal priority, and mixed-traffic encroachment reduce commercial speed despite exclusive median lanes.

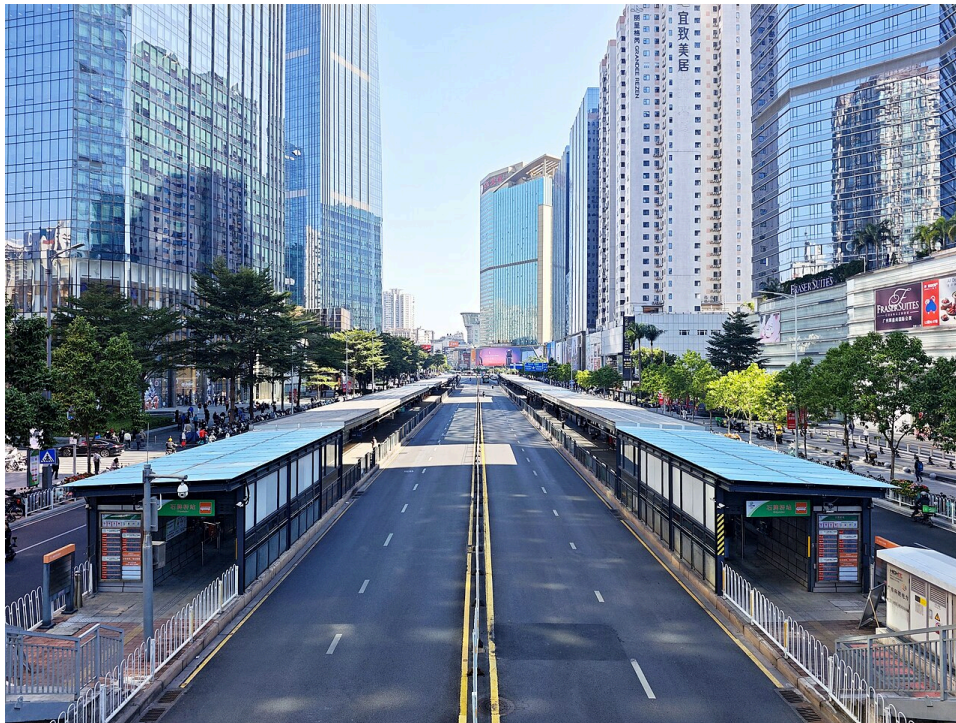


Figure 27. TransMilenio Trunk Corridor Network (Median-Running BRT System)

Data Sources: Enclosed Median Station with Multi-Berth Passing Configuration — Guangzhou BRT

Appendix B: Route-Level Performance Data

Performance data were compiled from agency dashboards, National Transit Database (NTD) reports, and internal datasets provided by partner agencies. Because reporting formats vary, values are presented as reported and standardized only where necessary. For screening purposes, fiscal-year (FY) and calendar-year (CY) totals are treated as functionally comparable.

Derived Metrics

- $\text{Net Subsidy} = \text{Total Operating Cost} - \text{Fare Revenue}$
- $\text{Subsidy per Passenger} = \text{Net Subsidy} \div \text{Passenger Trips}$
- $\text{Passengers per In-Service Hour} = \text{Passenger Trips} \div \text{Annual In-Service Hours}$
- $\text{Cost per In-Service Hour} = \text{Total Operating Cost} \div \text{Annual In-Service Hours}$
- $\text{Farebox Recovery Ratio} = \text{Fare Revenue} \div \text{Total Operating Cost}$

Annualization

Where full-year totals were unavailable, estimates were derived by annualizing quarterly (x4) or average monthly (x12) totals. The complete station-level dataset is provided as a [supplemental electronic file](#).



Appendix C: Station-Level Boardings and Alightings

Station-level boarding and alighting data were compiled directly from agency ridership datasets. Reported averages were converted to approximate annual totals to enable consistent comparison across stations and corridors.

Annualization Method

Annual station activity was estimated using the general formula:

- Annual Boardings = Average Boardings × Annual Service Days

Where agencies reported average weekday, weekly, or daily values, totals were annualized using consistent assumptions:

- Average weekday values × standardized number of weekdays per year
- Daily/Weekday Data: Average daily values × assumed annual service span
- Directional Data: Inbound and outbound values combined for total station activity
- Day-Specific Data: Weekday, Saturday, and Sunday averages weighted proportionally to estimate the annual total

Station Typology Classification

Stations were categorized into three general types:

- Freeway-median stations
- Direct-access / park-and-ride facilities
- Off-freeway or suburban stops

The complete station-level dataset is provided as a [supplemental electronic file](#).



Appendix D: Agency Correspondence and Practitioner Consultation

To supplement public reporting, direct consultation was conducted with planners, service analysts, and researchers across the evaluated transit systems. These engagements provided:

- Unpublished station-level and route-level operational data (Appendices B and C).
- Clarification of agency-specific reporting methodologies (e.g., cost allocation, service hours).
- Operational context regarding right-of-way constraints, station design performance, and multi-operator governance.
- Validation of the structural assumptions applied in the District 7 screening framework.

Agencies and Organizations Consulted

(Note: Individual names are withheld to maintain professional discretion; correspondence focused strictly on system-level data and operational practices.)

- Los Angeles Region: LA Metro, LADOT Transit, Torrance Transit, Foothill Transit, UCLA Institute of Transportation Studies
- San Diego Region: San Diego Metropolitan Transit System (MTS)
- Seattle Region: Sound Transit, King County Metro, Community Transit
- Minneapolis–Saint Paul Region: Metro Transit (Twin Cities)
- Pittsburgh Region: Pittsburgh Regional Transit
- International & Research: OC Transpo (Ottawa), Brisbane City Council / Translink (Brisbane), Adelaide Metro (Adelaide), TransMilenio (Bogotá), ITDP China / Far East Mobility (Guangzhou), ITDP U.S.

