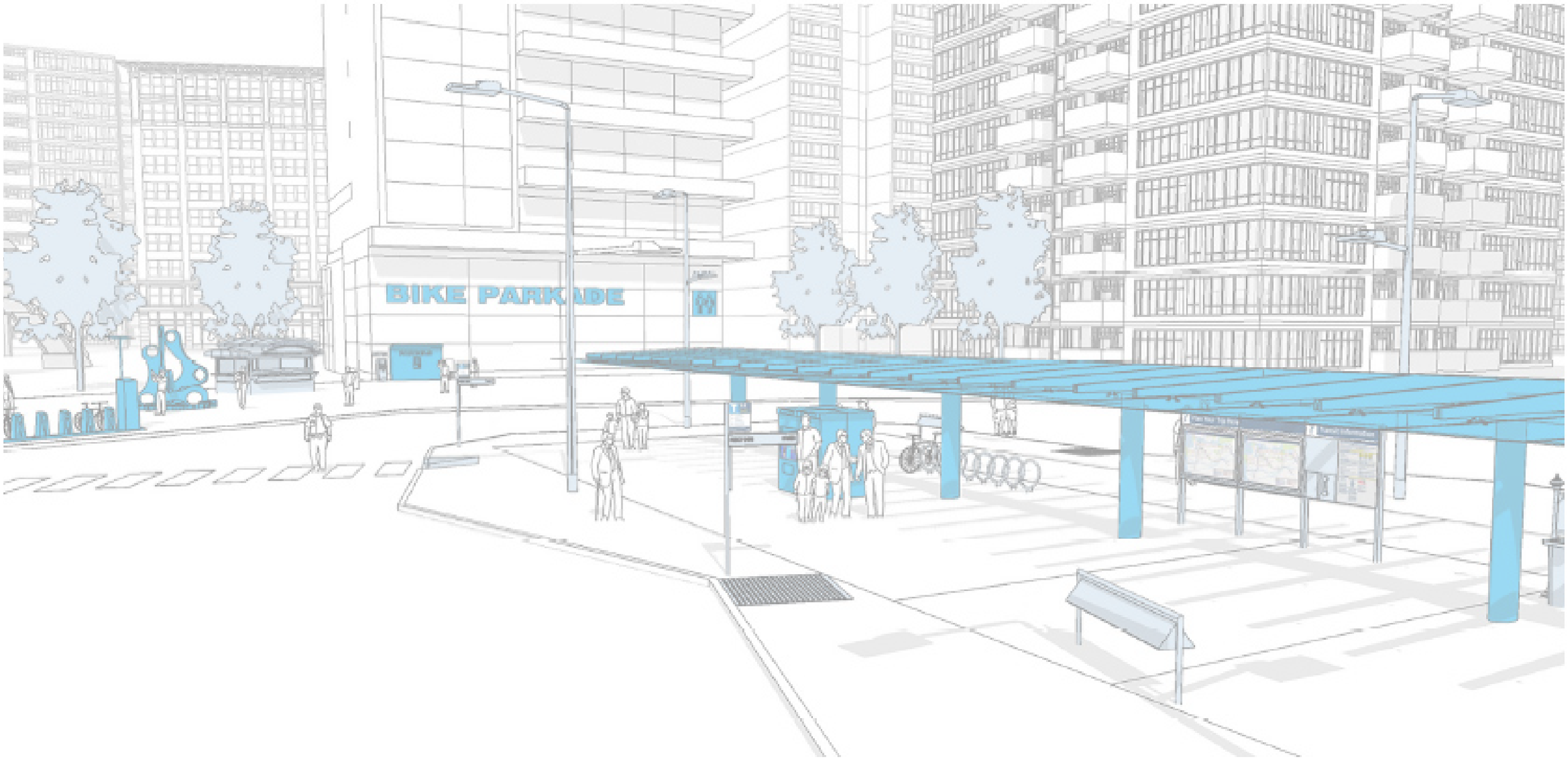
MODULARIZATION FOR SUSTAINABLE TRANSIT FACILITIES:

Exploring Modularization for Sustainable Transit Facilities: Design, Prefabrication, and End-of-Life Management Strategies



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DISCLAIMER

This report was produced as part of the UBC Sustainability Scholars Program, a partnership between the University of British Columbia and various local governments and organisations in support of providing graduate students with opportunities to do applied research on projects that advance sustainability and climate action across the region.

This project was conducted under the mentorship of TransLink staff. The opinions and recommendations in this report and any errors are those of the author and do not necessarily reflect the views of TransLink or the University of British Columbia.

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PROJECT OVERVIEW

This project explores modularization as a sustainable and adaptable approach to designing and constructing transit facilities, focusing on prefabrication, resource efficiency, and End-of-Life Management. Modular design offers opportunities to improve construction efficiency, reduce environmental impact, and enhance the adaptability of TransLink's facilities to meet future needs.

CONTEXT

The purpose of this project is to identify how modular design principles can be integrated into TransLink's current facilities and ongoing projects to support sustainability goals and operational efficiency. The outcomes will include actionable insights and strategies that provide a scalable and practical framework for implementing modular design, aligning with both immediate project requirements and long-term regional sustainability efforts.

BACKGROUND RESEARCH

A literature review set out to understand how TransLink currently incorporates (or omits) modular design principles in its transit facilities. The goal is to establish a baseline of current practices – identifying what is already done well and where gaps exist – to inform subsequent recommendations. This section evaluates existing manuals through two lenses, prescriptive-bespoke and highly-prescriptive. This section provides a first-person overview of my research process and findings, forming a foundation for later design improvement proposals.

SITE ANALYSIS

An analysis of eight transit stations was conducted using a revised framework informed by ISO standards for sustainable building and principles of circular design. This evaluation assessed how modular design concepts are integrated within each site, specifically examining the degree to which components are standardized, prefabricated, adaptable, and designed for long-term material efficiency and reuse.

The assessment was structured around three key lenses:

Environmental Sustainability: Examining the materials used, energy efficiency, durability, and strategies for lifecycle extension or end-of-life disassembly.

Modular Integration: Evaluating whether infrastructure elements are designed for disassembly, whether they exhibit repeatability and interchangeability across sites, how adaptable they are to varying contexts or functions, and how easily they can be installed, relocated, or maintained.

User Interface: Assessing how customers interact with modular elements at the station level. This includes evaluating whether components are intuitively placed and unobstructed, how they influence circulation and accessibility, and whether their modularity supports user comfort, wayfinding, and legibility across the transit network.

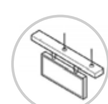
Operational Interface: Evaluating how transit staff, maintenance crews, and facility operators interact with modular infrastructure over time. This lens considers the behind-the-scenes functionality of modular systems and how well they support operations, inspections, cleaning, repairs, and upgrades.

GLOBAL BEST PRACTICES

This section provides an overview of global best practices in transit design that inform the development of the modular retrofit toolkit in the design applications. Drawing on coordinated "kit-of-parts" strategies, it highlights how integrated design approaches can enhance civic presence, modal connections, and long-term functionality while remaining contextually responsive.

DESIGN APPLICATIONS

The second phase of the project will culminate in the development of a visual phasing strategy guide, mapping which station components are best suited for modular retrofits and estimating the relative effort, time, and sequencing required for each.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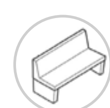
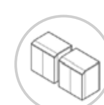

Modular Furniture Kit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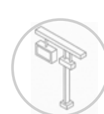
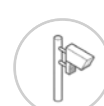

Modular Service Spine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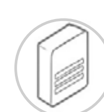

Prefab Retail Kiosks


Modular Utility Wall (BOH Chase)


Modular BOH Unit


Modular Elevator/ Stair Cores

BACKGROUND REVIEW

SUBJECTIVE REVIEW OF EXISTING GUIDELINES, CODES, AND PLANS RELATED TO TRANSIT MODULARIZATION IN METRO VANCOUVER

BACKGROUND

In this background research, I set out to understand how TransLink currently incorporates (or omits) modular design principles in its transit facilities. The goal is to establish a baseline of current practices – identifying what is already done well and where gaps exist – to inform subsequent recommendations. By examining TransLink's existing design guidelines and manuals, I aim to clarify how "kit-of-parts" or modular approaches are reflected in present-day designs, and why enhancing modularity could benefit future projects. This section provides a first-person overview of my research process and findings, forming a foundation for later design improvement proposals.

METHODOLOGY AND MATERIALS REVIEWED

The following key TransLink design documents were analyzed:

Bus Infrastructure Design Guidelines (2018) – Details standards for bus stops and exchanges, offering insight into how common elements (shelters, pads, signage, etc.) are standardized in bus infrastructure. This document provides optimal standards for bus stop layout, accessibility, signage, and shelter placement- but does not emphasize modularity or prefabrication- providing a foundation for universal design.

BCAP Final Report (2019) - The Bus Customer Amenity report is a strategic program framework to support bus stop upgrades and universal accessibility. The manual outlines policy direction for creating a highly prescriptive and repeatable bus stop standard, promoting modularity, consistency, and streamlined implementation. The forward-looking initiative informs future kit-of-parts development.

SkyTrain Design Manual – Upgrades, Volume 1: Architectural (2020) – This manual (for station upgrades and new designs) reveals how TransLink approaches station architecture, including whether modular construction or repeated design modules are employed in elevated and underground stations. This manual emphasizes context-sensitive design and passenger experience- offering high-level direction for scalable improvements. Modular design is mentioned (Section 2.3.2).

West Coast Express Design Manual (2022) – Governs design of the West Coast Express commuter rail station and facilities. This manual focuses on accessibility, comfort, and alignment with the heritage character of WCE. The manual encourages some repeatability in signage and amenities, however, modularity is not a central theme and more emphasis is placed on operational and architectural clarity.

TransLink Standard Bus Stop Amenity and Component Catalogue (2022)- defines standardized products (eg. ID poles, benches, waste bins) for bus stops. The catalogue promotes scalability and modular selection of street furniture by municipalities, components are designed to be interchangeable and bolt-on, supporting flexible deployment.

Shelter Product Catalogue (2022)- provides a product-level guide to modular bus shelters designed under BCAP. The catalogue establishes shared dimensions, plug-in amenities, and modular components such as roofs, ID signs, and lighting. This supports rapid deployment and consistency across municipalities.

UBC PIDs Pilot Summary (2022) - A pilot study evaluating modular Passenger Information Displays (PIDs) on UBC campus, exploring prefabricated plinths, poles, and podiums as modular structures for PIDs. The manual highlights design and operational challenges such as CMS integration and power/data connections.

KEY FINDINGS

This review categorizes modular design practices in TransLink's infrastructure through two lenses: **(1) prescriptive and bespoke architecture**, as seen in SkyTrain and West Coast Express facilities, and **(2) highly prescriptive and repeatable infrastructure**, such as BCAP bus stops and modular passenger amenities. This comparison highlights divergent strategies in modularization and how each approach aligns with the goals of sustainability, scalability, and construction efficiency.

(1) Prescriptive Bespoke:
The legacy of modular design is visible in the Expo Line SkyTrain stations, which followed a clear kit-of-parts logic that enabled prefabrication and efficient construction. This strategy created a consistent architectural identity across multiple sites. More recently, the Surrey–Langley SkyTrain extension appears to be reintroducing modular thinking through the use of repeated structural templates that enhance construction efficiency and reinforce a coherent family of stations. Similarly, the West Coast Express

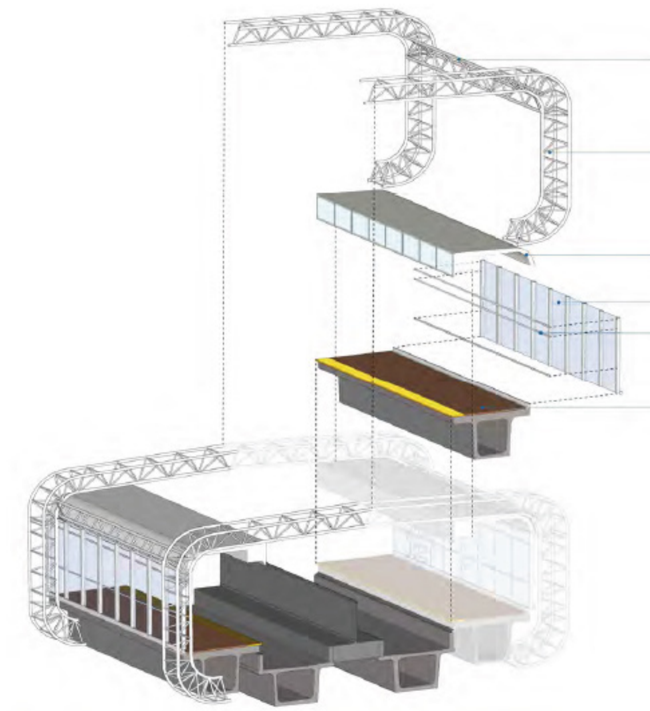
BACKGROUND REVIEW

SUBJECTIVE REVIEW OF EXISTING GUIDELINES, CODES, AND PLANS RELATED TO TRANSIT MODULARIZATION IN VANCOUVER

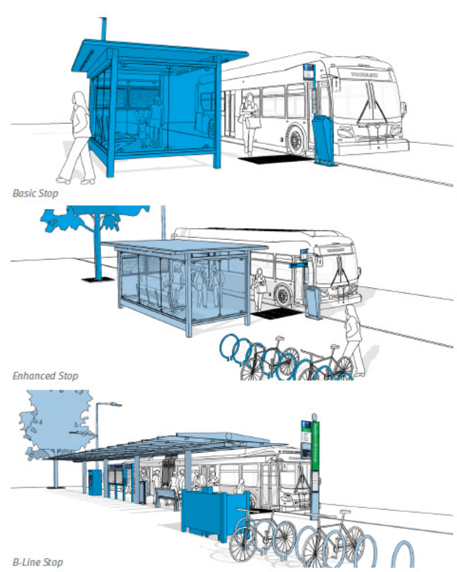
Design Manual balances system-wide consistency with local distinction by applying a framework of elements of continuity (such as tactile guidance and core amenities) and elements of distinction (such as contextual materials and roof profiles). While this bespoke approach offers site-sensitive flexibility, it lacks a modular production strategy, resulting in missed opportunities for scalable efficiencies.

(2) Highly Prescriptive:
TransLink's bus infrastructure, particularly through the BCAP program and Bus Stop Amenity Catalogue, demonstrates a more prescriptive and repeatable model of modularity. The catalogue standardizes dimensions, mounting details, and amenity configurations for shelters, signage, and street furniture, enabling municipalities to select and deploy elements in a flexible yet coherent manner. The Shelter Product Catalogue further refines this modular intent by offering plug-and-play shelter designs with universal attachment systems, shared extrusion profiles, and bolt-on options for lighting, branding, and seating. These initiatives illustrate a thoughtful approach to scaling modularity across diverse urban conditions while maintaining accessibility and operational consistency. The UBC PIDs Pilot adds to this framework by testing the deployment of prefabricated digital infrastructure using consistent base modules such as poles, plinths, and mounting brackets.

LIMITATIONS:
Despite these strengths, the research also revealed limitations in TransLink's current use of modular design- existing guidelines often function as best-practice references rather than enforceable standards, which allows for considerable variation in how modular principles are implemented across projects and modes. For example, while the Expo Line's standardized kit-of-parts approach offered a clear modular identity, this was not continued in subsequent lines such as the Millennium Line, which introduced more customized, one-off station designs. As a result, the broader system's design language has become increasingly fragmented over time. While manuals specify civil and architectural requirements, such as accessibility dimensions, safety thresholds, and minimum clearances, they generally do not articulate construction methods related to prefabrication, interchangeability, or design for disassembly. Repeatable features are specified for inclusion (such as seating, lighting, furniture, etc.), but rarely described as modular units that could be easily replicated, replaced, or reconfigured.



Prescriptive Standardization for Original Expo Stations Axonometric
Image Source: Skytrain Design Manual Upgrades Vol 1-Architectural (Translink)



Bus Stop Kit of Parts Approach
Image Source: 2019 BCAP FINAL REPORT (Translink)

BACKGROUND REVIEW

SUBJECTIVE REVIEW OF EXISTING GUIDELINES, CODES, AND PLANS RELATED TO TRANSIT MODULARIZATION IN VANCOUVER

Limitations Continued:

Another limitation is the relatively low emphasis on lifecycle planning or sustainable materials that enable reuse. Modular construction is not actively promoted in relation to construction speed, carbon impact, or end-of-life scenarios. The involvement of external suppliers, such as advertising companies for shelters or third-party digital vendors, also introduces inconsistencies in design quality and modular compatibility, making systemwide upgrades more difficult. In larger intermodal facilities or bus exchanges, the Bus Infrastructure Design Guidelines offer limited direction for scaling up modularity beyond individual bus stops. This gap indicates a missed opportunity to formalize modular design principles at a network level. Without a unifying kit-of-parts framework, TransLink's current design approach remains functional but fragmented, and does not fully capitalize on the potential of modular construction to accelerate delivery, reduce costs, and support future sustainability goals.

FURTHER RESEARCH

The gaps identified above point to several areas that warrant further research and action, which will guide the next phase of this project. First, to address the limitations, I will investigate design improvements that could introduce or enhance modular elements in TransLink's facilities. This will involve looking at global best practices in modular transit design (as a comparative benchmark) and assessing how those could be applied to TransLink's context.

Key questions include: How might standardized components or prefabricated modules be integrated into station and stop designs without compromising site-specific needs? And what organizational or policy changes are needed to implement a kit-of-parts approach across different transit modes? Additionally, further research is needed on material and end-of-life strategies such as exploring the use of modular construction with low-carbon materials (like mass timber) that can be disassembled and reused, aligning with TransLink's sustainability goals.

The findings from the current state analysis will directly shape the upcoming section of the report. In that next section, I will propose specific design improvement strategies targeting the weaknesses uncovered here. Each recommendation will be grounded in the background insights summarized above, ensuring that the proposed solutions build on TransLink's existing strengths and effectively bridge the identified gaps.

(1) Prescriptive + Bespoke	(2) Highly Prescriptive
Relevant Facilities: • SkyTrain stations (Expo Line, Millennium Line, Surrey–Langley Extension) • West Coast Express stations	**Relevant Facilities:** • Bus stops and shelters (BCAP, PIDs pilot sites, municipal installations)
Relevant Documents: • SkyTrain Design Manual: Upgrades Vol. 1 (2020) • West Coast Express Design Manual (2022)	**Relevant Documents:** • Bus Infrastructure Design Guidelines (2018) • TransLink Standard Bus Stop Amenity and Component Catalogue (2022) • BCAP Final Report (2019) • Shelter Product Catalogue (2022 Draft) • UBC PIDs Pilot Summary (2022)
Strengths: • Enables context-sensitive design integration for stations located in varied urban and suburban environments. • Offers opportunities for architectural distinction and place-specific materials, contributing to community identity. • Legacy modular strategies (e.g. Expo Line) provide useful precedent for kit-of-parts thinking in rail infrastructure. • Elements of continuity/ distinction framework ensures some level of system-wide user experience and branding.	**Strengths:** • Clear kit-of-parts systems facilitate efficient procurement, repeatable construction, and maintenance simplification. • Standardized amenities and mounting strategies allow for consistent deployment across diverse site types. • Modular shelters and digital infrastructure (e.g. PIDs) reduce construction timelines and site disruption. • Strong alignment with accessibility, customer comfort, and system branding objectives.
Weaknesses: • Modular strategies are inconsistently applied and often discontinued in later phases or across different lines. • Increased reliance on bespoke detailing introduces longer construction timelines, greater costs, and maintenance variability. • Lack of disassembly or reuse strategies; limited discussion of sustainability in the context of material life cycles and end of life strategies.	**Weaknesses:** • Focused mainly on bus stops, limiting transferability to higher-capacity modes like SkyTrain or commuter rail. • Some components provided through third-party vendors, limiting control over modular compatibility and visual coherence. • Risk of over-standardization, potentially constraining architectural flexibility and contextual responsiveness. • Lack of a network-wide strategy for modular scalability at major interchanges or multimodal facilities.

PROBLEM STATEMENT

While modular and prefabricated strategies have been explored across several areas of TransLink's infrastructure network, their application varies by facility type and project context. Some infrastructure, such as BCAP bus stops and select shelter systems, incorporates highly prescriptive, repeatable elements, while others, including rail and commuter stations, rely more heavily on bespoke, site-specific approaches. This reflects the diverse operational, spatial, and architectural demands of different transit modes.

However, across this spectrum of design approaches, there remains a gap in how modular strategies are deployed over time. Existing design manuals focus primarily on technical standards and spatial layouts, but may benefit from guidance on how modular elements can be introduced, replaced, or upgraded incrementally across a station's full lifecycle. Particularly in bespoke facilities like SkyTrain stations, the absence of a phasing framework limits opportunities to reduce disruptions, extend component lifespans, and improve carbon-efficiency (both operational & construction).

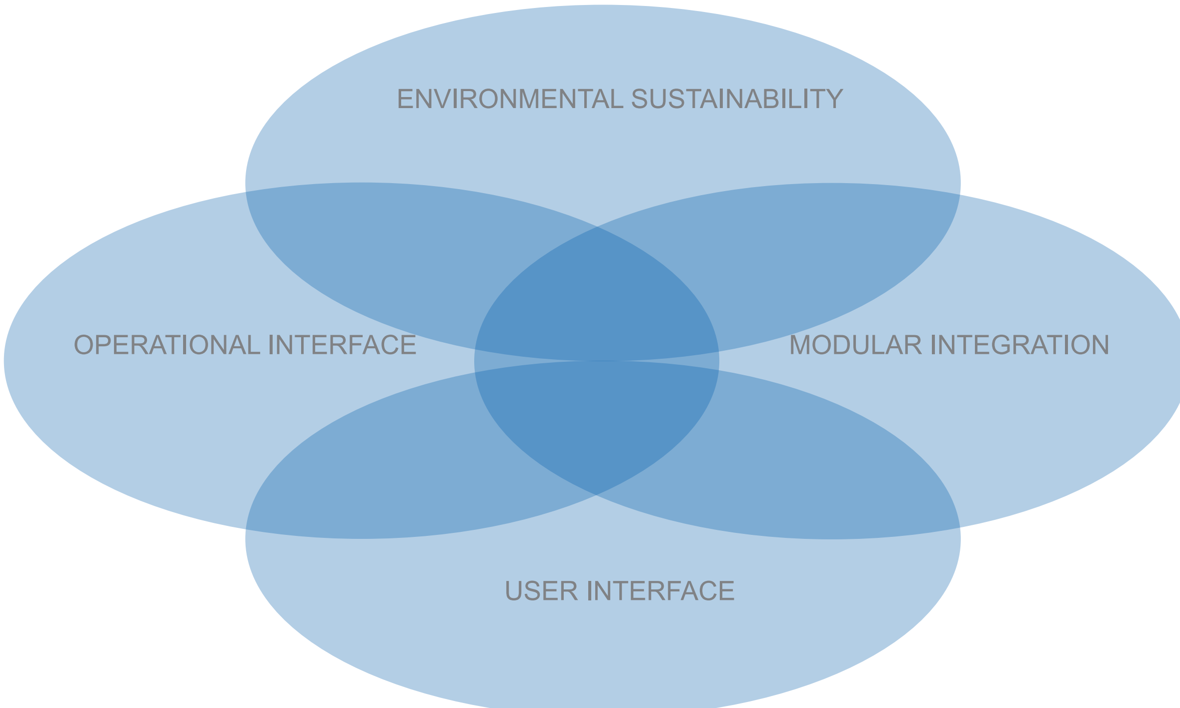
This project focuses on SkyTrain facilities as a priority, recognizing their complexity and the high variability of design across lines and eras. By examining how modularity can support phased upgrades at the component level,such as cladding, ticketing infrastructure, lighting, and shelter elements,the research aims to fill a gap between design intent and long-term asset planning.

The second phase of the project will culminate in the development of a visual phasing strategy guide, mapping which station components are best suited for modular retrofits and estimating the relative effort, time, and sequencing required for each. The guide will support TransLink in aligning future upgrades with lifecycle goals and operational realities, providing a practical tool for more resilient, scalable, and sustainable infrastructure delivery.

SITE ANALYSIS

SITE ANALYSIS METHODOLOGY

An analysis of eight transit stations was conducted using a revised framework informed by ISO standards for sustainable building and principles of circular design. This evaluation assessed how modular design concepts are integrated within each site, specifically examining the degree to which components are standardized, prefabricated, adaptable, and designed for long-term material efficiency and reuse.



PRIORITIES

The assessment was structured around four key lenses:

Environmental Sustainability: Examining the materials used, energy efficiency, durability, and strategies for lifecycle extension or end-of-life disassembly.

Modular Integration: Evaluating whether infrastructure elements are designed for disassembly, whether they exhibit repeatability and interchangeability across sites, how adaptable they are to varying contexts or functions, and how easily they can be installed, relocated, or maintained.

User Interface: Assessing how customers interact with modular elements at the station level. This includes evaluating whether components are intuitively placed and unobstructed, how they influence circulation and accessibility, and whether their modularity supports user comfort, wayfinding, and legibility across the transit network.

Operational Interface: Evaluating how transit staff, maintenance crews, and facility operators interact with modular infrastructure over time. This lens considers the behind the scenes functionality of modular systems and how well they support operations, inspections, cleaning, repairs, and upgrades.

SITE ANALYSIS METHODOLOGY

QUESTIONS TO ASK

This section guides deeper inquiry during site visits or stakeholder conversations by identifying key considerations beyond visual observation. The questions focus on uncovering intent, constraints, and performance outcomes behind the modular elements in use.

ENVIRONMENT SUSTAINABILITY

What materials are used for structural and finishing components? Are any visibly low-carbon, recycled, or natural such as wood, or perforated steel?

Are there signs of deterioration such as rust, cracks, or weathering that suggest poor material durability?

Are green or reflective roofs, vegetated surfaces, or bio-swales integrated into the site?

Is stormwater visibly managed (eg. trench drains, permeable pavers, sloped surfaces)?

Are any passive environmental systems in use, such as solar shading, light wells, or natural ventilation?

Are lighting systems LED or sensor activated for energy efficiency?

Is there any on-site renewable energy source, such as solar panels?

Are materials disassemblable or recyclable? Are there modular parts that seem reusable?

Do shelter structures or benches appear vandal-resistant and easy to clean?

Is signage resistant to fading or heat distortion?

Are materials uniform across multiple transit stations or context-specific to reduce redundancy?

Are maintenance procedures visibly easy (eg. access panels, exposed fasteners)?

Is there visible integration of sustainable finishes (eg. untreated wood, recycled plastic)?

Are energy systems independent (eg. solar-powered ticketing machines)?

Is there evidence of low-maintenance landscaping (eg. xeriscaping, native plants)?

MODULAR INTEGRATION

Are core elements (shelters, ID poles, lighting, bins) clearly repeated across multiple stations?

Are there bolted or clipped connections that allow for fast removal or upgrades?

Is each component distinguishable as a discrete unit (eg. modular canopy, modular bench unit)?

Are components sized in repeatable modules or dimensions (eg. panel widths, bench lengths)?

Do parts share materials, finishes, or construction methods across different installations?

Are modular units installed independent of complex groundwork or utility embedding?

Do joints and seams suggest ease of assembly or pre-fabrication (eg. bracketed posts, track systems)?

Is signage or wayfinding applied as overlays or inserts (rather than embedded), allowing easy updates?

Are elements designed to be scalable, can additional units be added or removed without redesign?

Do shelters or seating modules vary based on context (eg. tailored sizes but same basic components)?

Are any structures freestanding with visible anchoring systems (vs. permanent embedment)?

Do fixtures share mounting hardware or support systems (eg. shared poles, rails)?

Are components sourced from the same design family or manufacturer catalog?

Are modular units capable of adapting to multiple spatial contexts (eg. wide vs. narrow sidewalks)?

Is there consistency in the orientation, alignment, and placement logic across components?

SITE ANALYSIS METHODOLOGY

QUESTIONS TO ASK

This section guides deeper inquiry during site visits or stakeholder conversations by identifying key considerations beyond visual observation. The questions focus on uncovering intent, constraints, and performance outcomes behind the modular elements in use.

USER INTERFACE

Are pedestrian paths clear of obstructions from furniture, signage, or infrastructure?

Are shelter entrances oriented to protect from dominant wind or rain directions?

Is seating usable and intuitively placed (eg. facing the road, shaded, near ID poles)?

Is there consistent and logical spacing between modular components (eg. bins, lights, benches)?

Is tactile paving integrated logically with platform or crosswalk design?

Are information panels visible at eye level and in high-traffic waiting zones?

Are waiting areas clearly demarcated and distinguishable from walking zones?

Are visually impaired users supported by high-contrast finishes or textures?

Do elements like leaning rails or perch seating support diverse physical needs?

Is real-time information accessible and visible from multiple angles or distances?

Is signage multilingual, graphic, or color-coded for wayfinding accessibility?

Do design components contribute to perceived safety (eg. lighting, sightlines)?

Are emergency or help features accessible, clearly marked, and unobstructed?

Are rest points, seating, or shelter areas adequately provided for the anticipated foot traffic?

Are modular elements (benches, signs, lights) free of clutter, graffiti, or misuse?

OPERATIONAL INTERFACE

Are lighting, HVAC units, signage, or digital panels mounted in ways that facilitate quick and safe maintenance?

Are there modular enclosures or hatches that allow easy access to systems behind walls or ceilings?

Are components easily removable without specialized tools or extensive disassembly?

Is there visible wear that suggests modules are being replaced too frequently (or not frequently enough)?

Do standard modular elements (eg. electrical panels, service corridors, cleaning storage) appear in consistent locations across sites, making them intuitive for staff to use regardless of the station?

Are staff areas (ticket offices, storage, mechanical rooms) built with standardized layouts or fittings that could streamline construction and allow reuse of design templates?

Are materials and surfaces chosen for ease of cleaning and durability in high-use environments?

Does the modular design avoid creating awkward niches or corners that accumulate debris or are difficult to reach?

Can service infrastructure (such as conduits, fare gates, or PA systems) be easily expanded, relocated, or upgraded through modular pathways?

Do modular layouts support safe and ergonomic workflows for staff? For example, are electrical and mechanical systems consolidated in centralized service modules?

STATIONS

The six selected stations represent key moments in the evolution of modular transit infrastructure across Vancouver's SkyTrain system. Spanning from 1985 to 2016, they are chronologically ordered to trace how modular strategies shifted from the prescriptive, grid-based design of the Expo Line, to the fully integrated, sustainability-oriented approach of the Evergreen Extension.

Patterson Station (1985) (Expo)
A highly prescriptive Expo-era design that demonstrates enduring modular grid logic and bolt-on retrofit potential.

Brentwood Town Centre Station (2002) (Millennium)
Introduces modular identity through vaulted canopy forms and repeated circulation cores.

Lougheed Town Centre Station (2002) (Millennium)
Spatializes modularity via scalable platform vaults and structurally independent vertical pods.

Marine Drive Station (2009) (Canada)
A cost-driven Canada Line station where structural repetition persists but modular adaptability is sacrificed.

Commercial-Broadway Station (2009 Renovation)
A layered retrofit site that exemplifies how modular additions stairs, bridges, platforms, can be phased into legacy grids.

Burquitlam Station (2016) (Millennium- Evergreen Extension)
A mature Evergreen Extension example that integrates low-carbon materials, a full modular parts family, and decoupled service systems.

EXPO LINE: PATTERSON STATION

Boardings: ~4,403/day Year Built: 1985

ENVIRONMENTAL SUSTAINABILITY

- Exposed concrete and corrugated steel create a durable, long-lasting envelope, though not low-carbon, its longevity reduces the need for frequent replacements as opposed to newer stations which use mass timber
- Canopy provides full platform coverage- consistent guttering, reducing heat exposure and water pooling- passive weather strategy
- Adjacent Central Park adds passive shade and green buffer.



MODULAR INTEGRATION:

- Canopy spans use standardized repeated steel truss modules, an early form of standardized weather protection.
- Benches, ID poles, and bins are bolted into rhythmic concrete pads; later stations shift toward contextual spacing.
- Fare gate and ticketing zones are housed in modular bays with removable panels, allowing repeatable upgrades.
- Despite age, modular character is evident in the construction seams and maintenance zones, 1.25m module applied consistently.

USER INTERFACE:

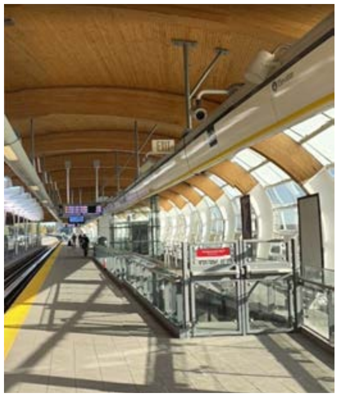
- Linear layout and open sightlines support intuitive wayfinding.
- Minimal seating provided, but positioned under shelter and oriented toward train approach; additional perches would support older riders.


OPERATIONAL INTERFACE:

- MEP systems are embedded in walls/ceilings with limited surface access, reflecting a pre-modular service logic that increases servicing time and complexity.
- Retrofit potential is high due to the simplicity and predictability of the station's grid layout, which would accommodate bracketed add-ons such as digital signage or modular kiosk zones.
- Drainage and utility conduits are coupled to core structure, complicating upgrades that risk impacting primary elements.

MILLENIUM LINE: BRENTWOOD TOWN CENTRE STATION

Boardings: ~6,000/day, Year Built: 2002, upgraded 2021-23



ENVIRONMENTAL SUSTAINABILITY

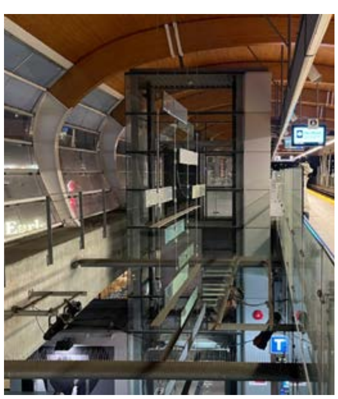
- Repeated prefabricated glulam roof segments form a scalable canopy system defining the Millennium Line's architectural identity.
- Platform structure and service zones follow a rhythmic structural grid, facilitating targeted expansions (e.g., new elevator tower) without full redesign.
- Translucent roof panels allow daylight while preserving weather protection.

MODULAR INTEGRATION:

- Lighting, guardrails, and signage mount to a bracketed steel system repeated across other stations (e.g., Lougheed, Gilmore), reinforcing line-wide modular logic.
- Circulation cores (elevators, stairs) are expressed as modular towers, glass shafts and steel stairs mirror layouts at adjacent stations.

USER INTERFACE:

- Separate but adjacent shafts for escalators and elevators streamline vertical accessibility.
- Visual connection to Brentwood Mall aids orientation; however, adding perch rails near transfer points could improve comfort.
- Multiple digital screens display upcoming train arrival times clearly.

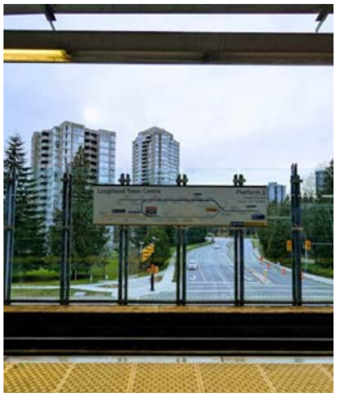


OPERATIONAL INTERFACE:

- Lighting and electrical enclosures are bracket-mounted in the canopy grid for straightforward access, this strategy could be extended to other overhead systems.
- Open layout and minimal cladding improve cleaning workflows; lack of modular janitor bays limits BOH efficiency.

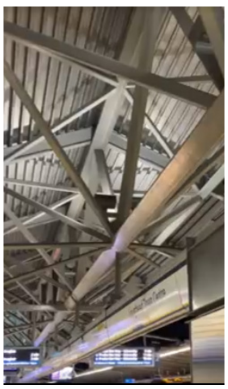
MILLENIUM LINE: LOUGHEED TOWN CENTRE STATION

Boardings: ~4,400/day, Year Built: 2002



ENVIRONMENTAL SUSTAINABILITY

- Open-air layout with large translucent canopies enables passive ventilation and daylighting, reducing energy demand year-round.
- Steel, glass, and concrete finishes remain durable after two decades, supporting sustainability through material longevity.
- Canopies offer broad shelter, but limited wind protection in winter suggests potential for modular infill screens.

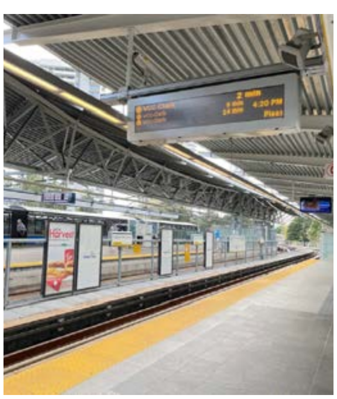


MODULAR INTEGRATION:

- Canopy vaults span approx. 8–10 m, allowing scalable platform coverage.
- Lighting and railings anchor into steel edge beams using plug-and-play brackets; consistent with Brentwood and Holdom, showing a shared Millennium-era system.
- Utility conduits (lighting, fire suppression) are mounted below canopy trusses, accessible but semi-integrated, limiting flexibility compared to Evergreen's fully exposed layouts.

USER INTERFACE:

- Platform width and rhythmic placement of lights, signs, and wayfinding panels support intuitive navigation.
- Seating is consistent in form and finish with other Millennium stations, using perforated steel benches bolted at consistent intervals.
- Wayfinding graphics align with TransLink standards.



OPERATIONAL INTERFACE:

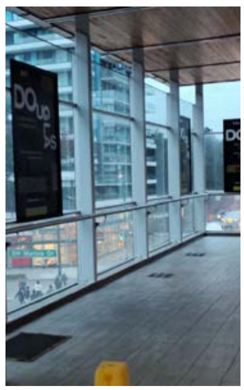
- Platform service grilles and panels (for power and drainage) appear to follow consistent spacing logic
- Catwalks and exposed beams provide safe maintenance access to lighting and PA systems
- Elevator shafts use prefabricated steel and glass modules with cladding that can be replaced independently from platform utilities.

CANADA LINE: MARINE DRIVE STATION

Boardings: ~8,200/day · Year Built: 2009 (Design by VIA Architecture)

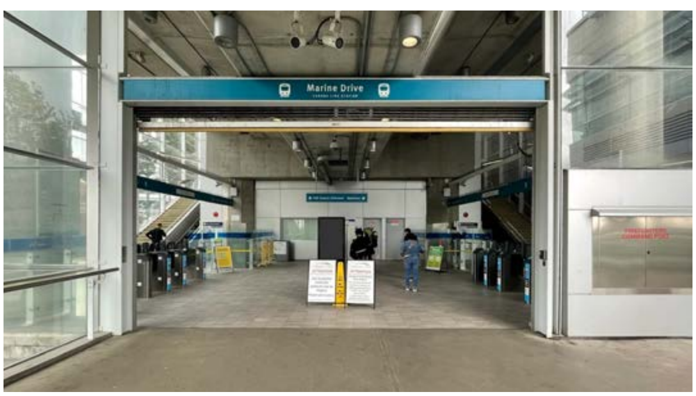
ENVIRONMENTAL SUSTAINABILITY

- Deep overhangs and glass cladding provide daylight and weather protection; however, climate responsiveness is limited due to minimal solar shading on west-facing facades.
- Durable materials (metal cladding, glass, concrete) support low maintenance and long service life.
- Limited integration with surrounding landscape or green infrastructure.



MODULAR INTEGRATION:

- Station follows Canada Line's design-build approach with standardized material palette and consistent canopy detailing across stations (e.g., Langara–49th, Oakridge–41st).
- Fixtures (seating, signage, lighting) are site-specific and inconsistent with other stations, showing a departure from the system-wide parts libraries seen in Millennium or Evergreen stations.
- Lighting and utility conduits are partially embedded



USER INTERFACE:

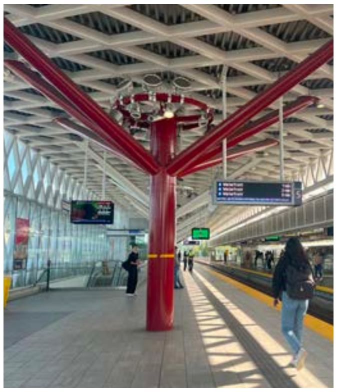
- Platform is linear and open with ample clear space; canopy design emphasizes visual connection along platform.
- Signage is legible and follows TransLink graphic standards, but its mounting hardware varies from station to station, reducing consistency and complicating replacement logistics.

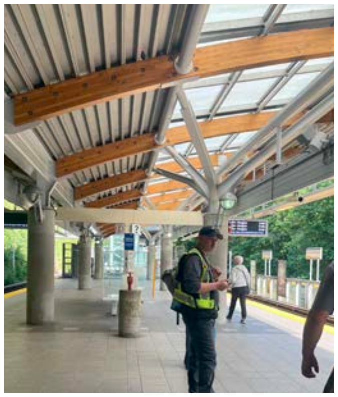
OPERATIONAL INTERFACE:

- Service access for lighting and MEP is through ceiling panels, requiring partial disassembly during maintenance.
- Janitor closets and staff back-of-house areas are functional but vary across Canada Line stations, no template or standardized layout is evident
- Integration with retail and residential above adds complexity to maintenance access and limits future spatial flexibility.

EXPO+MELLENNIUM LINE: COMMERCIAL BROADWAY

Boardings: ~11,600 / day Year Built: 1985 (Expo), 2002 (Millennium); merged 2009



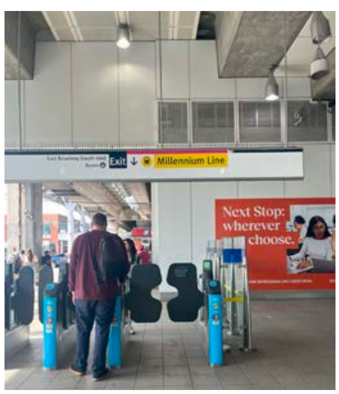


ENVIRONMENTAL SUSTAINABILITY

- Perforated steel, glass, and concrete in the recent upgrades reduces maintenance cycles and supports long-term durability.
- Daylighting from mezzanine apertures and skylights supports passive lighting strategies.
- Open-air bridge connections allow passive ventilation between levels.

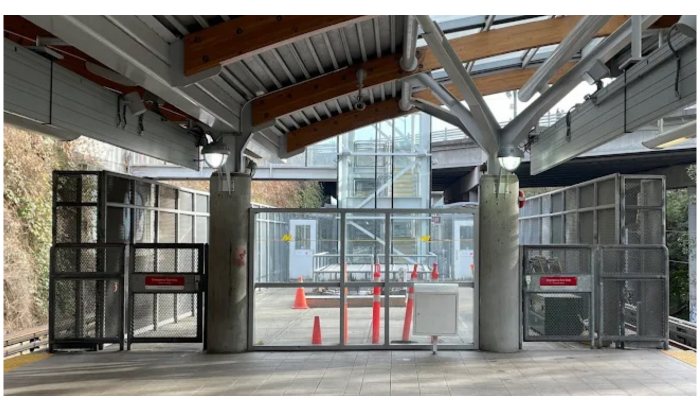
MODULAR INTEGRATION:

- PID screens, lighting, and signage mount to standardized steel frames and beams, bracket logic consistent with recent TransLink upgrades.
- Integration of new components occurred in phases, enabling upgrades without full station shutdown.
- Stacked elevator and stair cores (Millennium platform) use bolt-on steel construction, added post-2002.
- Furniture and finishes vary by zone, Expo platform retains older benches and signs, while new zones reflect TransLink's updated kit-of-parts.



USER INTERFACE:

- Multiple entry points (Broadway, Commercial, 10th Ave) are integrated using clear circulation routes and intuitive wayfinding panels. This spatial clarity is reinforced by differentiated color zones and consistent branding.
- Platform furniture and waiting zones are functional-expo seating is minimal, while newer Millennium areas benefit from improved shelter and sightlines.

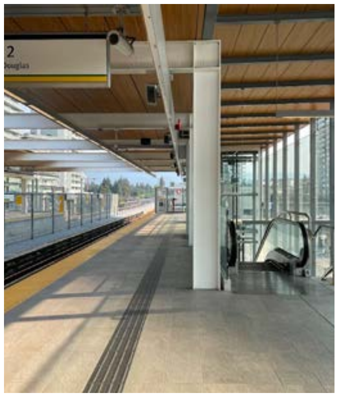


OPERATIONAL INTERFACE:

- New utility rooms and fare control zones are embedded within recent additions, some following modular panel layouts.
- Older Expo-era systems (drainage, electrical) are embedded in structure,
- Cleaning is facilitated by open sightlines, but level changes across multiple zones complicate BOH workflows.

EVERGREEN LINE: BURQUITLAM STATION

Boardings: ~5,800/day Year Built: 2016



ENVIRONMENTAL SUSTAINABILITY

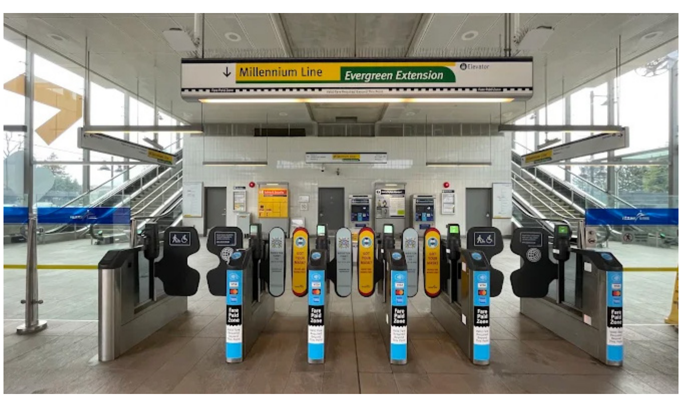
- The entrance and platform areas feature a timber canopy made of glulam panels, echoing a low-carbon material strategy consistent across the Evergreen Line.
- Large curtain wall façades allow ample natural light into stairwells, escalator zones, and concourses, reducing artificial lighting dependency.
- Landscaping around the entry plaza is minimal and functional, with tree pits and concrete planters but no permeable paving, or visible stormwater strategies

MODULAR INTEGRATION:

- Glulam canopy structure is delivered in clearly repeated bays, with bolted steel connections and bracketed lighting elements
- Platform elements, windscreens, railings, lighting, and fare gates, are all part of a consistent modular catalog used across Evergreen stations
- Vertical circulation elements are integrated into the station envelope but follow standardized layouts and construction systems.

USER INTERFACE:

- Circulation from entry plaza to platform is direct and intuitive, benefiting from the visibility created by the open glass façades and glazed vertical cores.
- Platform signage, map boards, and ticketing machines follow a unified design and positioning logic seen across the Evergreen Line.
- Seating is minimal but well-located; sightlines between entrance and train doors remain clear.
- Tactile strips and contrast nosing installed on stairs and platform edges.



OPERATIONAL INTERFACE:

- Bracketed MEP installations reduce service time; all systems mounted for visible access.
- Janitorial, electrical, and mechanical service zones are embedded within side wall volumes; however, there is no evidence of a shared back-of-house layout template.
- Prefabricated wall cladding panels and floor tiles are used throughout the concourse and platform zones with standardized sizing

SUMMARY

TABLE: SUMMARY OF KEY FINDINGS FROM SITE VISITS

Era	Structural Logic	Kit of Parts & Utilities	User/Operations Touchpoints	Lessons Carried forward
Expo Line (1985) - Patterson Station -Commercial Broadway Station	-concrete column grid and steel-truss canopy bays made every platform a repeatable "slice." -Full-length roof panels bolt into identical purlins, simplifying waterproofing and snow loads.	-Fixtures (benches, ID poles, bins) mounted in a uniform a rhythm tied to columns. -Utilities embedded inside walls/soffits are durable, but invasive to upgrade.	-Clear sightlines, intuitive platform flow. -Staff rooms when needed, back-of-house standardization	-Rigid grids age well and make retrofits possible -Hidden services create costly interventions later. -1.25m module proved highly effective for future additions
Millenium Line (2002) -Brentwood Station -Lougheed Station	-Curved vault canopies = modular steel truss ribs at 8-10 m spacing; scalable to any platform length -Vertical-core "pods" (glass elevator towers, stair shafts) bolt to platform edges.	-Bracketed rails, lights, signs: plug-and-play and line-wide identical -Services semi-exposed under trusses, easier to reach than Expo, but still partial integration	-Open, daylit concourses; repeatable signage hierarchy -little back-of-house standardization	-Modularity achieved through typology, not just dimensions; introduced prefabricated vertical cores for future add-ons.
Canada Line (2009)- -Marine Drive Station	-Cost-driven box-beam roofs trimmed canopy depth; fewer structural repetitions	-Many fixtures site-specified, breaking the catalog trend	-Operation zones vary widely between stations.	-Trimming canopy and catalog consistency saved capital dollars but created long-term comfort and maintenance gaps.
Evergreen Extension (2016) -Burquitlam Station -Inlet Station	-Prefabricated glulam roof modules re-embrace repeatable spans while adding low-carbon timber.	-Full family-of-parts reinstated: rails, windscreens, ticket housings identical across line -Utilities fully surface-mounted on bracket rails (true plug-and-swap)	-Daylit glass cores + clear tactile strips (still sparse in plazas -Back-of-house remains bespoke, but service panels standardized.	-Decoupled services, low-carbon structure, and the most cohesive parts catalog to date
Legacy Retrofit (2016-23) Commercial–Broadway upgrades	-New stairs, overpass, Platform 5 inserted into 1985 grid using bolted steel frames -Demonstrates layered modular retrofitting without shutting the line.	-Modern bracket rails graft onto Expo concrete, older and newer fixtures now share mounting datum	-Crowd flow eased, but furniture mix still visually fragmented -Ops zones still dual-standard (Expo vs Millennium)	-early grids + bolt-on logic let 40-year old stations evolve in place, provided a systemwide retrofit kit exists.

From the site visits, the Expo Line was observed to follow a prescriptive, grid-based logic, with station layouts and structural systems that support straightforward, system-wide modular upgrades. The Millennium Line applies a prescriptive kit-of-parts approach but layers bespoke detailing at each station to respond to specific site and community contexts. The Evergreen Extension demonstrates a blend of these two approaches, combining system-standard elements with localized adaptation. The Canada Line leans toward the bespoke end, with station designs individually tailored to their sites, suggesting partial kit-of-parts influence.

BUS STOPS

The selected bus exchanges, Commercial–Broadway Station (Tier 1), Carvolth Exchange (Tier 2), and Capilano University Exchange (Tier 3), were chosen based on their alignment with the BCAP (Bus Customer Amenity Program) guidelines and their status as recently upgraded or newly constructed facilities.

UBC Exchange (Tier 1 - Transit Hub)

UBC Exchange, rebuilt between 2017 and 2019 and fully upgraded under BCAP-aligned design, is a major transit hub serving UBC and the broader Metro Vancouver community.
The exchange balances high-frequency operations with ease of navigation, accessibility, and ongoing maintenance.

Carvolth Exchange (Tier 2 – Enhanced Exchange):

Located in Langley Township, Carvolth Exchange is a key park-and-ride facility supporting the R3 RapidBus corridor and multiple regional connections. Opened in 2012 and designed with long-term modular adaptability in mind, the exchange features prefabricated shelters, LED lighting, real-time signage, and landscaped buffers

Capilano University Exchange (Tier 3 – Basic Exchange):

Located in Langley Township, Carvolth Exchange is a key park-and-ride facility supporting the R3 RapidBus corridor and multiple regional connections. Opened in 2012 and designed with long-term modular adaptability in mind, the exchange features prefabricated shelters, LED lighting, real-time signage, and landscaped buffers

UBC Exchange

Tier 1 - Transit Hub

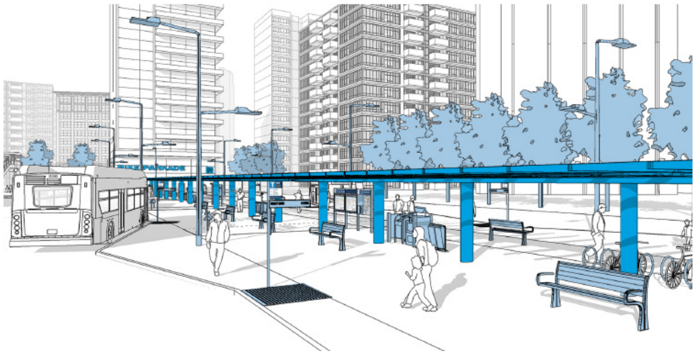


Image Source: BCAP Report 2019 Translink

Modular Integration

- Prefabricated shelter modules with standard-tooth anchoring, quickly installable and maintainable
- Shelter canopies follow patterns consistent with TransLink's BCAP shelter typologies for simplified replacement or expansion

User Interface

- First in network to trial Next Bus digital screens, with full-colour LCD and text-to-speech audio for improved wayfinding
- Queuing system installed for the 99 B-Line with designated boarding zones to streamline passenger flow .
- Clear sightlines across 13 bays, tactile surfaces, and multi-lingual signage enhance accessibility and orientation.

Operational Interface

- Modular mechanical/electrical cabinets and cabling located in service cores reduce equipment exposure.
- Design allows quick shelter repairs via elevated modules and standardized mounting hardware.

Amenity Framework Table Source: BCAP Report 2019 Tanslink

Amenity Group: Furniture	
Small Single Stream Litter Receptacle	◌
Multi-Stream Litter Receptacle	●
Bench OR Leaning Rail at Stop	●
Opportunity Seating (Plaza Seating, Additional Leaning Rails, etc.)	○
Amenity Group: Weather Protection	
Canopy	●
Continuous Weather Protection	○
Amenity Group: Information	
Bus Stop Signage	●
Static Schedule	●
Dynamic Real Time Information	●
Audible Information	○
Journey Planning Information	●
Information Totem	●
T-Branded Markers	●
Staff on Site	◌
Transit Information Signage	●
Interactive Kiosk	◌
Amenity Group: Services	
ATM	◌
Presence of Retail	○
Advertising Displays	◌
Customer Washrooms	◌
Commercial Kiosk	○
Flex/Multi-Use Space	◌
Mail/ Courier Services	○
Wifi	◌
Storage Lockers	◌
Newspaper Corrals	◌
Amenity Group: Security	
Lighting	●
Designated Waiting Area	●
First Aid Station	●
Emergency Telephone	●
Alarm System	●
CCTV	●

Amenity Group: Placemaking	
Landscaping	●
Enhanced Plaza Landscaping	●
Public Art	●
Interactive Feature	◌
Amenity Group: Accessibility	
Barrier-Free Access	●
Static Tactile Information	●
Tactile Walking Surface Indicators at ID Pole	●
Tacile Guideway	●
Priority Shelter Areas	●
Dedicated HandyDART Bay	●
Amenity Group: Bike Interface	
Bike Parking	●
Covered Bike Racks	●
Secure Bike Parking (Lockers)	◌
Enhanced Secure Bike Parking (Parkade)	○
Bike Share Docking Station	◌
Bike Repair Kit	◌
Dockless Micromobility Parking Area	◌
Amenity Group: Car Interface	
Passenger Pick-Up and Drop-Off Facilities	●
Dedicated Taxi / Ridehailing Pick-Up Zone	○
Priority Parking for Carpool Vehicles / Family Friendly Parking*	○
Accessible Parking Stalls*	●
Car Share Parking	◌
Amenity Group: Enhanced Operations	
All Door Boarding	◌
Dynamic Bay Assignment	◌
Compass Vending Machines	●
Raised Platforms (Level Boarding)	○
Passenger Queuing	◌

● essential ○ recommended ◌ opportunity

*Locations with Park and Ride facilities only

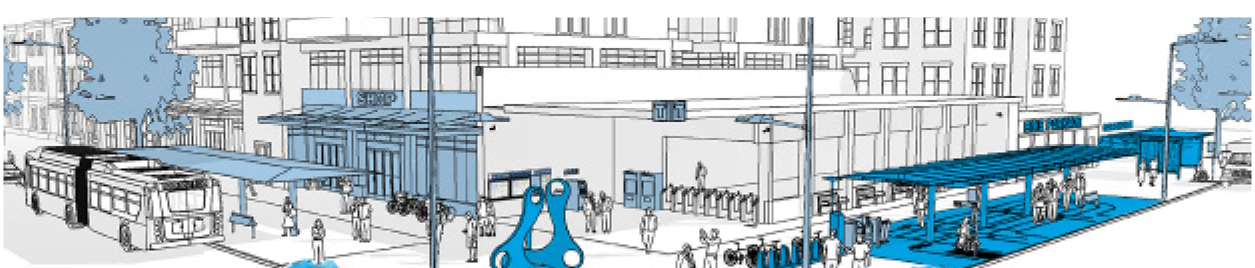


Image Source: BCAP Report 2019 Translink

Carvoth Exchange

Tier 2 - Enhanced Exchange

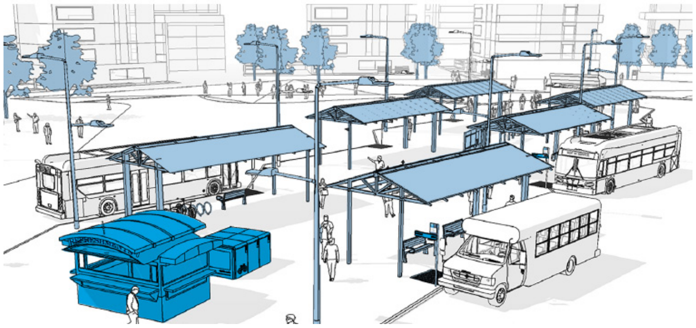


Image Source: BCAP Report 2019 Translink

Modular Integration

- Bus shelters are freestanding with visible anchor plates and detachable canopy panels.
- Seating modules and signage are standard across interchanges.
- Parking bollards, light posts, and bins use consistent hardware for streamlined replacement.

User Interface

- Clear pedestrian crossings marked with tactile warning surfaces.
- Seating aligned parallel to the roadway, under canopy shade.
- Compass vending machines located at primary pedestrian approach.
- High-contrast totems and maps placed at key entry points from parking, transit loop, and bike paths.

Operational Interface

- Modular electrical cabinets and camera poles distributed with logic for repair access.
- Large pull-in bus bays support multiple routes.
- Shelters are accessible for pressure washing and regular cleaning via curb access.

Amenity Framework Table Source: BCAP Report 2019 Tanslink

Amenity Group: Furniture	
Small Single Stream Litter Receptacle	◌
Multi-Stream Litter Receptacle	●
Bench OR Leaning Rail at Stop	●
Opportunity Seating (Plaza Seating, Additional Leaning Rails, etc.)	○
Amenity Group: Weather Protection	
Canopy	●
Continuous Weather Protection	○
Amenity Group: Information	
Bus Stop Signage	●
Static Schedule	●
Dynamic Real Time Information	●
Audible Information	○
Journey Planning Information	●
Information Totem	●
T-Branded Markers	●
Transit Information Signage	●
Interactive Kiosk	◌
Amenity Group: Services	
ATM	◌
Presence of Retail	○
Advertising Displays	◌
Customer Washrooms	◌
Commercial Kiosk	◌
Flex/Multi-Use Space	◌
Mail/Courier Services	◌
Wifi	◌
Newspaper Corrals	◌
Amenity Group: Security	
Lighting	●
Designated Waiting Area	○
First Aid Station	○
Emergency Telephone	○
Alarm System	○
CCTV	○

Amenity Group: Placemaking	
Landscaping	●
Enhanced Plaza Landscaping	○
Public Art	○
Interactive Feature	◌
Amenity Group: Accessibility	
Barrier-Free Access	●
Static Tactile Information	●
Tactile Walking Surface Indicators	●
Tactile Guideway	●
Priority Shelter Areas	○
Dedicated HandyDART Bay	●
Amenity Group: Bike Interface	
Bike Parking	●
Covered Bike Racks	○
Secure Bike Parking (Lockers)	○
Enhanced Secure Bike Parking (Parkades)	◌
Bike Share Docking Station	◌
Bike Repair Kit	◌
Dockless Micromobility Parking Area	◌
Amenity Group: Car Interface	
Passenger Pick-Up and Drop-Off Facilities	○
Dedicated Taxi / Ridehailing Pick-Up Zone	○
Priority Parking for Carpool Vehicles / Family Friendly Parking*	◌
Accessible Parking Stalls*	○
Car Share Parking	◌
Amenity Group: Enhanced Operations	
Dynamic Bay Assignment	◌
Compass Vending Machines	○
Raised Platforms (Level Boarding)	○
Passenger Queueing	◌

● essential ○ recommended ◌ opportunity

**Locations with Park and Ride facilities only*

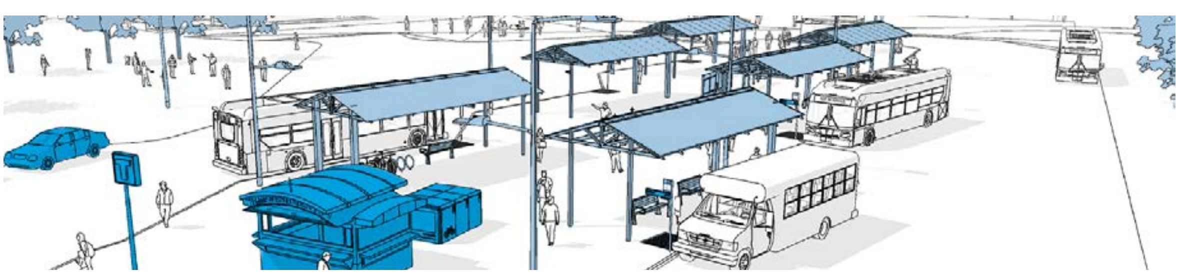


Image Source: BCAP Report 2019 Translink

Capilano University Exchange

Tier 3 - Basic Exchange

Image Source: BCAP Report 2019 Translink

Modular Integration

- ID poles, benches, and signage units mirror TransLink's modular kit for low-volume exchanges.
- Minimal embedment, all units appear relocatable
- Modular timetable holders and static panels clipped into aluminum stands.

User Interface

- Visual line-of-sight from campus pathways to each bus bay and shelter.
- Benches located close to ID poles with tactile cues present.
- Seating modules cater to short wait times.
- Limited wayfinding but adequate for the low volume and direct route structure.

Operational Interface

- Shelter units and signage are compact for easier campus maintenance.
- All structures raised slightly above grade to reduce splash and pooling.
- No ticketing hardware; operations supported off-site
- Exchange location and visibility allow for passive security via campus presence.

Amenity Framework Table Source: BCAP Report 2019 Tanslink

Amenity	Level
Amenity Group: Furniture	
Small Single Stream Litter Receptacle	opportunity
Multi-Stream Litter Receptacle	essential
Bench OR Leaning Rail at Stop	essential
Opportunity Seating (Plaza Seating, Additional Leaning Rails, etc.)	opportunity
Amenity Group: Weather Protection	
Canopy	essential
Amenity Group: Information	
Bus Stop Signage	essential
Static Schedule	essential
Dynamic Real Time Information	recommended
Audible Information	recommended
Journey Planning Information	essential
Information Totem	recommended
T-Branded Markers	recommended
Transit Information Signage	recommended
Amenity Group: Services	
ATM	opportunity
Presence of Retail	opportunity
Advertising Displays	opportunity
Wifi	opportunity
Customer Washrooms	opportunity
Newspaper Corrals	opportunity
Amenity Group: Security	
Lighting	essential
Designated Waiting Area	opportunity
First Aid Station	opportunity
Emergency Telephone	opportunity
Alarm System	opportunity
CCTV	opportunity

Amenity	Level
Amenity Group: Placemaking	
Landscaping	essential
Enhanced Plaza Landscaping	opportunity
Public Art	opportunity
Amenity Group: Accessibility	
Barrier-Free Access	essential
Static Tactile Information	essential
Tactile Walking Surface Indicators	essential
Tactile Guideway	recommended
Priority Shelter Areas	recommended
Dedicated HandyDART Bay	opportunity
Amenity Group: Bike Interface	
Bike Parking	recommended
Covered Bike Racks	opportunity
Secure Bike Parking (Lockers)	opportunity
Bike Share Docking Station	opportunity
Bike Repair Kit	opportunity
Dockless Micromobility Parking Area	opportunity
Amenity Group: Car Interface	
Passenger Pick-Up and Drop-Off Facilities	opportunity
Dedicated Taxi / Ridehailing Pick-Up Zone	opportunity
Amenity Group: Enhanced Operations	
Compass Vending Machines	opportunity
Raised Platforms (Level Boarding)	recommended
Passenger Queueing	opportunity

essential · recommended · opportunity

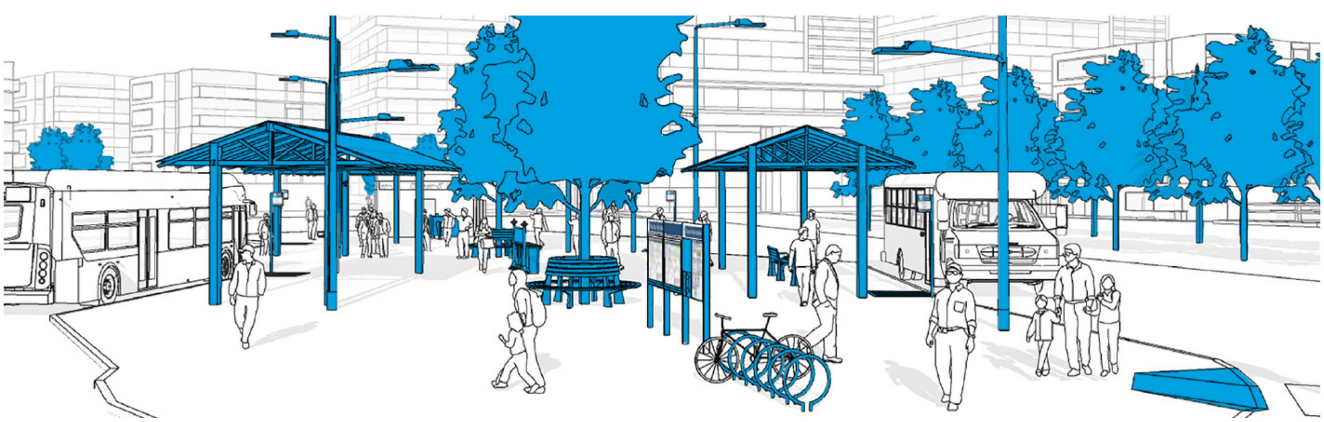


Image Source: BCAP Report 2019 Translink

GLOBAL BEST PRACTICES

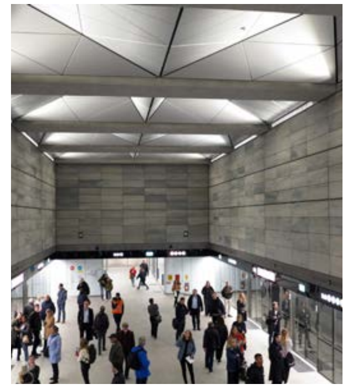
OVERVIEW

TRANSIT FACILITIES	KEY MODULAR MOVES	AVAILABLE RESOURCES	APPLICATION TO VANCOUVER
1. Copenhagen Cityringen M3/M4 2019 **Highly prescriptive**	-Pre-cast box-in-box chassis: structure, platform edge and concourse slabs all factory cast. -Back-of-house pod hoisted in fully wired. -All MEP lines stacked in one central spine.	Metroselskabet strategy & EIA docs	May help with future lines that extend underground-full prefabrication down to spare-parts logistics. Good example of a highly-prescriptive strategy for full standardization
1. Sydney Metro Northwest + City & Southwest (2019–2024) **Prescriptive**	-Station roof kits: identical rib-and-panel canopies craned in across eight stops. - Pre-wired service cores slide into a precast shell. - Furnishings, MEP racks and platform screen doors are all catalogue items.	Urban-design & station PDFs (Sections 1–4 of the UDCLP)	Elevated/at-grade typologies match Vancouver; the design packages outline service-core cartridges and BIM families. BOH strategy implemented into kit of parts design.
4. Doha Metro – Red/Gold/ Green (2019) **Prescriptive**	-Branding manual → modular finishes: one parametric vault shell, repeated theme cladding. -Platform equipment in plug-in "plinth strips." -Identical retail/ops pods across 30+ stations.	UNStudio design books & branding PDF	Offers a budget-minded recipe for rapid prefab on guideways, useful for future Expo Line infill stops. Identical operation (BOH) pods may inspire future Skyline designs.
5. New York City Street Furniture **Prescriptive**	Kit-of-parts system: shared frame, roof, and seating modules used across >3,500 sites. - Pre-fabricated aluminum/glass structures with bolted footings. - Modular signage, lighting, and ad units mounted to standard uprights.	Grimshaw project page, JCDecaux site, Billings Jackson case studies.	Demonstrates how a standardized parts system can unify streetscape design while allowing flexibility. Relevant for Vancouver's Tier 2 & 3 bus stop upgrades.
6. Wooden Modular Bus Stops, Sweden **Highly Prescriptive**	- Timber frame chassis with repeatable dimensions and customizable side panels. - Prefabricated canopy and bench components. - Passive drainage and lighting embedded in structural system.	State of Green press release, GPA project page.	Introduces low-carbon material strategy with mass-customizable structure. Offers a pathway for Vancouver to adopt sustainable, regional wood-based modular shelters, especially in rural and suburban areas.

In the reviewed global best practices, Sydney Metro Northwest + City & Southwest and Copenhagen Cityringen exemplify highly prescriptive systems, where station architecture is defined by repeatable structural modules, standardized service cores, and consistent component catalogues. New York City Street Furniture and Wooden Modular Bus Stops demonstrate prescriptive and prescriptive-bespoke qualities, employing standardized frames and components while allowing for contextual adaptation in finishes, configuration, and material selection. Across all precedents, there is a clear tendency toward the prescriptive side, with standard canopies, furnishings, finishes, and typologies repeated consistently throughout each station or facility to maintain cohesion and efficiency.

COPENHAGEN CITYRINGEN M3/M4 2019

Highly Prescriptive



Overview

Cityringen (M3) is a 15.5 km underground ring line in central Copenhagen, opened in 2019 with 17 stations, later connected to the M4 Nordhavn and Sydhavn branches. The design was led by the joint venture of COWI, Arup, and SYSTRA, with design architect KHR Arkitekter. This international collaboration produced a cohesive architectural language across all stations through a modular "kit of parts" system. Standardized components such as wall panels, lighting, and signage ensure construction efficiency and visual identity, while adaptable elements respond to each station's urban context.

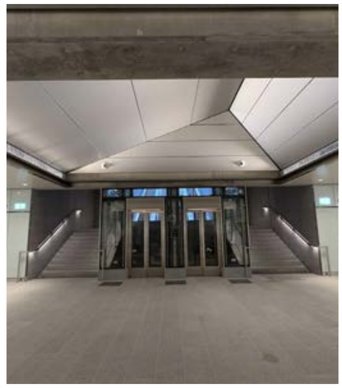
Sustainability Targets

Cityringen aimed to minimize environmental impact during construction and operation. Benchmarks were set via VVM (Environmental Impact Assessment) and aligned with Copenhagen's broader climate policies, targeting CO2 reductions, improved air quality, and energy efficiency. Specific goals included promoting public transport modal shift to reduce car dependency, minimizing noise and vibrations, and safeguarding groundwater. The project also evaluated zero-alternative scenarios (no build) and life cycle impacts, using climate modeling to predict long-term reductions in emissions due to mode shift and energy savings. Continuous monitoring ensures compliance with these targets, making Cityringen a leader in sustainable transit infrastructure.

Early Concept of a Cityringen Built with Mass Timber Source: JaJa Architects

COPENHAGEN CITYRINGEN (M3/M4) (2019)

Highly Prescriptive


Conceptual Approach to Kit of Parts

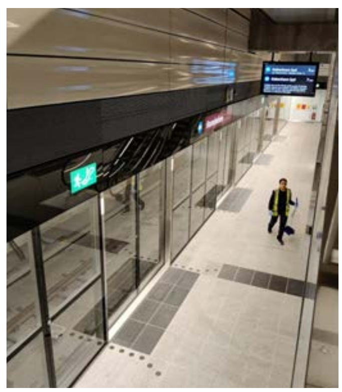
Cityringen's architecture is defined by a highly modular "kit of parts", allowing for consistent aesthetics, simplified maintenance, and faster construction. The system-wide elements are prefabricated and repeated across 17 stations to ensure efficiency.

Modular Components:

- Prefabricated concrete wall panels for platforms and concourses
- Standardized lighting fixtures and wayfinding systems
- Escalator and elevator configurations
- Uniform material palettes using steel, concrete, and ceramic finishes

Partial modular components:

- Surface entrance pavilions customized to urban site conditions
- Varying landscape integrations at station forecourts
- Bespoke art installations and furniture
- Acoustic and lighting features adapted to spatial geometry


Linewide Consistency and Identity

- All stations share a common underground spatial layout for ease of navigation and maintenance.
- Consistent use of materials like exposed concrete, anodized aluminum, and LED lighting throughout.
- Surface pavilions differ in form, reflecting the surrounding neighborhood character.
- Station walls use colored ceramic panels to distinguish individual stations within the system.
- No major typological deviations underground; identity is expressed subtly through color and surface treatments.

Cityringen's 17 underground stations largely share a standardized architectural layout, particularly below ground, to ensure consistency, efficiency, and ease of maintenance. This includes similar platform arrangements, wall panels, lighting, escalators, and elevator configurations. However, while the core spatial organization is consistent, there are minor typological adaptations driven by site-specific constraints, urban context, and access requirements.

COPENHAGEN CITYRINGEN (M3/M4) (2019)

Highly Prescriptive

Sustainable Design Practices

Metroselskabet partnered with COWI, Arup, and SYSTRA to embed environmental goals, including low embodied carbon, recyclable materials, energy efficiency, and operational resilience. A life-cycle assessment influenced the choice of materials, favoring long-life concrete and aluminum, and minimizing toxic materials. Operational strategies rely heavily on passive systems, supported by limited mechanical HVAC use due to underground thermal stability. The metro's design achieves significant emissions reductions by encouraging a shift from private vehicle use to efficient public transit. Embodied carbon data estimates ~500–700 kg $CO2/m^2$ per station

CO_2 Emissions in the Construction Phase

Activity	CO_2 Emissions in Construction Phase (tons)
Production of construction materials, concrete	218,000
Production of construction materials, steel	50,000
Construction machinery	29,000
Transport of soil and muck	4,000
Transport of concrete and concrete elements	1,000
Electrically powered equipment	78,000
Total CO_2 emissions in construction phase	380,000

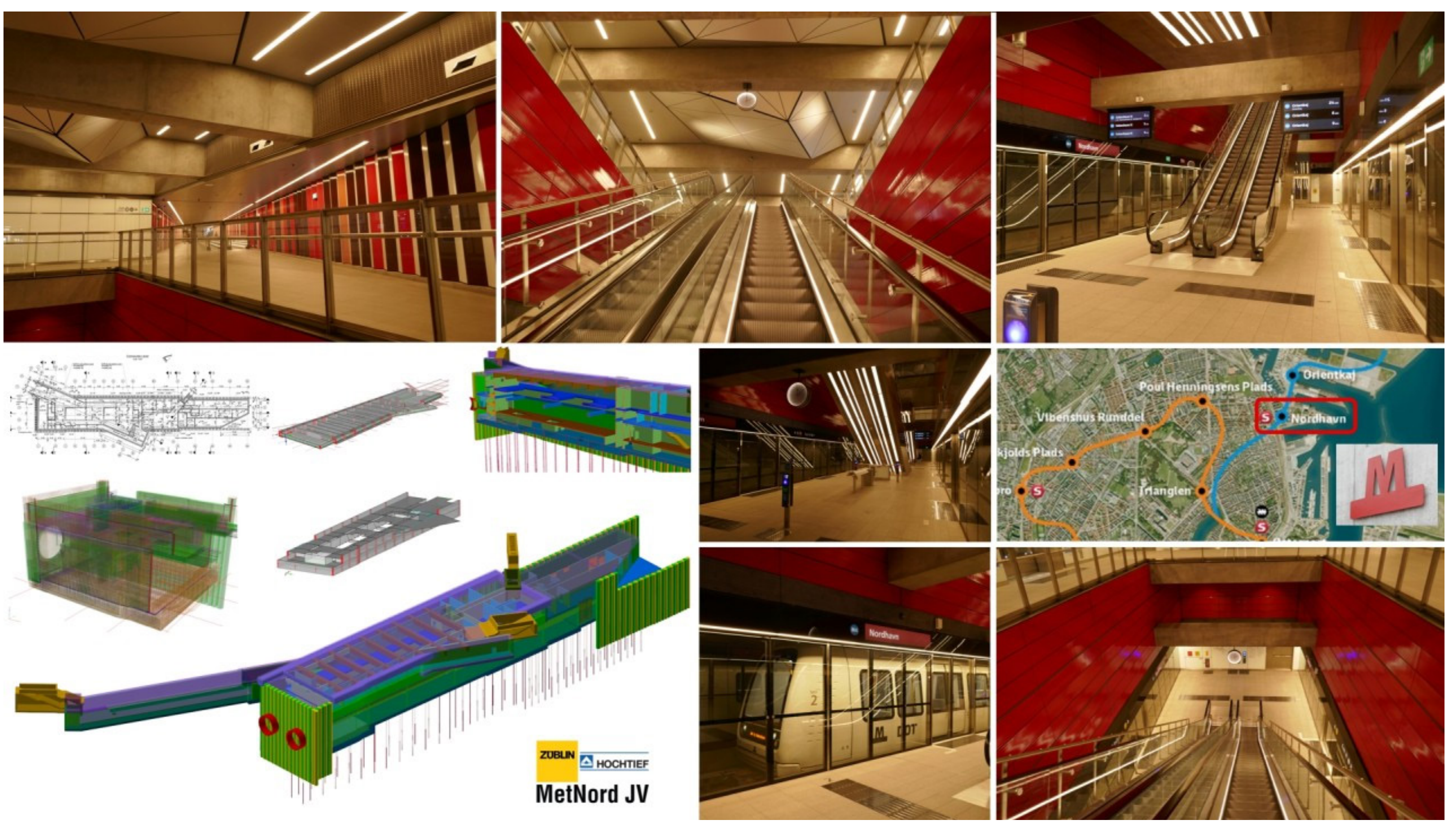
Source: VVM of Cityringen (Environmental Impact Assesment)

The total CO2 emissions from the construction of the Cityringen are estimated at approximately 380,000 tonnes

"In this basis, it can be concluded that the construction work will give rise to a not inconsiderable additional emission of CO2. However, this must be seen in the light of the fact that the plant has a lifespan of 100 years and that Cityringen can potentially contribute to a reduced use of fossil fuels in the long term by being electrically powered, and in the future it is expected that there will be an increased use of CO2 neutral fuels for the production of electricity. It is possible to reduce CO2 emissions from the construction works beyond the calculated approx. 380,000 tonnes. In the design phase, emphasis will be placed on choosing steel and concrete that are manufactured with the least possible use of energy, and on choosing methods and procedures that limit energy consumption."

Source: VVM of Cityringen (Environmental Impact Assesment)

Cityringen relies on a minimal set of active systems due to the metro's underground stability. HVAC systems are standardized across stations, activated only during extreme summer and winter peaks.



Source: Dr. Claas Heitz (Via Linkedin)

SYDNEY METRO NORTHWEST

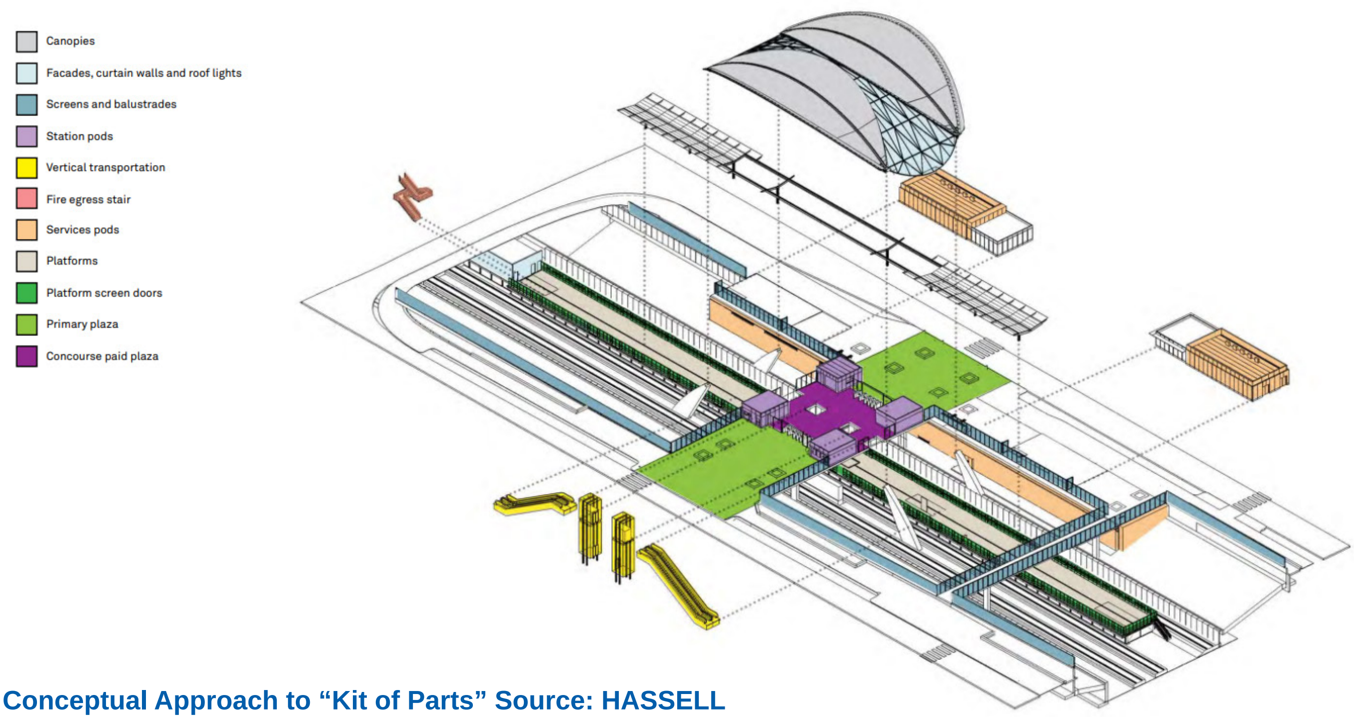
Prescriptive

Overview

The Sydney Metro Northwest line, opened in 2019, is Australia's first fully automated rapid transit system and represents a major milestone in sustainable, integrated infrastructure design. Delivered by Transport for NSW in partnership with design lead Hassell Studio and the John Holland CPB Ghella (JHCPBG) joint venture, the project introduced eight new stations across a 23-kilometre corridor from Epping to Rouse Hill. A defining feature of the project is its use of a modular "kit-of-parts" strategy, which standardizes architectural and public domain elements, such as canopies, façades, and service pods, while allowing each station to respond to its local context.

Sustainability Targets

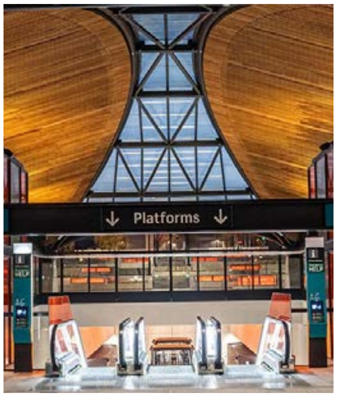
According to Sydney Metro's 2019 Sustainability review (including EY benchmarking of Northwest), sustainability targets were achievable and largely met - 85% fully, 10% partially. Dedicated sustainability personnel (both clients and contractors) proved essential for implementation success. Incentive mechanisms like bonus payments helped drive contractor performance and third-party rating tools (e.g. Green Star, ISCA) sharpened contractor focus and external accountability.

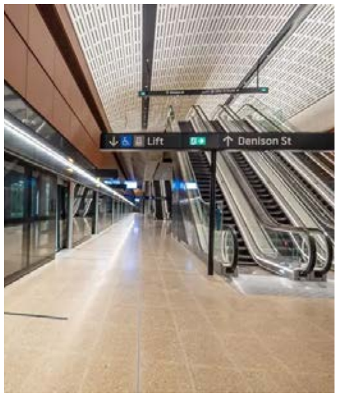


Conceptual Approach to "Kit of Parts" Source: HASSELL

SYDNEY METRO NORTHWEST

Prescriptive





Completely Modular Components

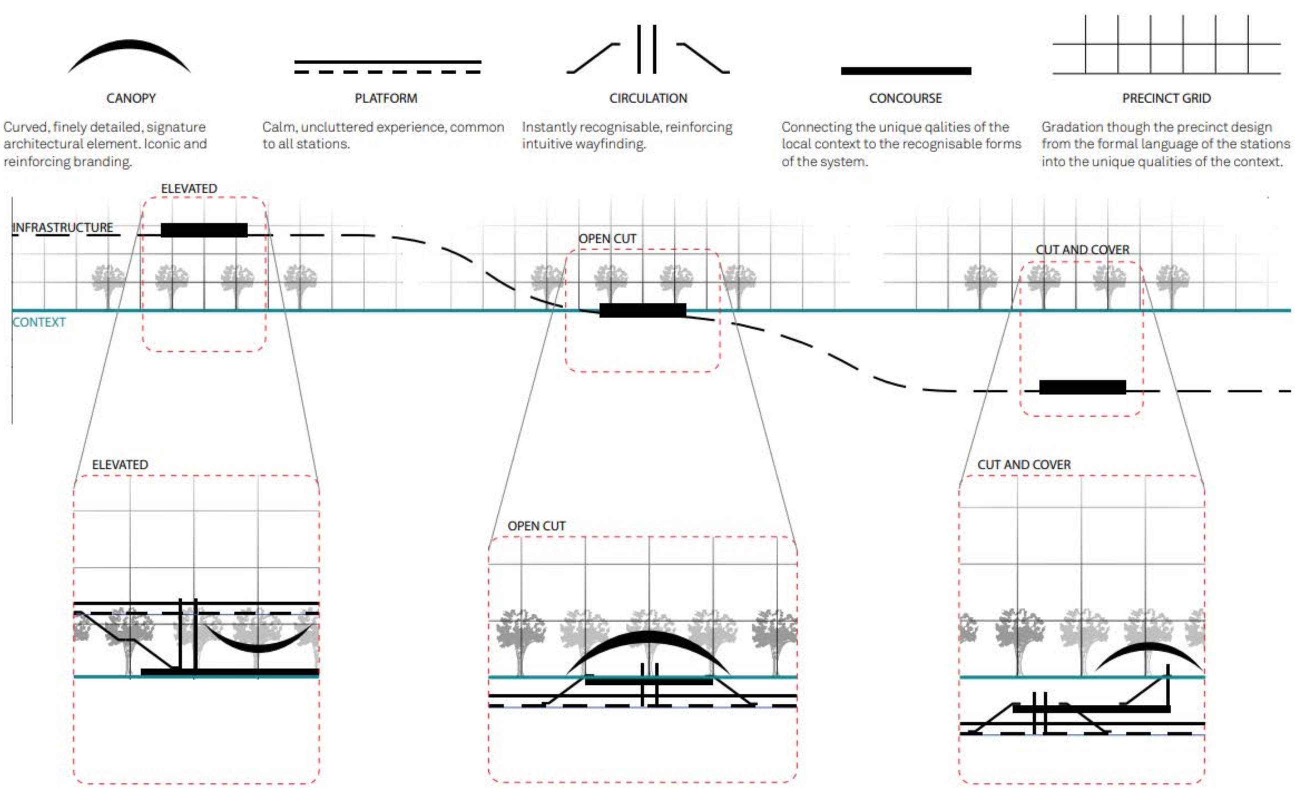
- Canopies & facade modules: Prefabricated timber batten panels and roof framing were standardized across stations.
- Structural frames & benches: Repeating frames and street furniture simplified on-site workflows.
- Façade linings: Independently fabricated timber elements installed as discrete modules.

Partially Or Non-Modular Components

- Station shells/platforms: Civil works such as platforms and station boxes were site-specific due to terrain and precast tunnel interfaces.
- Underground stations (Castle Hill, Norwest, Hills Showground): required bespoke structural adaptations.

Linewide Consistency And Identity

- Each station has a typology which relates to the individual precinct and emphasizes the relationship with the natural ground plane: Elevated, open cut, and cut and cover.
- Each station has a distinct identity which responds to the character of that landscape setting. See “Elements to Typologies Concept”

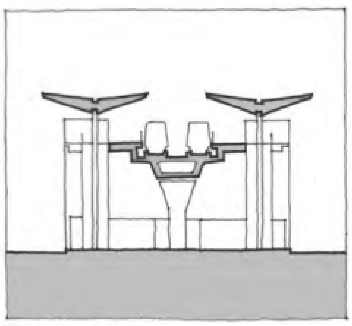


Elements to Typologies Concept Source: HASSELL

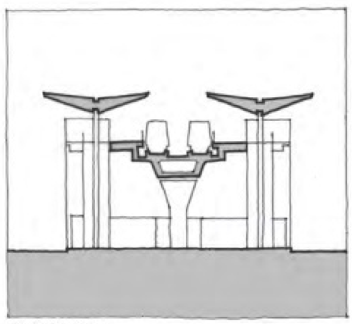
SYDNEY METRO NORTHWEST

Prescriptive

A defining feature of the project is its use of a modular "kit-of-parts" strategy, which standardizes architectural and public domain elements, such as canopies, façades, and service pods, while allowing each station to respond to its local context.



KELLYVILLE



ROUSE HILL

3 TYPOLOGIES IN DETAIL

Elevated

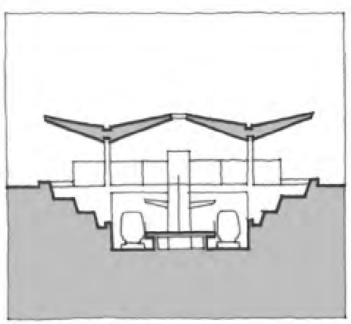
Used when the rail line is above ground level. Stations lift passengers vertically from the precinct up to the platform. (Kellyville and Rouse Hill.)

Open Cut

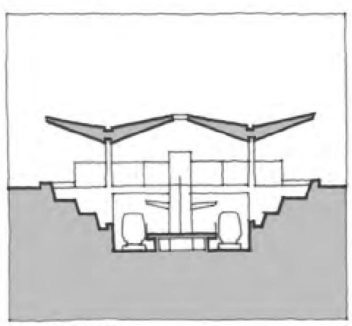
Used when the rail line is level with the ground. Stations guide passengers horizontally from the precinct into the platform area. (Showground, Norwest and Castle Hill)

Cut and Cover

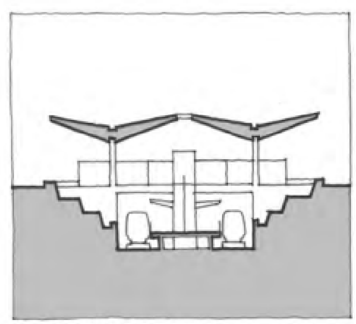
Applied when the rail line sits well below ground. Stations draw users downward into a detailed, below-grade space. (Cherrybrook, Bella Vista and Cudgegong Road)



CHERRYBROOK



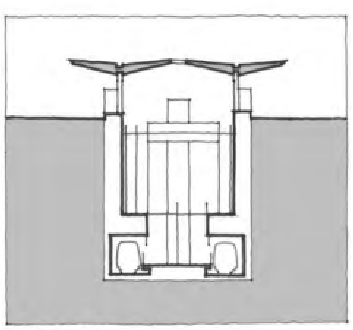
BELLA VISTA



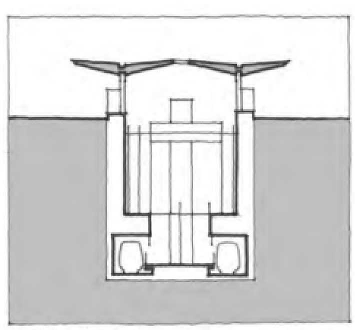
CUDGEGONG ROAD

Lighting Strategy

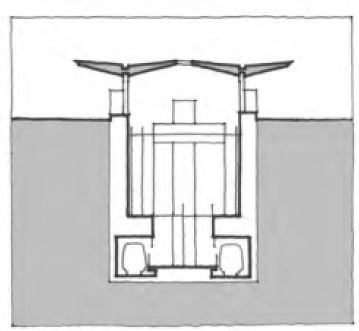
Stations along the Sydney Metro Northwest project are identified using place specific colours that are part of a wider colour palette concept for the Sydney Metro brand applied throughout the system up to the platform.



CASTLE HILL

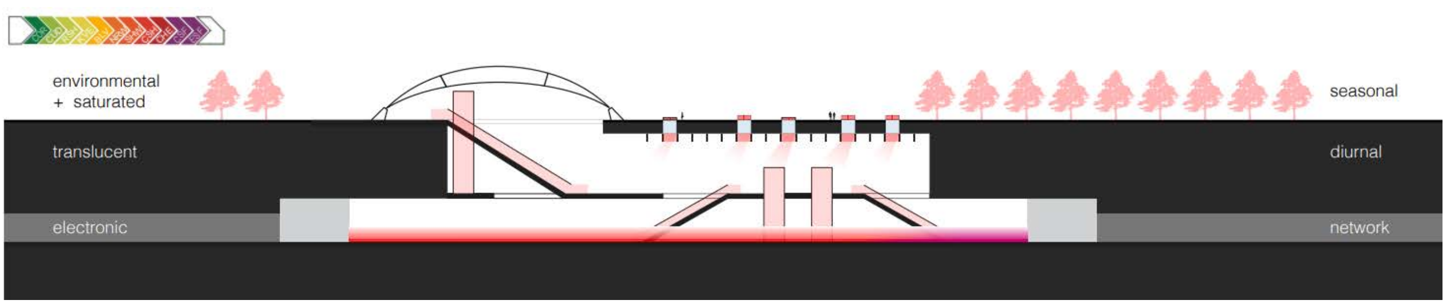


SHOWGROUND



NORWEST

For intuitive wayfinding, a subdued and calm station background is created through muted finishes and colours. Each station has an assigned accent colour that is used for where civic entries and accent features such as landscaping and lighting.

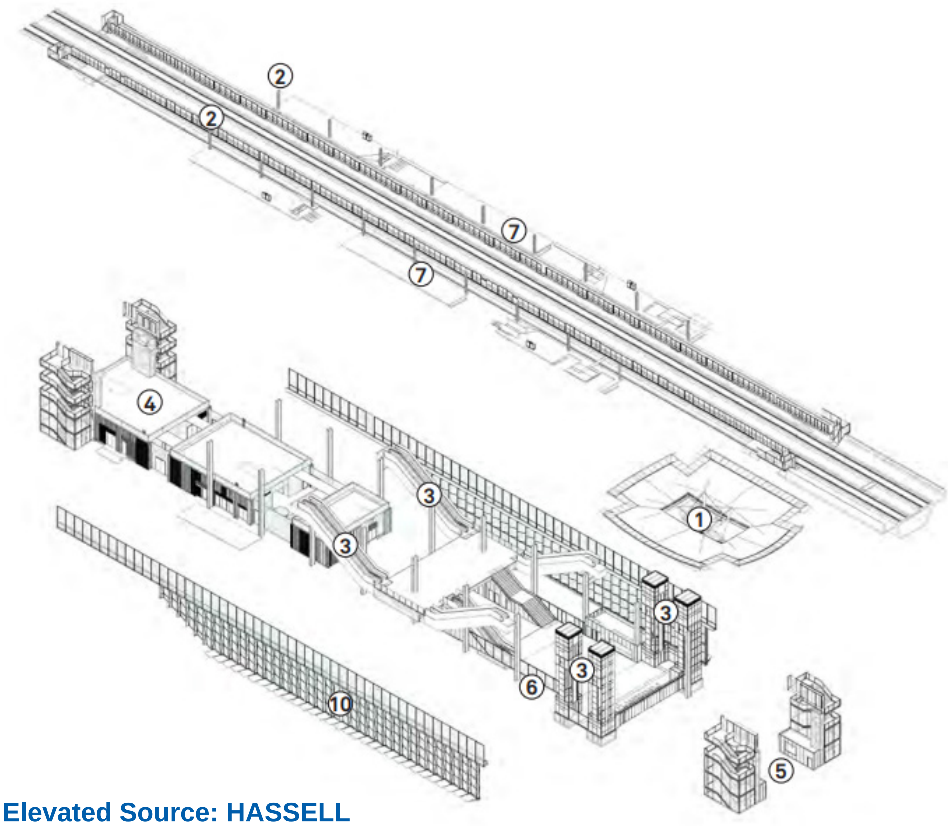


Section Illustrating Colour + Light + Time Concept Source: MWA with T+C Studio

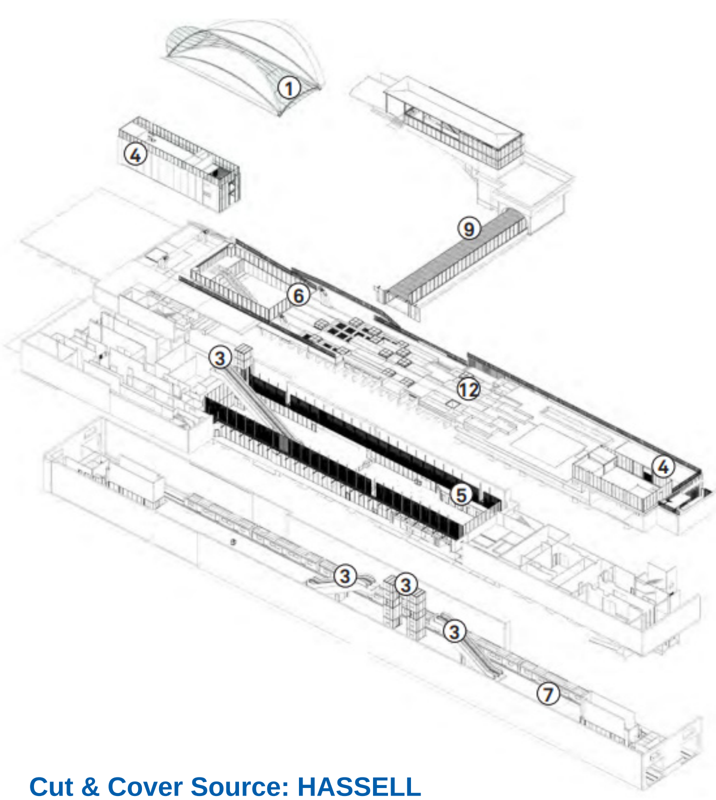
SYDNEY METRO NORTHWEST

Prescriptive

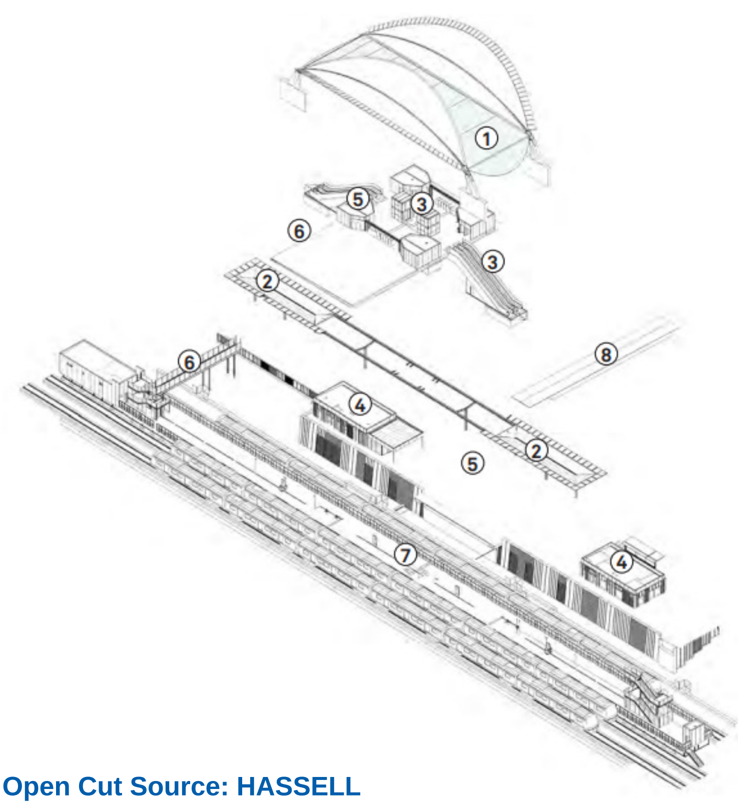
Typologies: Built Elements Typical System Wide Design Details



Elevated Source: HASSELL



Cut & Cover Source: HASSELL



Open Cut Source: HASSELL

KEY ELEMENTS AND ZONES.

1. Concourse Canopy
2. Platform Canopy
3. Vertical Transportation
4. Service Buildings
5. Concourse Pods
6. Screens, Balustrades and Fences
7. Platform
8. Pedestrian Bridges
9. Pedestrian Underpass
10. Facades
11. Car Park
12. Skylights

SYDNEY METRO NORTHWEST

Prescriptive

Key Sustainable Design Strategies:

Station architecture:

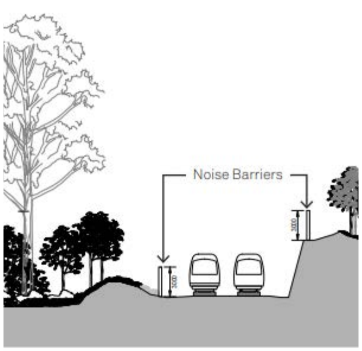
- Focus on passive design, efficient building orientation, compact layouts, sustainable materials, and functional furniture.
- Landscape and urban design: Incorporation of shared cycle paths, cyclist amenities, ecological enhancement, drought-resistant planting, and efficient irrigation systems.

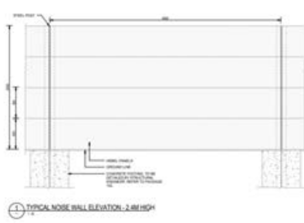
Passive Ventilation Strategies:

- Applicable in elevated stations, open cut stations, multideck car parks, and the upper levels of underground stations.
- In underground stations, cross-ventilation is achieved via perimeter glazed screens and roof canopies that draw warm air up from platforms.
- Multi-deck car parks are designed for natural cross-ventilation, with façade openings limited to 50% to support airflow.

Built Elements in the Landscape

Built elements must balance a contextually responsive approach with a consistent project-wide design that expresses the line wide identity. An example would be modular noise barriers that assist with noise control and vibration mitigation





Sustainability Criteria

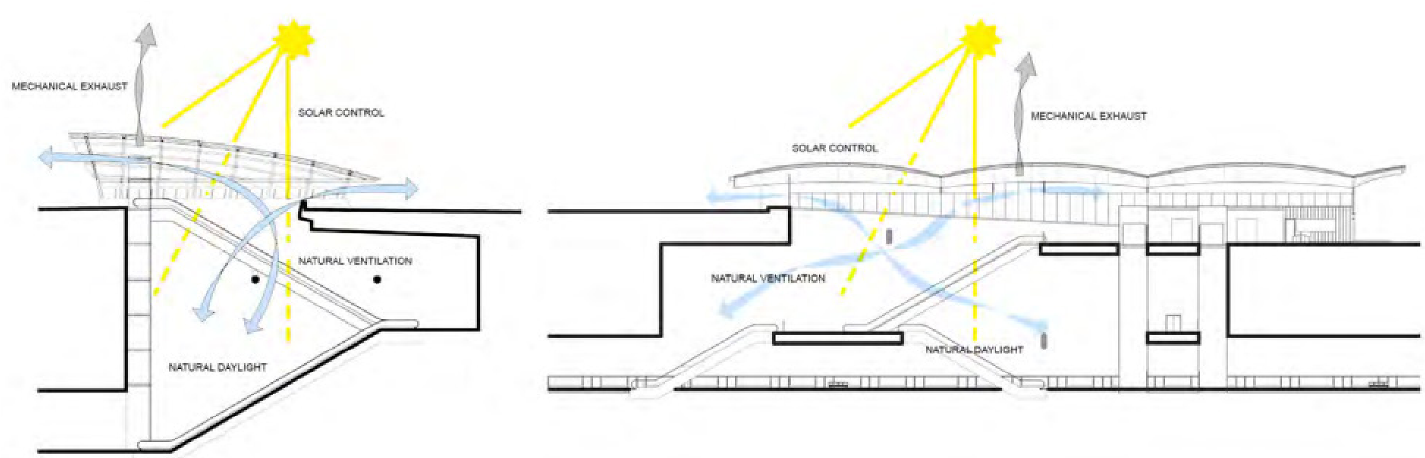
All stations, interchanges, car parks, and maintenance facilities were designed to meet the following standards:

ISCA Infrastructure Sustainability Rating (v1.0): Achieve an 'Excellent' rating for Design and As Built phases.

TfNSW Sustainable Design Guidelines (v3.0): Achieve a minimum 'Bronze' rating.

Embodied and Operational Strategies:

- Passive design to enhance natural daylight, improve ventilation, reduce glare, and optimize thermal comfort.
- Use of energy-efficient building services and control systems.
- Reduced embodied carbon through sustainable materials such as FSC-certified timber, low-carbon steel, and fly ash in concrete.
- Rainwater harvesting systems for irrigation. Integration of photovoltaic panels to offset low-voltage energy needs at each station.
- Climate resilience features to mitigate passenger heat stress, flooding, and equipment failures.



Station Ventilation Strategies Source: HASSELL

SYDNEY METRO NORTHWEST

Prescriptive

	Location
1	**Concourse Canopy Roof** _ Via articulated boom to centre of arch from primary plaza 1500 x1500 flat area _ From EWP attach to entry Anchor Point (AP) on roof and then disconnect from EWP AP and access roof _ To move about the roof transfer from entry AP to perimeter XSPlatforms rail system _ Perimeter rail set back 2m from edge - roof safe system – rail trolleys are to lock off in tension, suitable for rope access and fall arrest loadings, attached to roof sheeting and can be curved in two directions _ Additional surface mounted APs as required; suitable for rope access and fall arrest loadings _ Not necessary to walk along gutter _ Tap included at midpoint of roof for cleaning _ Pole wash glass roof from solid edge _ Glass clean and or replacement on sloped ends can be accessed by rope access positioning from the XSPlatforms rail system and or the surface mounted APs on both sides
2	**Service Buildings Generally if less than 6m tall** _ Ladder bracket _ Secure ladder and attach to anchor point _ Connect to strop in transferring _ Steps and flat platform required from parapet, top step can be flush with parapet _ If parapet is less than 1m then attach to perimeter lifeline set back 2m from edge
3	**Corner Service Building** _ Has external stair for access
4	**Lift** _ Access by EWP from concourse
5	**Underside of Entrance Roof Canopy Timber** _ Accessed by Arcitulated Boom
6	**Underside of Entrance Roof Canopy Glazing** _ Rope Access from concourse _ Climb through steel structure with loop fastener that locks under tension _ Glass raised above steel structure 150mm - XSPlatforms rail system to glazing structure as required - TBC _ Sections of glazing can be pole washed from escalators and concourse

Management/Operational Maintenance

Mechanical systems are primarily required for underground stations (cut and cover typology), where passive strategies alone are insufficient:

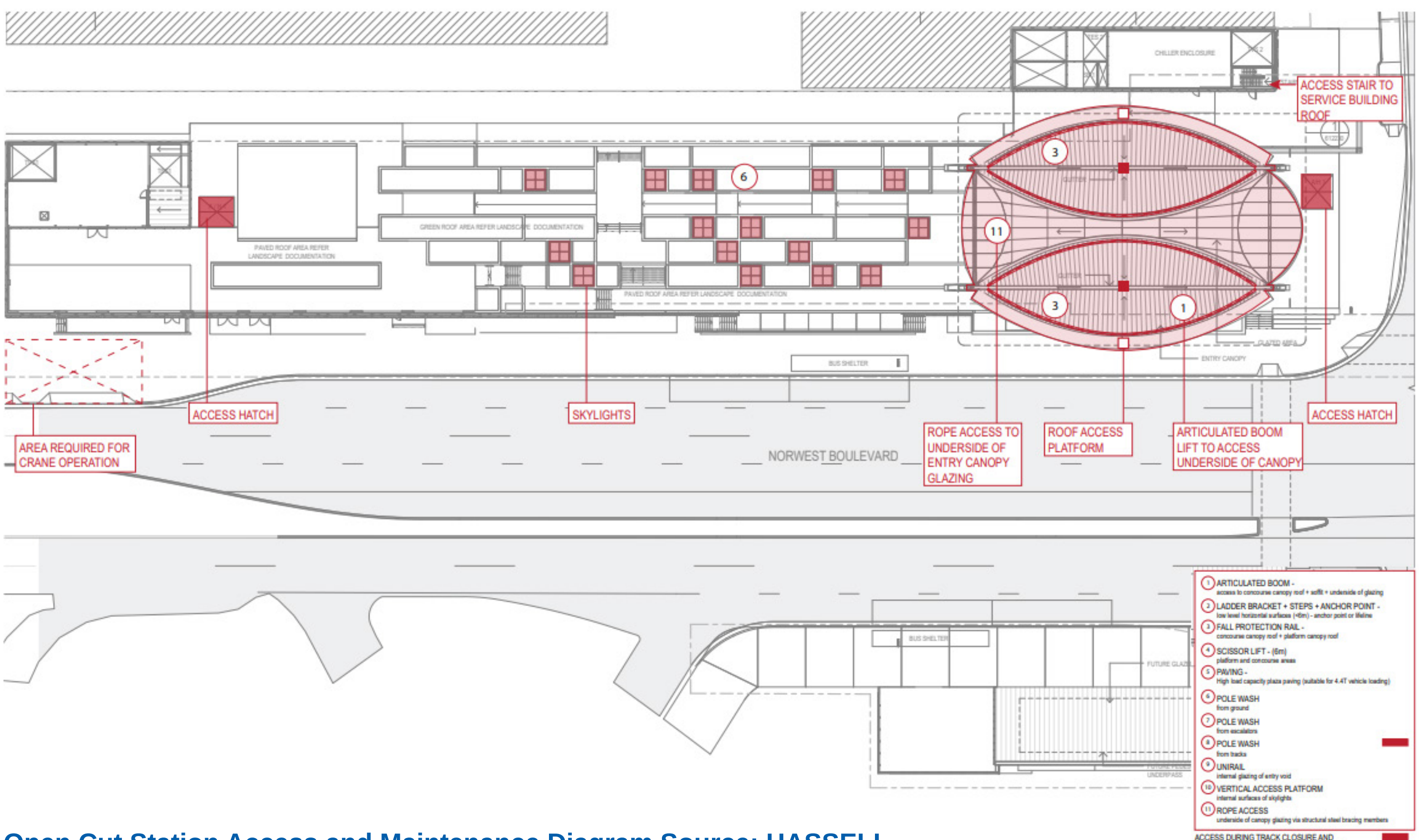
- Spot cooling and mechanical ventilation are provided at platform level to manage heat and humidity.
- Public areas remain unheated to reduce energy use.
- Reverse cycle air conditioning is limited to back-of-house spaces such as: Station Manager's offices, Ticketing offices, Staff and plant rooms with high thermal loads, and Electrical substations are typically placed at ground level with either natural ventilation or passive mechanical exhaust systems.

Access Maintenance Strategy:

An Access and Maintenance Strategy was developed to ensure that station and building designs across the Sydney Metro Northwest integrate safe and efficient access for cleaning and maintenance activities. A key objective is to embed these access requirements into the architectural design of critical components such as canopies, façades, and external surfaces, especially within the modular Kit-of-Parts system.

This strategy supports the long-term operational functionality of the transit system by prioritizing:

- Safe access for routine and periodic maintenance
- Efficient procedures for cleaning high-use areas
- Reduced operational disruptions through thoughtful integration of access features



Open Cut Station Access and Maintenance Diagram Source: HASSELL

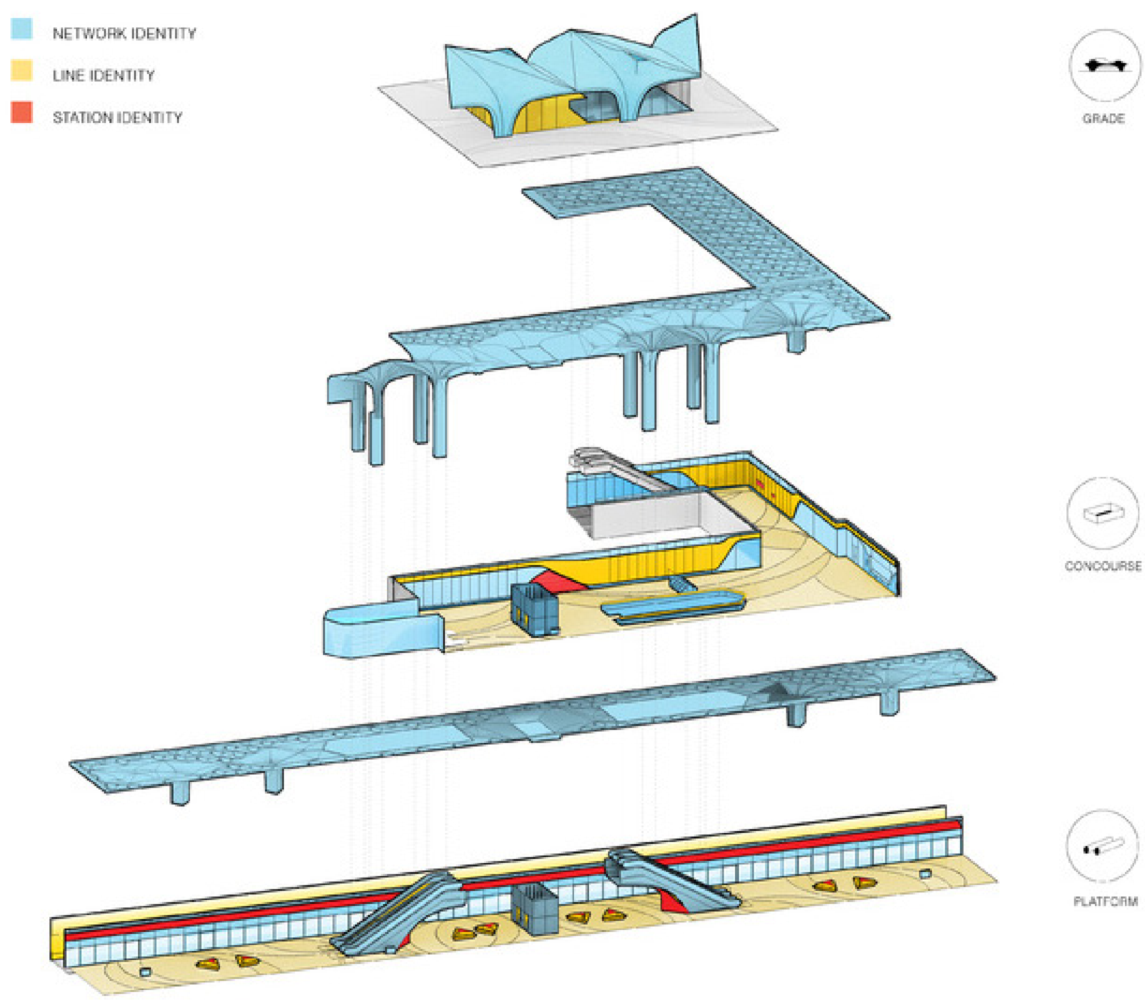
DOHA METRO 2019

Prescriptive

The Doha Metro is a rapid transit system located in Qatar's capital city, designed to provide high-capacity, climate-resilient transportation across the metropolitan region. Comprising three color-coded lines (Red, Green, and Gold) the system includes 37 driverless stations connected by over 76 km of track. Concept design was led by UNStudio, who developed the architectural identity and branding manual that governs all stations. The project integrates modularity, cultural expression, and sustainability through a unified design language known as the "Vaulted Spaces" system, inspired by regional architectural forms like desert caravanserais and Islamic vaults. Prefabricated components enabled rapid construction across multiple sites simultaneously. Recognized as a global benchmark in metro design, the Doha Metro show how standardized modular strategies can achieve architectural quality, local identity, and operational efficiency in an extreme climate.

A key concept within the design is one of creating varying scales of identity for the user: network identity, line identity and station identity.

The design further incorporates and integrates all functional and technical aspects of the stations and network into a coherent architectural expression with a view to making the Qatar Rail Metro Network a global benchmark in the service public transportation provides to the users and to the environment.



Source: Quatar Railways Company, designed by UNStudio

DOHA METRO 2019

Prescriptive

UNStudio's manual defines a scalable matrix of vault, column, petal-ceiling and skylight modules driven by a 16 m structural grid. The geometry is CNC-cut in GRC or aluminium, enabling quick casting and consistent quality control.

Modular Components:

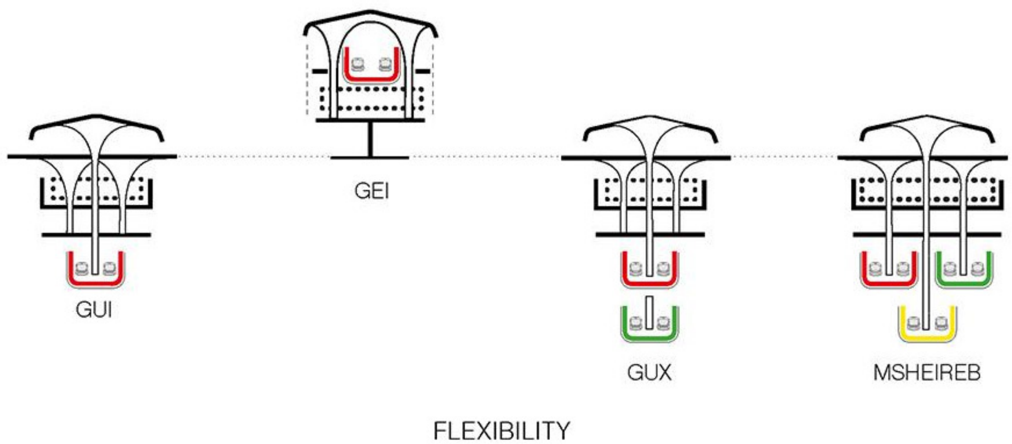
- Pre-cast vaulted roof shells and supporting "blade" columns
- Suspended petal-ceiling panels integrating lighting, sprinklers and way-finding
- Platform-screen-door façades with interchangeable cladding inserts
- Standardised entrance canopies sized in 3-bay, 5-bay or 7-bay sets

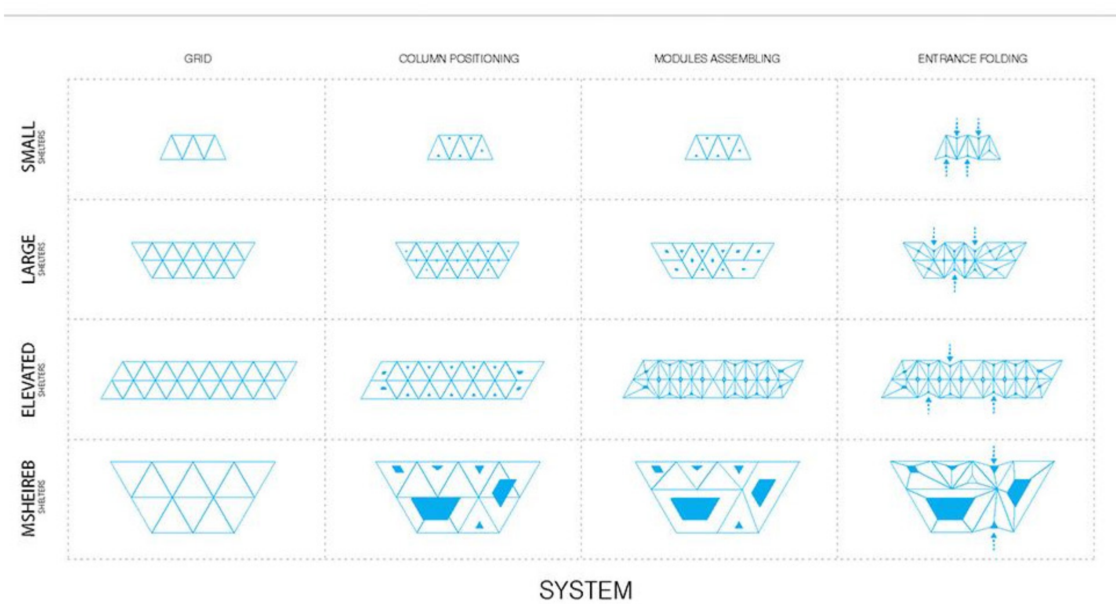
Partial Modular Components:

- exterior stone cladding colours that reference local geology
- Art walls and mashrabiya screens commissioned per neighbourhood
- Enlarged public halls at Interchange "Gateway" stations
- Site-specific skylight orientations responding to urban alignment

Site-wide Consistency and Identity

- Four station typologies- Interchange, Gateway, Key-node, Node (all using one vault language)
- Distinct identity arises from lighting tone and local art, not from form changes
- Uniform furniture, signage and flooring

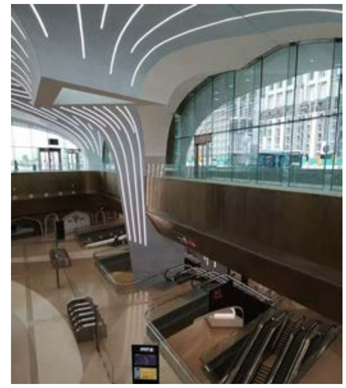




Source: Quatar Railways Company, Designed By Unstudio

DOHA METRO 2019

Prescriptive



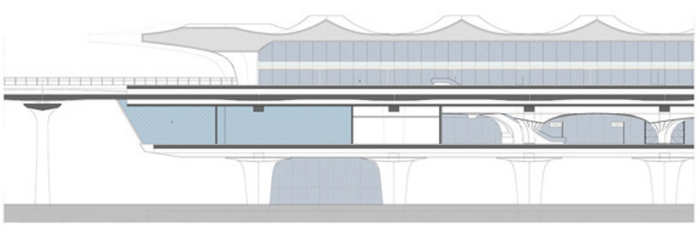
Sustainability Targets:

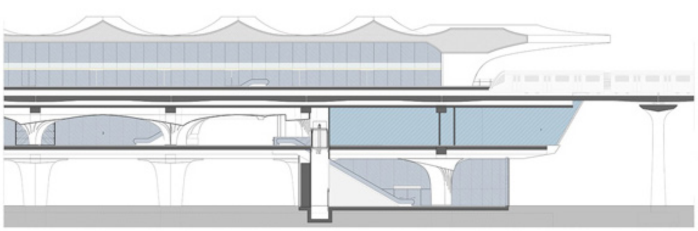
Qatar Rail required every station to achieve ≥ 4-Star GSAS-Railways certification, the first mass-transit network worldwide to mandate this level, and to secure LEED Gold where feasible (Msheireb achieved GSAS 5-Star + LEED Gold)

Specific Targets:

- 30 % reduction in operational energy versus ASHRAE 90.1 baseline.
- 50 % potable-water savings through low-flow fixtures and condensate recovery.
- 20 % minimum recycled or regionally sourced materials.
- 10 000 t CO_2 per year avoided by diverting an estimated 173 000 car trips to metro travel

Life-cycle models informed material selection; EPDs were mandatory for high-volume products, and design-for-disassembly clauses were built into contracts (e.g., removable roof steel at Msheireb)





Embodied Carbon Figures:

Education City, Al Bidda and Msheireb stations already hold GSAS-Operations Platinum, validating post-occupancy performance. Embodied-carbon figures are reported only at network level; internal audits show the kit-of-parts trimmed structural steel by 18 % and reduced embodied CO_2 by roughly 25 % vs. a conventional cast-in-situ baseline (≈500 kg CO_2 e/m^2)

Active Systems and Operational Maintenance

All stations share a water-cooled chiller plant, platform-screen door air-conditioning and smoke-extraction systems. Chillers run year-round but operate at partial load in winter; VFD fans and pumps ramp to just 20 % output during shoulder seasons.

HVAC/O&M strategies

- Uniform AHU, fan and filter specifications streamline spares stock.
- Filters slide out through ceiling petals without scaffold.
- Cable trays, lighting drivers and sprinkler heads mount on hinged access rails pre-integrated in the vault soffit.
- Quarterly deep-clean programme uses automated gantries that follow the grid-line slots inside the vaults.

NEW YORK CITY STREET FURNITURE

Prescriptive

Background:

The New York City street furniture project was designed by Grimshaw Architects, with industrial design led by Billings Jackson Design and project delivery by Cemusa (now JCDecaux) through a public-private partnership. Funded by advertising revenue in exchange for a 20-year franchise, the project delivered over 3,500 pieces of coordinated street furniture across NYC's five boroughs

Conceptual Approach to Kit of Parts:

- Shelter components were designed as a universal system with shared core structures (roof beams, columns, lighting, fasteners) applied across different sidewalk contexts.
- Site-specific elements, such as shelter length, number of seating bays, and ad panels, were designed to vary while using the same structural interfaces.
- All elements were fabricated off-site and shipped flat-packed, reducing installation time and disruption.
- The design leveraged a clean, rectilinear language that could adapt to multiple urban zones while maintaining a consistent civic identity.

Fully Modular Components:

- Roof canopy panels were standardized in width and mounting, allowing short, medium, or long versions using the same bracket system.
- Structural uprights/posts used a uniform bolt-down anchoring plate adaptable to different pavement types.
- Integrated LED lighting strips were embedded in pre-routed channels in the roof system, simplifying electrical runs.
- Bench seating modules were bolt-on units that could be added or removed depending on shelter size and expected footfall.

Partially Modular Components:

- Advertising panels (now managed by JCDecaux) were interchangeable but only installed in select locations based on zoning.
- Side glass panels varied in size or were omitted depending on sidewalk width and accessibility requirements.
- Wayfinding and map holders were mounted via a universal bracket system but varied in content or placement depending on borough and route density..

MODULAR WOODEN TRANSIT SHELTERS

Highly Prescriptive

Background:

The project was designed by Gottlieb Paludan Architects, winning a Danish national competition to create a modular series of transit stops in wood. Commissioned by Movia (Denmark's largest public transit agency), the project prioritized low-carbon materials, unified identity, and scalability across diverse urban and rural settings.

Conceptual Approach to Kit of Parts:

- Uses a modular timber frame system adaptable for varying stop sizes and functions.
- Shared structural logic: same core cross-section dimensions used for multiple configurations.
- Additive design approach allows for easy extension (e.g. more seating, digital signage, bike parking).
- Focuses on contextual flexibility while maintaining core visual and functional consistency.

Fuly Modular Components:

- Structural frames (columns and beams) prefabricated in standard timber modules.
- Roof profiles and eaves designed in repeating timber lengths.
- Lighting strips and digital signage integrated into modular mounts.
- Benches and wall panels clip into designated frame locations.

Partial Modular Components:

- Side panels vary in material (e.g. wood slats, glass, polycarbonate) based on site context.
- Wayfinding and service modules (e.g. trash bins, bike racks) added or omitted per location.
- Roof drainage features vary based on whether units are urban curbside or exposed rural installations.

System-Wide Consistency:

Despite regional variation, the shelters share a warm, human-scale aesthetic through uniform timber framing, modular dimensions, and consistent detailing. For Vancouver, the approach affirms the potential of wood-forward modular transit architecture that is both high-performance and use of local materials.

DESIGN APPLICATIONS

OVERVIEW

The global best practices studied (Sydney Metro Northwest, Copenhagen's Cityringen, and the Doha Metro) demonstrate a highly-prescriptive design consistency through clearly defined station typologies, modular kit-of-parts systems, and line-wide design strategies. These networks establish cohesive architectural languages by categorizing stations early in the design process based on size, function, and context, allowing prefabricated and repeatable components to be adapted across varied conditions without sacrificing identity or performance.

Metro Vancouver's current network exhibits a more varied modular approach. Existing design manuals focus primarily on technical standards and spatial layouts, and may benefit from research on how modular elements can be introduced, replaced, or upgraded incrementally across a station's full lifecycle. The clarity and foresight shown in the international examples directly inform this project's proposed phasing study,demonstrating how targeted, staged upgrades that are organized by typology (similar to Sydney and Doha) can support long-term maintainability, reduce disruption, and help establish a more unified transit design language across TransLink's diverse network.

The design recommendations will culminate in the development of a visual phasing strategy guide, mapping which station components are best suited for modular retrofits and estimating the relative effort, time, and sequencing required for each. The guide will support TransLink in aligning future upgrades with lifecycle goals and operational realities, providing a practical tool for more resilient, scalable, and sustainable infrastructure delivery

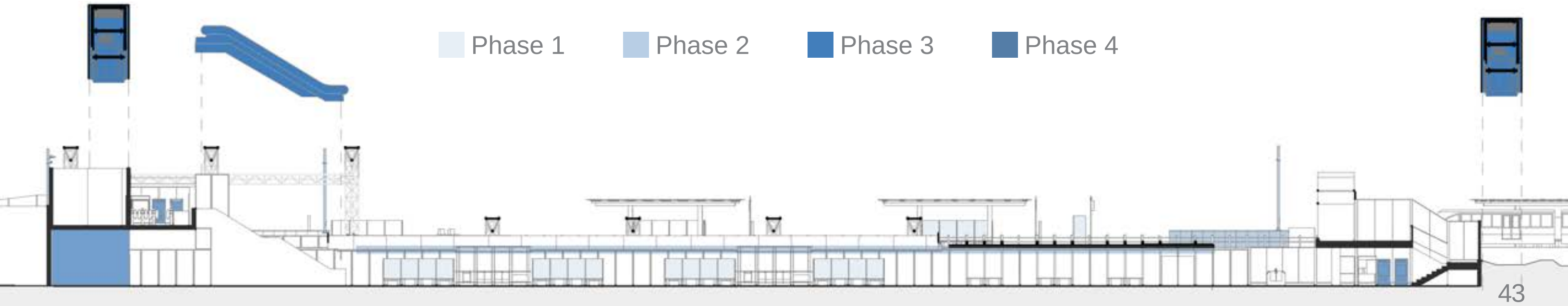
DESIGN APPLICATIONS - OVERVIEW

The proposed suggestions are grounded in a phasing strategy that applies a lifecycle-based approach to modular design. Organized into four key phases, this strategy offers a structured framework for implementing upgrades over time while minimizing disruption to day-to-day operations. Modular components are introduced not only for immediate construction efficiency but also with long-term adaptability, maintainability, and system-wide transformation in mind. This approach ensures that infrastructure evolves sustainably across the full lifespan of a transit station.

Phase	Name	Timeline	Characteristics	Elements	Operational Impact
1	Inherit	0-5 years	Carry forward existing standards or typologies within the same system family.	Lighting modules, signage, seating, PIDs, furniture	Minimal impact; can often be done during off-peak hours or at night. Downtime: 0–4 hrs
2	Adapt	Short- to mid-term (Year 0-10)	Apply successful strategies from one mode to another with minimal modification.	Service spines, Modular bike shelters/ lockers	Moderate impact; localized area closures or weekend work. Downtime: 1–3 days per module
3	Upgrade	Mid-term (Year 5-25)	Retrofit existing facilities using modular toolkit components.	Modular CCTV/PA mounts, Moduar utility walls	Medium impact; may require staged construction or phased closures. Downtime: 3 weeks - 3 months
4	Innovate	Mid- to long-term (Year 10+)	Create new modular components to support operational functions or long-term scalability.	Modular BOH pods, Modular elevator/stair cores	High impact; generally not intended to be upgraded except during large reconstruction.

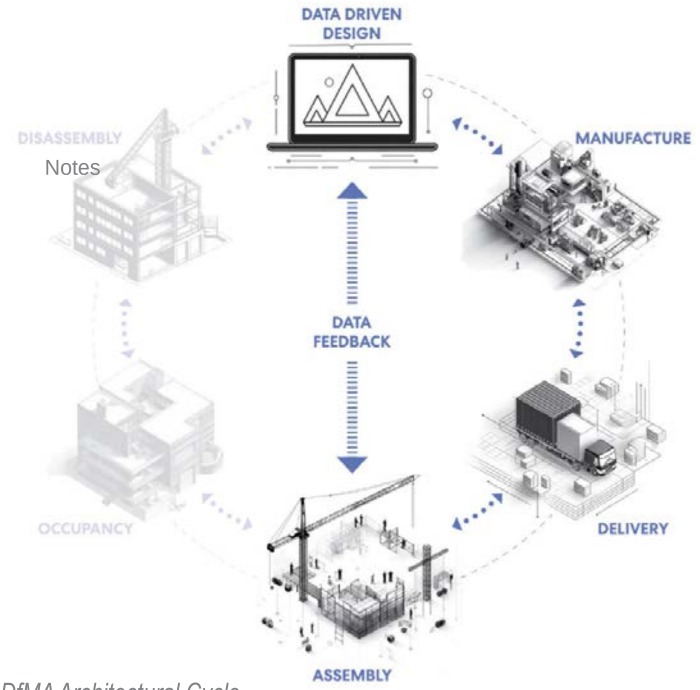
Design Goals

- Apply a lifecycle-based phasing strategy that guides modular upgrades from short- to long-term.
- Support early, low-disruption interventions in Phase 1 and 2 to address immediate needs with minimal impact.
- Enable flexible retrofits in Phase 3 through modular toolkits that respond to aging infrastructure.
- Introduce new modular systems in Phase 4 to support long-term operational adaptability and BOH performance.
- Ensure scalability and consistency across all station types and transit modes.

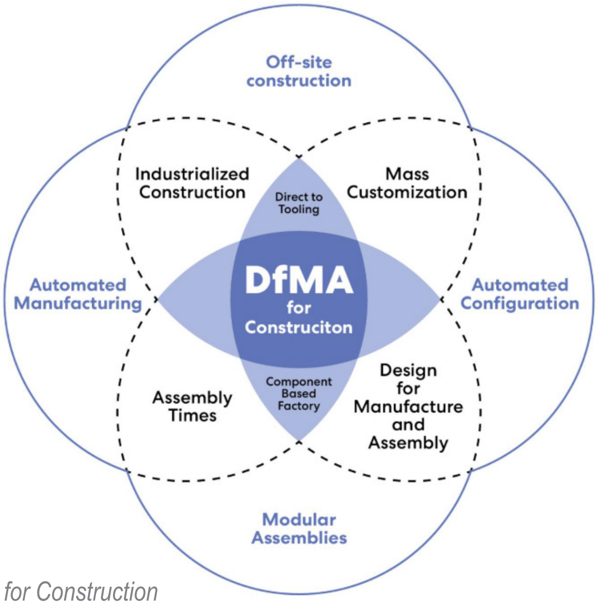


METHODOLOGIES

Design for Manufacture and Assembly



DfMA Architectural Cycle
Source: Perkins&Will,Design for Manufacture and Assembly,A Primer



DfMA for Construction
Source: Perkins&Will,Design for Manufacture and Assembly,A Primer

Incorporating DfMA principles in design recommendations ensures that proposed modular strategies are not only theoretically sound but practically scalable, cost-effective, and aligned with TransLink's aspirations for a resilient and adaptable transit network.

DfMA Principles

Perkins&Will,Design for Manufacture and Assembly,A Primer

1. Reduce the Number of Components
Fewer components streamline manufacturing and assembly, lower costs, and simplify automation. This leads to more reliable, easier-to-service end products.

2. Simplify Part Fabrication
Design each part to be as geometrically simple as possible, avoiding unnecessary complexity to ease production.

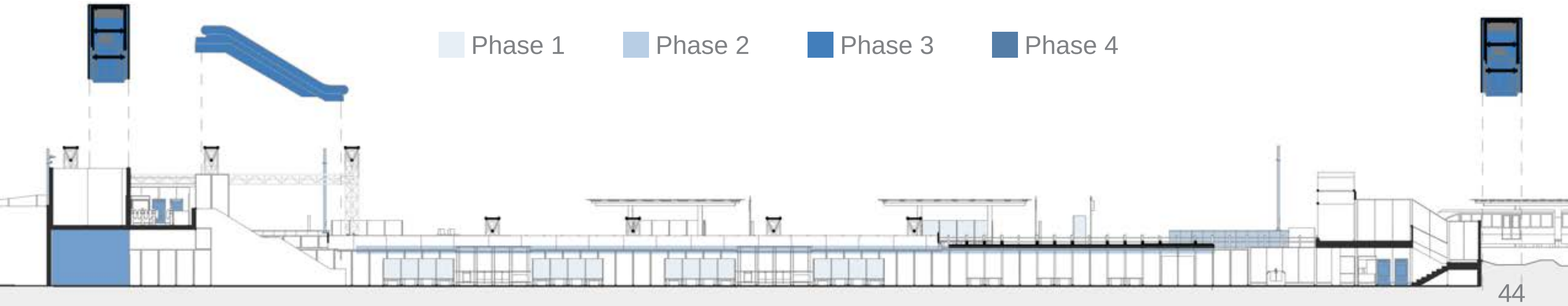
3. Account for Tolerances in Parts and Assemblies
Ensure parts are designed within system capabilities and allow for realistic assembly tolerances to reduce the need for post-processing.

4. Ensure Fail-Safe Assembly
Design components so they can only be assembled in the correct orientation or sequence, reducing errors during construction.

5. Limit the Use of Flexible Parts
Minimize elements like gaskets, cables, or rubber parts where possible, as these complicate handling and assembly.

6. Prioritize Ease of Assembly
Favor connection methods such as snap fits or adhesives over threaded fasteners. Include clear alignment features to speed up and standardize the assembly process.

7. Eliminate or Minimize On-Site Adjustments
Avoid designs that require field adjustments. Prefabricated components should arrive ready for immediate integration, reducing on-site errors and delays.

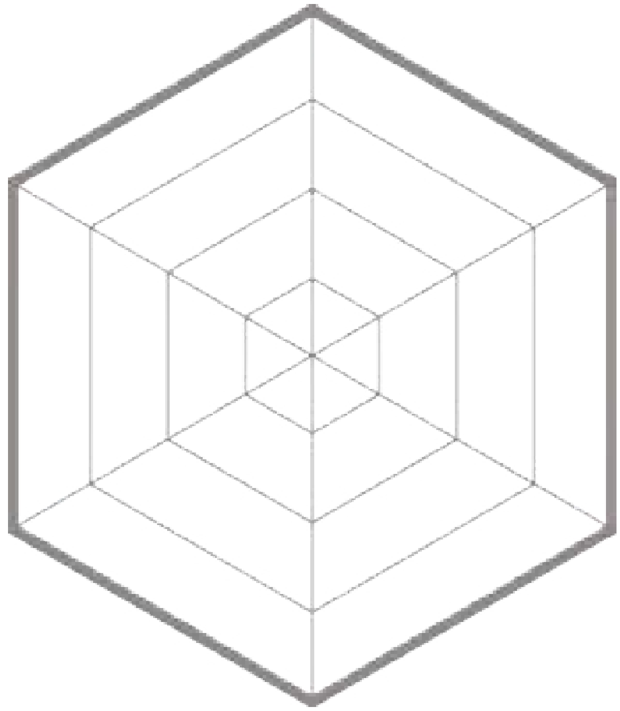


METHODOLOGIES

Evaluation Criteria

EASE OF RETROFIT
How easily the component can be installed within existing stations.

CONSTRUCTION FEASIBILITY
Practicality of fabrication, transport, and installation.



COST EFFICIENCY
Based on rough estimations, the intervention's cost may be:
* = $100 - $300 / sqm
** = $300 - $500 / sqm
*** = $500-$700 / sqm
**** = $700+ / sqm

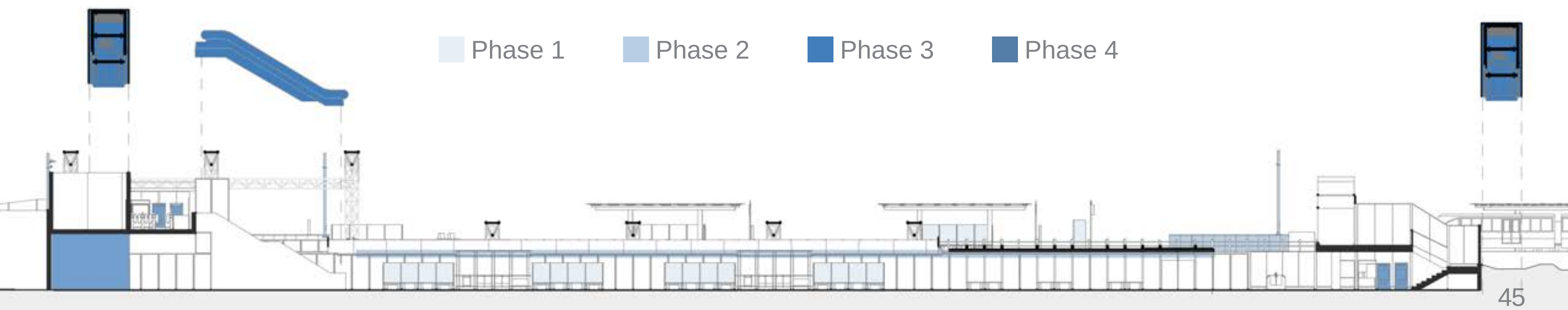
MAINTENANCE
Effort and frequency required to keep the component in working condition.

SCALABILITY / SYSTEM WIDE RELEVANCE
Applicability across different station types and contexts.

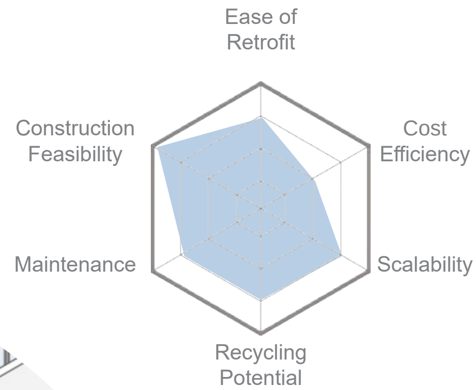
RECYCLING POTENTIAL
Capacity for reuse, disassembly, or material recovery.

Hexagonal Evaluation Matrix

A Hexagonal matrix is used to assess each design suggestion. Each axis represents a critical performance factor in lifecycle-oriented station upgrades. By visualizing trade-offs and strengths across multiple dimensions, the matrix supports more balanced, context-sensitive design decisions while aligning proposals with operational and circular design priorities.

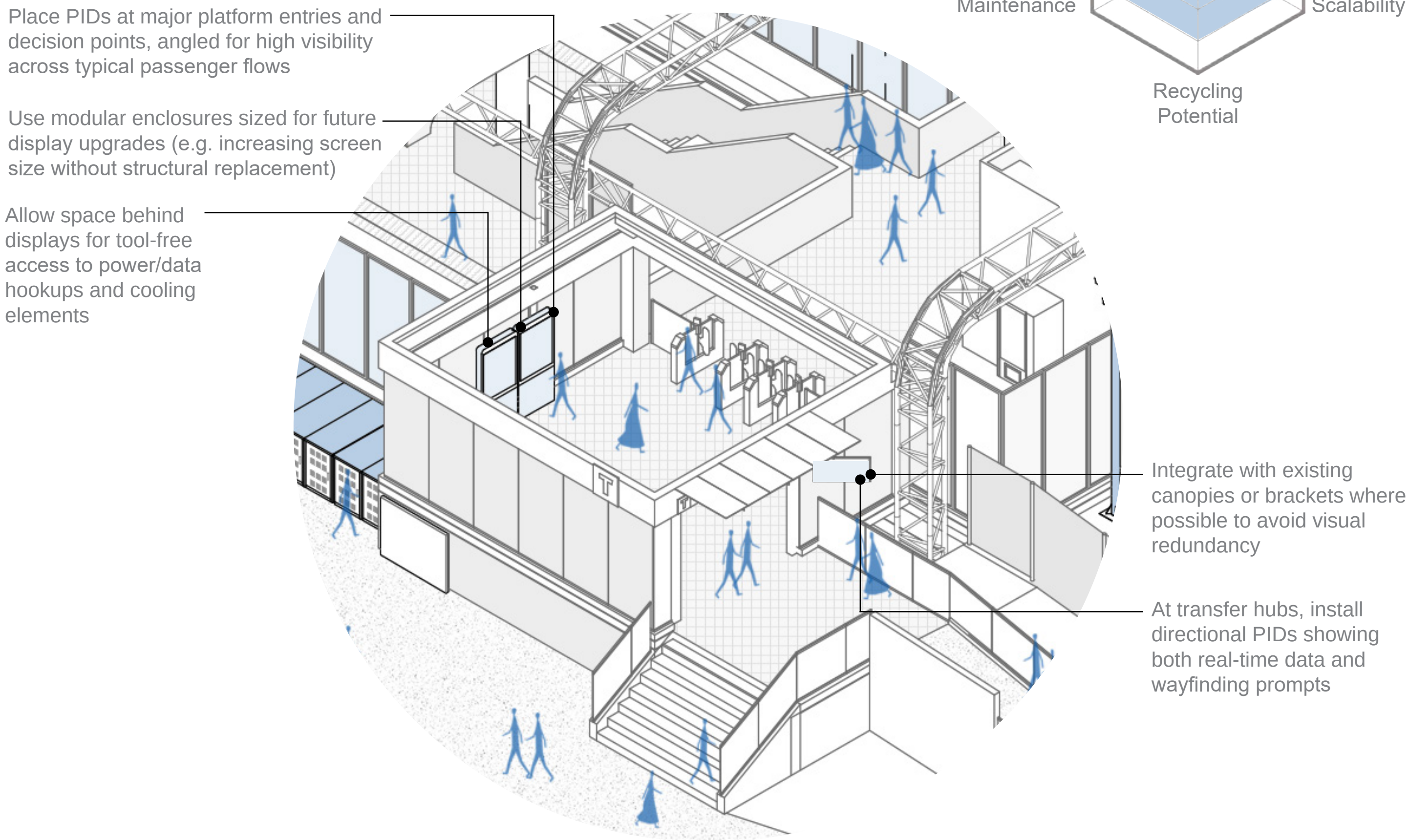


SYSTEM-WIDE PID UPDATES



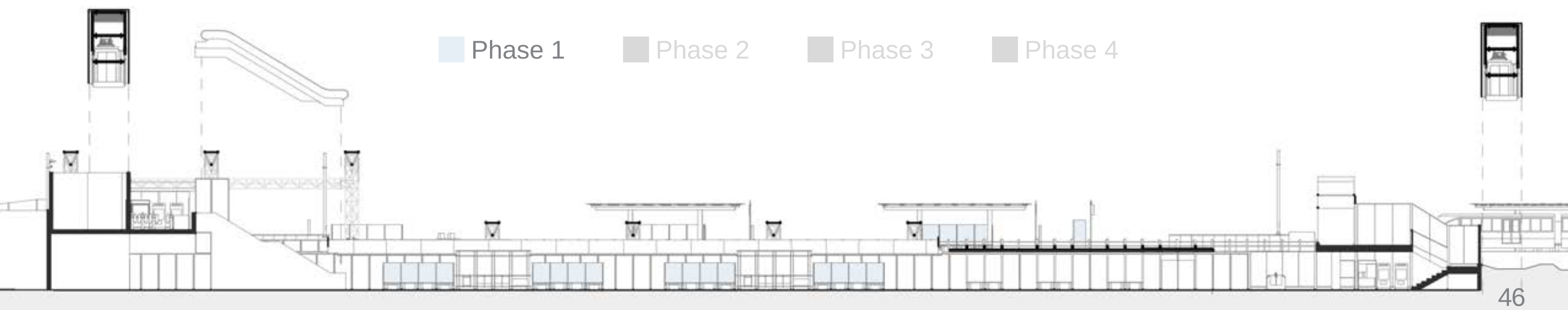
Phase 1: Inherit

Original Passenger Information Display's may be updated to address needs for real-time arrival data and accessible legibility; updating to modern, touch-enabled displays is needed to improve wayfinding and reduce passenger uncertainty.

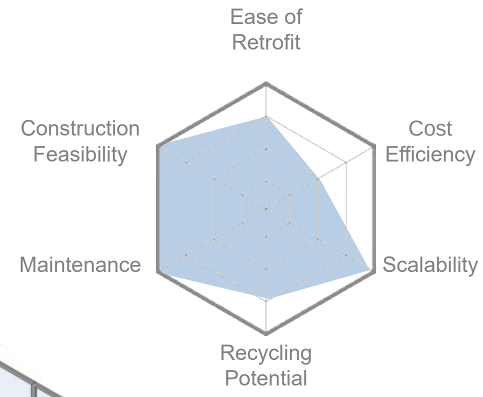


Precedents: Sweden wood-frame bus shelters; existing TransLink PID screens (Expo, Canada Line)
Gaps Addressed: Improves line-wide consistency for PID's and coordination between different modes of transit. Provides real-time communications across SkyTrain lines and reduces visual clutter from legacy or ad-hoc PID installations.
Life Cycle Planning: Display hardware is designed for short service cycles (5–10 years) and can be recycled through certified e-waste pathways. Enclosures and mounting frames have a 25+ year lifespan and can be reused in other transit contexts (e.g. RapidBus, BRT stations) or disassembled for materials recovery.

Standardized passenger information displays ensure real-time updates are accessible, clear, and uniformly located across all transit environments. These displays enhance wayfinding and reduce information gaps between modes or station types.

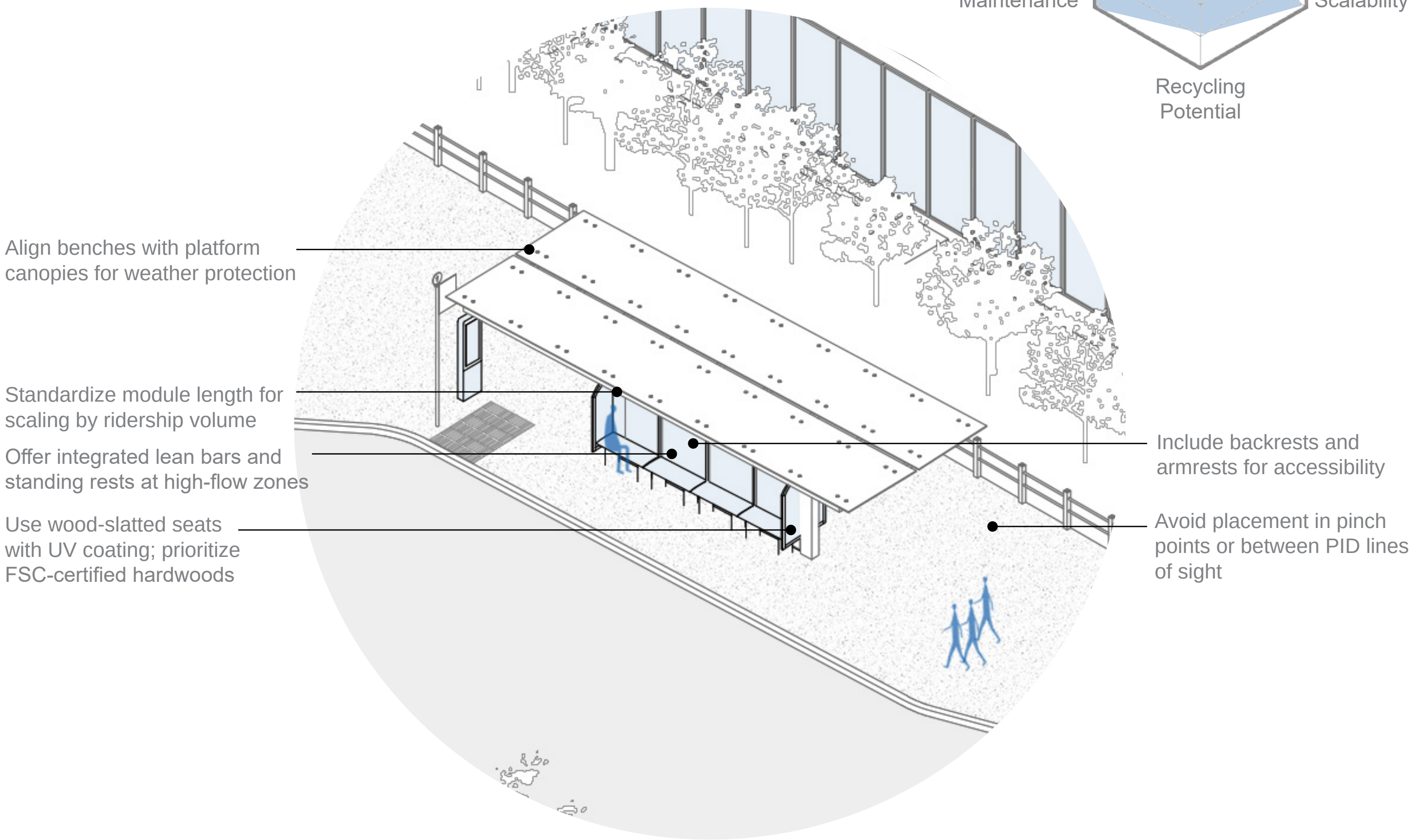


MODULAR FURNITURE KIT



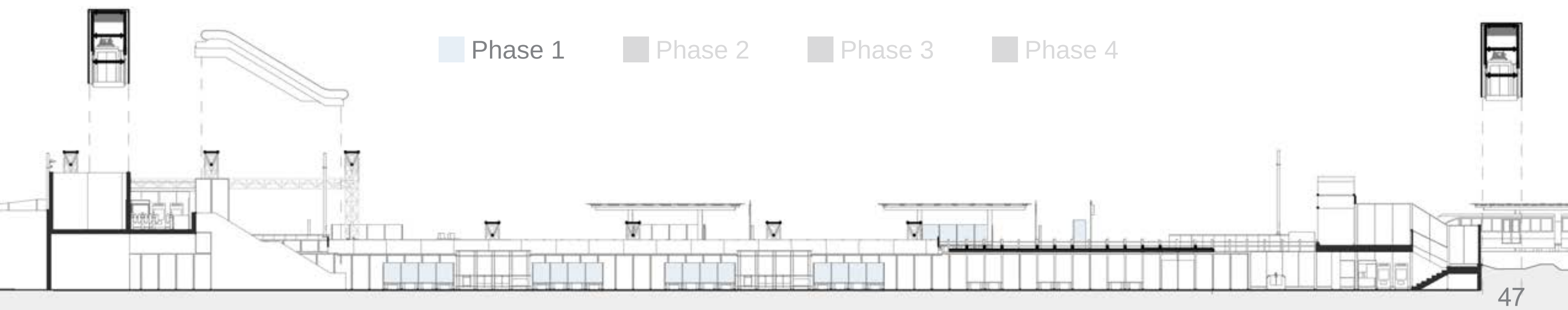
Phase 1: Inherit

Furniture may be updated to address needs for cane detection, tactile wayfinding, modular benches and lean-bars need to prioritize both comfort and ADA compliance.Furniture upgrades may be needed to accommodate a larger audience and wider range of passengers.

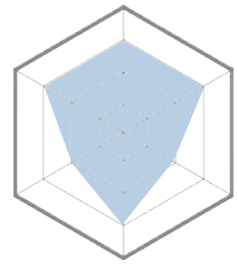


Precedents: Evergreen Extension benches; Sweden's modular wooden seating systems
Gaps Addressed: Improves visual consistency and comfort across transit environments.
Life Cycle Planning: Metal framing and anchor hardware (>25 years) is retained long-term. Slatted seating surfaces (10–15 years) are replaceable with minimal tools and can be remanufactured using recycled materials. Wood slats may be reclaimed for reuse or downcycled.

Pre-fabricated seating modules can be easily deployed and replaced to provide consistent comfort and identity across platforms. Materials and proportions are designed to align with existing canopy systems and ridership flow.

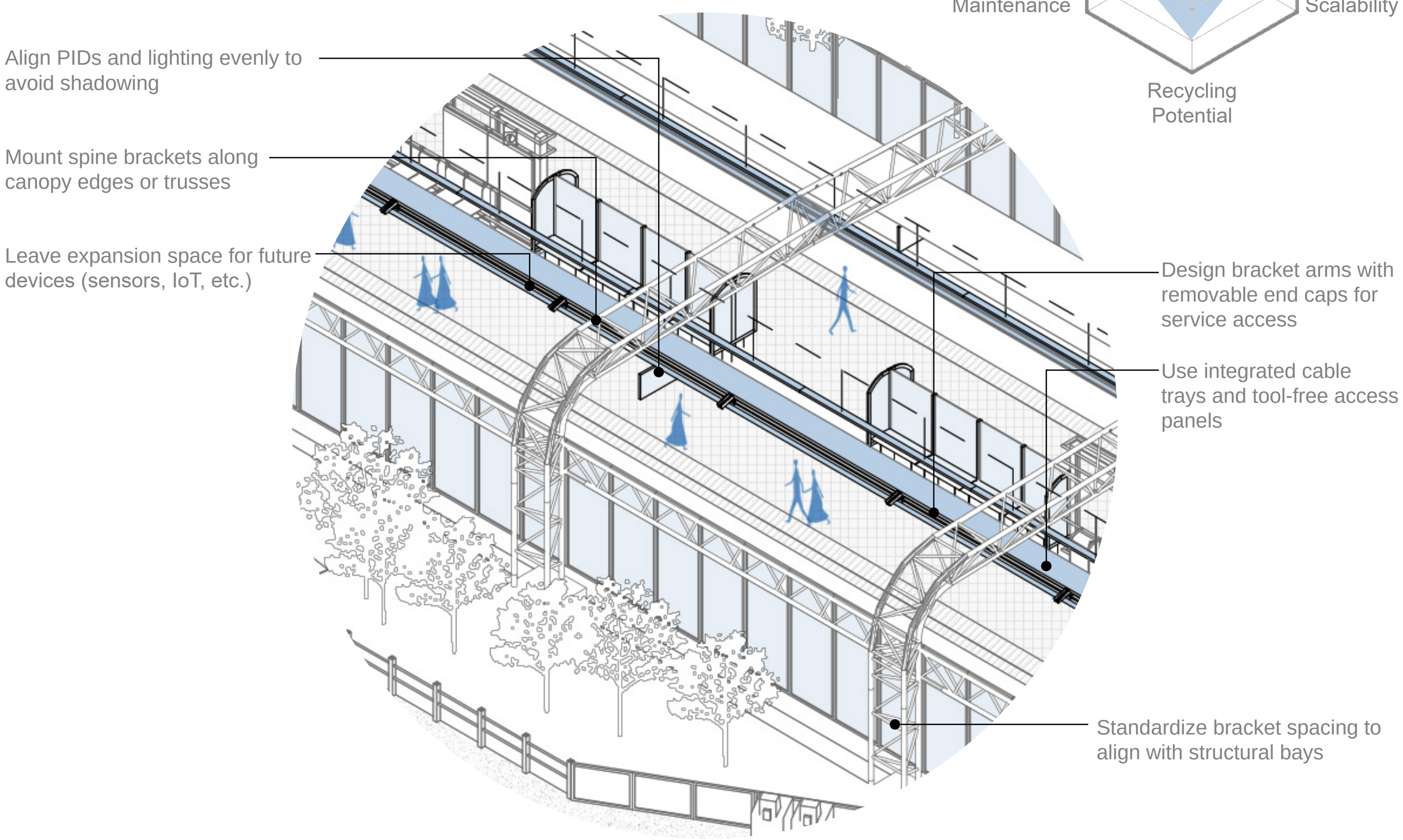


SERVICE SPINE BRACKET SYSTEM



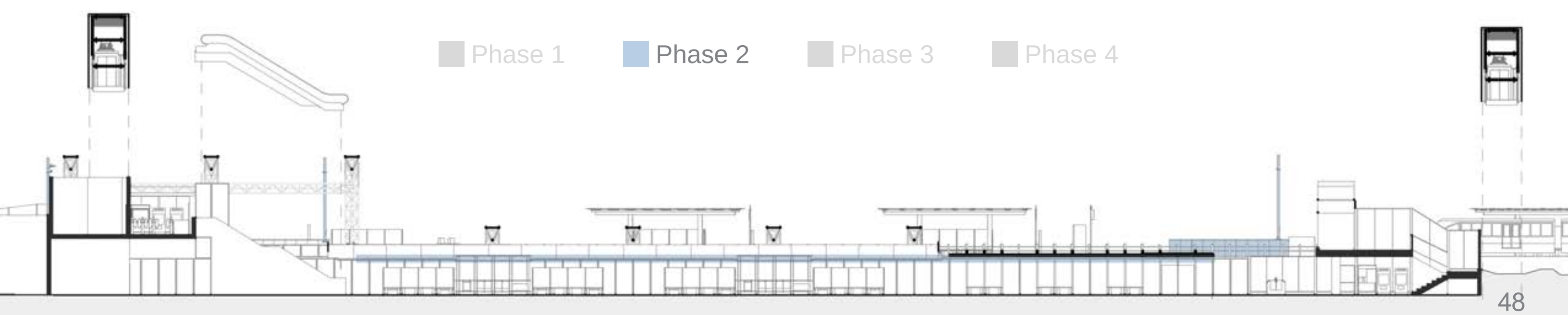
Phase 2: Adapt

Service spine bracket systems may be upgraded to address needs for a clear, modular infrastructure pathway that consolidates conduits, cabling, and PIDs into a single, maintainable spine, drawing on TransLink's SkyTrain Design Manual's principles for standardized service galleries.

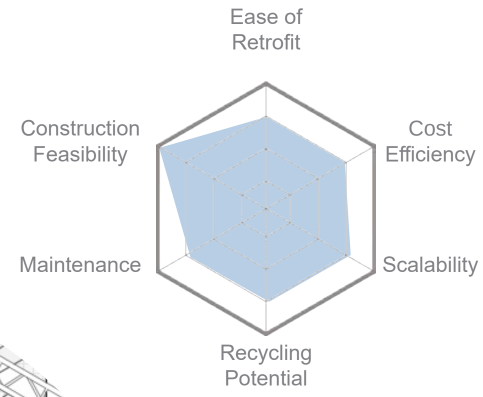


Precedents: Burquitlam Station (Evergreen Extension); Copenhagen Cityringen utility armature
Gaps Addressed: Improves system flexibility for lighting and digital services and simplifies lifecycle maintenance.
Life Cycle Planning: Bracket spine (50+ years) is retained across service cycles. Mounted devices like PIDs, lights, speakers, and cameras are replaced on 5–15 year intervals and are fully separable from the core spine.

Overhead service spines allow multiple devices(lighting, CCTV, signage, and sensors) to be mounted along shared brackets for coordinated upgrades. The system improves clarity, reduces clutter, and enables future digital infrastructure integration.

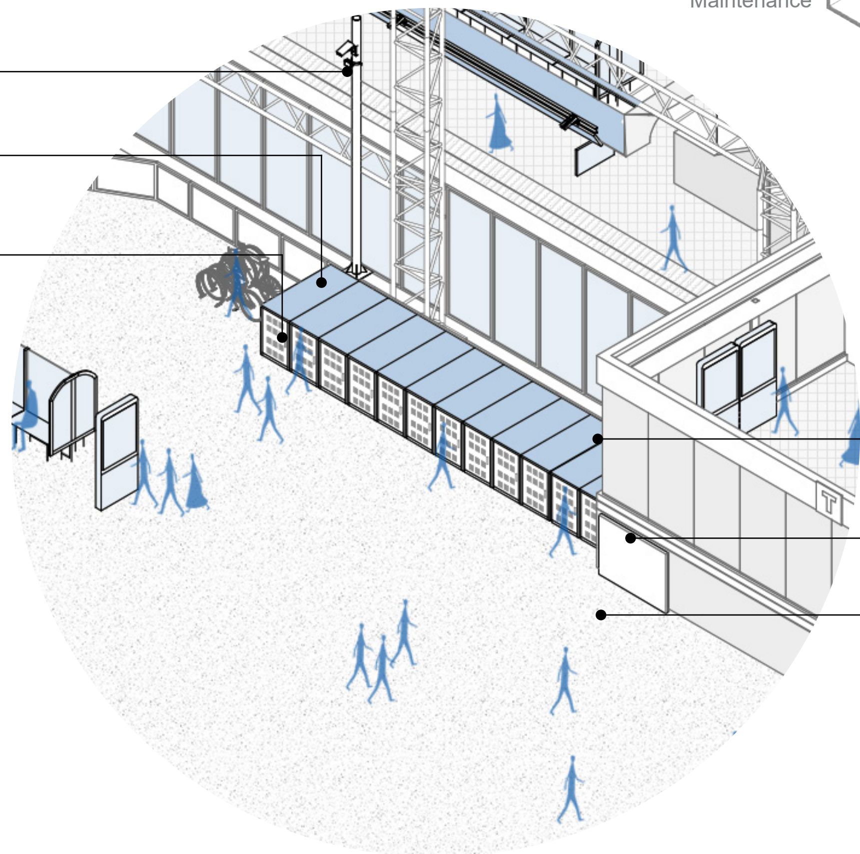


MODULAR BIKE LOCKERS



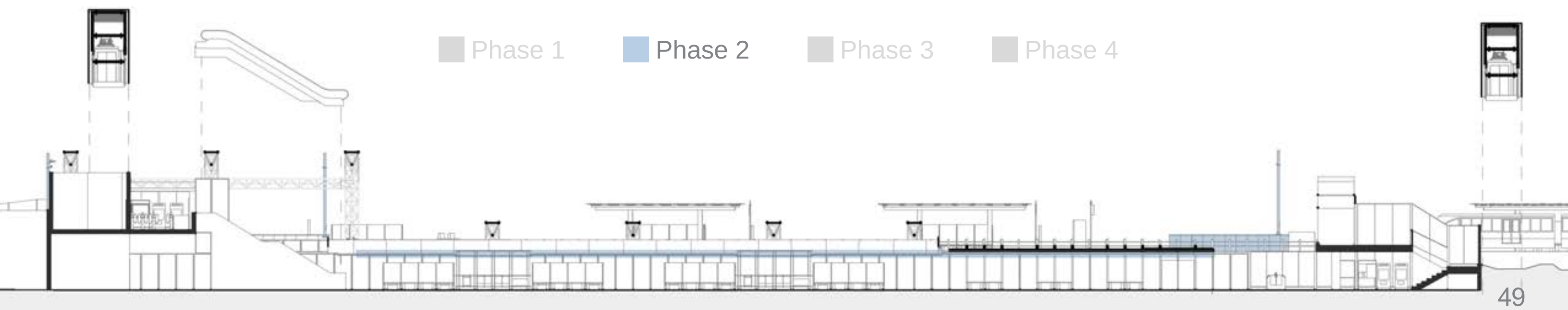
Phase 2: Adapt

Modular bike lockers may be installed to address needs for secure, weather-protected storage that can be easily scaled or relocated in response to shifting ridership patterns, in line with TransLink's Bicycle Facilities Design Guidelines.

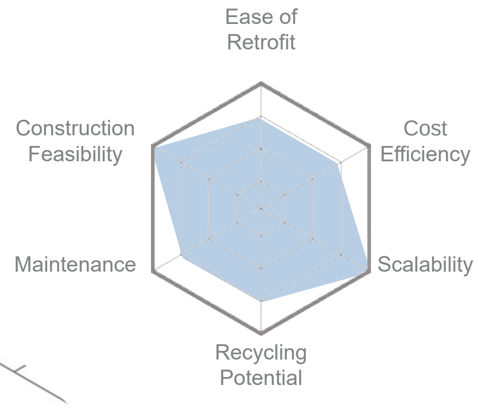


Precedents: Helsinki Transport bike pods; UBC Exchange modular lockers
Gaps Addressed: Improves active transportation integration across the system.
Life Cycle Planning: Bike locker enclosures (15–20 years) are designed for disassembly and replacement. Locking hardware and solar lighting are upgraded in 5–10 year cycles. Materials (steel, aluminum, wood) are recyclable or reclaimable.

Prefabricated bike shelters and lockers offer secure, weather-protected storage to encourage cycling as a first/last-mile mode. Modular sizing and translucent cladding allow placement flexibility while maintaining visual openness.

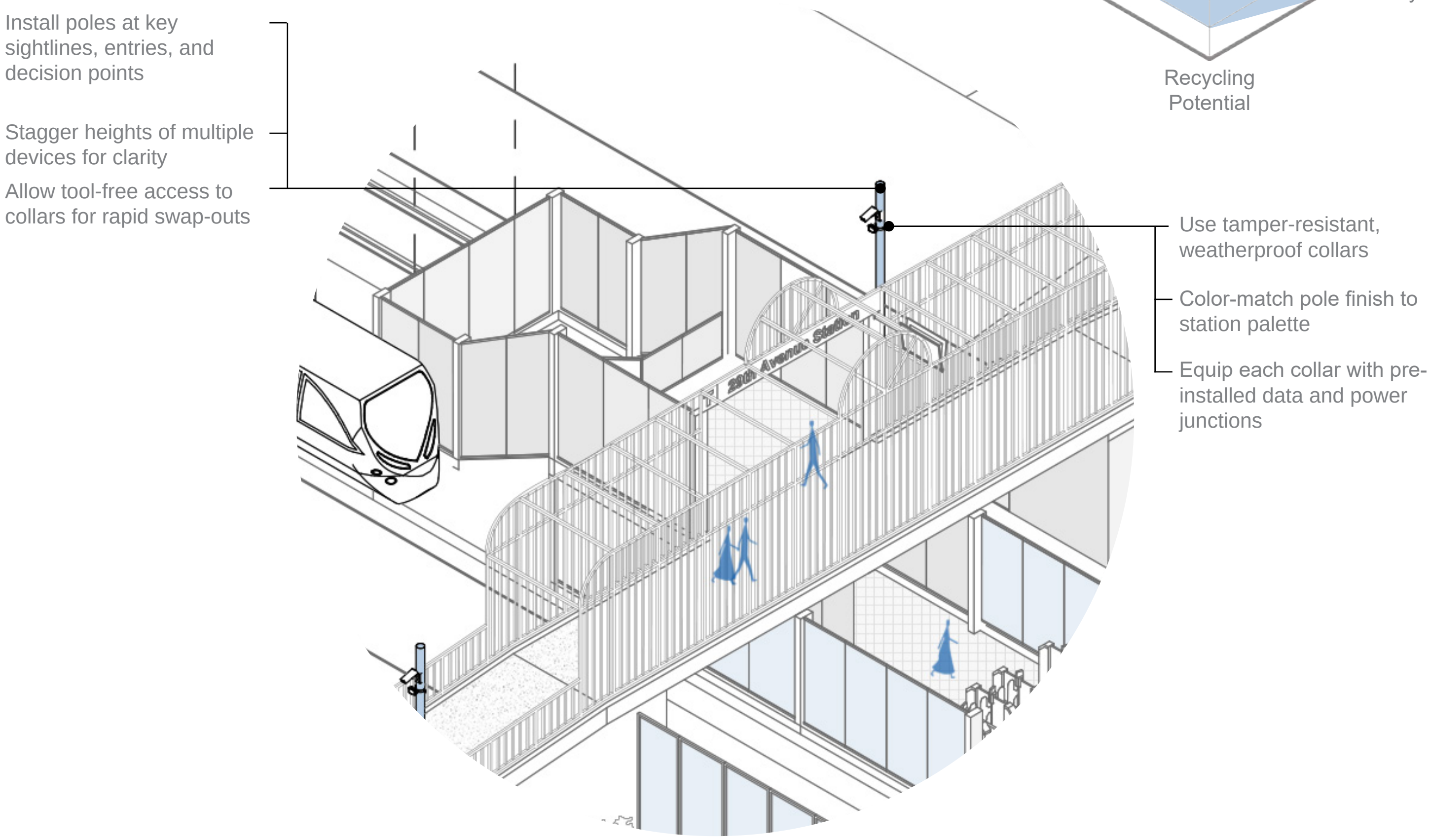


CCTV/ PA MODULAR MOUNTS



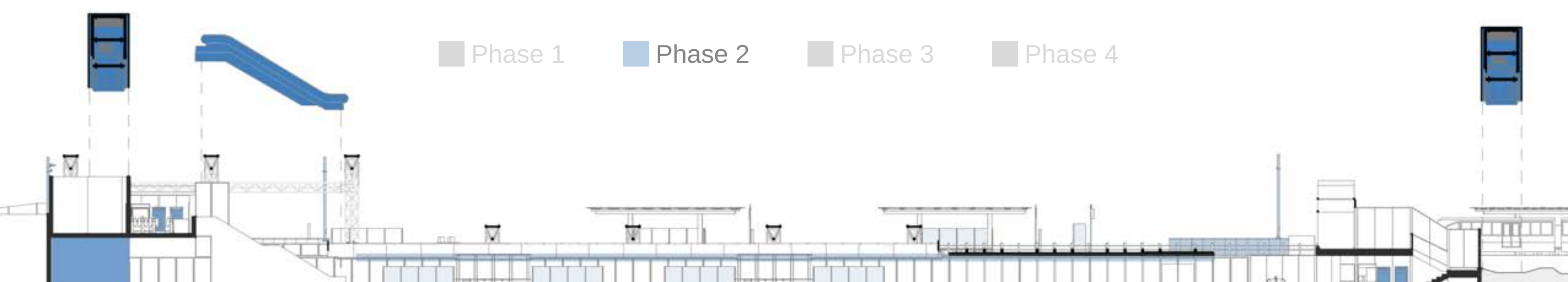
Phase 2: Adapt

CCTV / PA modular mounts may be upgraded to address needs for standardized, easily reconfigurable audio-visual coverage that can be relocated as platform layouts or security priorities change.

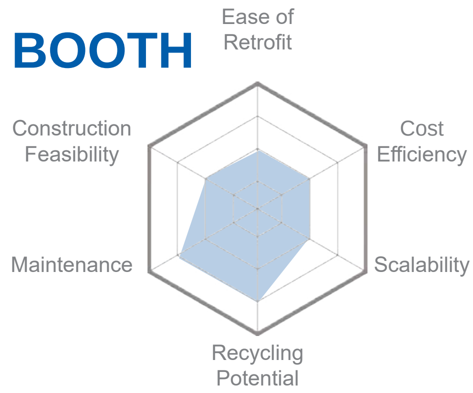


Precedents: Copenhagen Metro service poles; early Canada Line PA/CCTV posts
Gaps Addressed: Improves adaptability and ease of upgrade for surveillance and communication systems.
Life Cycle Planning: Structural poles (50+ years) remain in place while modular collars allow PA, CCTV, and sensors to be replaced on 5–10 year intervals. Removed components are separated for electronic recycling or reuse in secondary locations.

Plug-in collars on pole-mounted infrastructure allow PA systems, CCTV cameras, and sensors to be added, removed, or replaced without removing the structural pole. These collars make future tech upgrades seamless and reduce lifecycle waste.

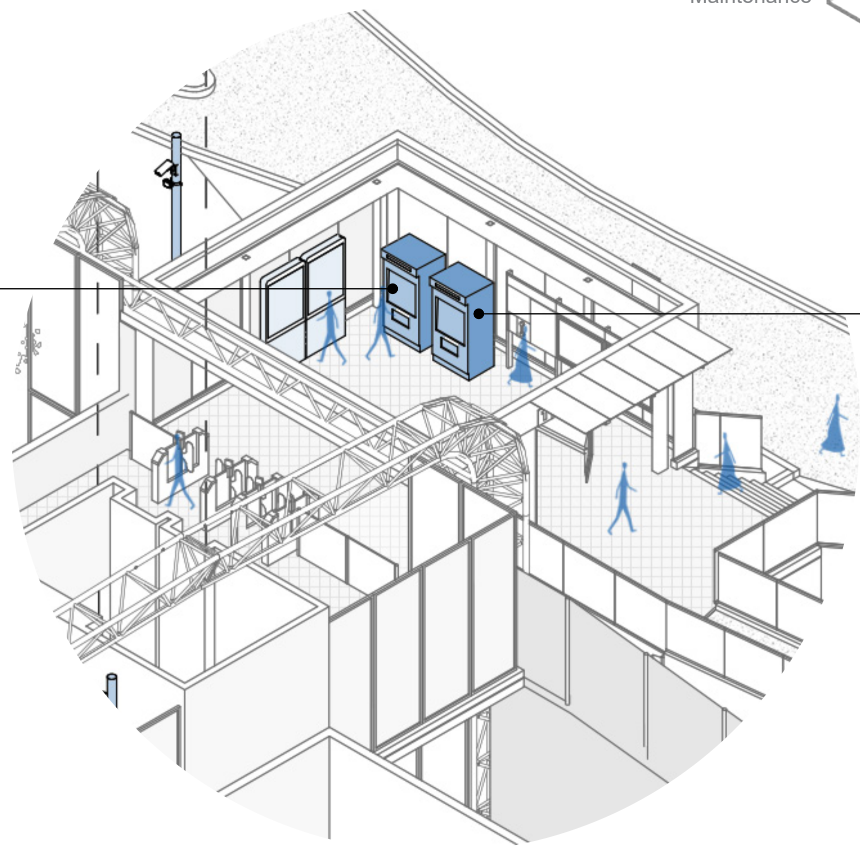


MODULAR RETAIL KIOSKS/ TICKETING BOOTH



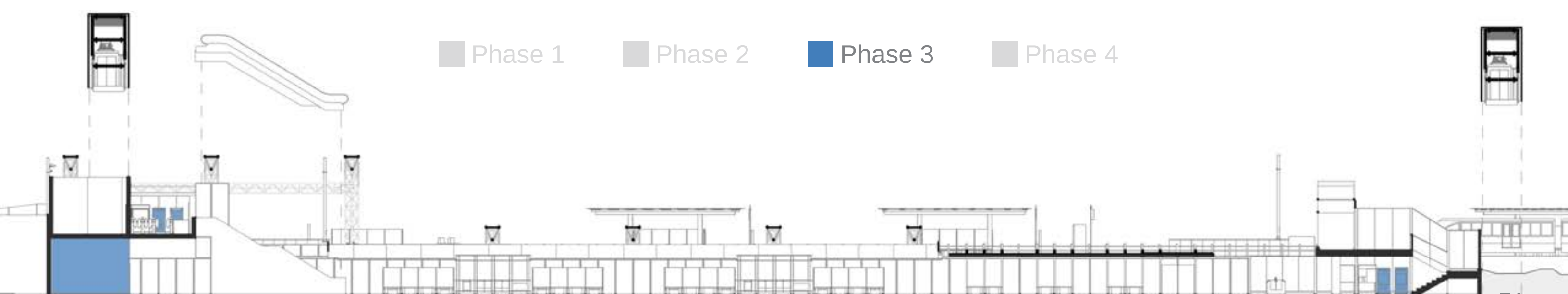
Phase 3: Upgrade

Modular retail kiosks / ticketing booths may be introduced to address needs for scalable passenger amenities that can be added or removed in response to ridership trends and retail partnerships.

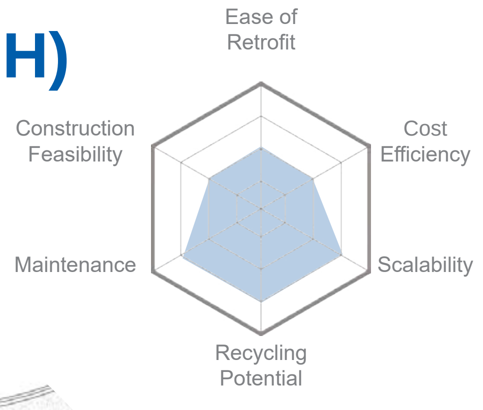


Precedents: VCC–Clark Compass pods; Doha Metro station retail modules
Gaps Addressed: Improves flexibility and reconfigurability of fare and retail programs.
Life Cycle Planning: Kiosk frames (25–30 years) are retained over multiple internal system refreshes. Panels, signage, and equipment replaced every 5–10 years. Units can be relocated or repurposed during station renovations.

Modular kiosks for Compass vending or station retail create flexible and reprogrammable service zones at key nodes. These units are designed for fast installation, operational adaptability, and seasonal or programmatic rotation.

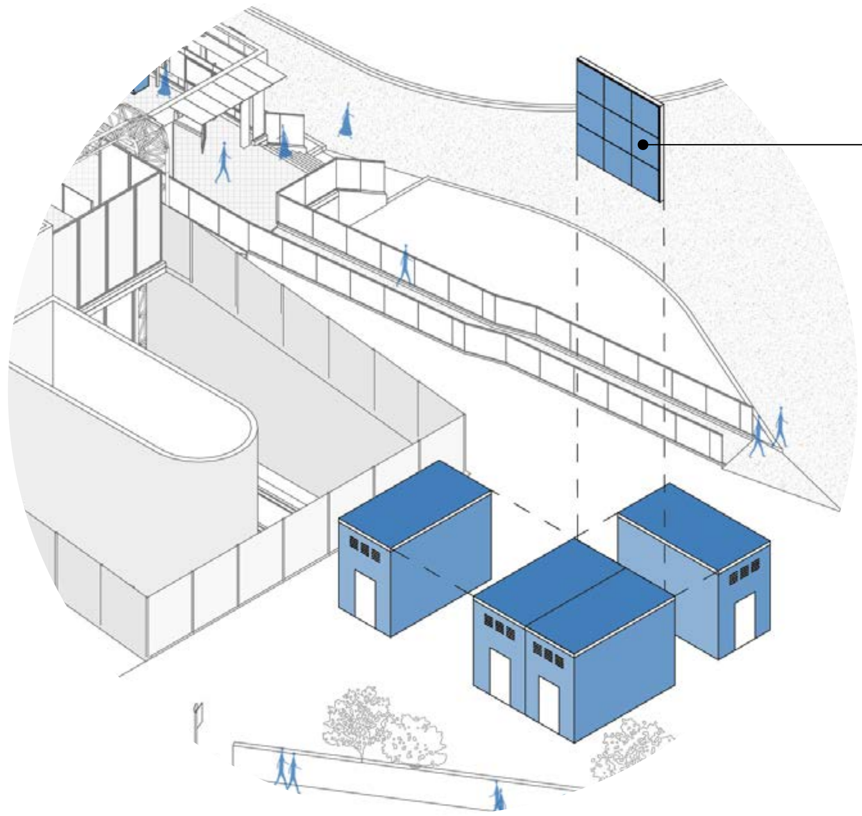


MODULAR UTILITY WALLS (BOH)



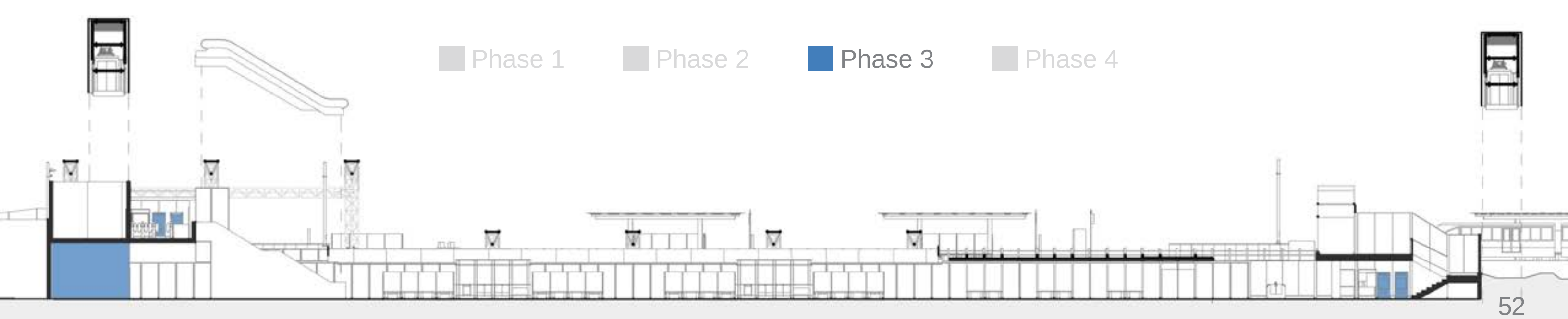
Phase 3: Upgrade

Modular utility walls may be installed to address needs for a repeatable back-of-house infrastructure spine (housing electrical panels, communications gear, and storage) in a single, maintainable wall assembly.



Precedents: Sydney Metro service walls; DfMA healthcare wall modules
Gaps Addressed: Improves MEP accessibility, maintenance efficiency, and BOH organization.
Life Cycle Planning: Core wall assemblies (50+ years) remain in place; internal chases and panels are reconfigurable every 10–15 years. Panel materials (GRC, metal, HPL) are recyclable or modularly swapped.

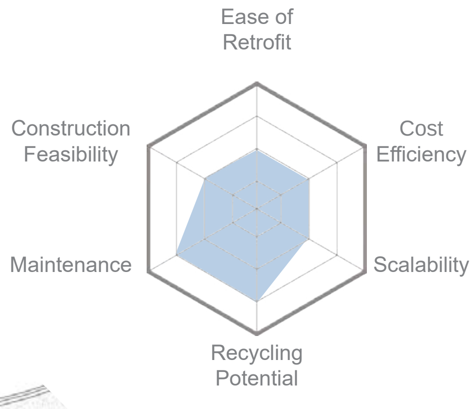
Service wall modules offer dedicated routing space for HVAC, electrical, and plumbing behind staff and operational zones. Their modularity allows clean, accessible upgrades while minimizing disruption to station operations.

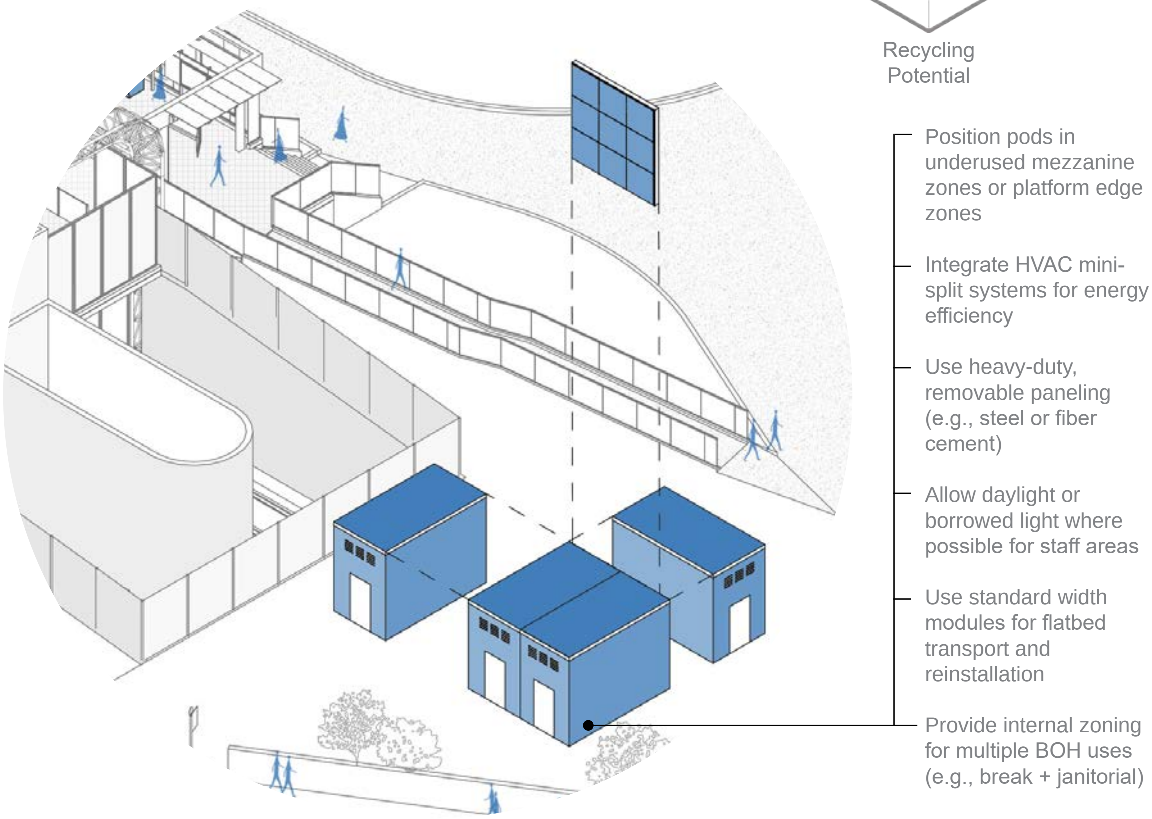


MODULAR BOH UNITS

Phase 4: Innovate

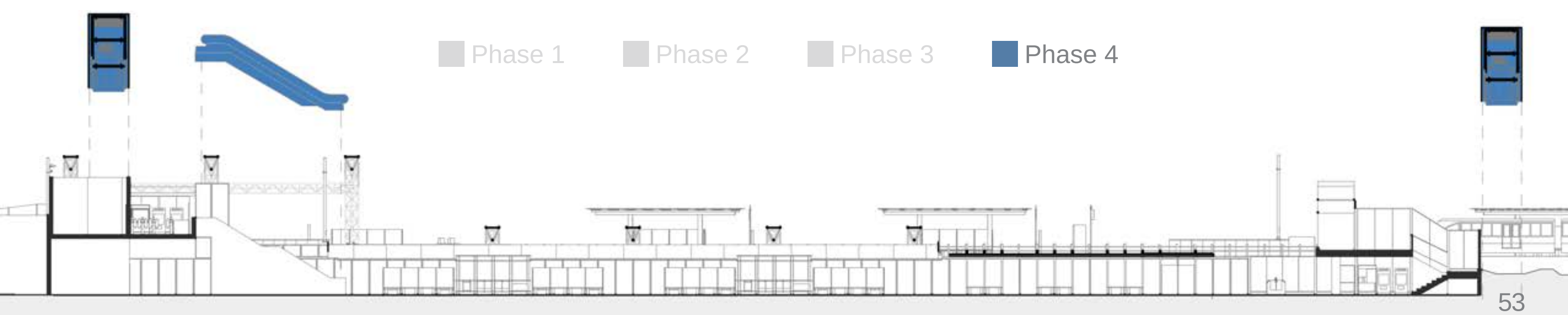
Modular BOH units may be deployed to address needs for compact, relocatable staff support rooms, providing rest areas, dispatch stations, and supply storage without permanent construction.



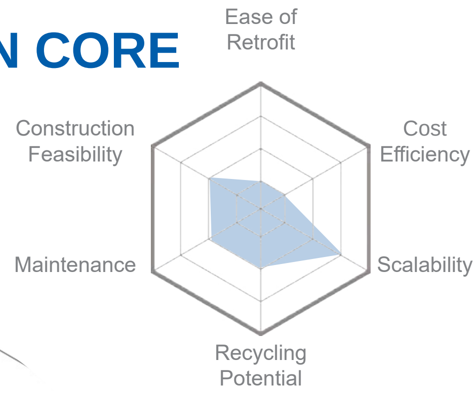


Precedents: Pro-Bel enclosures; prefabricated site service pods (industrial)
Gaps Addressed: Improves BOH performance, staff support, and operations in compact sites.
Life Cycle Planning: Pods are demountable and relocatable (30+ years); cladding, HVAC, and interior elements are updated on 10–15 year cycles. Panels are reused or replaced as layouts evolve.

Self-contained BOH pods provide staff support functions such as rest, cleaning supply storage, or dispatch in a compact, relocatable format. Designed to be dropped into mezzanines or platform edges, they upgrade staff conditions without permanent construction.

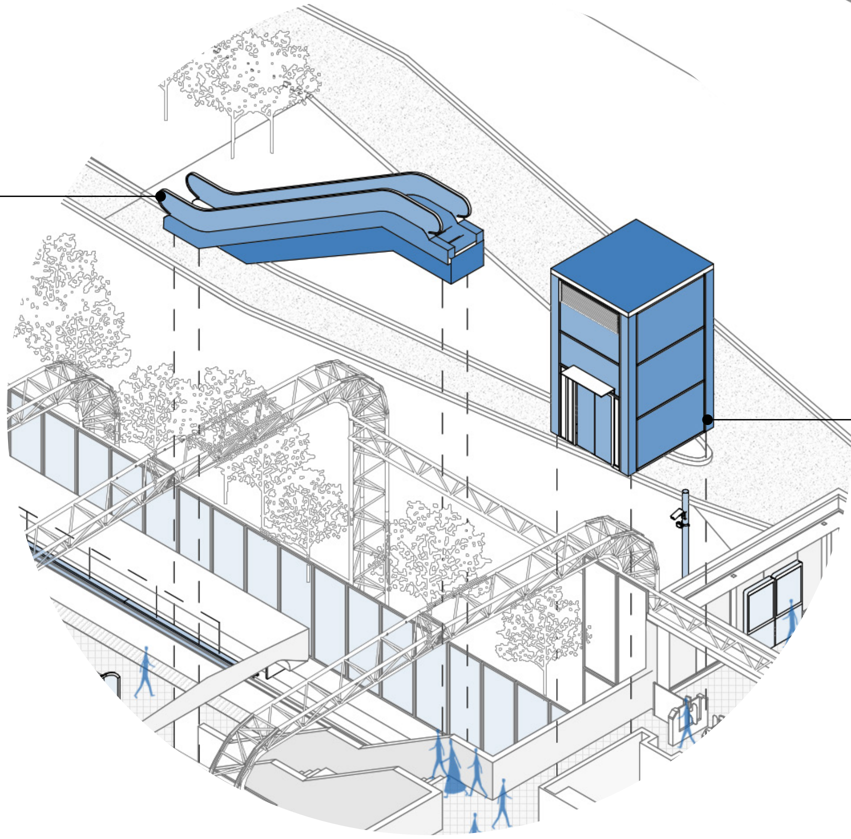


SYSTEM WIDE VERTICAL CIRCULATION CORE



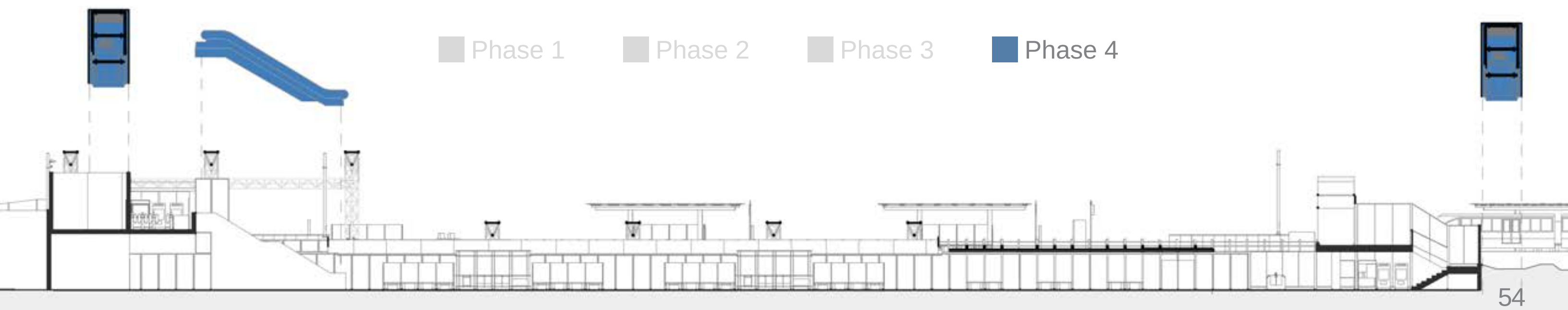
Phase 4: Innovate

System-wide stair / elevator cores may be standardized to address needs for consistent vertical-circulation modules that simplify design, procurement, and phased installation across multiple station types.



Precedents: Evergreen Extension precast stairs; UK DLR modular elevator towers
Gaps Addressed: Improves long-term adaptability of vertical circulation infrastructure.
Life Cycle Planning: Structural stair/elevator core (75–100 years) is designed for reusability and component separation. Interior railings, finishes, lifts, and glazing are replaced on 15–25 year cycles. Precast units can be reused or recycled into future builds. Upgrades will support emergency egress capacity changes through time.

Precast modular stair and elevator units are designed for repeatable use across station types. Their reusability allows for consistent vertical circulation strategies while supporting phased upgrades to railings, lifts, or finishes over time.



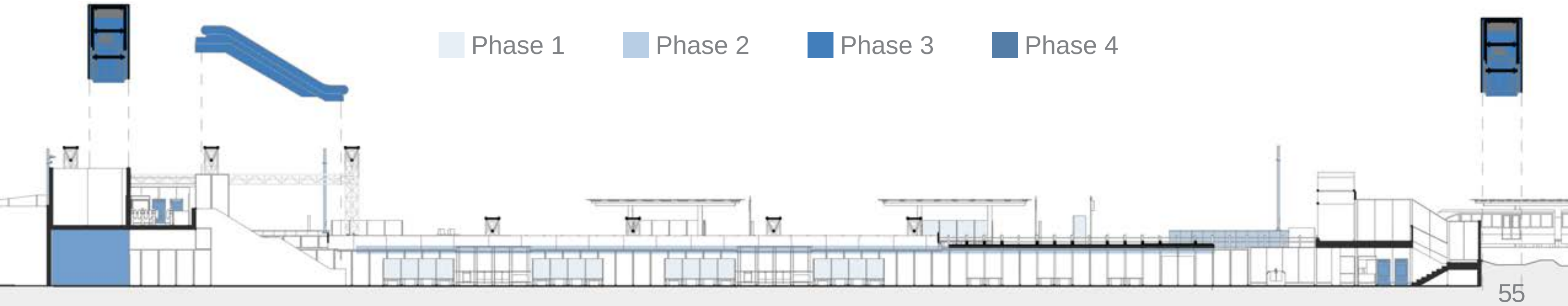
EVALUATION MATRIX SUMMARY

Suggestion	Ease of Retrofit	Cost Efficiency	Scalability	Recycling Potential	Maintenance	Construction Feasibility
System-wide PID Updates	3	2	3	3	3	4
Modular Furniture Kit	3	4	4	3	4	4
Service Spine Bracket System	3	3	2	3	2	3
Modular Bike Lockers	3	3	3	3	3	4
CCTV / PA Modular Mounts	3	3	4	3	3	4
Prefab Retail Kiosks	2	2	2	3	3	2
Modular Utility Walls	2	2	3	3	3	2
Modular BOH Units	2	2	2	3	3	2
System-wide Stair / Elevator Core	1	1	3	2	2	2

SUMMARY

The evaluation matrix on the following page summarizes the relative performance of each proposed retrofit intervention across six key criteria: ease of retrofit, cost efficiency, system-wide scalability, recycling potential, maintenance, and construction feasibility. These rankings provide a preliminary framework to compare modular strategies based on lifecycle alignment, implementation potential, and long-term adaptability.

It is important to note that while the matrix draws on site research, precedents, and professional insight, the evaluations are inherently qualitative and context-dependent. Further assessment,through costing studies, stakeholder feedback, and operational modeling,is recommended to validate and refine these scores. The matrix is intended as a strategic planning tool to help prioritize interventions and support decision-making in the early design phases of modular transit infrastructure upgrades.

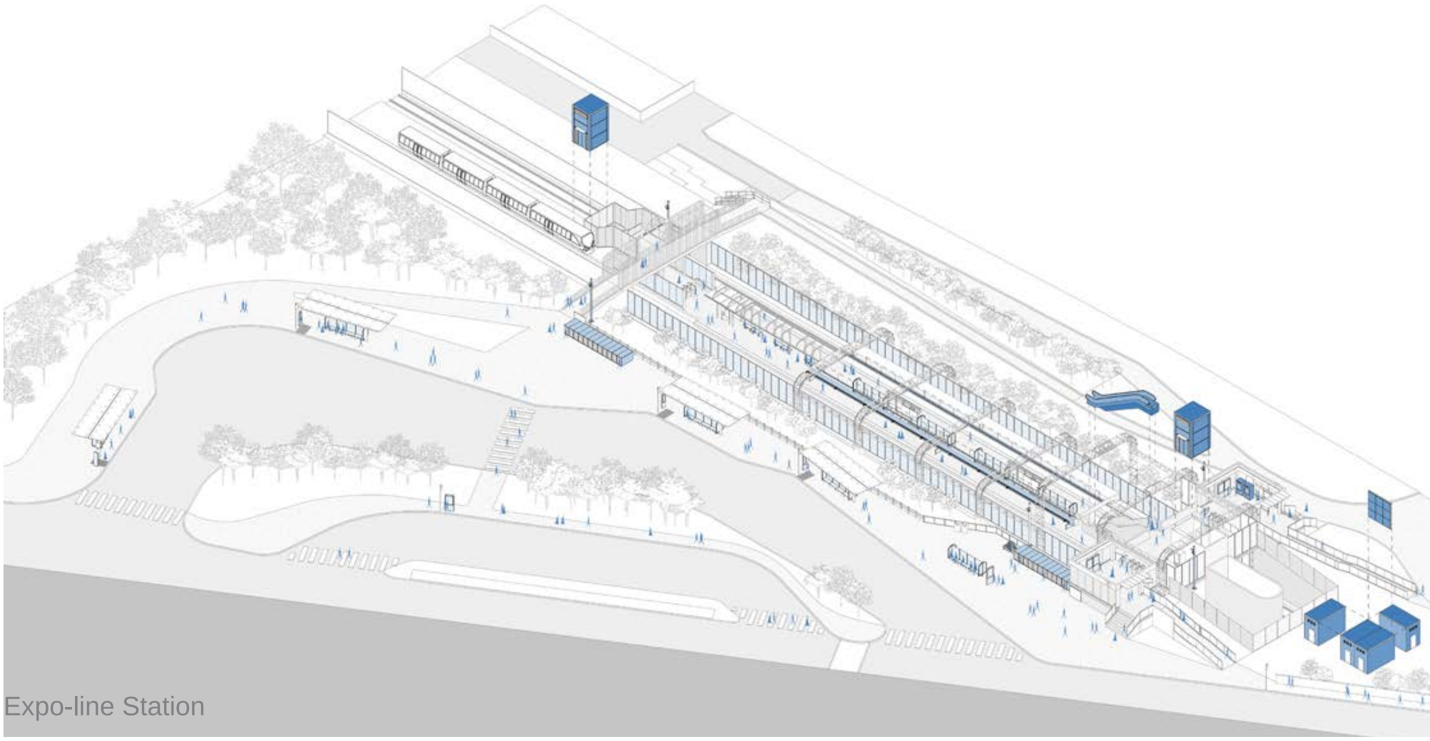


DESIGN SCENARIO

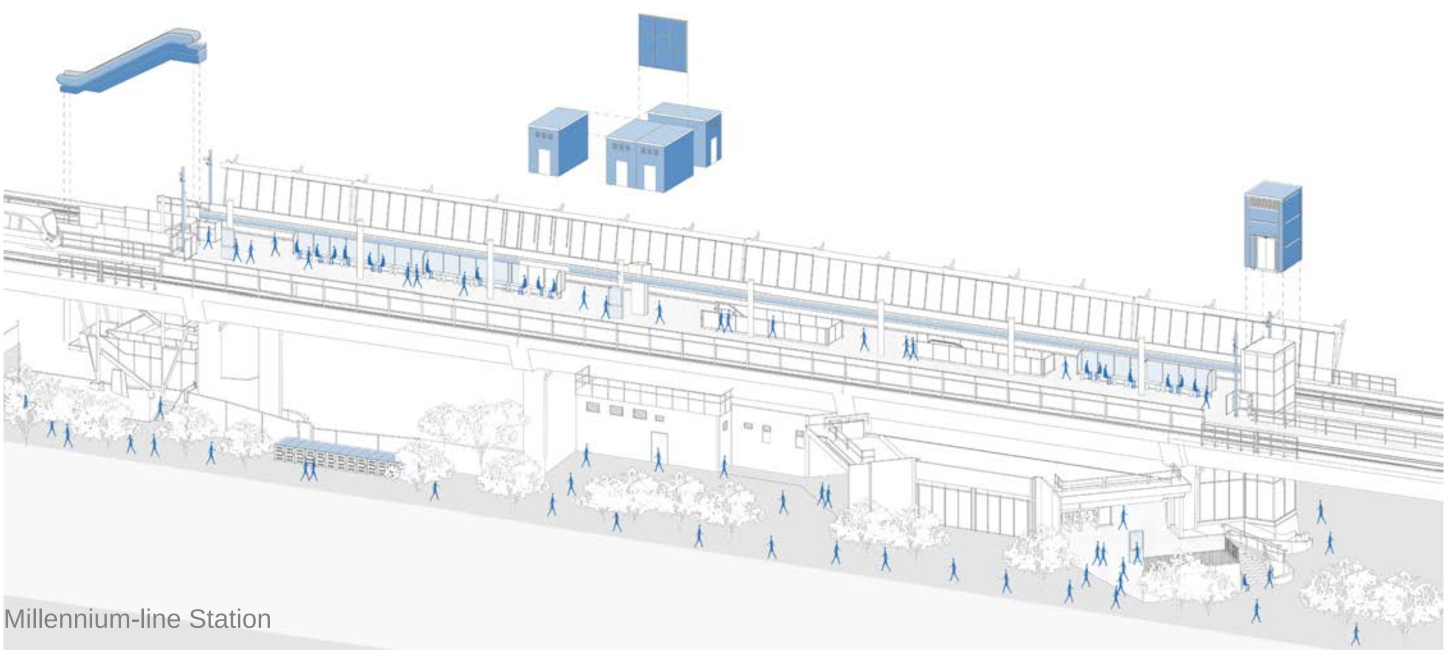
DESIGN SCENARIO

The design scenario illustrates a comparative application of the four-phase modular retrofit strategy across two SkyTrain lines: one legacy Expo Line station and one Millennium Line station. Though both stations are undergoing similar lifecycle-driven upgrades, their distinct baseline conditions (highly prescriptive vs. prescriptive-bespoke) affect how modular strategies are implemented and scaled.

By sequencing interventions across all four phases, the scenario underscores the value of modular strategies not only in extending the lifecycle of infrastructure, but also in accommodating architectural variability. The comparative example demonstrates that modularity is not a one-size-fits-all solution but a system of strategies adaptable to both legacy standardization and newer bespoke conditions.

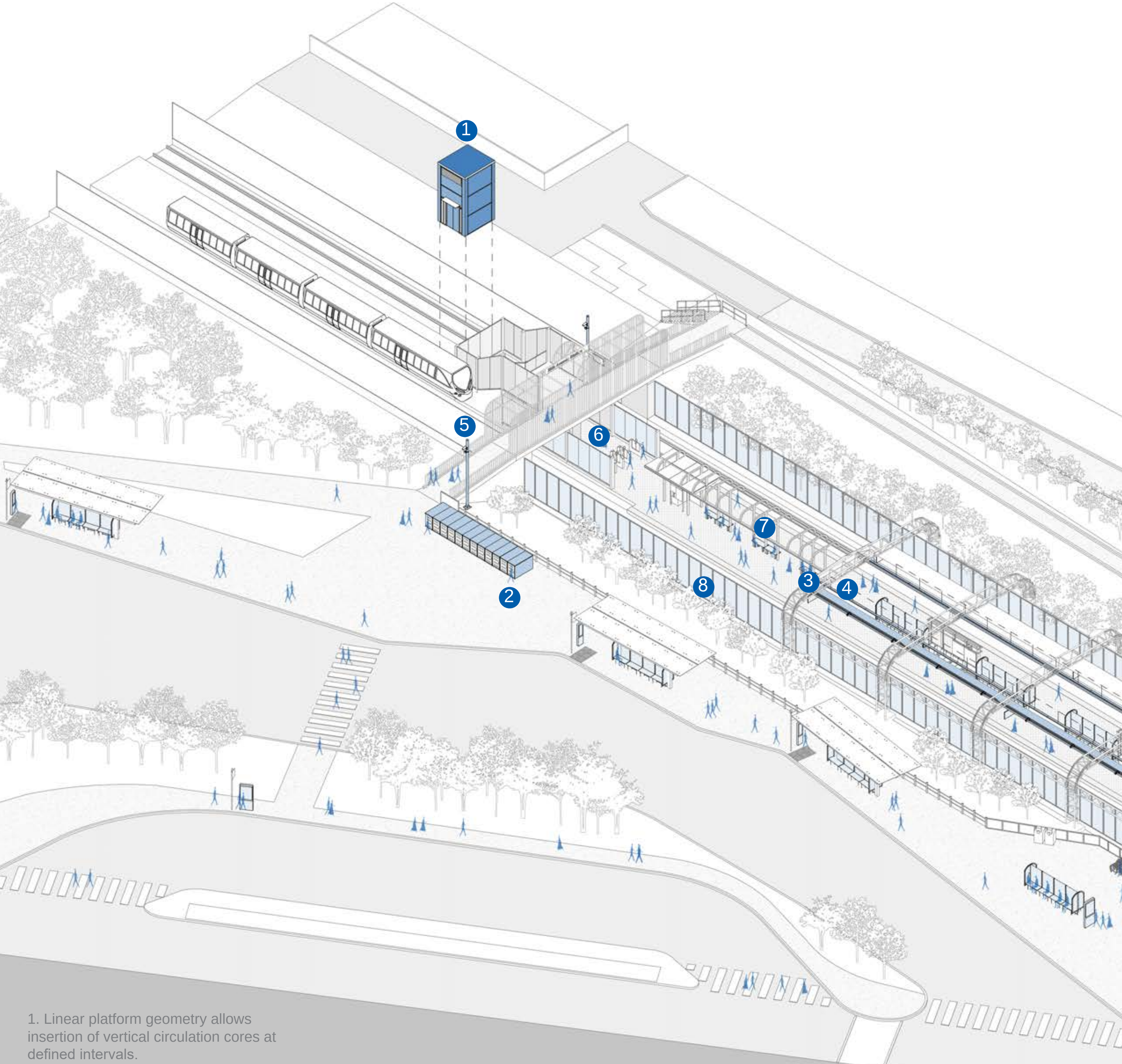


Expo-line Station



Millennium-line Station

Expo Station (highly prescriptive) - Opportunities



1. Linear platform geometry allows insertion of vertical circulation cores at defined intervals.

2. Standardized layouts across all stations allow for flexible placement and faster bike locker installation

3. Uniform canopy system enables consistent PID mounting and cabling routes.

4. Uniform canopy systems allows service spine bracket system to be installed consistently across multiple stations.

5 Poles and electrical pathways are already available and consistent across the line, making integration of modular collars easier.

6. Early Expo typologies have underused open zones, allowing for modular retail kiosks to be inserted near fare gates or mezzanines with consistent layouts

8. Standard platform widths and canopy supports allow direct bolt-on installation for furniture upgrades

9. Many expo line stations follow a consistent grid and placement for BOH systems- allowing uniform retrofit to be easier

Expo Station (highly prescriptive) - Challenges

1. Seating zones are often constrained by narrow side platforms and legacy clearances.

2. Retrofitting cores may conflict with adjacent built elements (e.g. retail, ticketing).

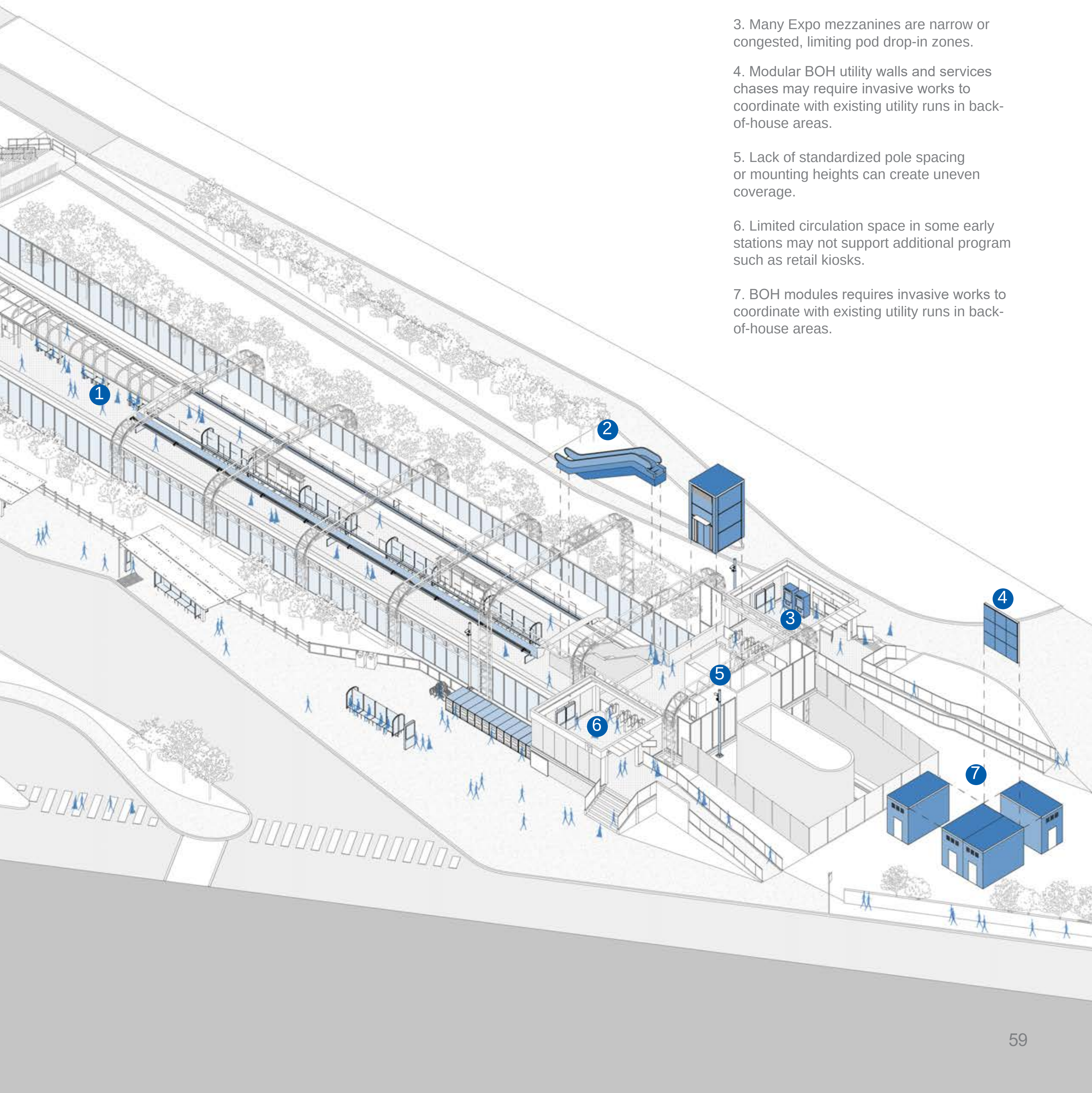
3. Many Expo mezzanines are narrow or congested, limiting pod drop-in zones.

4. Modular BOH utility walls and services chases may require invasive works to coordinate with existing utility runs in back-of-house areas.

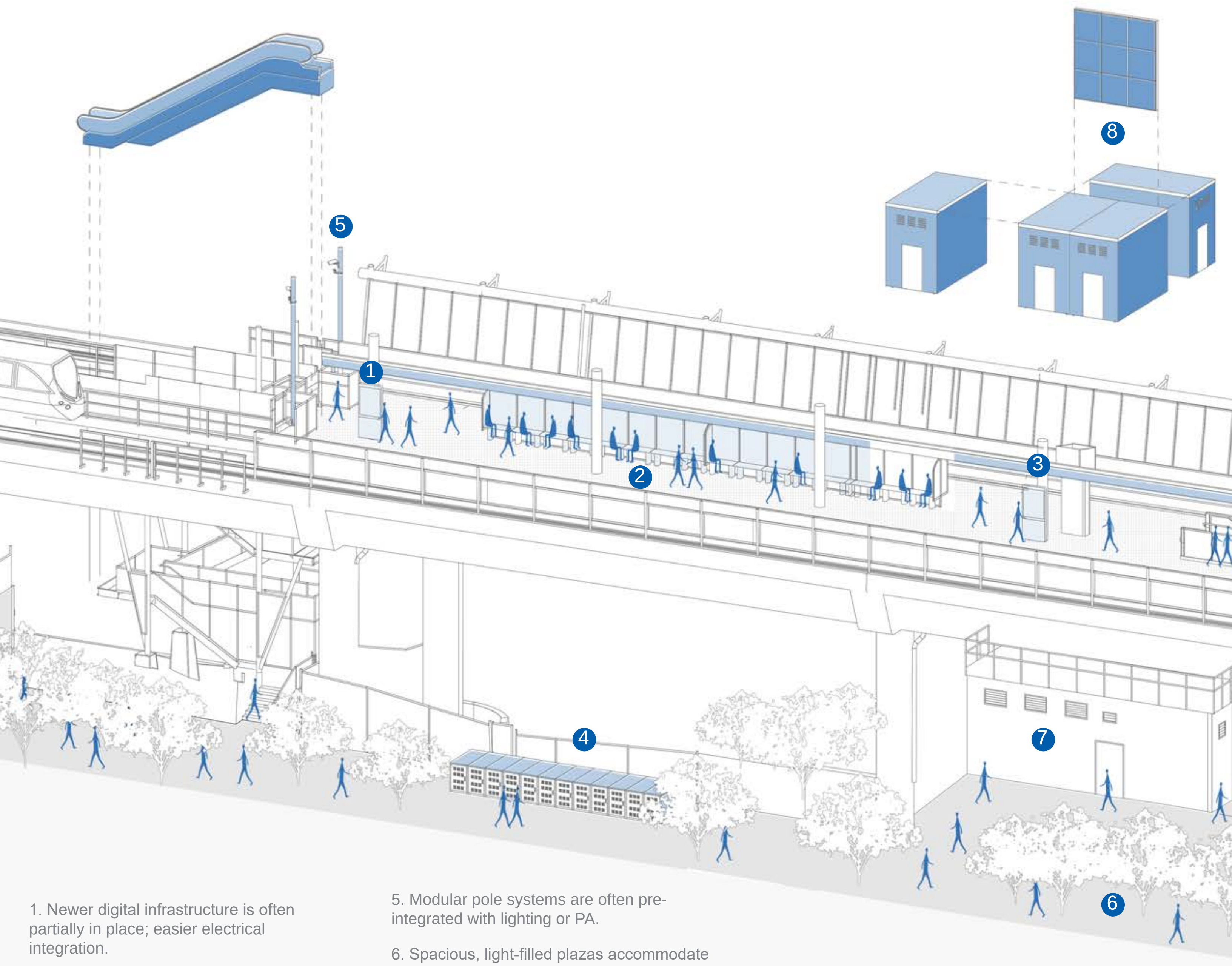
5. Lack of standardized pole spacing or mounting heights can create uneven coverage.

6. Limited circulation space in some early stations may not support additional program such as retail kiosks.

7. BOH modules requires invasive works to coordinate with existing utility runs in back-of-house areas.



Millenium Station (prescriptive-bespoke)- Opportunities



1. Newer digital infrastructure is often partially in place; easier electrical integration.

2. Stations often have ample plaza or concourse space to integrate new furniture flexibly.

3. Some stations already have integrated lighting/signage elements; upgrades can enhance existing tech.

4. Designed with pedestrian and bike access in mind; better context for first/last-mile facilities.

5. Modular pole systems are often pre-integrated with lighting or PA.

6. Spacious, light-filled plazas accommodate rotating or seasonal retail kiosks well.

7. Mezzanines and back-of-house areas sometimes designed with open ceilings, allowing easy retrofit..

8. Some Millennium stations have underutilized spaces that suit small staff units or modular lockers.

Millennium Station (prescriptive-bespoke)- Challenges

1. Each canopy and sightline layout is unique, complicating standard PID positioning and visibility angles.

2. Furniture placement must be tailored to unique architectural features or asymmetrical platform conditions.

3. Inconsistent canopy framing and exposed roof geometries complicate universal bracket installation.

4. Many stations integrate stairs and canopies sculpturally, limiting plug-and-play retrofit feasibility.

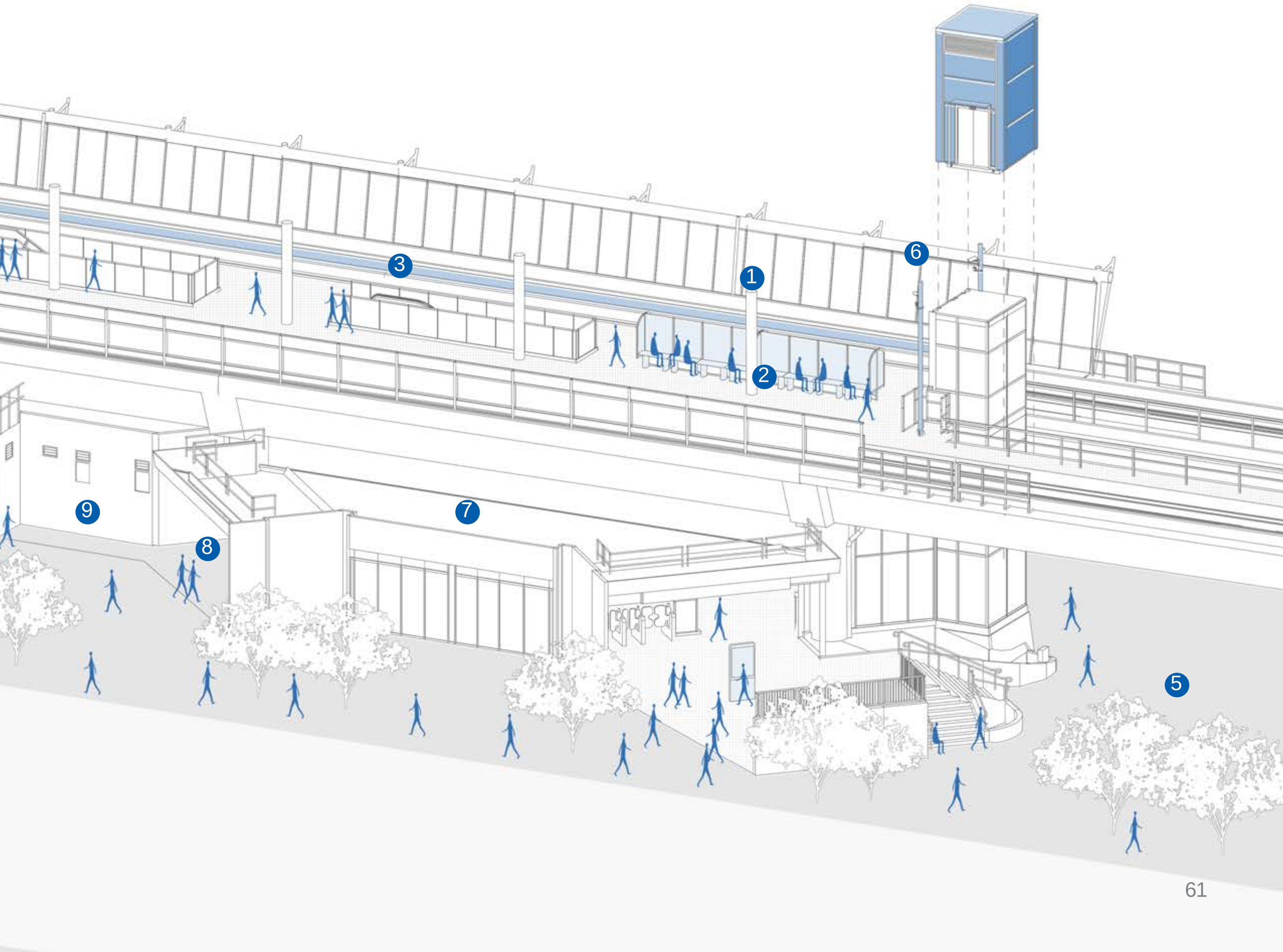
5. Terrain and landscaping around bespoke stations vary widely, requiring custom pad and access grading for moduar bike lockers.

6. Architecturally integrated poles or wall-concealed systems are harder to access or modify.

7. Unique floorplates and stair positioning create irregular zones unsuitable for modular unit footprints.

8. Irregular wall runs or structural interruptions complicate standardized utility chase installation.

9. BOH layouts are tailored per site; lack of repetition reduces ability to deploy standard pod types.



CONCLUSION

SUMMARY

Station Type	Spatial Standardization	Canopy Modularity	Vertical Circulation	BOH Expandability	Public Realm	Tech Readiness	Lifecycle Coordination	Site Complexity	TOTAL / 40
Expo Line (1980s)	5	4	4	3	3	5	5	2	**31**
Millennium Line (2000s)	3	2	3	3	5	3	3	4	**26**

Based on a detailed review of retrofit challenges and design variability across SkyTrain systems, the following analysis compares Expo Line and Millennium Line stations using a multi-criteria scoring system. This approach evaluates how forgiving or resistant each typology is to systematic modular upgrades, acknowledging that each type has different strengths under different conditions.

HIGHLY PRESCRIPTIVE

Strengths:

- The original Expo stations were strictly conceived on a 1.25 m kit-of-parts grid, making structural, canopy, and furniture modules easily interchangeable, so upgrades (e.g. escalators, Passenger Information Displayss, Back of House) can be phased in with minimal bespoke detailing.
- Systems (wiring, conduits, PIDs) are hidden behind soffit panels, allowing quick "drop-in" service access without visible breakdown of finishes, ideal for routine tech refreshes.
- Shared hoop-truss profiles and standardized finishes across stations build a clear network identity and yield procurement and maintenance economies.
- Early station designs were built with the intent to be expanded (eg. extendable platform lengths)
- Station designs accommodate system-wide lifecycle upgrades, such as PID updates or vertical cores, due to existing provisions from original design standards.

Challenges:

- The exoskeletal structure and exposed steel surfaces demand regular recoating to resist weathering and corrosion.
- Without strict enforcement, abandoned mounts, old conduits, and redundant monitor brackets often remain concealed in ceilings, complicating future renovations.
- Early stations provided minimal seating and tactile wayfinding, requiring targeted furniture and accessibility retrofits.

PRESCRIPTIVE-BESPOKE

Strengths:

- Bespoke canopy forms, finish palettes, and "running-frieze" wayfinding create strong local character and aid passenger orientation.
- Exposed conduit and mounting arms can speed up small equipment additions without ceiling demolition.
- Larger and more open station plazas and concourses offer generous spatial margins for integration of modular bike shelters, retail kiosks, or BOH pods.
- Better integrated with local urban design and landscape, offering potential for more context-responsive modular deployments.

Challenges:

- Inconsistent structural grids (1.25m ocassionally abandoned, especially in canopy) and unique canopy attachments mean nearly every retrofit (canopy, PIDs, BOH) requires custom bracketing and engineering.
- The finite space in the Millennium "running frieze" often fills quickly, forcing surface-mount workarounds that look ad-hoc.
- Stations respond to specific site topography (e.g., sloped or curved entries), complicating deployment of standardized stairs, elevators, or spine brackets
- Inconsistent BOH layouts make system-wide deployment of service walls or pods more logistically intensive.
- Disparate ceiling heights and exposed ribs necessitate extensive hoarding and staging areas, making even lighting or finish updates labor-intensive.

FINAL SUMMARY

This proposal presents a modular design toolkit to support phased, lifecycle-based upgrades of TransLink's transit stations. The research identifies typological and line-wide patterns through site visits and archival analysis, and introduces a retrofit toolkit that address operational, user interface, environmental, and modular priorities. Drawing from global precedents, the toolkit offers a timeline based phasing strategy aimed at improving long-term maintainability, supporting accessibility, and unifying the visual and functional language across Metro Vancouver's transit facilities.

Project Methodology Summary

The project began by identifying the need for consistent modular design strategies across TransLink's transit stations. Initial research drew from existing TransLink documents such as the BCAP Final Report and the SkyTrain Design Manual, highlighting a need for lifecycle upgrade planning, particularly in highly-prescriptive settings such as Skytrain stations. Site visits to six representative stations (one original and one upgraded) from each major SkyTrain line, and three bus stop facilities (one from each typology) enabled the scholar to assess modularity across diverse conditions, with attention paid to how current infrastructure facilitates or hinders adaptation.

This research was expanded through analysis of five international case studies: Sydney Metro Northwest, Copenhagen's Cityringen, the Doha Metro, Sweden's wooden modular bus stops, and the New York Street Furniture Project. These systems demonstrated strong internal consistency, achieved by organizing stations and bus stops into early typologies and deploying coordinated design strategies. Building on these insights, the proposal introduces a two-part Design Applications section. The first part evaluates how modular strategies perform across different transit typologies and introduces a flexible toolkit of nine prefabricated interventions. While the second phase walks through a compare and contrast between two design scenarios of varying flexibility (prescriptive & bespoke)Together, they provide a reflection on the design quality across TransLink's network through the lense of adaptability- which is key to designing modular architecture.

Toolkit goals

- Apply a lifecycle-based phasing strategy that guides modular upgrades from short- to long-term.
- Support early, low-disruption interventions in Phase 1 (Inherit) and 2 (Adapt) to address immediate needs with minimal impact.
- Enable flexible retrofits in Phase 3 (Upgrade) through modular toolkits that respond to aging infrastructure.
- Introduce new modular systems in Phase 4 (Innovate) to support long-term operational adaptability and BOH performance.
- Ensure scalability and consistency across all station types and transit modes.

Moving Forward

- The toolkit's flexible structure emphasizes the importance of engaging a broad spectrum of stakeholders, including residents, community organizations, local authorities, and transit experts, in the design process to ensure inclusivity and effectiveness.
- Incorporating lived experiences into decision-making will also ensure that interventions are tailored to meet diverse needs effectively.
- The proposal and assessment of each design typology with the design toolkit aims to provide a foundational framework for future upgrades and the ongoing enhancement of transit station design.
- A staged implementation approach, organized by typology, urgency, and lifecycle horizon, can reduce service disruption while strengthening long-term infrastructure resilience.

Reflections

Future transit facility retrofits should continue to balance modularity with sensitivity to both context and long-term operational needs. Conversations with designers revealed that earlier, more prescriptive station designs tend to be more forgiving for retrofits, underscoring that the strength of modularity lies in its capacity for adaptation without disrupting the broader system. In contrast, later bespoke stations (while offering lessons in detailing such as bracketed connections or plug-and-play components) often resist system-wide upgrades due to their one-off, context-specific nature. While these site-specific approaches may be effective for isolated interventions, they pose challenges for network-wide modernization. Ultimately, the toolkit emphasizes the importance of planning for future flexibility from the outset, supporting both incremental upgrades and the long-term evolution of transit infrastructure.

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