Elevated Structure for the Green Line in Calgary's Centre City

A Discussion Paper

North Central LRT Study

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City of Calgary

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Revision 2

Stantec

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Introduction

The Stantec Team completed an analysis for the downtown alignment of the Green Line in 2014 April. Up to the time of this analysis, there were two major requirements for the downtown portion of the Green Line:

1. Provide an interlined or otherwise very direct connection between the north and southeast segments of the Green Line; and
2. Provide high quality connections to the existing 7 Avenue South LRT corridor and the future tunneled 8 Avenue LRT corridor.

With few constraints, a wide range of alternatives were developed as part of the downtown analysis. However, at that time elevated options were not considered. At the time of the analysis, it was assumed that any grade separation would be achieved through tunneling as opposed to elevated structures. The reasons behind this assumption were that underground stations would provide customers with protection from the elements, reduce snow removal efforts, avoid interference with Calgary's overhead walkway network (the +15 network), and preserve natural light on the sidewalks, which is generally considered important in winter cities like Calgary.

More recently, the Stantec Team was requested to discuss the feasibility of an elevated structure in downtown in the interest of reducing construction costs, reducing the impacts of flooding, and preserving roadway capacity for surface transit vehicles, and automobiles. Such a structure would presumably cross over the +15 network, 7 Avenue LRT line and the CPR tracks on a viaduct structure, connecting to the approved alignment for the Green Line Southeast, on 10 Avenue S.

This report will first discuss how elevated structures have been integrated into the downtowns of other cities and how an elevated structure for LRT supports and does not support the Centre City Plan and the Centre City Mobility Plan. Then it will consider the feasibility of an elevated structure in terms of existing infrastructure, roadway geometry, shadows, noise, stations, safety, maintenance, Green Line continuity, cost and public acceptance.

Urban LRT Networks

Elevated LRT lines are very common, although less so in Central Business Districts (CBD). Cities generally opt for tunneling in CBDs due to limited roadway space for vehicles and pedestrians and limited airspace. However, elevated structures might be considered when ground conditions or utility work renders tunneling costs prohibitive but grade separation is still required in the interest of pedestrian safety and traffic operations. The following are some discussions of how elevated structures have been used in various cities, including Calgary:

Vancouver

Metro Vancouver's Canada Line travels underground through the CBD and most of the City of Vancouver, but travels above grade through the City of Richmond. The following images provide an indication of the scale of the elevated structures, how they are integrated into the street, and what they look like. **Figure 1** shows a portion of the Canada Line alignment through Richmond, BC, which runs fairly low to the ground. In downtown Calgary, elevated rail would need to be significantly higher off the ground in order to travel over the existing overhead walkway network. The pillars in Richmond appear to be almost as wide as a full lane of traffic, although as shown in the figure, they are placed in a sidewalk. **Figure 2** shows a station for an elevated alignment in Richmond. It matches the look of the adjacent building, and as an extension of that space, provides an inviting place. However, it takes up more space at street level than a station in downtown Calgary would be able to occupy, unless space was available for such a structure off of the street.

Figure 1: Canada Line Through Richmond

Figure 2: Canada Line Station in Richmond

Chicago

Downtown Chicago is famous for The Loop: the overhead train tracks that support five rail lines. **Figure 3** provides a typical view of The Loop from street level. In some locations, columns are placed on the sidewalks, and in others, they are placed within the roadway. Traffic lanes are striped to accommodate the columns in the street. It is notable that the structure casts a shadow over most of the street, including both sidewalks. Noise and dust from the overhead rail operation are continuous throughout the day. Passengers access the stations via the sidewalks, and this provides the same level of convenience as a subway. Many of these elevated stations have been equipped with elevators to improve accessibility.

Figure 3: Under The Loop in Downtown Chicago

Source: Google Maps

Seattle

While more of a tourist attraction than a transit service, Seattle's monorail provides an example of an elevated structure in a downtown area. **Figure 4** shows how a structure can be placed within a street to minimize the blockage of sunlight. Of particular note in **Figure 4** is the station in the upper left corner of the image, as it is integrated into the adjacent building (Westlake Center). **Figure 5** provides an image of the structure from street level and how the piers fit within the roadway cross section.

Figure 4: Seattle Monorail from Above

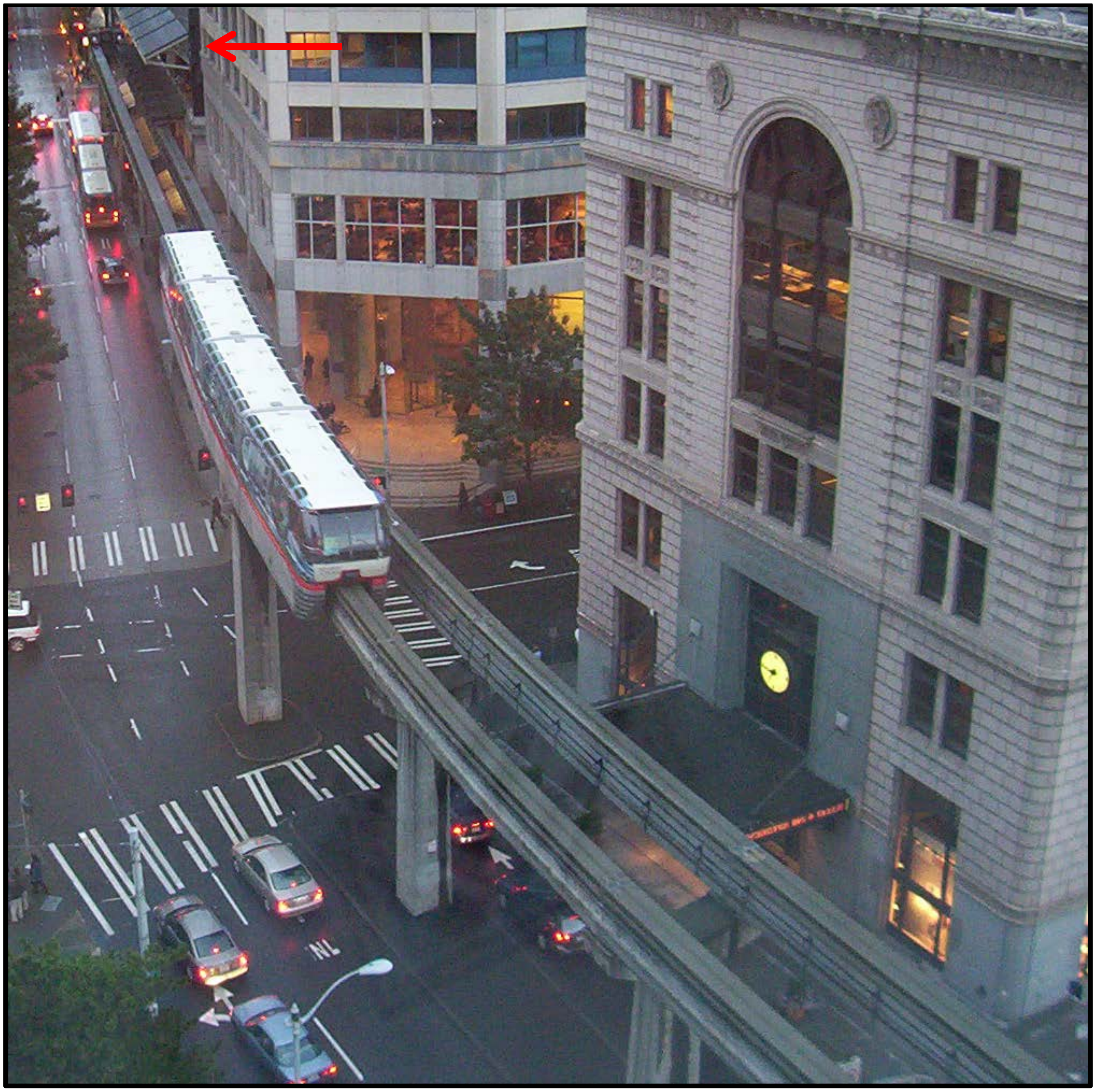


Figure 5: Seattle Monorail From Below

Bangkok

Bangkok has an elevated rail line in its Central Business District called SkyTrain. **Figure 6** shows an image of the alignment under construction and how it will fit into the roadway. This image gives a useful indication to Calgary of the scale of the piers that would be required if an elevated alignment had to rise two levels above the roadway level in order to pass over the overhead walkway structures. In this image, it appears that plenty of light reaches the sidewalks, but this is due to the fact that the street is very wide and can accommodate three lanes of traffic in each direction.

Figure 7 provides a reminder that elevated train systems can serve as a component of a city's brand and/or a source of advertising revenue as a result of their visibility. The short wall over the tracks themselves also indicates that there has been some noise mitigation included in the design.

Figure 6: Bangkok SkyTrain Piers

Figure 7: Bangkok SkyTrain

Calgary

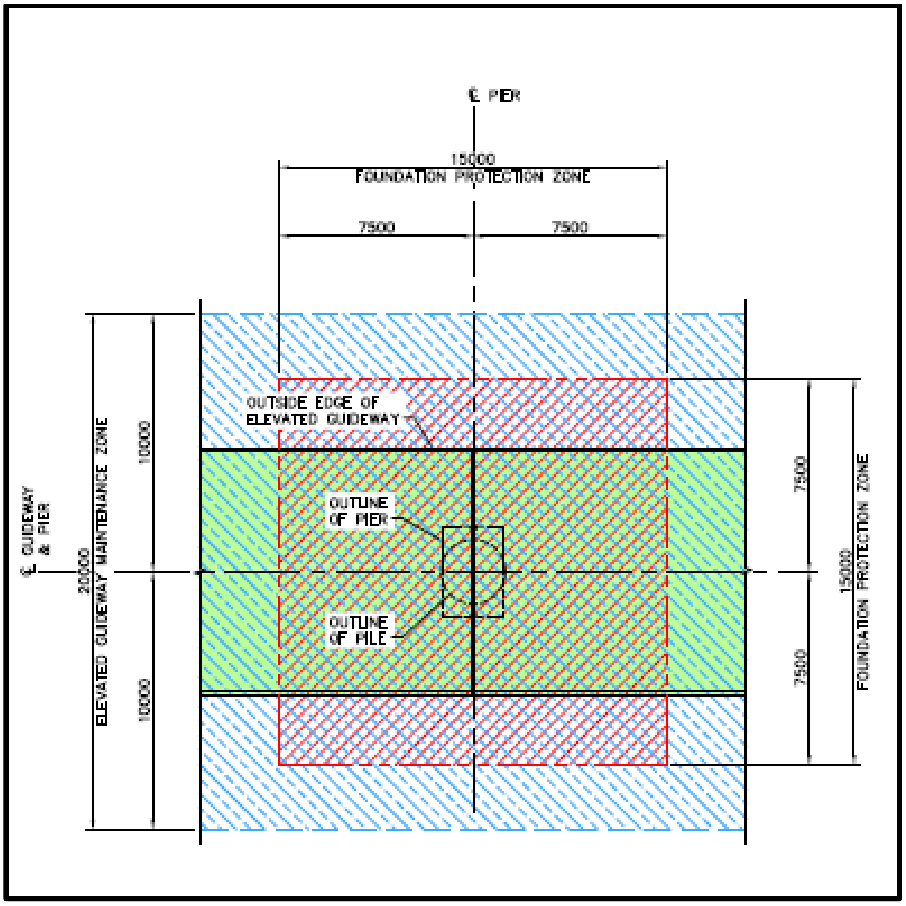
Calgary's most recent addition to its LRT system, the West LRT line, included an elevated station and structure to the west of the Centre City. The station, shown in **Figure 8**, cost $21 million and the elevated structure, which was 1.3 km in length, cost $41 million. The structure and station had to be elevated in order to provide grade separation from the CPR tracks. The clearance provided was 15 metres.

Figure 8: Sunalta Station on the West LRT Line

Photo courtesy Joe Schreiber

Figure 9 is the design for a typical pier along the West LRT line. It shows that at minimum, a 20 metre wide clearance is needed for the elevated structure itself, as well as for a maintenance zone. While the piers appear to be fairly narrow, the pier foundations are shown to be 15 metre by 15 metre blocks underneath the ground. Such dimensions suggest that the alignment would be able to fit within the downtown, which has a ROW width between 21 metres and 25 metres, but it would be a tight fit in some locations. The size of the foundations also indicates that the utility relocations would be a major effort.

Figure 9: Typical Elevated Guideway Foundation and Maintenance Protection Zone



Planning Context

Centre City Plan (2007)

The Centre City Plan describes a vision for downtown Calgary as it evolves and the residential population grows. When the Centre City Plan was developed, the assumption was that North Central LRT would use the existing 7 Avenue Transitway. This would require construction of the 8 Avenue South tunnel to accommodate the Northwest to South LRT line. The Centre City Plan also shows the Council-approved alignment for the Southeast LRT in a north-south tunnel under 2 Street SW. Some assumptions have changed since the development of the plan, however the principles it describes are still of use in assessing the consistency of an elevated structure in the CBD with existing plans.

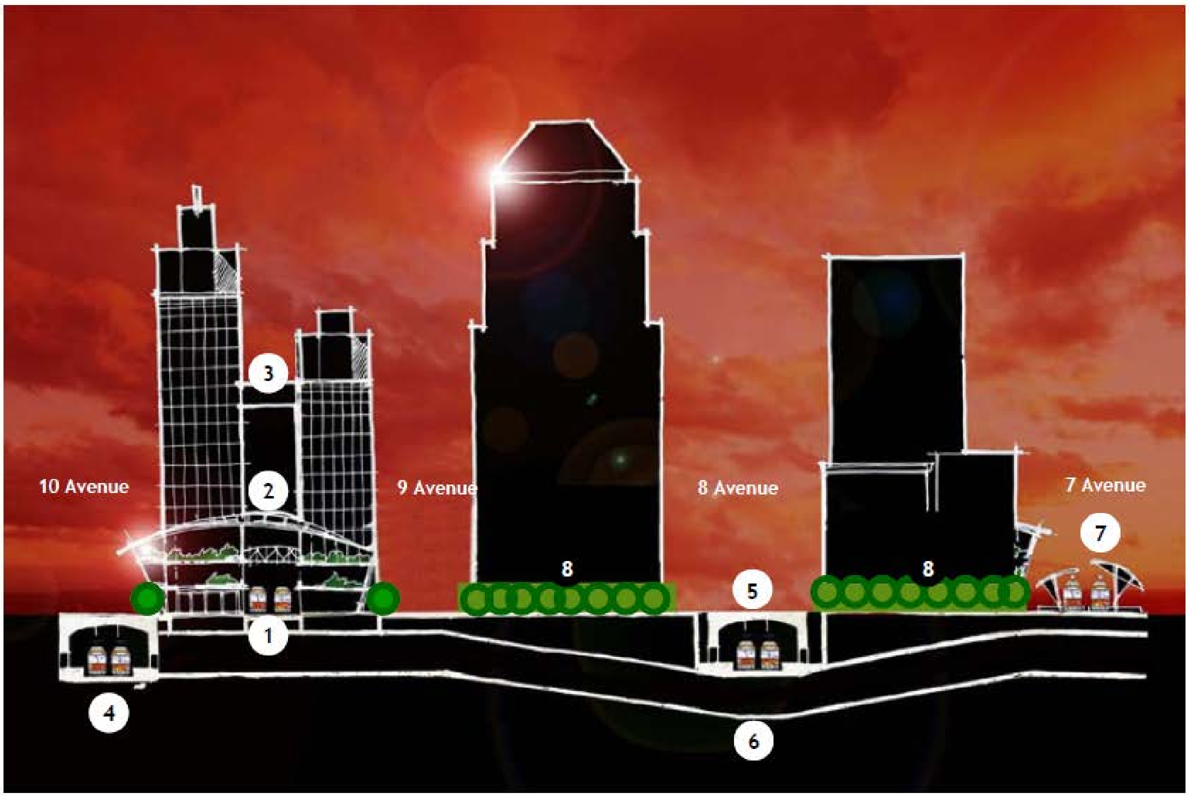
The plan places high priority on making the Centre City an exciting and lively place for pedestrians. While it strongly supports the expansion of the +15 network, it notes that even its bridges create issues for the pedestrian realm in the form of shadows and wind that require consideration and possible mitigation.[1]

Figure 10 illustrates another element of the Centre City Plan: a recommendation for a special area along the Canadian Pacific Railroad Corridor. The purpose of this concept is to make

[1] Centre City Plan, pp. 88-90

better use of the land adjacent to, and above, the railroad lands. It essentially recommends building over the tracks so that this swathe of land is better used and so the downtown and Beltline become better integrated. An elevated line could potentially be integrated into such a concept with the placement of a station directly above the CPR tracks. The downside of such a concept, however, is that it may also block east-west movement through this special district.

Figure 10: Canadian Pacific Railway Special Area Corridor and Multi-modal Transit Station



LEGEND

1. CPR Tracks
2. Future Multi-modal Transit"Station"
3. Future Mixed-use development
4. Future South East LRT @ 10 Avenue and 2 Street SW
5. Future Subway
6. South East LRT subway
7. 7th Avenue LRT Station
8. 2 Street SW Enhanced streetscape

Multi-modal Transit "Station" is the focal point of the CPR corridor and is located in the heart of the Centre City, in close proximity to major businesses, entertainment and cultural amenities. It consists of multi-level (at-grade, underground, +15 and +30) interconnected and climate-controlled interface points between the CPR train, SE leg of the LRT on 10 Avenue S, Calgary Transit (buses and LRT) on 9 and 10 Avenues S, future 8 Avenue S and existing Transit Mall on 7 Avenue S.

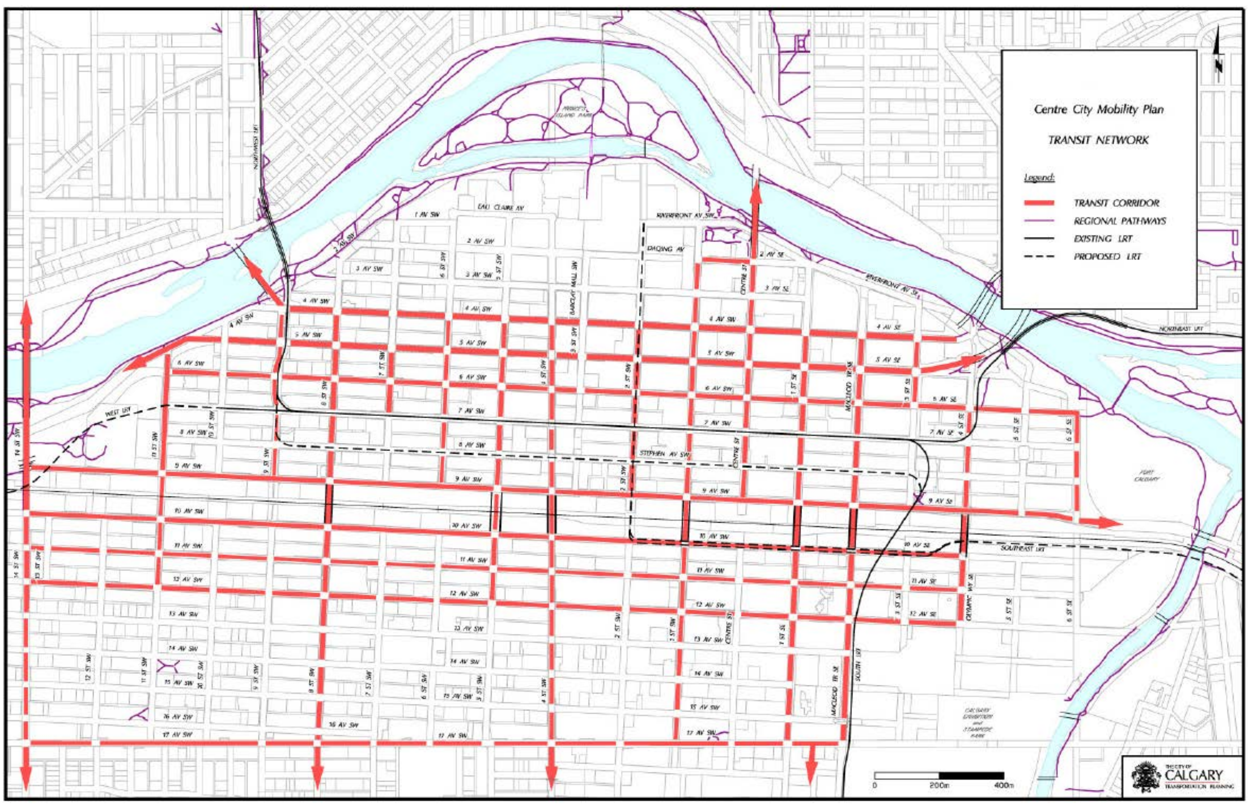
Another principle noted in the Centre City Plan is the preservation of viewsheds. A notable viewshed in the downtown area is the view of the City looking south from the Centre Street bridge and from Centre Street, in the heart of downtown, north to the Centre Street bridge. Both of these viewsheds would presumably be obstructed by an elevated structure.

Centre City Mobility Plan (2010)

The Centre City Mobility Plan builds on the Calgary Transportation Plan and the Centre City Plan. It identifies the road classifications and the pedestrian, bicycle, and transit networks in the Centre City, defined as the area bounded to the north by the Bow River, to the east by the Elbow River, to the south by 17 Avenue SW, and to the west by 14 Street SW. Transit corridors are shown in **Figure 11,** indicated by red lines. It reflects a strong emphasis on sustainable modes, particularly pedestrian needs in the form of wide and unobstructed sidewalks.

An important element of this plan is that no property is required to meet its objectives. In particular, it assumes no major bus facilities (e.g., exclusive bus lanes) would be implemented in the downtown, given the impact this type of infrastructure would have on other users, but that intermittent bus lanes or transit signal priority would be appropriate. However, at the time of this plan, plans for future rail lines in the downtown had not been developed in great detail. Some property acquisition will likely be required for the Green Line in downtown, regardless of whether it is elevated, underground, or at-grade, particularly for stations.

Figure 11: Transit Corridor Map From the Centre City Mobility Plan



Feasibility

Existing Infrastructure

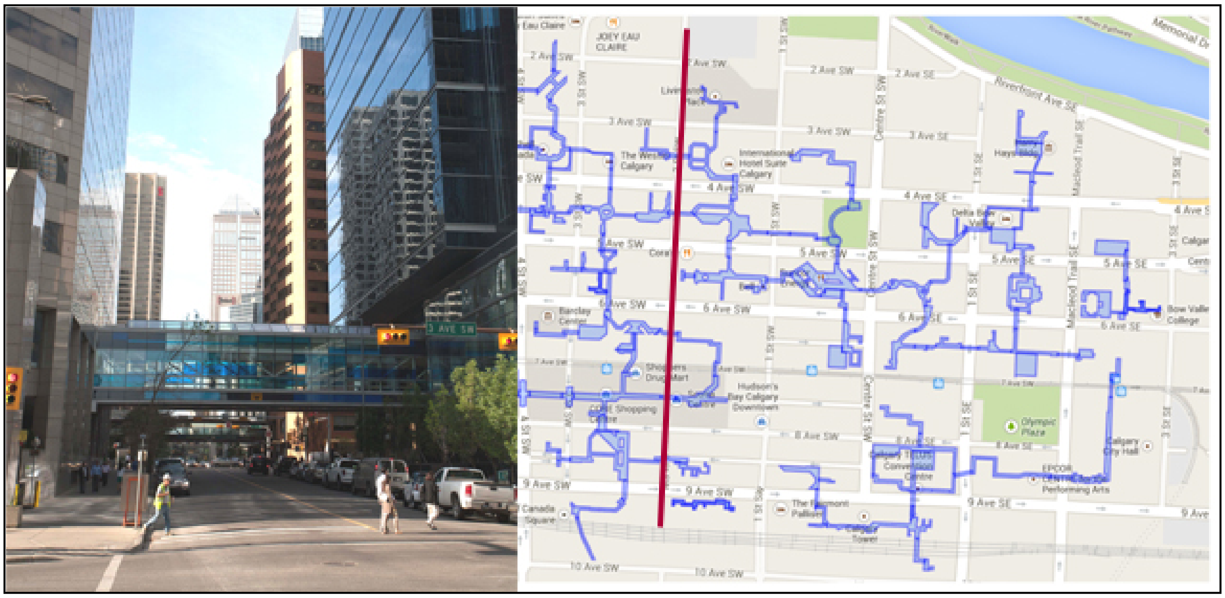
The existing infrastructure in downtown provides some constraints on a future elevated structure. The elevated structure would have to pass over the 7 Avenue LRT catenary wires, shown in **Figure 12** (location of wires indicated with red arrows). In addition, it would also have to avoid interfering with the existing +15 network bridges, shown in **Figure 13** and in the background of **Figure 12**. This network is continually being expanded and improved and will require an elevated LRT structure to rise at least three stories (or twelve metres) above street level. In some locations, the overhead walkways are particularly high off the ground. For example, on 3 Street SW and 4 Street SW, the passenger bridges connect the second, third, and fourth floors of the CORE Shopping Centre. Also, there is a passenger bridge that connects the second and third floors of buildings on 2 Street SW. These elevated structures may preclude an elevated LRT structure from using these streets. Alternatively, they would require an elevated LRT structure to be very high off of the ground, with the corresponding challenges of station access, emergency access, and pier widths that would increase with the height of the structures.

Additional constraints are the Calgary Tower, which would preclude an elevated structure from crossing into the downtown from the Beltline via Centre Street and the Canadian Pacific Railway building and dome which may preclude an elevated structure from being built along 1 Street SW.

For reasons of cost, passenger comfort, and noise abatement, it is likely preferable for an elevated alignment to maintain a constant elevation throughout the downtown; operating above most of the +15 network.

Figure 12: 7 Avenue LRT Catenary Wires (indicated with red arrows)

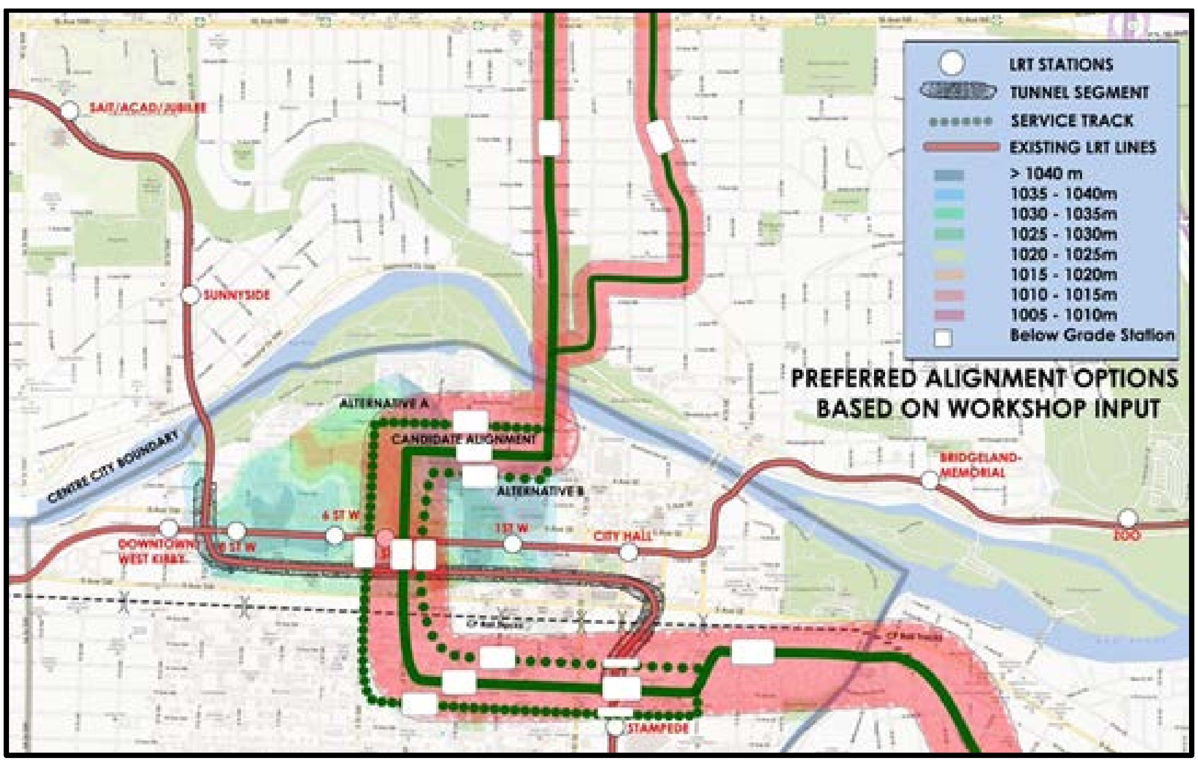
Figure 13: Centre City +15 Network (2 Street SW highlighted in red, shown in inset)



Roadway Geometry

The question of geometry pertains to the question of how an elevated structure would fit into the available space above roadways and intersections, and how the supporting piers would fit into the roadways at street level. For this discussion, it is assumed that the alignment would follow the street network and resemble the conceptual alignment that was developed by consolidating all of the input from the downtown analysis workshop, shown in **Figure 14**.

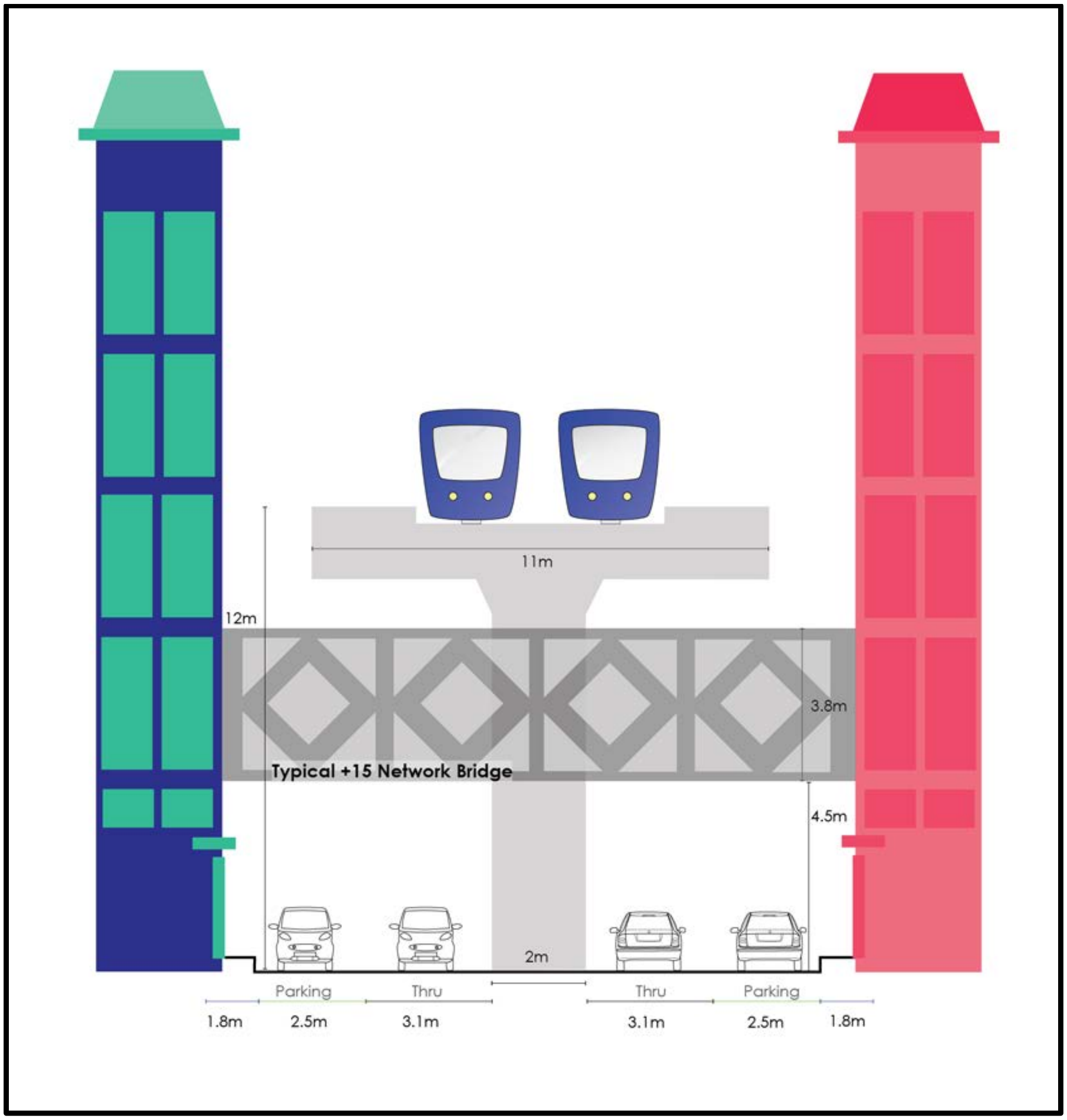
Figure 14: Conceptual Alignment Developed from Downtown Analysis Workshop



90 degree turns occur in the Chicago Loop above intersections, suggesting that the above alignments are also feasible in elevated structures with trains traveling at slower speeds.

At street level, it is unlikely that sufficient space will be available in the downtown roadways for piers to be placed in sidewalks, as was done in Richmond for the Canada Line, without severely impacting the pedestrian environment. Rather, the piers will probably be placed in the median of the streets, as was done for the Seattle Monorail. This will slightly reduce shadows and preserve pedestrian space, but will require considerable redesign of the streets, including the possible disruption to utilities and removal of a lane of traffic. The presence of piers in the street median also creates potential collision hazards for cars and trucks. Another consideration is that the taller the elevated structure is, the wider the supporting piers must be. A possible cross section that includes this configuration is shown in **Figure 15**.

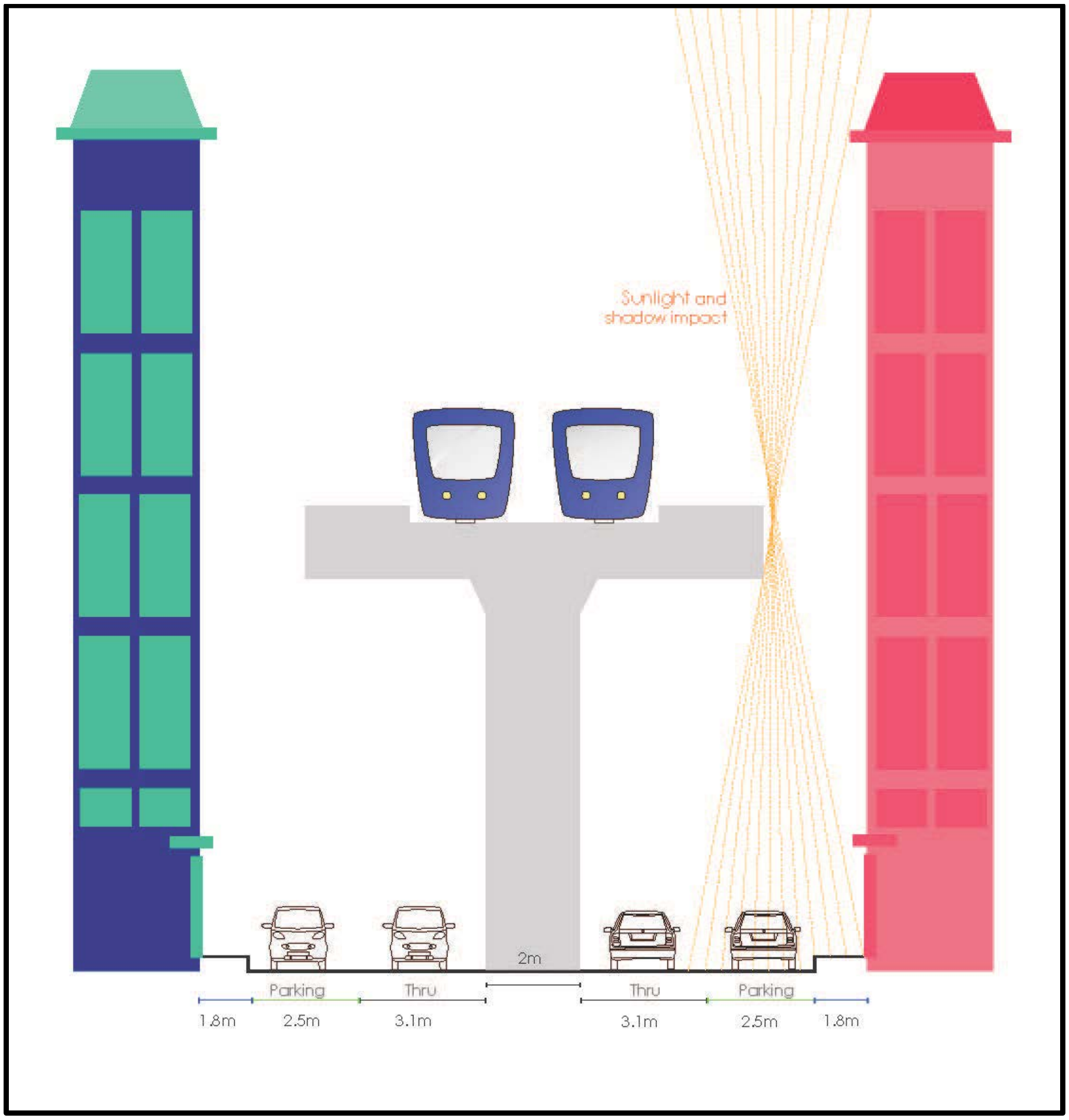
Figure 15: Typical Centre City Street Cross Section with Elevated Structure



Shadows

As a northern city, Calgary's streets will be impacted greatly by the presence of an elevated structure that is more than two levels above the street. However, mitigation may be possible through additional lighting, heating, and wind protection. The impacts may also be reduced if stations are integrated into buildings, as one of Seattle Monorail's stations is, rather than built as stand-alone structures. This opportunity will only present itself during new building construction or significant remodeling at a station location. **Figure 16** illustrates how an elevated structure above a downtown street could impact the amount of sunlight that reaches the street level. It is noted that given the height of buildings, sidewalks are already in shadow most of the day throughout the year.

Figure 16: Shadows Created by Elevated Structure



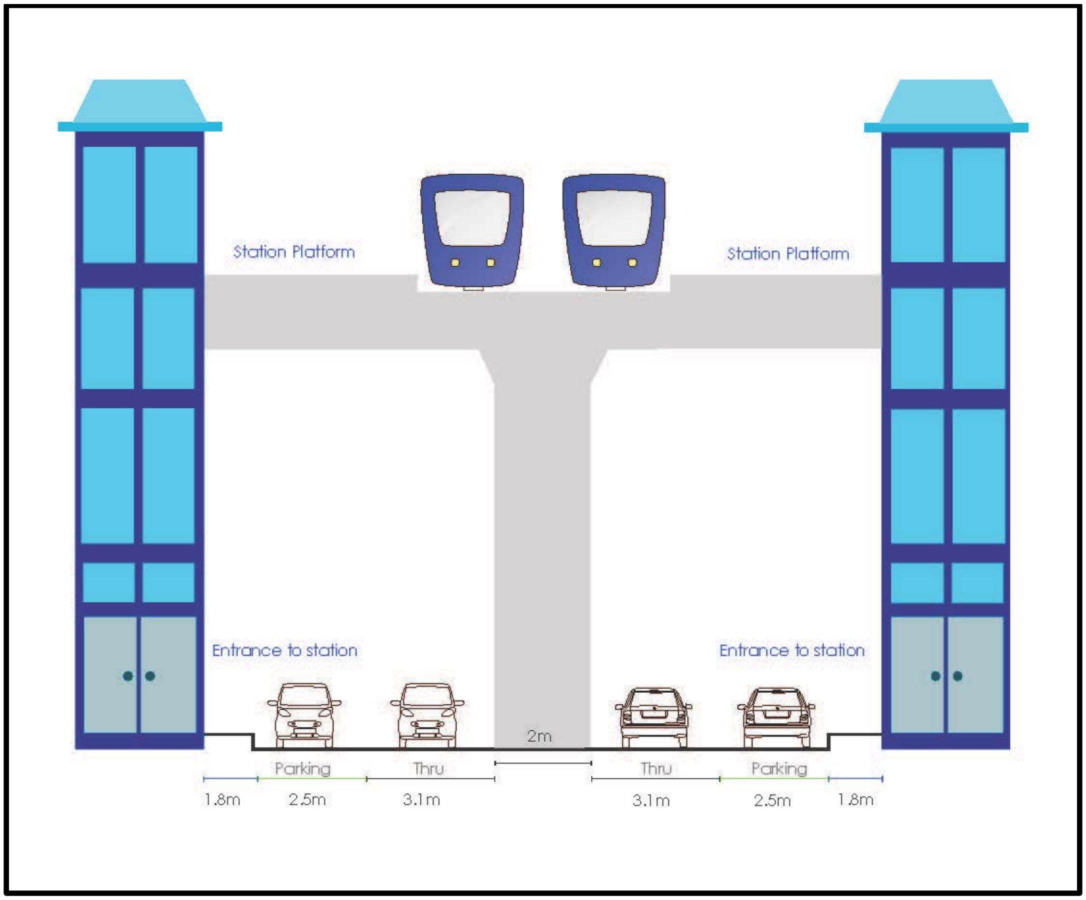
Noise and Vibration

Elevated tracks will create a new noise source, separate from the general traffic noise coming from street level. Tenants in the third and fourth floors of buildings will be particularly impacted by noises associated with turns and announcements at stations. There will likely need to be switches in the Centre City to accommodate train operations, such as short turns, and these tend to introduce additional noise as a result of trains traveling over switches. Noise walls may be able to mitigate the impacts of noise to some extent, although they create additional visual impacts.

Stations

In elevated alignments, stations are typically large and visible, as the required platforms, elevators, escalators, and stairs are all within plain sight. However, there are possible opportunities for integrating elevated stations into new buildings and into the existing overhead walkway network. Stations on elevated structures also have passenger comfort impacts; wind speeds tend to increase with elevation, so passengers waiting on an elevated platform tend to be colder than ones waiting on a street level platform. **Figure 17** illustrates a potential scenario in which an elevated station is not integrated into nearby buildings or the +15 network and relies on stand-alone structures for access to the platforms. These structures would provide elevator, escalator, and stairway connections to the platforms.

Figure 17: Potential Elevated Station Configuration



Safety and Security

On one hand, the safety offered by an elevated system in downtown would be an improvement compared to that of an at-grade system due to the separation of rail operation from roadway traffic. However, there may be additional security concerns with the stations being located away from the street. This is because there would not be the passive security provided by additional pedestrians and “eyes on the street” that there would be in an at-grade option and which could be enhanced through the application of CPTED concepts. Evacuations are another concern. Due to the need for a sufficiently wide and safe evacuation route, the cross section of an elevated alignment may have to be wider than it would be for either an at-grade or underground alignment. This will increase the impacts of shadows.

Maintenance

Elevated structures create various maintenance challenges that are different than they are for at-grade or underground structures. For one, access is more difficult, and so maintenance crews will need special equipment, and for safety reasons, regular traffic may have to be stopped if overhead maintenance is taking place.

Green Line Continuity

Green Line continuity is a consideration for an elevated alignment in the downtown. An elevated structure is likely compatible with at-grade operation across the Centre Street bridge, but a connection to a tunnel under the Bow River is likely infeasible and uneconomical. There are likely no issues with connecting an elevated LRT structure in the Centre City to an at-grade alignment that is approved for the Southeast LRT on 10 Avenue SE in the Beltline.

Transfers

An elevated structure will change the transfer experience as compared to a tunnel. With an elevated station, transfers between the 7 Avenue LRT and Green Line will take place largely outdoors. The transfers between the Green Line and a future 8 Avenue tunnel will require a significant elevation change that will likely not be comfortably completed by most people on foot, so extensive escalators and elevators may be required, increasing the cost and footprint of the stations.

Cost

An elevated structure will likely be less costly than a tunnel through downtown. As indicated in the RouteAhead document, an above ground LRT would be expected to cost between $50 and $100 million per km, while an underground LRT would typically cost between $200 and $250 million per km. Pursuing a less expensive elevated structure in the Centre City would potentially allow for the earlier construction of a rail line.

There are various indications, however, that an elevated structure would be more expensive than typical in the Centre City. As described earlier in the memo, building a structure that is high enough to clear the +15 network has the following to contend with:

- It is expected that for every increase in height by five meters (the height of a building story), there would be a 25% increase in structure cost.

- The additional height of the stations would likely require more elevators and station-related costs than a typical station.
- The pier foundations also increase construction costs. Because the piers are so large, the utility impacts of an elevated structure might be comparable to the utility impacts of an underground structure.

Storm and Flood Resistance

The flooding that occurred in the City of Calgary in 2013 has made City staff and residents more aware of the risks that are inherent to The City's transportation systems. While an elevated LRT line might recover faster from flooding than a tunnel, it is still exposed to certain risks, such as damage to its structures from floating debris and to its elevators, escalators, and substations from ground level and subsurface water.

Public Acceptance

There is evidence from past studies that the public has various concerns about elevated structures for rail transit, notably that they will decrease property values and negatively impact views.

Conclusion

Underground alignments tend to be selected for Central Business Districts because they optimize transit operations while preserving the street level for pedestrians, surface transit operations, goods movement, and general traffic. In initial studies of the downtown portion of the Green Line alignment in Calgary, an underground alignment between 10 Avenue South and 4 Avenue South was considered necessary to preserve current at-grade LRT operations on 7 Avenue South and to avoid the CPR tracks. However, there are examples of cities that have incorporated elevated LRT into their downtowns, and such a solution is technically feasible for Calgary to reduce the costs of the downtown portion of the alignment (when compared to a tunnel) and avoid the risks of a tunnel. However, an elevated alignment would bring about a wide range of issues related to shadows, noise and vibrations, station access, safety, maintenance, transfers, and public acceptance. Design solutions are available for some of these items, but not all of them.

Also of note, is that the cross sections of many of downtown Calgary's streets are narrower than those in some of the example cities, such as Richmond's and Bangkok's. If The City of Calgary pursues elevated LRT in its downtown, it should consider shadow-reduction strategies, station integration into privately-owned buildings. Further investigation should include the branding strategies used in Seattle, the success of elevated-to-subway transfers in downtown Chicago, and the noise and vibration mitigation strategies used in downtown Bangkok.