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Attachment 8



Green Line LRT

Technical Report

Alignment Options Review Summary Report

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Executive Summary

Introduction

The purpose of this report is to summarise the outcomes of the Alignment Options Review undertaken for the Green Line LRT project program. This Alignment Options Review was undertaken as directed by the City of Calgary Council on July 29, 2019, in response to Administration report TT2019-0811. City Council directed Administration to review the Green Line program to ensure the project continued to meet the original objectives set by Council and that the project would deliver the best possible outcomes for Calgarians within the approved budget threshold.

Overview of Evaluation (MAE) Methodology

To support the Alignment Options Review, a Multiple Account Evaluation (MAE) framework was used to review and assess a range of potential options to ensure that the Green Line project delivers the best value for Calgarians with the available budget. This is an established process for deciding between several options, considering a range of potential factors or criteria which may impact the decision.

The MAE process provides a documented, evidence-based approach to decision making that provides an audit trail for the public and elected officials as to how options were selected and, for the options that were rejected, why that was the case. The MAE framework flows from the project vision and desired project outcomes, which inform the evaluation themes and ultimately the evaluation criteria.

The Green Line Project Vision and project outcomes were established following a broad-based public engagement process led by the City of Calgary, along with the development of an initial evaluation framework.

The MAE framework and evaluation process uses readily available data and professional judgement to:

- Considers a range of quantitative and qualitative impacts and benefits and identifies and informs the trade-offs between potentially conflicting objectives;
- Assesses the alternatives against the project vision and outcomes, examining the direct and broader public policy impacts; and
- Provides decision makers and the public with a transparent, user-friendly, evidence-based tool to help them examine, engage, evaluate and document alternatives.

Green Line Project Vision, Outcomes, Themes and Criteria

The Green Line Project Vision and project outcomes were established in 2015 following a broad-based public engagement process led by the City of Calgary, along with the development of an initial evaluation framework. The Green Line Project Vision was reconfirmed by Calgary Council on January 13, 2020 as:

"**A city-shaping transit service that improves mobility in communities in north and southeast Calgary, connecting people and places and enhancing the quality of life in the city.**"

Further on January 13, 2020 Calgary Council approved the following *Outcomes for Calgarians* for the Green Line project:

A transit service that:

1. Improves mobility by providing a frequent, reliable, and affordable service.
2. Contributes to an efficient transportation network that promotes transportation choice and reduces congestion, travel times and greenhouse gases.
3. Enhance connectivity between people and places including connections to the broader transit network.
4. Create a positive transportation experience – safe, accessible, comfortable and convenient.
5. Contribute positively to urban realm, community development and revitalization.
6. Contribute to the vitality of businesses in the community.
7. Protect the environment by enhancing City's environmental stewardship.

Supporting the Project vision and the Outcomes for Calgarians, six themes and criteria were established as set out below.

Evaluation Theme	Threshold Assessment	Criteria
Mobility: A transit project that improves mobility	Ability to carry the projected demand	Design capacity and expandability
		Upgradeability/Expandability
		System ridership and benefits
		Vehicular and Active modes
Connectivity: Connecting People to People and Places	Connectivity to people	People served by the Green Line
		Strategic transit network connections
Development: Urban and Regional Development	Connectivity to jobs	Downtown (north of 9th) jobs served by the Green Line
		Minimizing impact to existing developments
		Maximizing opportunities for future development
Environmental	Potential environmental impacts and risks of construction	Quantitative assessment of environmental risks and unmitigable impacts from construction and operations
Cost and Value	Funding Availability and Eligibility	Capital cost
		Operating and maintenance costs
		Eligibility for provincial and federal funding
		Value and lifespan of investment
Risk and Constructability	Project risk assessment	Identification of significant project/owner technical, delivery or financial risks

Summary of Options Evaluated

The options in the following table were evaluated against the criteria using information provided by the project team using available information and, where required, used appropriate professional skill and judgement to assess the relative impacts or performance of the option. Data sources included City transportation model data, population and employment data sets, and data provided by Calgary Transit. Not all options were modelled in full; where applicable, data was interpolated/extrapolated to undertake the evaluation.

Option Number	Description
A1	2017 Council Approved Stage 1 Alignment - 16 Avenue N to Shepard
A2	Updated Stage 1 Alignment - 16 Avenue N to Shepard with North BRT Improvements
B1	North BRT and Southeast BRT
B2	North BRT and Southeast LRT terminating in Beltline
B3	North BRT and Southeast LRT connection to Red Line
B4	North LRT and Southeast BRT
C1	Southeast LRT connects to Red Line, terminates on 8 Avenue S; North LRT terminates on Centre Street S - Two systems
C2	Southeast LRT terminates in Beltline; North LRT terminates in Centre City - Two systems

Alignment Options Review Recommendations

Considering the performance of each option against the Project Vision, Outcomes for Calgarians, themes and criteria within the MAE, and, importantly, the capital cost and other constraints of the Alignment Options Review, **Option A2, the Updated Stage 1 Alignment - 16 Avenue N to Shepard, is the highest performing option**. The performance of the recommended option (Option A2) has been summarized below against the other options.

Criteria	A1	A2	B1	B2	B3	B4	C1	C2
Mobility	◕	●	◔	◑	◑	◕	◕	◕
Connectivity	●	●	●	◑	◕	◕	◕	◑
Development	●	●	◕	◑	●	●	●	◑
Environmental	◑	◕	●	●	◕	●	◕	●
Cost + Value	◑	◕	◑	◔	◔	◑	◑	◑
Risk + Constructability	◑	◕	◑	◕	◔	◑	◔	◕

Mobility – Option A2 can meet the projected long-term demand, as can A1, C1 and C2, while options B2 and B3 accommodate the projected long-term demand south of the Centre City only and B4 only accommodates the long term demand in the north. Upgrading the North BRT LRT poses challenges for options B1, B2, and B3, while operational impacts during the upgrade of the South BRT in options B1 and B4 could be limited to the off-peak direction. Option A2 has no requirement to be upgraded and therefore has no issues.

Connectivity - Option A2 provides a direct north-south connection through the Centre City, as do A1 and B1, while options A1, A2, B4 and C2 also provide LRT connections to the Red and Blue line and option B3 and C1 only provide a connection to the Red Line LRT. All options except Option B1 fail to serve the full population to the north and south, however with A2, improved BRT service will be extended beyond 16 Avenue North improving connectivity for new and existing north central BRT users.

Development – Options B2 and C2 require a walk connection to sections of Centre City and do not provide LRT directly into the Downtown, while all other options provide direct connections to key employment destinations in the Centre City.

Environmental – Environmental risks are relatively equal across options, with Option A1 posing the greatest risk of disrupting contaminated soils due to significant tunnelling and Option A2 introducing additional risks from a new river crossing. Options B2, B3 B4, C1 and C2 are slightly less risky with reduced tunnelling and associated soil contamination impacts.

Cost and Value - Option B1 delivers full system, maximizing operational cost benefits at the lowest estimated capital cost, but the capacity provided does not meet long term projected demand. Long term capacity needs are also not met by sections of B2, B3 and B4 limiting their long-term value due to the cost of upgrading.

The estimated capital costs for options A1, C1, and C2 exceed the existing funding envelope. Significant operating costs may be associated with providing feeder bus service north and south of terminus locations (N+SE: options A1, A2, C1 and C2; SE only: options B2, B3 and B4). Option A2 sits within the funding envelope, provides value in that it meets projected demand and does not require upgrading, although it does still incur significant bus operating costs until the system is expanded.

Risk and Constructability – Options A1 and A2 include geotechnical risks due to significant underground infrastructure, A1 more so than A2, while Option A2 includes new Bow River crossing. Option B1 poses challenges for vehicle movements and bus operations within the Centre City. Public perception of BRT as an inferior mode relative to LRT has the potential to impact ridership for options B1, B2, B3, and B4. Additional political and public perception risks are associated with changes to previously announced corridor technologies in Option B4. In addition, options that include LRT to the North would incur significant schedule delay (2+ years) which may create challenges with the availability of funding from senior levels of government.

Conclusions

The evaluation indicates that that within the constraints of the review, **the updated Stage 1 alignment (Option A2) is the best performing option across a broad range of the criteria.** Option A2 is a variation on the original project, but that focuses on reducing the tunnelling risk and trades off the cost of tunnelling and underground options with the impacts of running at-grade. The inclusion of BRT improvements will provide additional benefits to new and existing north central BRT riders over Option A1. Option A2 also provides improved service to the communities in both the north and southeast and provides direct connectivity to the Centre City as well as to the Red and Blue LRT lines and the MAX Orange bus line. In addition, this option addresses the most technically complex and capital intensive aspects of the long-term vision and has the highest state of delivery readiness. It will also best facilitate future extensions and demonstrates the City's commitment to implementing the long-term vision for the Green Line LRT – a cornerstone of Council's approved transit plan – RouteAhead*: A Strategic Plan for Transit in Calgary*.

1 Introduction

1.1 Project Development to Date

The long-term vision for the Green Line light rail transit (LRT) project is to serve and connect the growing populations in north central and southeast Calgary with a fast, frequent and reliable, high quality transit system. These communities are growing quickly and, over the next 30 years, the population in the north central is expected to increase by over 50% from 170,000 to over 250,000 people and in the southeast, the population will double from 135,000 to over 270,000 residents. The full project will ultimately be 46km in length, serve Calgarians in more than 27 communities with 29 planned stations and eventually carry over 200,000 trips a day.

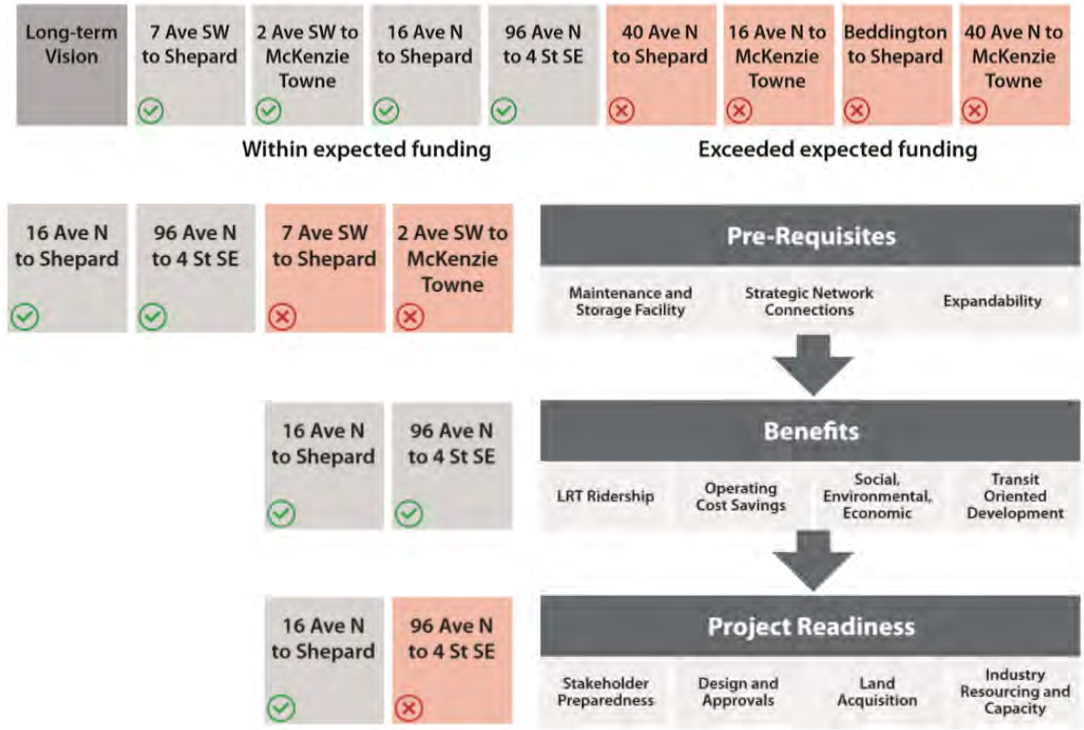
The Green Line project is included in the Council's approved transit plan – RouteAhead*: A Strategic Plan for Transit in Calgary* and is a key element in successfully meeting the long-term Municipal Development Plan (MDP) and Calgary Transportation Plan (CTP) goals. The Green Line will improve mobility choices, connect people and places and enhance the quality of life of the communities that it connects. It will deliver high quality transit service to Calgarians in the north central and southeast and is a key part in the future transit network in the city. Along with the new MAX bus rapid transit lines, Calgarians will have fast, frequent and reliable transit service that strategically connects communities, employment hubs, and key destinations across the city.

In 2015, the project received nearly $5B in funding from a combination of the Federal, Provincial and City governments and recognising that, like the Red and Blue Lines, the Green Line would need to be delivered in stages, the project team considered a range of initial options for the first stage of the line (Stage 1). A detailed evaluation was completed to compare and contrast the numerous options recognising that all options needed to meet the following pre-requisites to be considered:

- Network Connections – To support opening day and projected ridership growth, the core project must connect to the Centre City and provide seamless connectivity with the existing Red and Blue lines. Network connectivity could be further enhanced by providing integrated connections to the MAX rapid transit routes.
- Maintenance and Storage Facility – Provision of a light rail vehicle facility to clean, repair and protect from the environment when parked.
- Expandability - The ability to implement the long-term vision in stages when further investments are made. This positions The City to deliver future affordable and achievable expansions.

Eight preliminary options were identified, four of which were considered above the $5B funding available. Of the remaining four options, two provided considerably less benefit in terms of their network connections and expandability and were dropped from further consideration. The remaining two options – 16th Ave N-Shepard and 96 Ave N to 4 St SE – were both viewed as providing similar benefits however, the 16th Ave N-Shepard option was significantly more advanced in terms of project readiness, in part due to earlier planning work for the Southeast TransitWay (SETWAY) bus rapid transit (BRT) project, and was much less complex to deliver from a land assembly perspective and was therefore selected at the Stage 1 project. This evaluation and sifting process is illustrated in Figure 1.1.

Figure 1-1 Green Line Stage 1 Selection Process



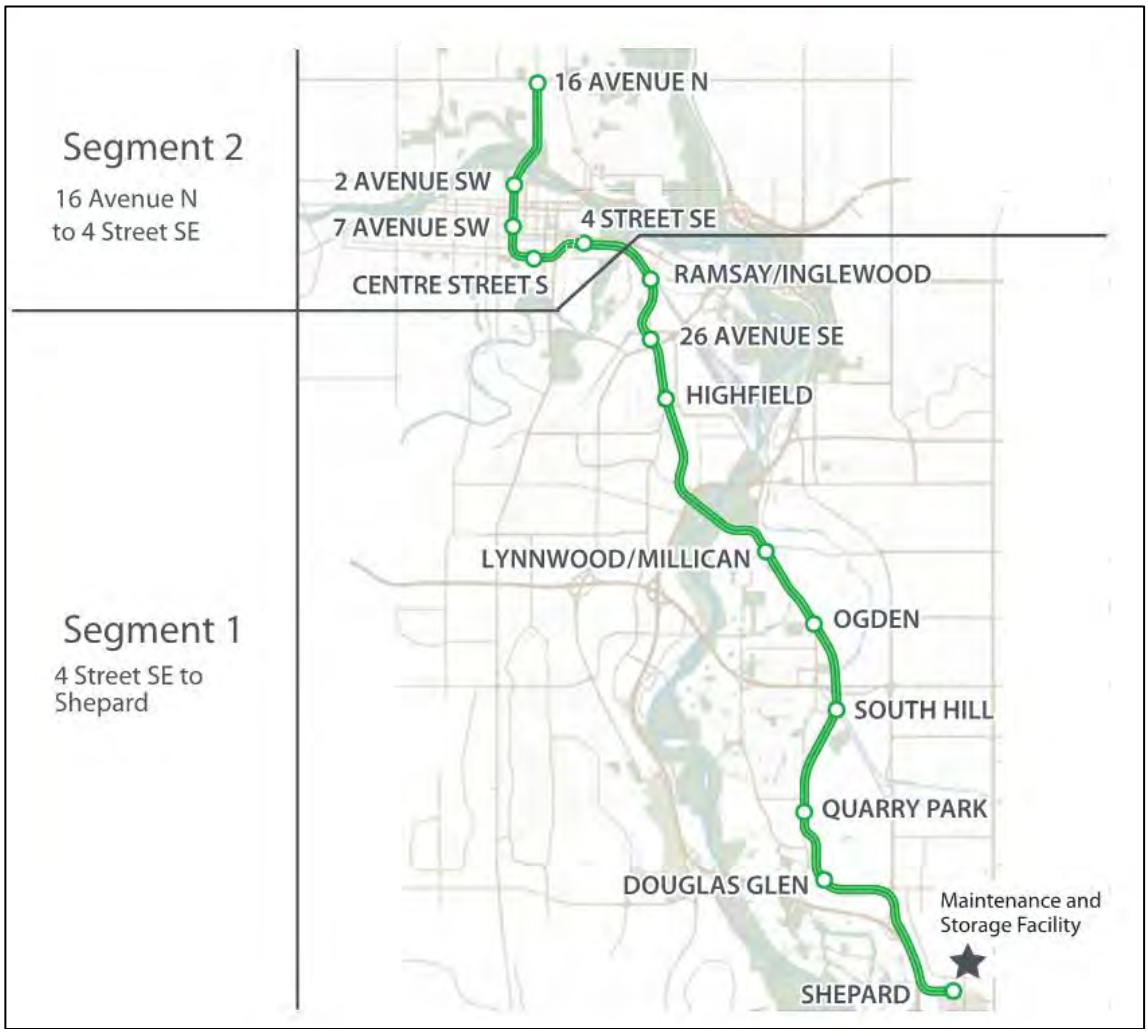
In June 2017, Council approved a Stage 1 alignment from 16 Avenue N to Shephard with a tunnel under the Bow River and through the downtown.

In summer 2019, Administration advised Council about the need to re-evaluate the scope of Stage 1 due to concerns related to the project cost estimate, which exceeded the capital budget by 10%, construction risk resulting from deep underground stations, and to improve the design to improve the customer experience and achieve the overall vision of the project. In order to continue to progress project development, the Stage 1 project was split into two segments (and potential construction contracts) as shown in Figure 1.2. The Segment 1 portion continued with a Request for Qualifications for construction issued in 2019 and Administration proceeded with a re-evaluation of the alignment in Segment 2.

In addition to re-evaluating the Segment 2 alignment, City Council directed Administration to review the Green Line program to ensure the project continued to meet the original objectives set by Council and that the project would deliver the best possible outcomes for Calgarians within the approved budget threshold. As part of that review, the Green Line LRT project team has undertaken a Alignment Options Review of the existing project as well as a range of potential options.

Reviews such as this are best practice on any major infrastructure project and are typically undertaken prior to entering into the final contracting phase(s) to ensure that the current project continues to provide the same balance of costs and benefits as the original approved project and/or scope.

Figure 1-2 Green Line Segments



1.2 Purpose of this Document

This report was prepared by Steer Davies Gleave North America Inc. (Steer) and Stantec Inc. (Stantec) for the City of Calgary (The City) as part of the Green Line LRT program to summarize the work undertaken through the Alignment Options Review to evaluate which alignment option delivers the best possible outcome for Calgarians.

2 Evaluation Process

2.1 Multiple Account Evaluation (MAE) Framework

To support the Alignment Options Review, a Multiple Account Evaluation (MAE) framework was used to review and assess a range of potential options to ensure that the Green Line project delivers the best value for Calgarians with the available budget. This is an established process for deciding between several options, considering a range of potential factors or criteria which may impact the decision.

The MAE process provides a documented, evidence-based approach to decision-making that provides an audit trail for the public and elected officials as to how options were selected and, for the options that were rejected, why that was the case. While the specific criteria selected for use in an MAE framework will vary depending on the type of decision being made, it is important to select criteria that allow differentiation between the options. No matter what specific criteria are selected, an MAE framework should always be clearly linked back to the project vision, desired project outcomes, evaluation themes, and evaluation criteria.

The project vision defines the successful 'outcome' of a project and provides the 'big-picture' focus. It should be referred to as the project progresses to inform priorities and decision making. It can be used to ensure that the solutions identified and evaluated as part of the process address the underlying needs and issues.

The project outcomes provide further detail over and above the project vision and clarify how the options will be measured and compared against each other. They also help to inform the evaluation themes and detailed evaluation criteria to explain, justify, and prioritise trade-offs between options.

Each evaluation theme is supported by detailed evaluation criteria that are used to measure and assess the relative performance of the options. When developing and applying evaluation criteria, it is important to consider the results that can be achieved given the available time, resources and project scope.

The Green Line project vision and project outcomes were established following a broad-based public engagement process led by The City of Calgary, along with the development of an initial evaluation framework. That evaluation framework was revisited and adapted for use in this Alignment Options Review using input from the project team alongside input from stakeholders and feedback received during earlier rounds of public engagement. Evaluation themes were established to provide the core focus areas of the evaluation, with more detailed evaluation criteria then defined to allow for the assessment of the options considered using more detailed performance metrics.

The MAE framework and evaluation process:

- Considers a range of quantitative and qualitative impacts and benefits and identifies and informs the trade-offs between potentially conflicting objectives;
- Assesses the alternatives against the project vision and outcomes, examining the direct and broader public policy impacts;

- Uses readily available data and professional judgement to limit the amount of abortive or excessive work being undertaken on options that are not viable and allows resources to be focused on the options with the most potential; and
- Provides decision makers and the public with a transparent, user-friendly, evidence-based tool to help them examine, engage, evaluate and document alternatives.

2.2 Green Line Project Vision and Outcomes

The Green Line project vision and project outcomes were first established in 2015 following a broad-based public engagement process led by The City of Calgary, and which were reconfirmed by Calgary Council on January 13, 2020 as:

"**A city-shaping transit service that improves mobility in communities in north and southeast Calgary, connecting people and places and enhancing the quality of life in the city."**

Further on January 13, 2020 Calgary Council approved the following *Outcomes for Calgarians* for the Green Line project:

A transit service that:

1. Improves mobility by providing a frequent, reliable, and affordable service.
2. Contributes to an efficient transportation network that promotes transportation choice and reduces congestion, travel times and greenhouse gases.
3. Enhance connectivity between people and places including connections to the broader transit network.
4. Create a positive transportation experience – safe, accessible, comfortable and convenient.
5. Contribute positively to urban realm, community development and revitalization.
6. Contribute to the vitality of businesses in the community.
7. Protect the environment by enhancing City's environmental stewardship.

The project vision and project outcomes were used to develop the evaluation themes and detailed evaluation criteria as part of the options evaluation process for the Alignment Options Review.

2.3 Green Line Themes and Criteria

As noted above, the evaluation themes and criteria established during previous phases of the Green Line project were reviewed and incorporated where appropriate, while also being adapted where needed to ensure that they were appropriate for this Alignment Options Review. Refinements included ensuring the ability for the data to be compiled within the required timescales, as well as providing detailed evaluation criteria that would help differentiate between the options being considered.

Table 2-1 lists the evaluation themes and associated evaluation criteria used in the Alignment Options Review.

Table 2-1 Green Line Evaluation Themes and Criteria

Evaluation Theme	Threshold Assessment	Criteria
Mobility: A transit project that improves mobility	Ability to carry the projected demand	Design capacity and expandability
		Upgradeability
		System ridership and benefits
		Vehicular and Active modes
Connectivity: Connecting People to People and Places	Connectivity to people	People served by the Green Line
		Strategic transit network connections
Development: Urban and Regional Development	Connectivity to jobs	Downtown (north of 9th) jobs served by the Green Line
		Minimizing impact to existing developments
		Maximizing opportunities for future development
Environmental	Potential environmental impacts and risks of construction	Quantitative assessment of environmental risks and unmitigable impacts from construction and operations
Cost and Value	Funding Availability and Eligibility	Capital cost
		Operating and maintenance costs
		Eligibility for provincial and federal funding
		Value and lifespan of investment
Risk and Constructability	Project risk assessment	Identification of significant project/owner technical, delivery or financial risks

The criteria set out in the table above were used to evaluate the options considered using readily available data and professional judgement. This included use of The City's transportation model data, population and employment data sets, and data provided by Calgary Transit. Given the available timescales, not all options were modelled in full; where applicable, data was interpolated/extrapolated to undertake the evaluation.

2.3.1 Mobility Theme

Under the mobility theme, the following criteria were used to evaluate the options considered:

Design Capacity

- Maximum capacity (passengers per hour per direction) was calculated using maximum headways and vehicle capacity thresholds

Expandability

- Qualitative assessment on whether the system can be expanded / upgraded in the future

Ridership

- Modeling and estimates derived from modeled scenarios undertaken by the City's forecasting team
- Considers passenger boardings/alightings on both the north and southeast sections
- The impact on overall system ridership was also considered

- Note that full modelling of each of the scenarios was not completed due to the available timescales, however ridership was interpolated/extrapolated and based on available information

Impact on Vehicular Traffic

- Qualitative assessment of impacts to vehicular traffic, local access, and circulation (primarily focussed within the Centre City)

Impact on Active Modes

- Qualitative assessment of impacts to walking and cycling (primarily focussed within the City Centre)

2.3.2 Connectivity Theme

Under the connectivity theme, the following criteria were used to evaluate the options considered:

People Served by the Green Line in 2048

- Catchment analysis assessment undertaken in GIS using forecast population in 2048

Strategic Transit Network Connections

- Qualitative assessment noting where direct connections between the north and southeast sections of the line exist and/or connections to other LRT and MAX lines
- It is assumed that the existing bus network would be restructured to integrate with each option

2.3.3 Development Theme

Under the development theme, the following criteria were used to evaluate the options considered:

Jobs served by the Green Line in 2048

- Catchment analysis assessment undertaken in GIS using forecast employment in 2048

Minimizing Impacts / Maximizing Opportunities

- Qualitative assessment considering impacts to existing development access and identifying where particular options provided new or increased potential for future development

2.3.4 Environmental Theme

Under the environment theme, the following criteria were used to evaluate the options considered:

Environmental Impacts

- A qualitative assessment considering the potential risk to sensitive habitats (e.g. river and riparian ecosystems)
- A qualitative assessment considering the potential risk of geotechnical activity and tunnelling disturbing contaminated soils requiring remediation

2.3.5 Cost and Value Theme

Under the cost and value theme, the following criteria were used to evaluate the options considered:

Capital Cost

- Quantitative estimate of construction costs based on the preliminary plan and profile design concepts provided by the project team

Operating and Maintenance Cost

- Quantitative estimate of operational costs based on mode type (BRT vs LRT), station operating costs (underground vs at-grade) and any bus operating cost savings provided by the project team

Eligibility for Provincial and Federal Funding

- Initial consideration of funding eligibility (based on existing agreements and subject to change)
- Federal eligibility may depend on mode and timing of construction
- Provincial eligibility may depend on mode and how the river is crossed (at-grade or tunnel)

Value and Lifespan of Investment

- Considers how long the project meets the anticipated demand and the lifespan of the infrastructure
- Sunk cost for interim solutions and the potential to ultimately increase capacity / upgrade system and the order of magnitude cost

2.3.6 Risk and Constructability Theme

Under the risk and constructability theme, the following criteria were used to evaluate the options considered:

Risk Identification

- Identification of significant project/owner technical, delivery, schedule or financial risks

3 Options Reviewed

3.1 Overview

In parallel with the development of the MAE framework, the project team developed potential options to be considered within this review process. While there was a recognition that, if The City had funding for the full, 46 km Green Line project, that remained the priority, the development of options focussed on a set of possible alternatives within the available Stage 1 funding envelope (i.e. approximately $5B). If additional funding were available or there was a need to deliver project for significantly less money, then a broader set of projects and options would need to be considered. And, while it was important that the scope of the options reviewed was not artificially constrained, it was also critical to limit the options to a representative set that could be evaluated within the timescales set by Council.

Within these constraints, a range of options were considered, including different LRT and BRT combinations, alternative routing, termini locations, and alternative options for the amount of tunnelling in the Centre City and for the crossing of the Bow River. A high-level summary of the options evaluated is set out below, followed by more detailed descriptions and figures.

Table 3-1 Green Line Option Descriptions

Option Number	Description
A1	2017 Council Approved Stage 1 Alignment - 16 Avenue N to Shepard
A2	Updated Stage 1 Alignment - 16 Avenue N to Shepard with North BRT Improvements
B1	North BRT and Southeast BRT
B2	North BRT and Southeast LRT terminating in Beltline
B3	North BRT and Southeast LRT connection to Red Line
B4	North LRT and Southeast BRT
C1	Southeast LRT connects to Red Line, terminates on 8 Avenue S; North LRT terminates on Centre Street S - Two systems
C2	Southeast LRT terminates in Beltline; North LRT terminates in Centre City - Two systems

3.2 Detailed Option Descriptions

The options set out below were developed by the project team in conjunction with Calgary Transit and other project stakeholders. There are multiple variations on each of these that could have been considered, but this set of options was considered to be representative of the different options and trade-offs that needed to be considered as part of this process.

Option A1 – 2017 Council Approved Stage 1 Alignment - 16 Avenue N to Shepard

This option reflects the original Stage 1 Alignment approved by City Council in June 2017, running from 16 Avenue N to Shepard. A full twin-bore tunnel is used in the Centre City with underground stations from 16 Avenue N to 4 Street SE.

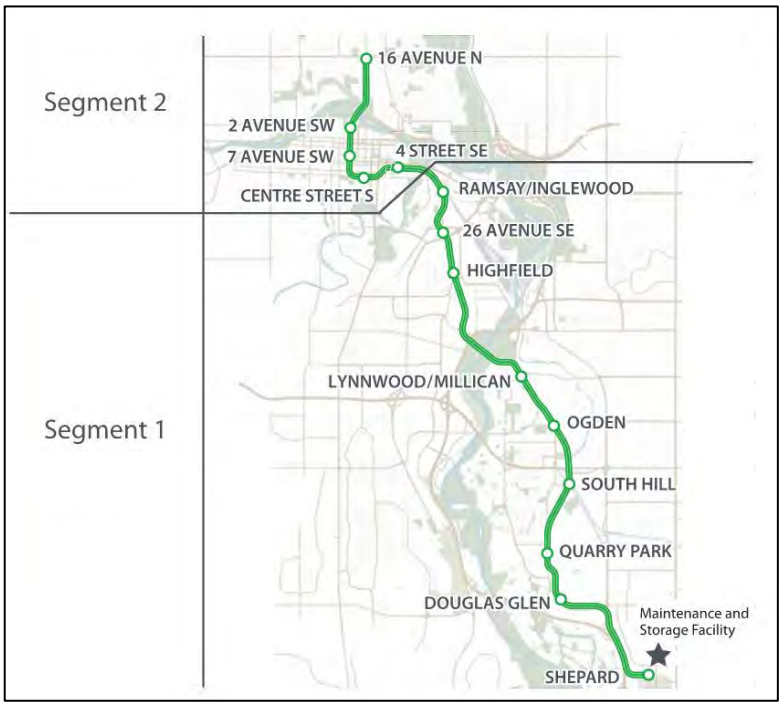


Figure 3-1 Option A1 – 2017 Council Approved Stage 1 Alignment - 16 Avenue N to Shepard

Option A2 - Updated Stage 1 Alignment - 16 Avenue N to Shepard with North BRT Improvements

Option A2, the updated Stage 1 alignment follows a similar alignment to A1, connecting 16 Avenue N to Shepard. A2 differs from A1 in Segment 2 (Centre City) where it has surface running LRT on Centre Street N, a bridge to cross the Bow River, and a tunnel through downtown and Beltline. A2 includes two surface stations on Centre Street N, and four underground stations in the downtown and Beltline. Segment 1, Elbow River to Shepard, is the same as the alignment approved by City Council in June 2017. The North section of the alignment beyond 16 Avenue N includes a series of customer service and transit priority improvements to the existing BRT service.

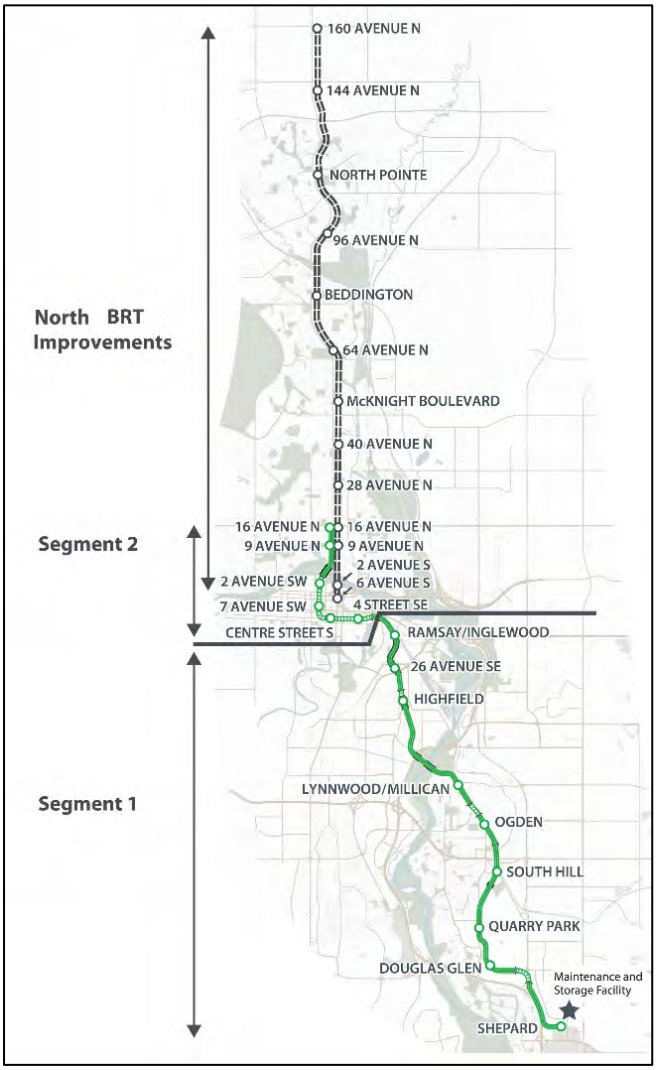


Figure 3-2 Option A2 – Updated Stage 1 Alignment - 16 Avenue N to Shepard with North BRT Improvements

Option B1 - North BRT and Southeast BRT

The Southeast BRT alignment follows the June 2017 City Council approved LRT alignment between 4 Street SE station and Seton. The North BRT service connects the Centre City to Harvest Hills Blvd Corridor via Centre Street N. The Centre City connection is to be determined.

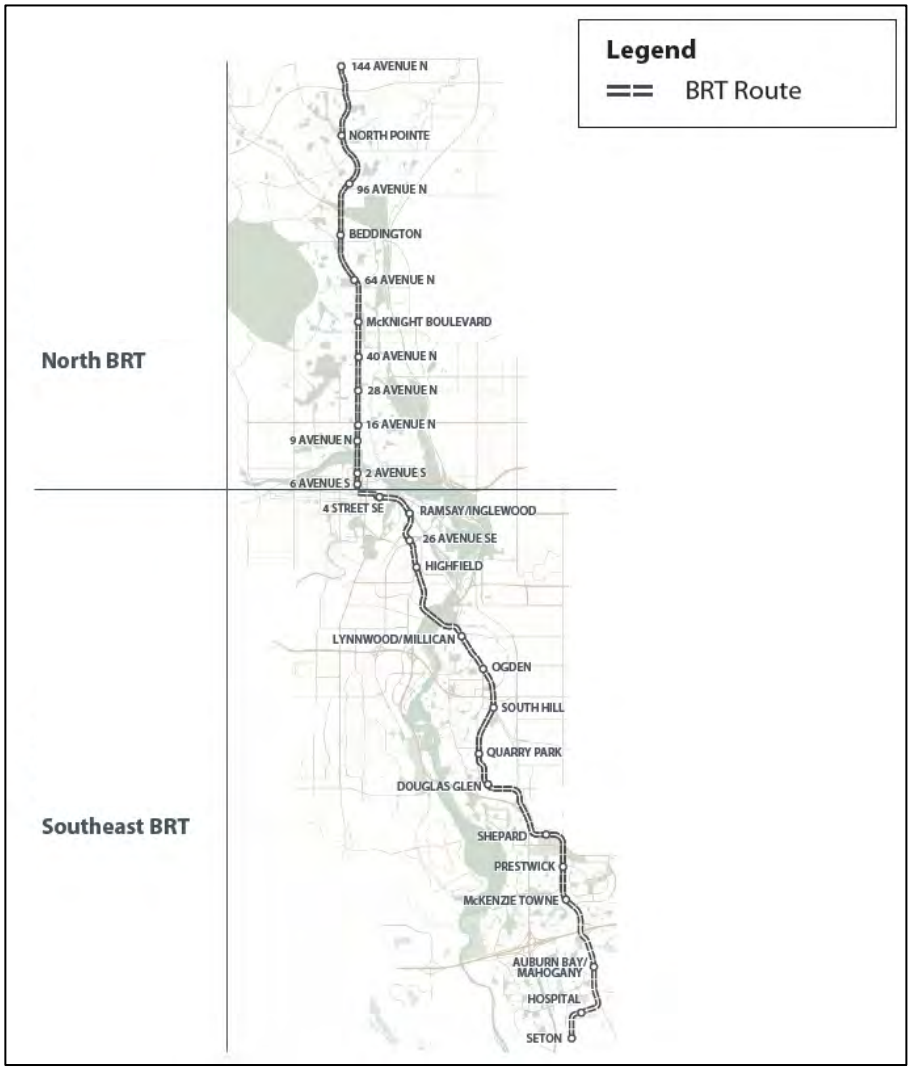


Figure 3-3 Option B1 - North BRT and Southeast BRT

Option B2 - North BRT and Southeast LRT terminates in Beltline

This option uses the LRT alignment approved by City Council in June 2017 between 4 Street SE station and McKenzie Towne, with an elevated alignment on 10 Avenue SW and terminus at 2 Street SW. There is one elevated station at 10 Avenue and 2 Street SW and a pedestrian bridge connection from 2 Street SW station over the CPR tracks to downtown. The North BRT service connects the Centre City to Harvest Hills Blvd Corridor via Centre Street N.. It does not allow for a future connection to a Green Line LRT alignment north of the Centre City.

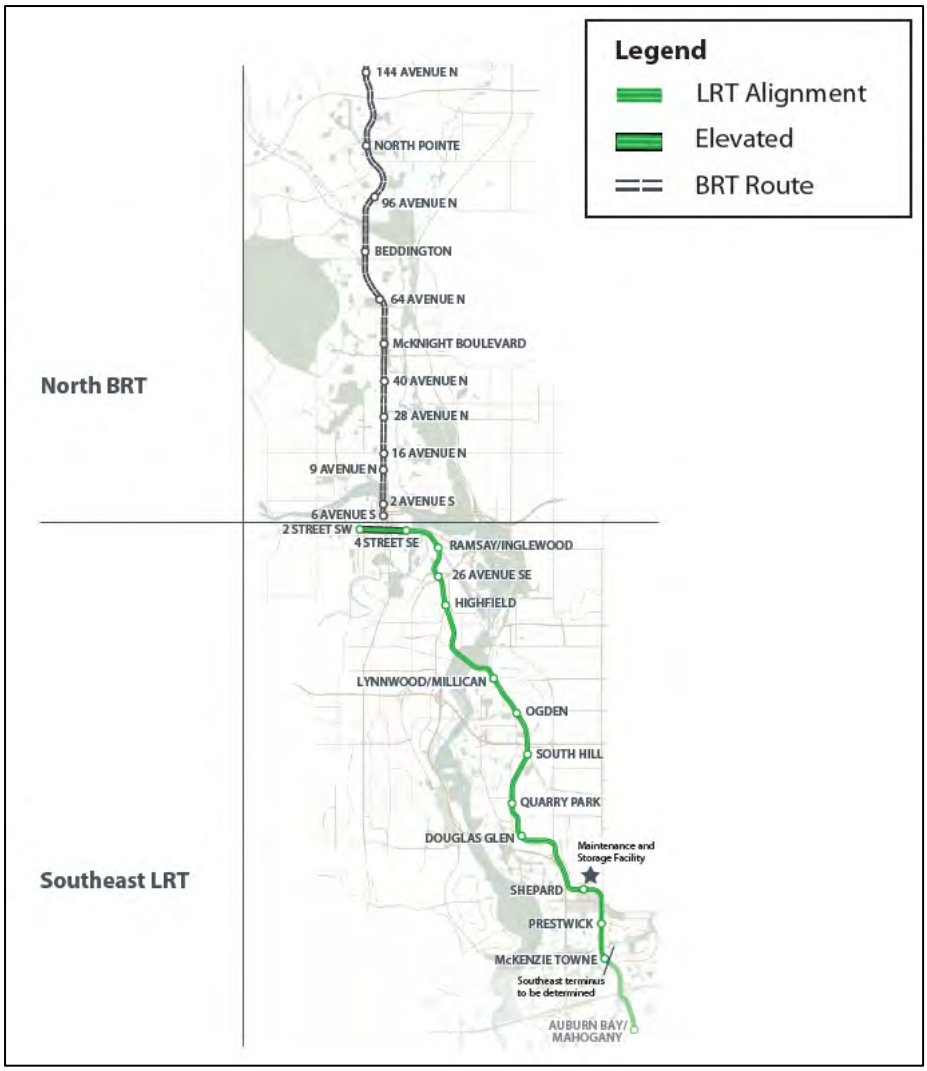


Figure 3-4 Option B2 - North BRT and Southeast LRT terminates in Beltline

Option B3 - North BRT and Southeast LRT connection to Red Line

This option uses a high-floor system on the alignment approved by City Council in June 2017 between Shepard and the Ramsay/ Inglewood station, then connects into the existing Red Line tunnel north of Stampede Park, runs north towards City Hall, departs the Red Line tunnel and turns west via a pre-built tunnel under City Hall, and then runs underground along 8 Ave S with a terminus at 2 Street SW. There would be underground stations at the Event Centre, City Hall, and 2 Street SW. The North BRT service connects the Centre City to Harvest Hills Blvd Corridor via Centre Street N.. It does not allow for a future connection to a Green Line LRT alignment north of the Centre City.

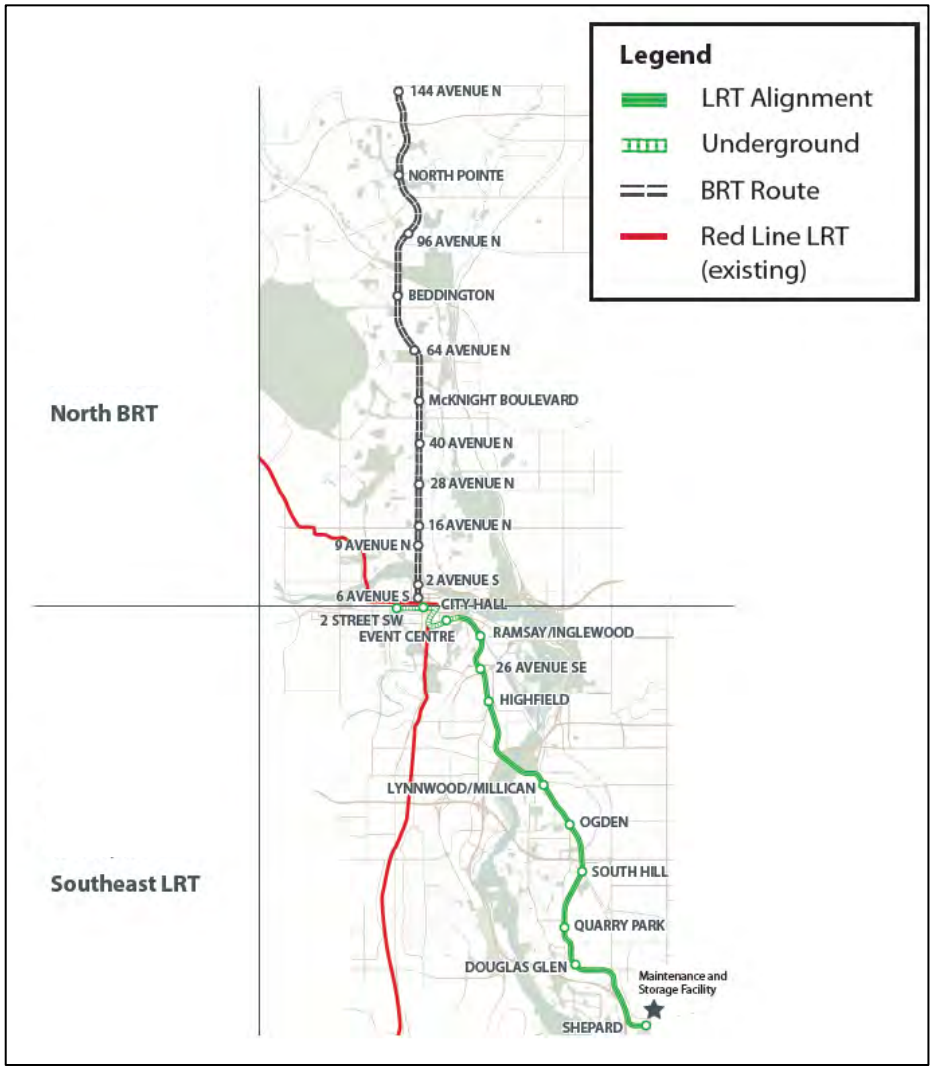


Figure 3-5 Option B3 - North BRT and Southeast LRT connection to Red Line

Option B4 - North LRT and Southeast BRT

In Option B4, the southeast BRT follows the approved LRT alignment between Downtown and Seton, with the terminus in the Centre City to be determined. The North LRT is a separate low-floor LRT system operating on a surface-running alignment on Centre Street N, crossing the Bow River on the existing Centre Street bridge. The south terminus station is at 6 Avenue S on Centre Street S, with the north terminus at 96 Avenue N.

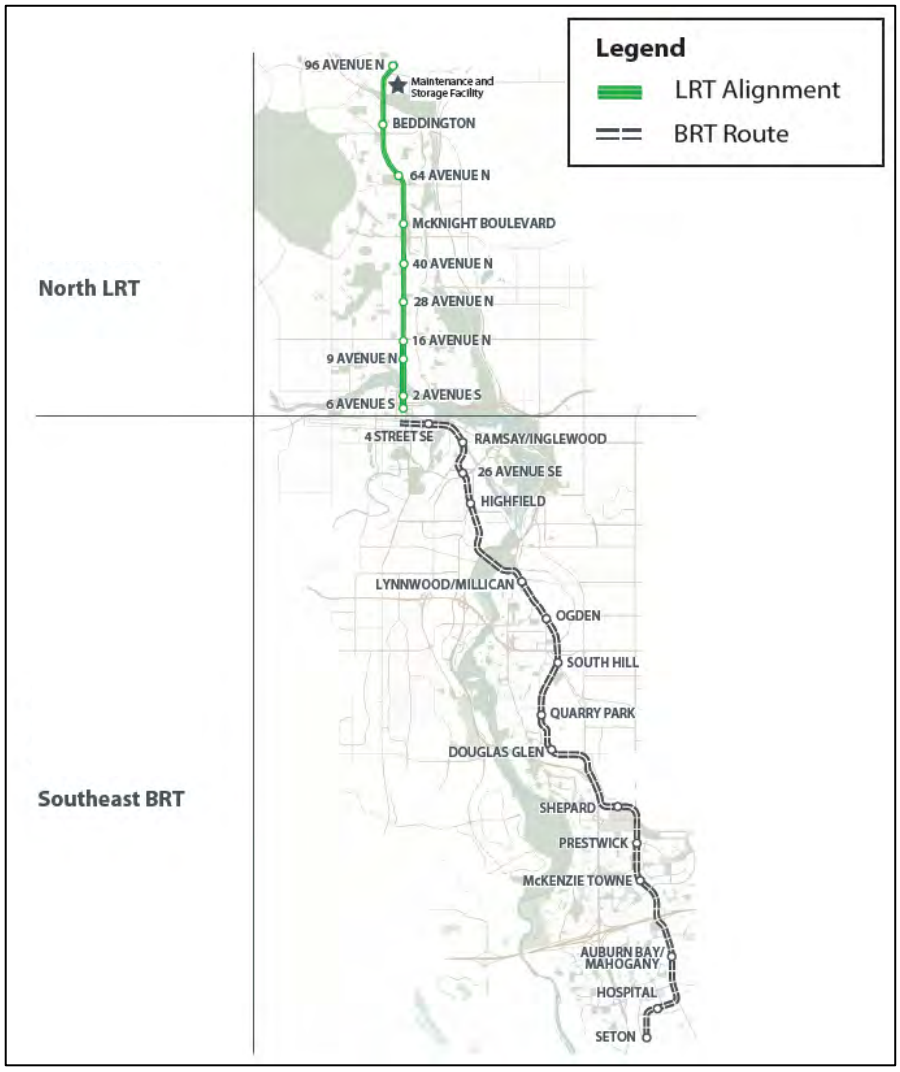


Figure 3-6 Option B4 – North LRT and Southeast BRT

Option C1 - Southeast LRT Connects to Red Line, terminates on 8 Avenue S; North LRT terminates on Centre Street S – Two Systems

This option includes two separate LRT systems. The Southeast LRT uses a high-floor system on the alignment approved by City Council in June 2017 between Shepard and the Ramsay/Inglewood station, then connects into the existing Red Line tunnel north of Stampede Park, runs north towards City Hall, departs the Red Line tunnel and turns west via a pre-built tunnel under City Hall, and then runs underground along 8 Ave S with a terminus at 2 Street SW. There would be underground stations at the Event Centre, City Hall, and 2 Street SW. A separate low-floor, surface-running North LRT operates on Centre Street N with a south terminus at 6 Street S and north terminus at approximately 64 Avenue N. The North LRT crosses the Bow River on the existing Centre Street bridge. This option would not allow for future connection between the North LRT and the Southeast LRT in the Centre City, and requires separate maintenance and storage facilities for each line.

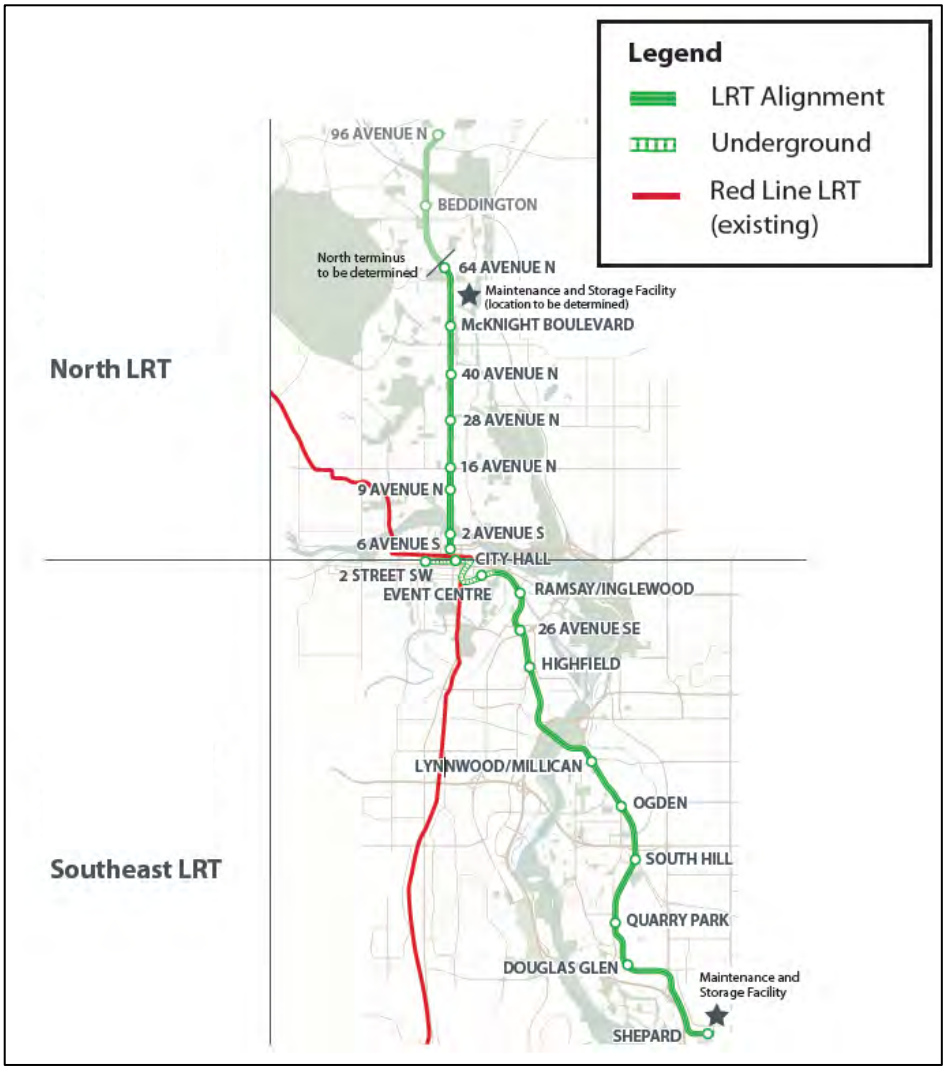


Figure 3-7 Option C1 - Southeast LRT Connects to Red Line, terminates on 8 Avenue S; North LRT terminates on Centre Street S – Two Systems

Option C2 - Southeast LRT terminates in Beltline; North LRT terminates in Centre City - Two Systems

This option includes two separate LRT systems. This option uses the LRT alignment approved by City Council in June 2017 alignment between 4 Street SE station and Shepard, with an elevated alignment on 10 Avenue SW and terminus at 2 Street SW. There is one elevated station at 10 Avenue and 2 Street SW and a pedestrian bridge connection from 2 Street SW station over the CPR tracks to downtown. A separate low-floor, surface-running North LRT operates on Centre Street N with a south terminus at 6 Street S and north terminus at approximately 64 Avenue N. The North LRT crosses the Bow River on the existing Centre Street bridge. This option would not allow for future connection between the North LRT and the Southeast LRT in the Centre City, and requires separate maintenance and storage facilities for each line.

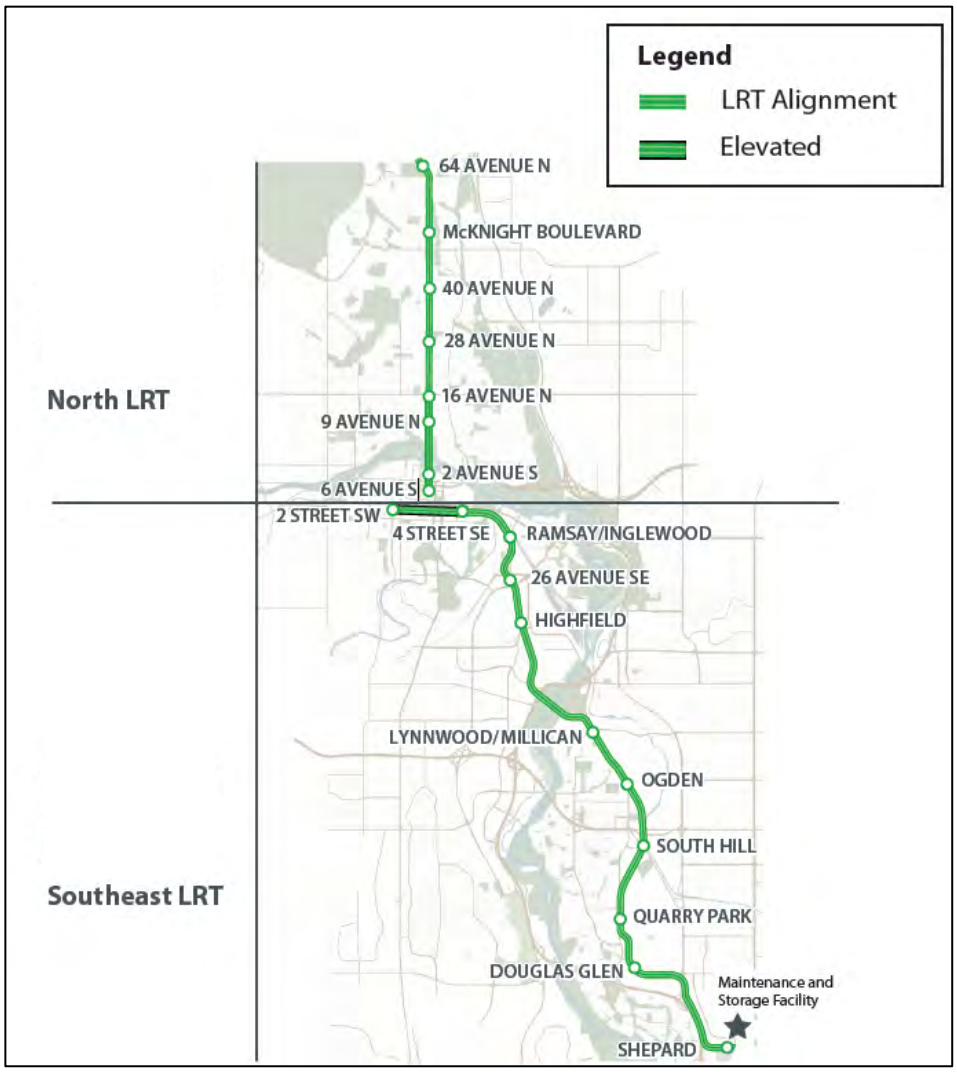


Figure 3-8 Option C2 - Southeast LRT terminates in Beltline; North LRT terminates in Centre City - Two Systems

3.3 Option Summary

The table below summarizes the extents of the options, the anticipated mode for each of the options as well as what / how the options are connected in the Downtown. This is the basis for the evaluation that has been undertaken.

Table 3-2 Table Summarizing Options for Evaluation

Option	Description	Mode	North Terminus	South Terminus	Mode	North Terminus	South Terminus
A1	2017 Council Approved Stage 1 Alignment - 16 Avenue N to Shepard	LRT	16 Avenue N	Shepard	-	-	
A2	Updated Stage 1 Alignment - 16 Avenue N to Shepard with North BRT Improvements	LRT	16 Avenue N	Shepard	BRT	160 Avenue N	Centre City
Option	**Description**	**North of Centre City**			**South of Centre City**		
		Mode	**North Terminus**	**South Terminus**	**Mode**	**North Terminus**	**South Terminus**
B1	North BRT and Southeast BRT	BRT	144 Avenue N	Centre City	BRT	Centre City	Seton
B2	North BRT and Southeast LRT terminating in Beltline	BRT	144 Avenue N	Centre City	LRT	10 Avenue S & 2 Street SW	McKenzie Towne
B3	North BRT and Southeast LRT connects to Red Line, terminates on 8 Avenue S	BRT	144 Avenue N	Centre City	LRT	8 Avenue S & 2 Street SW	Shepard
B4	North LRT and Southeast BRT	LRT	96 Avenue N	6 Avenue S & Centre Street S	BRT	Centre City	Seton
C1	Southeast LRT connects to Red Line, terminates on 8 Avenue S; North LRT terminates on Centre Street S (two separate LRT systems)	LRT	64 Avenue N	6 Avenue S & Centre Street S	LRT	8 Avenue S & 2 Street SW	Shepard
C2	Southeast LRT terminates in Beltline; North LRT terminates in Centre City (two separate LRT systems)	LRT	64 Avenue N	6 Avenue S & Centre Street S	LRT	10 Avenue S & 2 Street SW	Shepard

4 Evaluation Findings

For each of the different options, the criteria were evaluated either qualitatively or quantitatively as appropriate. The full evaluation tables are set out in the sections that follow.

It should be noted that no scoring is applied, nor has weighting been used to the criteria as they are not directly comparable. The data compiled in the sections below was based on information provided by the project team using available information and, where required, used appropriate professional skill and judgement to assess the relative impacts or performance of the option.

4.1 Themes and Criteria

The table presented previously in Section 2.3 of the report is reproduced here as a summary of the evaluation themes and associated evaluation criteria used to assess the options being considered.

Table 4-1 Green Line Evaluation Themes and Criteria

Evaluation Theme	Threshold Assessment	Criteria
Mobility: A transit project that improves mobility	Ability to carry the projected demand	Design capacity and expandability
		Upgradeability
		System ridership and benefits
		Vehicular and Active modes
Connectivity: Connecting People to People and Places	Connectivity to people	People served by the Green Line
		Strategic transit network connections
Development: Urban and Regional Development	Connectivity to jobs	Downtown (north of 9th) jobs served by the Green Line
		Minimizing impact to existing developments
		Maximizing opportunities for future development
Environmental	Potential environmental impacts and risks of construction	Quantitative assessment of environmental risks and unmitigable impacts from construction and operations
Cost and Value	Funding Availability and Eligibility	Capital cost
		Operating and maintenance costs
		Eligibility for provincial and federal funding
		Value and lifespan of investment
Risk and Constructability	Project risk assessment	Identification of significant project/owner technical, delivery or financial risks

4.2 Mobility Theme

Table 4-2 Mobility Theme Evaluation Assumptions

	Assumptions	A1 2017 Council Approved Stage 1 Alignment - 16 Avenue N to Shepard	A2 Updated Stage 1 Alignment - 16 Avenue N to Shepard with North BRT Improvements	B1 North BRT and Southeast BRT	B2 North BRT and Southeast LRT terminating in Beltline	B3 North BRT and Southeast LRT connection to Red Line	B4 North LRT and Southeast BRT	C1 Southeast LRT connects to Red Line, terminates on 8 Avenue S; North LRT terminates on Centre Street S (two systems)	C2 Southeast LRT terminates in Beltline; North LRT terminates in Centre City (two systems)
North	Mode / terminus (current phase)	LRT - 16 Avenue N through running to southeast LRT	LRT - 16 Avenue N through running to southeast LRT BRT Improvements - 144 Avenue to Centre City	BRT - 144 Avenue to Centre City	BRT - 144 Avenue to Centre City	BRT - 144 Avenue to Centre City	LRT - 96 Avenue N to 6 Avenue & Centre Street S	LRT - 64 Avenue N to 6 Avenue & Centre Street S	LRT - 64 Avenue N to 6 Avenue & Centre Street S
	Service Pattern Peak Headway – Maximum (full build out)	3 minutes (requires full priority)	3 minutes (requires full priority)	1.5 minutes	1.5 minutes	1.5 minutes	4 minutes - assumes TSP operation	4 minutes - assumes TSP operation	4 minutes - assumes TSP operation
South	Mode / terminus (current phase)	LRT - through running to Shepard	LRT - through running to Shepard	BRT - Centre City to Seton	LRT - 10 Avenue & 2 Street SW to McKenzie Towne	LRT - 8 Avenue & 2 Street SW to Shepard	BRT - Centre City to Seton	LRT - 8 Avenue & 2 Street SW to Shepard (via Red Line)	LRT -10 Avenue & 2 Street SW to Shepard (no connection)
	Service Pattern Peak Headway – Maximum full build out)	3 minutes - assumes full priority	3 minutes - assumes full priority	1.5 minutes	3 minutes - assumes full priority	3 minutes - assumes full priority	1.5 minutes	3 minutes - assumes full priority	3 minutes - assumes full priority
	LRT Planning Capacity (2 car train)	414	414		414	414	414	414	414
	BRT Planning Capacity (1 articulated bus)			90	90	90	90		

Table 4-3 Mobility Theme Evaluation

Criteria	A1 2017 Council Approved Stage 1 Alignment - 16 Avenue N to Shepard	A2 Updated Stage 1 Alignment - 16 Avenue N to Shepard with North BRT Improvements	B1 North BRT and Southeast BRT	B2 North BRT and Southeast LRT terminating in Beltline	B3 North BRT and Southeast LRT connection to Red Line	B4 North LRT and Southeast BRT	C1 Southeast LRT connects to Red Line, terminates on 8 Avenue S; North LRT terminates on Centre Street S (two systems)	C2 Southeast LRT terminates in Beltline; North LRT terminates in Centre City (two systems)
Design Capacity Passengers per Hour per Direction	8,280	8,280	N =3,600 SE = 3,600	N = 3,600 SE = 8,280	N = 3,600 SE = 8,145* *3-car high floor at 3 min headway	N = 6,210 SE = 3,600	N = 6,210 SE = 8,280	N = 6,210 SE = 8,210
Ability to meet demand (2048)	Yes	Yes	No	North – No Southeast – Yes	North – No Southeast – No (or would require Red Line investment)	North – Yes Southeast – No	North – No Southeast – No (or would require Red Line investment)	Yes
Total daily option ridership (2028)	60K - 65K	75K - 85K	50K - 70K	60K - 75K	70K - 85K	50K - 70K	70K - 85K	60K - 75K
Expandability	• Yes for Green Line N, typical at-grade extension. • Yes for Green Line SE LRT, typical at-grade extension.	• Yes for Green Line N, typical at-grade extension • Yes for Green Line SE LRT, typical at-grade extension.	• N/A once BRT reaches capacity; will need to convert alignment to LRT.	• N/A once North BRT reaches capacity; will need to convert alignment to LRT. • Yes for Green Line SE LRT extension south, typical at-grade extension although likely some throwaway costs at terminus. • No for Green Line SE LRT extension to the Centre City, system is elevated and not able to connect to future Green Line North.	• N/A once North BRT reaches capacity will need to convert alignment to LRT. • Yes for Red Line tunnel extension at cost premium. • Yes for Green Line SE LRT extension south, typical at-grade extension.	• Yes for Green Line North LRT extension north (but not further into downtown as that is ultimate terminus). • N/A once South BRT reaches capacity will need to convert alignment to LRT	• Yes for Green Line North LRT extension north (but not further into downtown as that is ultimate terminus). • Yes for Red Line tunnel extension to go west but at cost premium; • Yes for Green Line SE LRT extension south, typical at-grade extension.	• Yes for Green Line North LRT extension north but not further into downtown. • Yes for Green Line SE LRT extension south, typical at-grade extension although likely some throwaway costs at terminus. • No for Green Line SE LRT extension to the Centre City, system is elevated and not able to connect to future Green Line North.

Criteria	A1 2017 Council Approved Stage 1 Alignment - 16 Avenue N to Shepard	A2 Updated Stage 1 Alignment - 16 Avenue N to Shepard with North BRT Improvements	B1 North BRT and Southeast BRT	B2 North BRT and Southeast LRT terminating in Beltline	B3 North BRT and Southeast LRT connection to Red Line	B4 North LRT and Southeast BRT	C1 Southeast LRT connects to Red Line, terminates on 8 Avenue S; North LRT terminates on Centre Street S (two systems)	C2 Southeast LRT terminates in Beltline; North LRT terminates in Centre City (two systems)
Vehicular impacts (current phase)	Preserves surface options	Impact to Centre Street N	Impact to Centre Street N and downtown access	Impact to Centre Street N and downtown access	Impact to Centre Street N and downtown access	Impact to Centre Street N and downtown access	Impact to Centre Street N and downtown access	Impact to Centre Street N and downtown access
Active mode impacts	Preserves surface options	Disruption to Centre Street N east-west connectivity	Disruption to Centre Street N east-west connectivity	Disruption to Centre Street N east-west connectivity	Disruption to Centre Street N east-west connectivity	Disruption to Centre Street N east-west connectivity	Disruption to Centre Street N east-west connectivity	Disruption to Centre Street N east-west connectivity

The projected long-term demand can be accommodated by options A1, A2, C1, and C2, while options B2 and B3 accommodate the projected long-term demand south of the Centre City only and B4 only accommodates the long term demand in the north. Upgrading the North BRT LRT poses challenges for options B1, B2, and B3, while operational impacts during the upgrade of the South BRT in options B1 and B4 could be limited to the off-peak direction.

4.3 Connectivity Theme

Table 4-4 Connectivity Theme Evaluation

Criteria	A1 2017 Council Approved Stage 1 Alignment - 16 Avenue N to Shepard	A2 Updated Stage 1 Alignment - 16 Avenue N to Shepard with North BRT Improvements	B1 North BRT and Southeast BRT	B2 North BRT and Southeast LRT terminating in Beltline	B3 North BRT and Southeast LRT connection to Red Line	B4 North LRT and Southeast BRT	C1 Southeast LRT connects to Red Line, terminates on 8 Avenue S; North LRT terminates on Centre Street S (two systems)	C2 Southeast LRT terminates in Beltline; North LRT terminates in Centre City (two systems)
Total population catchment* (2048)	N: 134,500 LRT: 99,500	N: 134,500 LRT: 99,500	N = 134,500 SE = 121,000	N = 134,500 SE = 89,000	N = 134,500 SE = 81,000	N = 83,500 SE = 121,000	N = 66,000 SE = 81,000	N = 66,000 SE = 89,000
Strategic Transit Network Connectivity	• Through connectivity on Green Line • Direct connection to Blue and Red Line • Connection to MAX Orange	• Through connectivity on Green Line • Direct connection to Blue and Red Line • Connection to MAX Orange	• Potential connectivity with a number of lines depending on bus scheduling	• No direct Green Line or Centre City connection from Southeast	• No direct Green Line connection • Direct connection to Red Line	• No direct Green Line connection • Direct connection to Blue and Red Line • Connection to MAX Orange	• No direct Green Line connection • Direct connection to Red Line	• No direct Green Line connection • Direct connection to Blue and Red Line • Connection to MAX Orange • No direct Centre City connection from Southeast

* Total catchment is the 800m station catchment and is not the sum of north and southeast catchments due to overlapping station catchments

Options A1 and A2 provide a direct north-south connection through the Centre City and options A1, A2, B4 and C2 provide LRT connections to the Red and Blue line and option B3 and C1 provides a connection to the Red Line LRT. All options except option B1 fail to serve the full population to the north and south.

4.4 Development Theme

Table 4-5 Development Theme Evaluation

Criteria	A1 2017 Council Approved Stage 1 Alignment - 16 Avenue N to Shepard	A2 Updated Stage 1 Alignment - 16 Avenue N to Shepard with North BRT Improvements	B1 North BRT and Southeast BRT	B2 North BRT and Southeast LRT terminating in Beltline	B3 North BRT and Southeast LRT connection to Red Line	B4 North LRT and Southeast BRT	C1 Southeast LRT connects to Red Line, terminates on 8 Avenue S; North LRT terminates on Centre Street S (two systems)	C2 Southeast LRT terminates in Beltline; North LRT terminates in Centre City (two systems)
Total employment catchment* (2048)	N: 207,500 LRT: 216,000	N: 207,500 LRT: 216,000	N = 207,500 SE = 230,000	N = 207,500 SE = 188,500	N = 207,500 SE = 208,500	N = 154,500 SE = 230,000	N = 148,000 SE = 208,500	N = 148,500 SE = 188,500
Minimizing impact to existing and future developments	Preserves surface options	Impact to Centre Street N	Impact to Centre Street N and downtown access Impact to development in downtown	Impact to Centre Street N and downtown access Impact to development in downtown	Impact to Centre Street N and downtown access Impact to development in downtown	Impact to Centre Street N and downtown access Impact to development in downtown	Impact to Centre Street N and downtown access Impact to development in downtown	Impact to Centre Street N and downtown access Impact to development in downtown

* Total catchment is the 800m station catchment and is not the sum of north and southeast catchments due to overlapping station catchments

Options B2 and C2 require a walk connection to sections of Centre City, while all other options provide direct connections to key employment destinations in the Centre City.

4.5 Environmental Theme

Table 4-6 Environment Theme Evaluation

Criteria	A1 2017 Council Approved Stage 1 Alignment - 16 Avenue N to Shepard	A2 Updated Stage 1 Alignment - 16 Avenue N to Shepard with North BRT Improvements	B1 North BRT and Southeast BRT	B2 North BRT and Southeast LRT terminating in Beltline	B3 North BRT and Southeast LRT connection to Red Line	B4 North LRT and Southeast BRT	C1 Southeast LRT connects to Red Line, terminates on 8 Avenue S; North LRT terminates on Centre Street S (two systems)	C2 Southeast LRT terminates in Beltline; North LRT terminates in Centre City (two systems)
Potential Environmental Risk to habitat – river ecosystem	No new bridge over Bow River	New river crossing over Bow River/Princess Island	No new bridge over Bow River	No new bridge over Bow River	No new bridge over Bow River	No new bridge over Bow River	No new bridge over Bow River	No new bridge over Bow River
Potential Environmental Risk – tunnelling disturbs contaminated land	Significant tunnelling increases environmental risk	Reduced length of tunnelling – reduced environmental risk	No tunnelling	No tunnelling	Limited tunnelling – limited environmental risk	No tunnelling	Limited tunnelling – limited environmental risk	No tunnelling

Environmental risks are relatively equal across options, with option A1 posing the greatest risk of disrupting contaminated soils due to significant tunnelling and option A2 introducing risks from a new river crossing. Options B2, B3 B4, C1 and C2 are slightly less risky with reduced or no tunnelling and associated soil contamination impacts.

4.6 Cost and Value Theme

Table 4-7 Cost and Value Theme Evaluation

Criteria	A1 2017 Council Approved Stage 1 Alignment - 16 Avenue N to Shepard	A2 Updated Stage 1 Alignment - 16 Avenue N to Shepard with North BRT Improvements	B1 North BRT and Southeast BRT	B2 North BRT and Southeast LRT terminating in Beltline	B3 North BRT and Southeast LRT connection to Red Line	B4 North LRT and Southeast BRT	C1 Southeast LRT connects to Red Line, terminates on 8 Avenue S; North LRT terminates on Centre Street S (two systems)	C2 Southeast LRT terminates in Beltline; North LRT terminates in Centre City (two systems)
Capital Cost	$5.4B	$4.9B	$2.2B	$4.4B	$4.8B	$3.8B	$6.1B	$5.6B
Operating Cost (annual) (2028)	North - $6M South - $28M	North - $6M South - $28M	North - $56M South - $48M	North - $56M South - $28M	North - $56M South - $28M	North - $34M South - $48M	North - $34M South - $28M	North - $34M South - $28M
Federal and Provincial funding eligibility	Potentially - additional funding may be required	Yes – although there may be an issue with timelines	May require renegotiation due to lack of LRT	May require renegotiation due to change in scope	May require renegotiation due to change in scope	May require renegotiation due to change in scope	Potentially - additional funding may be required	Potentially - additional funding may be required

Option B1 delivers full system, maximizing operational cost benefits at the lowest estimated capital cost, but provided capacity does not meet long term projected demand and would need to be upgraded to LRT in 10-20 years. The estimated capital costs for options A1, C1, and C2 exceed the existing funding envelope. Significant operating costs may be associated with providing bus service north and south of terminus locations (N+SE: options A1, A2, C1 and C2; SE only: options B2, B3 and B4).

4.7 Risk and Deliverability

Table 4-8 Risk and Deliverability Theme Evaluation

Criteria	A1 2017 Council Approved Stage 1 Alignment - 16 Avenue N to Shepard	A2 Updated Stage 1 Alignment - 16 Avenue N to Shepard with North BRT Improvements	B1 North BRT and Southeast BRT	B2 North BRT and Southeast LRT terminating in Beltline	B3 North BRT and Southeast LRT connection to Red Line	B4 North LRT and Southeast BRT	C1 Southeast LRT connects to Red Line, terminates on 8 Avenue S; North LRT terminates on Centre Street S (two systems)	C2 Southeast LRT terminates in Beltline; North LRT terminates in Centre City (two systems)
Significant Stakeholder Risks/Concerns	Affordability of option and ownership of risks	Concerns with surface running and bridge over river	Deviation from LRT commitments	Impacts of not serving the downtown core and deviation from LRT commitments	Impacts of not serving the north of downtown and deviation from LRT commitments	Concerns with surface running and deviation from LRT commitments in the southeast	Concerns about surface running and a disconnected system and deviation from LRT commitments	Concerns about surface running, a disconnected system and not serving the downtown core from the southeast, and deviation from LRT commitments
Major (Unique) Technical Risks	Risks associated with tunnelling.	Bridge impacts and traffic impacts from street running LRT operations. Risks associated with tunneling.	Required bus volumes to service the demand would create operational challenges for the BRT service in the Centre City (e.g. layover and passenger facilities) Challenges of upgrading BRT to LRT in the north given the more constrained right of way and the longer-term demand forecasts	Challenges of upgrading BRT to LRT in the north given the more constrained right of way and the longer-term demand forecasts	Utilising the Red Line tunnel has major impacts on Red Line operations and capacity. Disruption during construction on 8 Avenue S. Challenges of upgrading BRT to LRT in the north given the more constrained right of way and the longer-term demand forecasts	Traffic impacts from street running LRT operations.	Utilising the Red Line tunnel has major impacts on Red Line operations and capacity. Disruption during construction on 8 Avenue S.	Traffic impacts from street running LRT operations.

Options A1 and A2 include geotechnical risks due to significant underground infrastructure, and option A2 includes new Bow River crossing. Option B1 poses challenges for vehicle movements and bus operations within the Centre City. Public perception of BRT as an inferior mode relative to LRT has the potential to impact ridership for options B1, B2, B3, and B4. Additional political and public perception risks are associated with changes to previously announced corridor technologies in option B4.

4.8 Evaluation Summary

The table below summarizes the key differentiating factors for each of the options that support the recommendations in the final section.

Table 4-9 Evaluation Summary Table

Criteria	A1 2017 Council Approved Stage 1 Alignment - 16 Avenue N to Shepard	A2 Updated Stage 1 Alignment - 16 Avenue N to Shepard with North BRT Improvements	B1 North BRT and Southeast BRT	B2 North BRT and Southeast LRT terminating in Beltline	B3 North BRT and Southeast LRT connection to Red Line	B4 North LRT and Southeast BRT	C1 Southeast LRT connects to Red Line, terminates on 8 Avenue S; North LRT terminates on Centre Street S (two systems)	C2 Southeast LRT terminates in Beltline; North LRT terminates in Centre City (two systems)
Mobility: A transit project that improves mobility	Capacity can accommodate projected demand in the **long term**	Capacity can accommodate projected demand in the **long term**	Capacity meets anticipated demand in **medium term** only	Capacity meets anticipated demand in **medium term** for north and **longer term** in south	Capacity meets anticipated demand in **medium term** for north and **long term** in south (but would require Red Line upgrades)	Capacity meets anticipated demand in **long term** for north and **medium term** in south	Capacity can accommodate projected demand in the **long term** (but would require Red Line upgrades)	Capacity can accommodate projected demand in the **long term**
			Once North BRT reaches capacity it will need to be converted to LRT.	Once North BRT reaches capacity it will need to be converted to LRT and Southeast LRT cannot connect to future Green Line North.	Once North BRT reaches capacity it will need to be converted to LRT and Red Line tunnel could be extended at cost premium.	Once South BRT reaches capacity it will need to be converted to LRT.	Red Line tunnel could be extended at cost premium	Southeast LRT cannot connect to future Green Line North.
Connectivity: Connecting People to People and Places	Connectivity through Centre City and connects north and south	Connectivity through Centre City and connects north and south	Connectivity through Centre City and connects north and south	No direct north south connection	No direct north south Green Line connection but Red Line connection	No direct north south connection	No direct north south connection	No direct north south connection

Criteria	A1 2017 Council Approved Stage 1 Alignment - 16 Avenue N to Shepard	A2 Updated Stage 1 Alignment - 16 Avenue N to Shepard with North BRT Improvements	B1 North BRT and Southeast BRT	B2 North BRT and Southeast LRT terminating in Beltline	B3 North BRT and Southeast LRT connection to Red Line	B4 North LRT and Southeast BRT	C1 Southeast LRT connects to Red Line, terminates on 8 Avenue S; North LRT terminates on Centre Street S (two systems)	C2 Southeast LRT terminates in Beltline; North LRT terminates in Centre City (two systems)
	Population at northern and southern extents not served	Population at southern extent not served	Full north to south population served	Population at southern extent not served	Population at southern extent not served	Population at northern extent not served	Population at northern and southern extents potentially not served	Population at northern and southern extents potentially not served
	Beyond Stage 1 impacts due to tunnel portals, little to no impact on vehicular traffic in Centre City due to underground alignment	Potential Stage 1 impact on vehicular traffic through surface running sections	Significant impact on vehicular traffic due to significant bus numbers running downtown	Vehicular traffic impacts slightly worse than today with increased bus volumes	Vehicular traffic impacts similar to today although with increased bus volume	Impact to traffic in Centre City due to lane reduction on centre street N and centre street S	Impact to traffic in Centre City due to lane reduction on centre street N and centre street S	Impact to traffic in Centre City due to lane reduction on centre street N and centre street S
Development: Urban and Regional Development	Connects to key Centre City employment destinations directly	Connects to key Centre City employment destinations directly	Connects to key Centre City employment destinations directly	Requires a walk connection to sections of Centre City	Connects to key Centre City employment destinations directly	Connects to key Centre City employment destinations directly	Connects to key Centre City employment destinations directly	Requires a walk connection to sections of Centre City
Environmental	No significant environmental issues beyond tunnelling impacts	Beyond tunnelling impacts, new river crossing may have minor environmental impacts	No significant environmental issues	No significant environmental issues	No significant environmental issues	No significant environmental issues	No significant environmental issues	No significant environmental issues
Cost and Value	Capital cost is **outside** existing funding envelope	Capital cost is **within** existing funding envelope	**Lowest capital cost** project and is **within** existing funding envelope	Capital cost is **within** existing funding envelope	Capital cost is **within** existing funding envelope	Capital cost is **within** existing funding envelope	Capital cost is **outside** existing funding envelope	Capital cost is **outside** existing funding envelope

Criteria	A1 2017 Council Approved Stage 1 Alignment - 16 Avenue N to Shepard	A2 Updated Stage 1 Alignment - 16 Avenue N to Shepard with North BRT Improvements	B1 North BRT and Southeast BRT	B2 North BRT and Southeast LRT terminating in Beltline	B3 North BRT and Southeast LRT connection to Red Line	B4 North LRT and Southeast BRT	C1 Southeast LRT connects to Red Line, terminates on 8 Avenue S; North LRT terminates on Centre Street S (two systems)	C2 Southeast LRT terminates in Beltline; North LRT terminates in Centre City (two systems)
	With north and south terminus locations there is still significant feeder bus operating costs	With north and south terminus locations there is still significant feeder bus operating costs	Full system maximizes operating cost benefits	North full extent maximizes bus operating cost benefits Southeast terminus still requires significant feeder bus operating costs	North full extent maximizes bus operating cost benefits Southeast terminus still requires significant feeder bus operating costs	North extent still requires significant operating costs Southeast full extent maximizes bus operating cost benefits	With north and south terminus locations there is still significant feeder bus operating costs	With north and south terminus locations there is still significant feeder bus operating costs
	Long term investment (meets long term demand)	Long term investment (meets long term demand)	Medium- term investment (does not meet long term demand)	Medium- term investment (does not meet long term demand)	Medium- term investment (does not meet long term demand)	Medium- term investment (does not meet long term demand)	Long term investment (meets long term demand)	Long term investment (meets long term demand)

Criteria	A1 2017 Council Approved Stage 1 Alignment - 16 Avenue N to Shepard	A2 Updated Stage 1 Alignment - 16 Avenue N to Shepard with North BRT Improvements	B1 North BRT and Southeast BRT	B2 North BRT and Southeast LRT terminating in Beltline	B3 North BRT and Southeast LRT connection to Red Line	B4 North LRT and Southeast BRT	C1 Southeast LRT connects to Red Line, terminates on 8 Avenue S; North LRT terminates on Centre Street S (two systems)	C2 Southeast LRT terminates in Beltline; North LRT terminates in Centre City (two systems)
Risk and Constructability	Significant underground infrastructure and risk of geotechnical challenges	Significant underground infrastructure and risk of geotechnical challenges and new Bow River crossing Could be delivered in Phases to reduce cost and risk.	Volume of buses downtown will have potentially unresolvable impact on vehicular movements. Building BRT in the north leads to capacity limitations with significant challenges and costs and rider impact to upgrade to LRT Public perception of BRT as an inferior mode to LRT may limit ridership potential	Building BRT in the north leads to capacity limitations with significant challenges and costs and rider impact to upgrade to LRT Public perception of BRT as an inferior mode to LRT may limit ridership potential	BRT in the north has capacity limitations with significant costs and rider impact to upgrade Public perception of BRT as an inferior mode to LRT may limit ridership potential Connection to Red Line has potential impacts during construction and operation for Red Line passengers	Public / political perspective of 'flipping' projects Issues with property acquisition and related timescales	Connection to Red Line has potential impacts during construction and operation for Red Line passengers Extent and duration of construction impacts along 8 Avenue S Could be delivered in Phases to reduce cost and risk.	Issues with property acquisition and related timescales Could be delivered in Phases to reduce cost and risk.

5 Alignment Options Review Recommendations

The table below provides a summary of the evaluation outcomes from each option as set out in the previous section.

Table 5-1 MAE Outcomes

Criteria	A1	A2	B1	B2	B3	B4	C1	C2
Mobility	◕	●	◔	◑	◑	◕	◕	◕
Connectivity	●	●	●	◑	◕	◕	◕	◑
Development	●	●	◕	◑	●	●	●	◑
Environmental	◑	◕	●	●	◕	●	◕	●
Cost + Value	◑	◕	◑	◔	◔	◑	◑	◑
Risk + Constructability	◑	◕	◑	◕	◔	◑	◔	◕

Considering the performance of each against the Project Vision, Outcomes for Calgarians, themes and criteria within the MAE, and, importantly, the capital cost and other constraints of this review, **Option A2 is the highest performing option – the Updated Stage 1 Alignment Green Line LRT: 16 Avenue N to Shepard**. The performance of the recommended option (Option A2) is detailed below, followed by summaries of each of the other options and relative performance comparisons to the recommended option A2.

5.1 Recommended Option - A2 - Updated Stage 1 Alignment - 16 Avenue N to Shepard with North BRT Improvements

This option has the capacity to accommodate the projected demand in the long term and can be easily, affordably and incrementally expanded to the north and south in the future. The inclusion of BRT improvements in the north increases the wider benefits of the project and supports the continued development of ridership in the north, with the ultimate potential to extend the LRT northwards from 16 Avenue N once funding becomes available.

It provides good connectivity through downtown, provides strategic transit connections, and connects employment centres north and south of the City. Given this updated version of the project has minimized the amount of tunnelled infrastructure and maximized at-grade running, there will be localised impacts to vehicular traffic that will require further planning and mitigation. In addition, moving more of the alignment to at-grade reduces the risk and capital costs of this option. While this option still has high capital costs, the proposed changes from Option A1 will reduce the total overall cost to within the funding envelope.

5.2 A1- 2017 Council Approved Stage 1 Alignment - 16 Avenue N to Shepard

Comparing this option against Option A2 under the Cost and Value theme, this option is more expensive due to the greater portion of the alignment being underground. There is less value associated with the A1, as it terminates at 16 Avenue N, in comparison with Option A2 which includes BRT improvements to the northern communities.

Both options provide good connectivity through downtown connecting with employment centres, however the additional cost of Option A2 for tunnelling does provide an improvement to traffic and mobility impacts on Centre Street. The tunneling does however pose more potential environmental impacts and technical challenges around risk and project delivery.

Overall, Option A2 outperforms Option A1 under three of the six themes and is equal with it in three of the six themes.

5.3 B1- North BRT and Southeast BRT

Option B1 is the most affordable option and would have the longest length, but compared to Option A2, it is not forecast to meet the projected demand beyond the medium-term time horizon. Upgrading Option B1 to LRT in the future to resolve this demand issue is also challenging and costly and does not provide the best value.

While from an environmental perspective, B1 performs better, there is significant risk that due to the number of buses required to meet the required demand, it would present significant operational challenges and risk compared to Option A2.

Given the very frequent BRT headways that would be required to meet the forecast demand, this would have significant and potentially unresolvable operational challenges. These challenges would include significant pressure on road space downtown, potentially to the detriment of private vehicle movements as well as the ability to maintain transit vehicle spacing, headways and reliability.

The final risk around this project is of public perception of BRT as a lesser mode to LRT – this may result in a decrease in private sector investment/development, lower ridership and lower mode shift.

Overall Option A2 outperforms Option B1 under three of the six themes and performs slightly less well in two of the six themes and performs equally well in one of the six themes.

5.4 B2 - North BRT and Southeast LRT terminating in Beltline

Compared to Option A2, this option lacks a direct connection between the north and south as it operates as two distinct systems and modes. The LRT terminus point in the Beltline means that passengers are required to walk considerable distances (800m +) to certain areas of the Centre City, reducing the ease of access to downtown employment and eliminating the connections to the strategic transit network when compared to Option A2 which runs through the Centre City.

For the north section of the system, in the medium term it is forecast that under Option B2, BRT in the north would not meet the projected demand and the system would be difficult to upgrade to LRT without significant disruption to passengers. This compares to Option A2 which provides a solution which can meet the long-term projected demands.

Option B2 has fewer environmental impacts than Option A2 and has fewer risk and constructability issues. Overall Option A2 outperforms Option B2 under four of the six themes and performs less well in two of the six themes.

5.5 B3 - North BRT and Southeast LRT connection to Red Line

Compared to Option A2, this option lacks a direct connection between the Green Line north and south as it operates as two distinct systems and modes. In comparison, Option B3 connects to the Red Line but leads to potential risk to of operational impacts on both the Red Line tunnel as well as Green Line Southeast LRT operations. This may limit the capacity of both lines under Option B3 compared to Option A2, as under B3 they would share infrastructure and introduce operating risk under Option B3.

For the north section of the system, in the medium term it is forecast that under Option B2, BRT in the north would not meet the projected demand and the system would be difficult to upgrade to LRT without significant disruption to passengers. This compares to Option A2 which provides a solution which can meet the long-term projected demands.

Overall Option A2 outperforms Option B3 under three of the six themes and performs equally well in three of the six themes.

5.6 B4 - North LRT and Southeast BRT

Compared to Option A2, this option lacks a direct connection between the Green Line north and southeast as it operates as two distinct systems and modes. Given project development to date has focussed on Option A1/A2, the LRT designs in the North (North LRT) are considerably further behind than Option A1/A2. In particular, property impacts and acquisition north of 16 Avenue N have not begun and adopting Option B4 would result in a considerable (2+ year) delay in project delivery.

The Centre City LRT terminus (on Centre Street S) is also two to three blocks east of the main centre of downtown which negatively impacts on ridership potential when compared to Option A2 which runs through the core of the downtown. The southern terminus location maximizes the bus operating cost savings, whereas the north terminus still requires significant bus resources to connect to communities north of the project end point.

A further consideration is the long-term viability of a BRT service in the southeast. Modelling completed to date suggests that while a BRT could support the medium-longer term projected demand, it would require upgrading to LRT once the system reaches capacity in approximately 10-20 years.

A further key and potentially significant risk for Option B4, would be the decision to 'flip' the modes for the north and south from LRT to BRT and the timescales that would be required to get the project to construction readiness.

Overall Option A2 significantly outperforms Option B4 under two of the six themes and performs slightly less well in one of the six themes and performs equally well in three of the six themes. The gap in performance in the Mobility and Risk themes (i.e. project readiness) are key in the decision of Option A2 as the preferred option over Option B4.

5.7 C1- Southeast LRT connects to Red Line, terminates on 8 Avenue S; North LRT terminates on Centre Street S (two separate LRT systems)

Similar to Option B3, option C1 lacks a direct connection between the Green Line north and south as it operates as two distinct systems and modes. In comparison, Option C1 connects to the Red Line but leads to potential risk to of operational impacts on both the Red Line tunnel as well as Green Line Southeast LRT operations. This may limit the capacity of both lines under Option C1 compared to Option A2, as under C1, similar to B3, they would share infrastructure and introduce operating risk under Option B3.

As with option B4, project development to date has focussed on Option A1/A2 and the LRT designs in the North (North LRT) are considerably further behind than Option A1/A2. In particular, property impacts and acquisition north of 16 Avenue N have not begun and adopting Option C1 would result in a considerable (2+ year) delay in project delivery.

The Centre City North LRT terminus (on Centre Street S) is also two to three blocks east of the main centre of downtown which negatively impacts on ridership potential when compared to A2 which runs through the core of the downtown.

With two LRT systems included in this option, initial cost estimates are above the existing capital funding available and, significantly higher than option A2. Overall Option A2 outperforms Option C1 under two of the six themes and performs equally well in four of the six themes.

5.8 C2 – Southeast LRT terminates in Beltline; North LRT terminates in Centre City (two separate LRT systems)

Compared to Option A2, Option C2 lacks a direct connection between the Green Line north and southeast as it operates as two distinct systems and modes. The LRT south terminus point in the Beltline means that passengers are required to walk considerable distances to certain areas of Downtown (800m +), reducing the ease of access to downtown employment and eliminating the connections to the strategic transit network when compared to Option A2 which runs through the Centre City.

As with Option B4, project development to date has focussed on Option A1/A2 and the LRT designs in the North (North LRT) are considerably further behind than Option A1/A2. In particular, property impacts and acquisition north of 16 Avenue N have not begun and adopting Option C2 would result in a considerable (2+ year) delay in project delivery.

The Centre City North LRT terminus (on Centre Street S) is also two to three blocks east of the main centre of downtown which negatively impacts on ridership potential when compared to Option A2 which runs through the core of the downtown.

With two LRT systems included in this option, initial cost estimates are above the existing capital funding available and, significantly higher than Option A2. However, if funding were to become further constrained, a phased version of Option C2 could be explored with the SE LRT proceeding within the existing funding (approximately $3.5B) and the North LRT delivered later.

Overall Option A2 outperforms Option C2 under four of the six themes, performs slightly less well in one of the six themes and performs equally well in one of the six themes.

5.9 Conclusions

The evaluation indicates that that within the constraints of the review, **the updated Stage 1 alignment (Option A2) is the best performing option across a broad range of the criteria.** Option A2 is a variation on the original project, but that focuses on reducing the tunnelling risk and trades off the cost of tunnelling and underground options with the impacts of running at-grade. The inclusion of BRT improvements will provide additional benefits to new and existing north central BRT riders over Option A1. Option A2 also provides improved service to the communities in both the north and southeast and provides direct connectivity to the Centre City as well as to the Red and Blue LRT lines and the MAX Orange bus line. In addition, this option addresses the most technically complex and capital intensive aspects of the long-term vision and has the highest state of delivery readiness. It will also best facilitate future extensions and demonstrates the City's commitment to implementing the long-term vision for the Green Line LRT – a cornerstone of Council's approved transit plan – RouteAhead*: A Strategic Plan for Transit in Calgary*.