Eglinton West LRT - Toronto Segment
Conceptual Design and Cost Estimate

Final Report

Submitted to: City of Toronto

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1. Introduction

1.1 Project Scope

The concept plan for the Eglinton West Light Rail Transit (LRT) line between Mount Dennis and Renforth has been developed over several years and is reasonably well understood. It is to follow a median guideway along Eglinton Avenue, and previous projects such as the Eglinton Crosstown LRT and the Renforth Gateway terminal have protected for its future implementation. There are, however, alternative concepts on the table (e.g. tunneled version) that can only be fully assessed or discounted if the City has viable plans and defensible cost estimates for all the options. Creating that information and consistent conceptual approach is the basic thrust of this assignment.

The specific deliverables for this effort are:

1. Final Work Plan
2. Data Requirements Memo
3. Updated Class 5 Cost Estimates
4. Maintenance and Storage Analysis
5. Special Track Work Memo
6. Conceptual design package
7. Class 4 cost estimate
8. Final Report

This work draws on the collected experience and expertise of AECOM and City staff versed in the following fields:

- LRT design
- Railway and Track Engineering
- Civil, Structure, and Bridge Engineering
- Utility Engineering
- Multi-modal Transportation Planning
- Cost Estimation
- Road Design
- Tunnelling
- Structural Engineering
- LRT Systems
- Geotechnical Engineering
- AFP Process
- Quality Management
1.2 Cost Estimation

This study uses the five-class methodology of The Association for the Advancement of Cost Engineering (AACE) for defining the level of accuracy of the cost estimates. The tables in this Section are drawn from AACE International Recommended Practice No. 18R-97, 2005. The five classes of cost estimate are summarized in Table 1, per Figure 1 in AACE 18R-97.

Table 1: Five Classes of Cost Estimates

<table>
<thead>
<tr>
<th>ESTIMATE CLASS</th>
<th>END USAGE</th>
<th>EXPECTED ACCURACY RANGE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Typical purpose of estimate</td>
<td>Typical variation in low and high ranges [a]</td>
</tr>
<tr>
<td>Class 5</td>
<td>Concept Screening</td>
<td>L: -20% to -50% H: +30% to +100%</td>
</tr>
<tr>
<td>Class 4</td>
<td>Study or Feasibility</td>
<td>L: -15% to -30% H: +20% to +50%</td>
</tr>
<tr>
<td>Class 3</td>
<td>Budget, Authorization, or Control</td>
<td>L: -10% to -20% H: +10% to +30%</td>
</tr>
<tr>
<td>Class 2</td>
<td>Control or Bid/ Tender</td>
<td>L: -5% to -15% H: +5% to +20%</td>
</tr>
<tr>
<td>Class 1</td>
<td>Check Estimate or Bid/Tender</td>
<td>L: -3% to -10% H: +3% to +15%</td>
</tr>
</tbody>
</table>

The alternative LRT concepts under study are developed to a basic level of detail, and cannot support detailed cost estimation. Furthermore, it is unnecessary to develop detailed engineering plans to be able to compare the “ballpark costs” of alternatives. At the initial comparative stage, costing is done to the Class 5 level. Information on Class 5 level estimate is presented in Figure 1, per Figure 2a in AACE18R-97.
CLASS 5 ESTIMATE

Description:
Class 5 estimates are generally prepared based on very limited information, and subsequently have wide accuracy ranges. As such, some companies and organizations have elected to determine that due to the inherent inaccuracies, such estimates cannot be classified in a conventional and systemic manner. Class 5 estimates, due to the requirements of end use, may be prepared within a very limited amount of time and with little effort expended—sometimes requiring less than an hour to prepare. Often, little more than proposed plant type, location, and capacity are known at the time of estimate preparation.

Level of Project Definition Required:
0% to 2% of full project definition.

End Usage:
Class 5 estimates are prepared for any number of strategic business planning purposes, such as but not limited to market studies, assessment of initial viability, evaluation of alternate schemes, project screening, project location studies, evaluation of resource needs and budgeting, long-range capital planning, etc.

Estimating Methods Used:
Class 5 estimates virtually always use stochastic estimating methods such as cost/capacity curves and factors, scale of operations factors, Lang factors, Hand factors, Chilton factors, Peters-Timmerhaus factors, Guthrie factors, and other parametric and modeling techniques.

Expected Accuracy Range:
Typical accuracy ranges for Class 5 estimates are -20% to -50% on the low side, and +30% to +100% on the high side, depending on the technological complexity of the project, appropriate reference information, and the inclusion of an appropriate contingency determination. Ranges could exceed those shown in unusual circumstances.

Effort to Prepare (for US$20MM project):
As little as 1 hour or less to perhaps more than 200 hours, depending on the project and the estimating methodology used.

ANSI Standard Reference Z94.2-1989 Name:
Order of magnitude estimate (typically -30% to +50%).

Figure 1: Class 5 Cost Estimate

Capital cost is only one analysis factor; the lowest-cost alternative is not necessarily preferred over others that may better meet project objectives. Once the alternatives have been analyzed and a preferred alternative identified, it is developed to a greater level of engineering detail (focusing on areas where greater cost uncertainty exists). At this level of design, a Class 4 estimate can be supported. Information on Class 4 level estimate is presented in Figure 2, per Figure 2b in AACE 18R-97.

CLASS 4 ESTIMATE

Description:
Class 4 estimates are generally prepared based on limited information and subsequently have fairly wide accuracy ranges. They are typically used for project screening, determination of feasibility, concept evaluation, and preliminary budget approval. Typically, engineering is from 1% to 15% complete, and would comprise at a minimum the following: plant capacity, block schematics, indicated layout, process flow diagrams (PFDs) for main process systems, and preliminary engineered process and utility equipment lists.

Level of Project Definition Required:
1% to 15% of full project definition.

End Usage:
Class 4 estimates are prepared for a number of purposes, such as but not limited to, detailed strategic planning, business development, project screening at more developed stages, alternative scheme analysis, confirmation of economic and/or technical feasibility, and preliminary budget approval or approval to proceed to next stage.

Estimating Methods Used:
Class 4 estimates virtually always use stochastic estimating methods such as equipment factors, Lang factors, Hand factors, Chilton factors, Peters-Timmerhaus factors, Guthrie factors, the Miller method, gross unit costs/ratios, and other parametric and modeling techniques.

Expected Accuracy Range:
Typical accuracy ranges for Class 4 estimates are -15% to -30% on the low side, and +20% to +50% on the high side, depending on the technological complexity of the project, appropriate reference information, and the inclusion of an appropriate contingency determination. Ranges could exceed those shown in unusual circumstances.

Effort to Prepare (for US$20MM project):
Typically, as little as 20 hours or less to perhaps more than 300 hours, depending on the project and the estimating methodology used.

ANSI Standard Reference Z94.2-1989 Name:
Budget estimate (typically -15% to +30%).

Figure 2: Class 4 Cost Estimate
2. Study Area Existing / Planned Conditions

The existing and planned study area conditions are documented in the Eglinton Crosstown Light Rail Transit, Transit Project Assessment Study, Environmental Project Report (March, 2010), the EPR Addendum (2013), and the Eglinton West LRT Planning and Technical Update (2016).

2.1 Utilities

As is expected with any major road corridor, Eglinton Avenue within the study area accommodates and/or is crossed by all major utilities: storm sewer, sanitary sewer, water main, Bell and Rogers telecommunications lines, and Enbridge gas mains. Toronto hydro pole lines run the length of the corridor, with leads to street lights and traffic signals. Two major high voltage electric power transmission corridors cross Eglinton Avenue in the vicinity of Highway 427 – Martin Grove Road. As well, a major Sun Canadian oil pipeline runs parallel to the south side of Eglinton Avenue east of Renforth Drive for 700 m before crossing under the road to get to the north side of Highway 401.

The widening of Eglinton Avenue to accommodate the LRT guideway will affect all utilities, but some more than others. The at-grade guideway creates a utility “exclusion zone” below it, where no utilities are permitted (other than crossings) in order that future utility access for maintenance or repair can occur without impacting LRT operations. Many hydro poles will need to be shifted away from the new roadway, and the shifted curb will also trigger modified or new catch basins for road drainage, even if the storm sewers themselves need not move (although the additional non-permeable surface and other considerations such as resiliency and the age of the infrastructure may require sewer upgrades in any case.

The tunneled alternatives would be deep enough so as to avoid impacts on almost all utilities, although buried and aerial utilities would still need to be rerouted around each station box.

Potentially the most costly and disruptive utility to deal with is Enbridge’s 30 inch diameter high pressure trunk gas main. There are several long segments of pipe that fall within the surface guideway exclusion zone, and either the guideway and road will have to be designed to avoid the pipe, or the pipe relocated out of the zone. The concept plans are premised on the latter.

A Level D Subsurface Utility Engineering (SUE) investigation was carried out as part of the cost estimation process. While there was inadequate information available to be definitive about the presence of all utilities and the impact on them of the LRT design, there were close to 160 points of potential conflict identified.

3. Conceptual LRT Alternatives

3.1 Overview

The Eglinton West LRT concept has been defined and developed through several previous studies, notably the Environmental Assessment of 2010. The current study uses updated versions of that original concept, to reflect current corridor conditions and the design parameters used in the Eglinton Crosstown project, now under construction from Mount Dennis easterly.
3.2 Construction and Design

The basic design principles are:

- Construction of the below-grade section is assumed to be twin bored tunnels with cut-and-cover stations.
- Below- and above-grade stops (stations) will be consistent with the Eglinton Crosstown standards, including the Design Excellence program and AODA requirements for built environment.
- Each stop / station would consist of a centre island platform, two side platforms, or two far-side platforms and basic station amenities.
- Underground stations would feature a pedestrian concourse level to allow movement between the platform and any of the four corners at the surface.

Table 2 sets out the specific design guidance used.

<table>
<thead>
<tr>
<th>Item</th>
<th>Assumption</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1.0 Vehicle</strong></td>
<td></td>
</tr>
<tr>
<td>Minimum vertical clearance</td>
<td>Measured from top of rail: 3.8 m min, 5.485 m nominal, 6.4 m max</td>
</tr>
<tr>
<td>LRV capacity</td>
<td>163 pass/vehicle (489 for 3-car train)</td>
</tr>
<tr>
<td>Consist length</td>
<td>32 m</td>
</tr>
<tr>
<td>2-car consist length</td>
<td>64 m</td>
</tr>
<tr>
<td>3-car consist length</td>
<td>96 m</td>
</tr>
<tr>
<td>Vehicle load</td>
<td>Weight @ AW1 (empty) ≤ 49,500 kg</td>
</tr>
<tr>
<td></td>
<td>Weight @ AWS (crush) ≤ 70,000 kg</td>
</tr>
<tr>
<td>Number of seats</td>
<td>56-60 depending on single or double cab configuration</td>
</tr>
<tr>
<td>Rolling resistance</td>
<td>R = (2197.44) + (0.883v^2)</td>
</tr>
<tr>
<td>(Davies Equation), tunnels</td>
<td>R = (2197.44) + (2.207v^2)</td>
</tr>
<tr>
<td>Rotating mass factor</td>
<td>7% of W4 weight</td>
</tr>
<tr>
<td>Max tractive effort</td>
<td>84kN</td>
</tr>
<tr>
<td><strong>2.0 Stops</strong></td>
<td></td>
</tr>
<tr>
<td>Max. Stop Grade</td>
<td>Max. 2 %</td>
</tr>
<tr>
<td>Side platform width</td>
<td>Minimum 3 m wide from outside edge of platform edge strip to outside edge of platform on the street-side, excluding street-side curb</td>
</tr>
<tr>
<td>Island/Centre platform width</td>
<td>Minimum 5 m wide</td>
</tr>
<tr>
<td></td>
<td>Exact width to be determined based on forecasted passenger volume</td>
</tr>
<tr>
<td>Stop platform length</td>
<td>98 m</td>
</tr>
<tr>
<td><strong>3.0 LRT Alignment</strong></td>
<td></td>
</tr>
<tr>
<td>Track centres:</td>
<td>3.9 m min</td>
</tr>
<tr>
<td>LRT right of way width</td>
<td>7.4 m – midblock (per EPR)</td>
</tr>
<tr>
<td></td>
<td>No specific min. in LA. 7.8 m – shown on drawings</td>
</tr>
<tr>
<td>Turning radius for a 2-and 3-car consist train operating on a main line</td>
<td>Minimum radius achievable by train is 25 m. In bored tunnel sections, minimum radius achievable by TBM is 250 m</td>
</tr>
<tr>
<td>Horizontal minimum spiral lengths and tangents between reverse curves</td>
<td>Spirals not required when R&gt;3000 m, zero superelevation, and unbalanced superelevation is max 25 mm. For non-superelevated curves where unbalanced superelevation is ≤30 mm, 10 m min spiral length. For superelevated curves, min spiral length determined as greatest result from formulas in PA (ensuring that max lateral acceleration = 0.1 g and max. jerk = 0.03 g/s).</td>
</tr>
<tr>
<td>Item</td>
<td>Assumption</td>
</tr>
<tr>
<td>----------------------------------------------------------------------</td>
<td>------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Horizontal minimum tangents</td>
<td>Absolute minimum tangent length between curves is 14 m</td>
</tr>
<tr>
<td></td>
<td>Minimum horizontal tangent length beyond special trackwork located on mainline track and connecting track is 14 m (min. design = 32 m between curves)</td>
</tr>
<tr>
<td>Min. vertical curves length and tangent between vertical curves</td>
<td>Min equivalent radius of 285 m for crest curves</td>
</tr>
<tr>
<td></td>
<td>Min equivalent radius of 521 m for sag curves (min. design = 884 m)</td>
</tr>
<tr>
<td>Min. separation between special trackwork and horizontal curves/spirals and platform</td>
<td>Min horizontal tangent length beyond special trackwork located on mainline track and connecting track of 14 m</td>
</tr>
<tr>
<td></td>
<td>Min horizontal tangent distance of 10 m between end of station/stop platforms and special trackwork</td>
</tr>
<tr>
<td></td>
<td>Min distance of 14 m from transitions between different types of track form or structure type</td>
</tr>
<tr>
<td>Pocket track and cross-over spacing</td>
<td>Pocket track east of Midland Cross-overs every 1.5 to 2 km</td>
</tr>
<tr>
<td>Length of pocket track</td>
<td>As per PA, 3 LRV storage capacity + safe braking distance (min. design = 124m between points of switch)</td>
</tr>
<tr>
<td>Max grade of pocket track</td>
<td>0.3 % or provide means of mitigating vehicle rollaway. (max. design = -1.5 % coupled with +1.8 % sag alignment)</td>
</tr>
<tr>
<td>Turnout Type</td>
<td>Inline: Minimum AREMA No.6 or VDV 50m</td>
</tr>
<tr>
<td></td>
<td>At terminal stations: Minimum AREMA No.8 or VDV 100m (min. design = No.6 AREMA 86.5m)</td>
</tr>
<tr>
<td>Turnout max grade</td>
<td>Acceptable maximum grade of 2 % for mainline turnout</td>
</tr>
<tr>
<td></td>
<td>Absolute maximum grade of 4.5 % for mainline turnout</td>
</tr>
<tr>
<td>Track Centres</td>
<td>Based on LRV dynamic envelope; clearance requirements including min. 50mm running clearances, tolerances, and account for track curvature and superelevation; as well as OCS pole characteristics. (min. design = 3.9 m)</td>
</tr>
<tr>
<td>Track Centres widening on curves</td>
<td>Same as track centres (min. design = 3.9 m)</td>
</tr>
<tr>
<td>Max grades</td>
<td>Max grade of 4 % for unlimited distance</td>
</tr>
<tr>
<td></td>
<td>Grades of between 4-5 % for max 250 m</td>
</tr>
<tr>
<td></td>
<td>Grades over 5 % not permitted</td>
</tr>
<tr>
<td>Tangent before/after platforms</td>
<td>Minimum tangent length of 10m before and after platforms</td>
</tr>
<tr>
<td><strong>4.0 LRT Operations</strong></td>
<td></td>
</tr>
<tr>
<td>Dwell Time</td>
<td>Inline: 30 s</td>
</tr>
<tr>
<td></td>
<td>Turnback: 120 s</td>
</tr>
<tr>
<td>Operating speed of LRT vehicle</td>
<td>60 km/h in semi-exclusive ROW (at-grade)</td>
</tr>
<tr>
<td></td>
<td>80 km/h in fully exclusive ROW (grade-separated or physically separated from other modes, e.g. with fence)</td>
</tr>
<tr>
<td>Operating speed of LRT vehicles travelling straight through intersections</td>
<td>40 km/h</td>
</tr>
<tr>
<td>Operating speed of LRT vehicles traveling through intersections while making a turn</td>
<td>15 km/h</td>
</tr>
<tr>
<td>Operating speed of LRV when travelling over a cross-over section</td>
<td>24 km/h for #6, 32 km/h for # 8</td>
</tr>
<tr>
<td>Regular service deceleration/braking rate</td>
<td>0.9 m/s² (dev. 0.3 m/s²)</td>
</tr>
<tr>
<td>Regular service acceleration rate</td>
<td>0.9 m/s² (dev. 0.3 m/s²)</td>
</tr>
</tbody>
</table>
## Item Assumption

### Acceleration based on different grades

<table>
<thead>
<tr>
<th>Grade</th>
<th>Max Acceleration</th>
</tr>
</thead>
<tbody>
<tr>
<td>0%</td>
<td>1.2m/s²</td>
</tr>
<tr>
<td>1%</td>
<td>1.12m/s²</td>
</tr>
<tr>
<td>2%</td>
<td>1.03m/s²</td>
</tr>
<tr>
<td>3%</td>
<td>0.94m/s²</td>
</tr>
<tr>
<td>4%</td>
<td>0.85m/s²</td>
</tr>
<tr>
<td>5%</td>
<td>0.76m/s²</td>
</tr>
<tr>
<td>6%</td>
<td>0.67m/s²</td>
</tr>
</tbody>
</table>

Values for higher loading (seated + 5 pass/m²) are roughly 0.04 m/s² less. Values for highest loading (seated + 7 pass/m²) are roughly 0.08 m/s² less.

### Required intersection clearance calculations/formulas

- **For two car trains**
  - From 50 km/h to stop on the far-side platform: 17 Seconds
  - From 30 km/h to stop on the far-side platform: 21 Seconds
  - From 25 km/h to stop on the far-side platform: 23 Seconds

- **For three car trains**
  - From 50 km/h to stop on the far-side platform: 20 Seconds
  - From 30 km/h to stop on the far-side platform: 25 Seconds
  - From 25 km/h to stop on the far-side platform: 28 Seconds

### Speed profiles for curves and positive/negative grades

- 2%, 55 km/h
- 4%, 35 km/h
- 5%, 19 km/h

### Max vertical gradient for 2- and 3-car train consists at max speed

- Main line absolute max sustained grade of 4%
- Grades between 4-5% may be sustained for absolute max distance of 250m
- Main line absolute max sustained grade up to 250m long is 5%

### Max vertical gradient for 2- and 3-car train consists when towing / pushing another vehicle at max speed

- Max grade of 5% with speed of 19 km/h

### Speed restrictions on horizontal curves

- No standards for ECLRT - refer to TCRP track design handbook

### Staffed stations and stops

- All stations will be staffed by Operator personnel on full time basis during revenue service hours (station attendant booth at each station).
- Surface stops will not be staffed.

### All stop vs request stop service

- Request stop service at operator’s discretion
- HOWEVER, all-stop service should be assumed for the purpose of analysis (all stops will be used in peak periods)

### 5.0 LRT Service

- **Peak headway**: 4 min

### 6.0 Transit Signal Priority

- **Vehicle parent phases**: The Light Rail Vehicle (LRV) is to be served concurrently with non-conflicting vehicle parent phases. In most cases along Eglinton Ave, the LRV will operate with the eastbound and westbound through vehicle phases.

- **Transit signal phasing**: Use TSP - API without truncation.

- **Auto left turns**: All left turn movements from Eglinton Ave that cross the LRV’s path will be coded to be fully protected. The calculated split that is to be assigned to the fully protected left turn movements shall be determined on the overall intersection LOS and the left turn demand.

- **Clearance timing**: Left turn clearance times at intersections with Transitway shall be extended as required.

| Cycle lengths | 130 s |
### Item | Assumption
--- | ---
Pedestrian crossings | 2 stage crossings not used in City. TS has agreed to use TTC alternative approach to 2 stage crossings.
API alternative | If API cannot be fixed, maximum green extension for transit phase to be set to 30 s
Added cycles | TTC to provide email for source if existing policy for added cycles - This method to be used.
Dwell Time | Use a fixed dwell time of 30 secs for all stops – as per the EELRT/Crosstown Turnback: 120 s

The evaluation / analysis does not include consideration for any potential road network changes or design options currently under review in the Eglinton + Martin Grove Area Traffic Network study.

### 3.3 Alternatives

The current investigation begins with six alternatives. Each has essentially the same horizontal alignment; the differences are in the vertical alignment (tunnel vs. at grade vs. elevated) and in the number of stations.

Each alternative has a common eastern terminus, at the tunnel “stub” immediately east of Weston Road, and west of the Mount Dennis station being built as part of the Eglinton Crosstown LRT line. While the Mount Dennis station is technically at grade (it is at street level, under the Metrolinx Kitchener rail line), the LRT guideway extension to the west would be below grade.

#### 3.3.1 Alternative A: At-Grade

The alignment approved by Toronto City Council in December 2017 would include 14 stops based on the 2010 Eglinton Crosstown LRT Environmental Assessment (EA), emerging from the below grade (underground) stop at Mount Dennis identified in a 2013 EA amendment and running at grade (street level) to Pearson Airport.

**Stops**
- **At-grade (street level)** stops would be located at Jane Street, Scarlett, Mulham, Royal York, Islington, Wincott / Bemersyde, Kipling, Widdicombe / Lloyd Manor, Martin Grove, and Commerce Blvd at Renforth Station in Mississauga

Beyond Commerce, the LRT would continue with an elevated structure over Highway 401, and additional stops at Convair, Silver Dart, and the planned Regional Transit and Passenger Centre (RTPC) at Pearson Airport. A schematic of Alternative A is illustrated in Figure 3.
3.3.2 Alternative B: Tunnel

The Tunnel option for the Eglinton West LRT would be entirely below grade from Mount Dennis westerly to Renforth Drive. In Mississauga, the tunnel would come to surface west of Renforth Drive and terminate at the Commerce Station (Renforth Transit Hub); it is not physically or operationally feasible to create a tunneled stop under the Transitway at Renforth. A future / separate extension to the planned RTPC at Pearson Airport would cross Highway 401 on a new LRT bridge, and include stops at Convair and Silver Dart Drive.

Stops
- **Below-grade (underground)** stops would be located at Jane Street, Scarlett, Mulham, Royal York, Islington, Wincott / Bemersyde, Kipling, Widdicombe / Lloyd Manor, Martin Grove
- **At Grade** stop at Commerce Blvd (Renforth Station) in Mississauga

3.3.3 Alternative C: Hybrid 3 Stations

This alternative limits the tunnelled segment to between west of Scarlett Station and east of Commerce Boulevard. It features an elevated segment (instead of tunnel) across the Eglinton Flats / Humber River valley between Mount Dennis and Scarlett. The number of stations is reduced to a minimum in order to optimize LRT operations, maximize travel speed, and reduce construction cost.

Stops
- **Elevated** stop at Jane Street
- **Underground** stop at Kipling Avenue
- **At Grade** stop at Commerce Blvd (Renforth Station) in Mississauga

A schematic of Alternative C is illustrated in Figure 4.
3.3.4 Alternative D: Hybrid 7 Stations

This alternative adds four stations to the three in Alternative C, to allow better local access and network connections.

Stops

- **Elevated** stops at Jane Street and Scarlett Road
- **Underground** stops at Royal York Road, Islington Avenue, Kipling Avenue, and Martin Grove Road
- **At Grade** stop at Commerce Blvd (Renforth Station) in Mississauga

3.3.5 CWG Alternatives

The Community Working Group (CWG) has put forth two additional concepts for consideration.

3.3.5.1 CWG Alternative #1

**CWG Option 1** would be above grade (elevated) at Jane and Scarlett (including elevated trackwork between), and below grade (underground) from Royal York to west of Martin Grove. Emerging from a portal near Rangoon Road to the west of the Highway 427 overpass, the LRT would briefly run at grade along the south side of Eglinton Avenue before moving onto an elevated structure east of Matheson Boulevard and the Transitway off ramps so as to avoid interactions with other traffic. The elevated structure includes a stop at Commerce and would continue over Highway 401. The LRT would return to grade at Convair, and proceed below grade from shortly after Convair to Pearson Airport RTPC.

Stops

- **Elevated (above ground)** stops would be located at Jane, Scarlett, and Commerce
- **One at grade (street level)** stop would be located at Convair
- **Below-grade (underground)** stops would be located at Royal York, Islington, Kipling, Martin Grove, and the planned RTPC at Pearson Airport

A schematic of Alternative CWG Alternative #1 is illustrated in Figure 5.
3.3.5.2 CWG Alternative #2

CWG Option 2 would be entirely below grade (underground) from Mount Dennis to Pearson Airport with 10 stops, generally at intersecting major arterials and surface bus services.

**Stops**
- **Elevated (above ground)** stops would be located at Jane and Scarlett
- **Below-grade (underground)** stops would be located at Royal York, Islington, Kipling, Martin Grove, Commerce Blvd (under Renforth Station in Mississauga)

The LRT would continue below grade (underground) past Commerce, under Highway 401 into the GTAA lands, and stopping at Convair and the planned RTPC at Pearson Airport. A schematic of CWG Alternative #2 is illustrated in Figure 6.
4. Class 5 Cost Estimates and Analysis of LRT Alternatives

4.1 CWG Alternatives Screening

The CWG alternatives (1 and 2) were not taken through the cost estimate process. The only difference between the CWG alternatives and the others is the treatment in the Highway 427 – Renforth area, where Alternatives A – D use a common at-grade stop on Commerce Boulevard directly adjacent to the Renforth terminal while CWG #1 has an elevated stop and CWG #2 has a tunnelled stop at Renforth.

The reason to grade separate the LRT from surface roads is to avoid traffic impact (noting that the additional level is usually negative in terms of the transit user experience and always significantly higher in terms of cost). Commerce Boulevard is unlike the major north-south arterials to the east where the time taken for LRT movement has a significant impact on the capacity remaining for high volumes of vehicular turning and through movement. Since Commerce Boulevard itself is a lightly-travelled side street, only two blocks long, with numerous alternatives for traffic flow, and the surface LRT turn into and out of Eglinton Avenue at Commerce would have a minor effect on westbound through and eastbound left turning traffic only, there is not a compelling traffic impact case to grade separate that move. There is no system-wide benefit to a grade separation at the Commerce / Eglinton intersection; the Renforth / Eglinton intersection just to the east faces much more significant traffic volumes, turning moves, and delays. The grade separation (either elevated or tunnelled) would be extraordinarily costly relative to the potential benefits, as the infrastructure would extend well beyond the Commerce stop in either direction.

For CWG #1, an elevated station at Commerce would require (below grade) Transitway passengers to change two levels rather than one to transfer to/from the LRT line; this would increase transfer time and impact customer convenience, with a negative effect on transit...
ridership. For the guideway, due to the distance it would take to bring LRVs from a tunnel depth
to an elevated guideway (a vertical climb of approximately 22 m; at 4 % maximum grade,
corresponding to a 600 m length), there would not be enough length to do so between the
Renforth Drive and Commerce Boulevard intersections. This means that the transition would
have to occur east of the Matheson / Eglinton intersection, which would yield an LRT viaduct
approximately 1.6 km in length (from west of Highway 427 to the north side of Highway 401). An
elevated guideway would conflict with the Hydro One high voltage transmission lines which
cross Eglinton Avenue east of Matheson Boulevard, and the transition grade east of Matheson
is also likely to intercept a major Enbridge trunk gas main. These utility conflicts, combined with
the extraordinary amount of infrastructure required to create a single elevated stop, imply that
this alternative would fail any Benefit / Cost analysis relative to the at-grade alternatives.

For CWG #2, the continuation of the tunnel would yield a very deep station at Commerce (since
the LRT would need to pass under the Transitway station and bridge foundations, which
themselves sit below Commerce Boulevard) with the associated high capital cost and
passenger disbenefit. There is not enough distance to allow the deep tunnel guideway to
surface between the Commerce station and Matheson Boulevard, so it would need to extend
right under Highway 401 to reach the Airport lands. This is an increase in tunnel length of
approximately 1 km compared to the at-grade Alternative. Again, the benefits of doing so in
terms of minimizing traffic impact are relatively minor and would not support a Benefit / Cost
analysis or Business Case relative to the at-grade alternative at Commerce Boulevard. It may
also be noted that Commerce Boulevard is not located within the City of Toronto; any traffic
benefits would accrue to users of Mississauga roads.

4.2 Vehicle Requirements as Input to Cost Estimation

TTC has provided estimate of vehicle allocation to the EWLRT service. These estimates are
shown in Table 3.

Table 3: Vehicle Allocation Estimates for EWLRT

<table>
<thead>
<tr>
<th>Alt.</th>
<th>Peak Vehicles: EWLRT Only</th>
<th>Spares (15 %)</th>
<th>Total Vehicles: EWLRT Only</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>57</td>
<td>9</td>
<td>66</td>
</tr>
<tr>
<td>B</td>
<td>48</td>
<td>8</td>
<td>56</td>
</tr>
<tr>
<td>C</td>
<td>36</td>
<td>6</td>
<td>42</td>
</tr>
<tr>
<td>D</td>
<td>42</td>
<td>7</td>
<td>49</td>
</tr>
</tbody>
</table>

The cost per vehicle is provided by Metrolinx.

4.3 Class 5 Cost Estimate

Class 5 Cost Estimates were prepared for Alternatives A – D. It may be noted that the
alternatives are identical (at grade) at the Commerce station. The comparative cost estimates
include only the segment of the LRT project between Mount Dennis and Commerce Boulevard;
they do NOT cover the extension across Highway 401 to Pearson Airport, which is being
addressed separately. Because this analysis has common end points, it can be considered on a
standalone basis and does not affect any development or assessment of alternatives in the
Airport area.
The CWG concepts were not costed, for reasons described above; it may be reasonably assumed that they would be more costly to build than Alternative B.

Table 5 summarized the Class 5 comparative cost estimate for Alternatives A – D. This is a high-level estimate based on the alternative plans and profiles developed for each alternative (see Appendix A) and on the study team’s knowledge of the study corridor.

The cost estimate in Table 5 is based on the following:

**Exclusions**

- Operations & Maintenance Costs (by TTC).
- Life-cycle costing and cash flow charts (by Metrolinx)
- AFP/P3 Related Soft Costs (including short and long term financing, IO and transaction costs, Legal Fees, Lender’s Technical Advisor Fees, etc.)

**Assumptions**

- Assumed AFP/P3 procurement / project delivery method.

**Notes**

- Quantities provided by AECOM transportation Design/Engineering Team.
- Based on sketches prepared by AECOM as included in Appendix A.
- Canadian Dollar at the Fourth Quarter of 2018
- Class 5 Estimate level of accuracy per AACE
- Escalation (price inflation) to the actual year of construction is NOT included.

**Alternatives**

Table 4 illustrates the stop configurations for Alternatives A – D.

**Table 4: Stop Configuration for Alternatives A – D**

<table>
<thead>
<tr>
<th>Station</th>
<th>Alternative</th>
<th>A - At Grade</th>
<th>B - tunnel</th>
<th>C - tunnel</th>
<th>D - tunnel</th>
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<tr>
<td>Jane</td>
<td>at grade</td>
<td>below grade</td>
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<td>elevated</td>
<td></td>
</tr>
<tr>
<td>Scarlett</td>
<td>at grade</td>
<td>below grade</td>
<td>-</td>
<td>elevated</td>
<td></td>
</tr>
<tr>
<td>Mulham</td>
<td>at grade</td>
<td>below grade</td>
<td></td>
<td></td>
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<tr>
<td>Royal York</td>
<td>at grade</td>
<td>below grade</td>
<td>below grade</td>
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<td></td>
</tr>
<tr>
<td>Islington</td>
<td>at grade</td>
<td>below grade</td>
<td>-</td>
<td>below grade</td>
<td></td>
</tr>
<tr>
<td>Wincott</td>
<td>at grade</td>
<td>below grade</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kipling</td>
<td>at grade</td>
<td>below grade</td>
<td>below grade</td>
<td>below grade</td>
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<tr>
<td>Widdicombe / Lloyd Manor</td>
<td>at grade</td>
<td>below grade</td>
<td>below grade</td>
<td>below grade</td>
<td>below grade</td>
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<tr>
<td>Martin Grove</td>
<td>at grade</td>
<td>below grade</td>
<td>-</td>
<td>below grade</td>
<td></td>
</tr>
<tr>
<td>Commerce</td>
<td>at grade</td>
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<td>at grade</td>
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### Table 5: Class 5 Comparative Cost Estimate – Alternatives A – D

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<th>FTA Code</th>
<th>Description</th>
<th>Unit</th>
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<th>Amount</th>
<th>Qty</th>
<th>Amount</th>
<th>Qty</th>
<th>Amount</th>
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<tr>
<td>01</td>
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<td>$0</td>
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<td>Guideway - At grade semi-exclusive</td>
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<td>Guideway - At grade mixed traffic</td>
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</tbody>
</table>

### Comments
- **OPTION A**: 10 Stops At Grade
- **OPTION B**: 10 Stops Tunneled
- **OPTION C**: 3 Stops Tunneled & Elevated
- **OPTION D**: 7 Stops Tunneled & Elevated

- **Comments**: no exclusive guideway in this project
- **Includes**: granular base, reinforced concrete base, concrete, ties, steel rails, additional concrete toppings
- **Includes**: twin bored tunnels; $30,000/m x 2 tunnels
- **Includes**: tunneling by TBM, supply/install precast tunnel segments, and grouting
- **Includes**: haul away excavated material, TBM procurement, trackwork and infill, launch & extraction shafts, temporary staging areas, signals/systems, EEB's/tunnel cross-over structures and ventilation shafts, track cross-over box structures (costed separately)
- **Includes**: direct fixation at grade
- **Includes**: embedded in tunnels / viaducts and intersections (assume 40 m per crossing); incl rail welding, cross ties, bolts, precast ties, concrete, asphalt at crossings, tracklaying
- **Includes**: no ballasted track in this project
- **Includes**: 100 m long x $30,000/m
- **Includes**: ventilation, monitoring, emergency systems, controls
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<thead>
<tr>
<th>FTA Code</th>
<th>MK Sub-code</th>
<th>Description</th>
<th>Unit</th>
<th>Rate</th>
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<th>Amount</th>
<th>Comments</th>
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<tbody>
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<td>At-Grade Stop (Centre Island platform)</td>
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<td>$8,000,000</td>
<td>1</td>
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<td>1</td>
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<td>1</td>
<td>$2,000,000</td>
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<td>INCLUDES STATION LEVEL AND CONSTRUCTION LEVEL, ELEVATORS, STAIRS, ETC.</td>
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<td>VERTICAL PEDISTRIAN ACCESS STRUCTURE / STATION ENTRANCE, ELEVATORS, ETC.</td>
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<tr>
<td>01</td>
<td></td>
<td>Administration Building</td>
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<td>NOT IN SCOPE; PART OF MT. DENNIS MSF</td>
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<td>NOT IN SCOPE; PART OF MT. DENNIS MSF</td>
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<td>Yard or Yard Track</td>
<td>m</td>
<td>$450</td>
<td>0</td>
<td>$0</td>
<td>0</td>
<td>$0</td>
<td>0</td>
<td>$0</td>
<td>0</td>
<td>$0</td>
<td>0</td>
<td>$0</td>
<td>NOT IN SCOPE; PART OF MT. DENNIS MSF</td>
</tr>
<tr>
<td>06</td>
<td></td>
<td>Additional EWLRT Provisions at Mt Dennis MSF</td>
<td>ls</td>
<td>$25,245,702</td>
<td>1</td>
<td>$25,245,702</td>
<td>1</td>
<td>$25,245,702</td>
<td>1</td>
<td>$25,245,702</td>
<td>1</td>
<td>$25,245,702</td>
<td>ADDITIONAL EWLRT PROVISIONS AT MT. DENNIS MSF</td>
<td></td>
<td></td>
</tr>
<tr>
<td>01</td>
<td></td>
<td>Demolition, Clearing, Earthwork</td>
<td>km</td>
<td>$850,000</td>
<td>9</td>
<td>$7,650,000</td>
<td>1</td>
<td>$850,000</td>
<td>3</td>
<td>$2,550,000</td>
<td>3</td>
<td>$2,550,000</td>
<td>BASED ON FINCH WEST LRT ESTIMATE OF $9 M FOR 11 KM, INC. MOBILIZATION, SITE OFFICES, PERMITS, ROAD REMOVALS, CLEARING AND CRUBBING, ETC.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>02</td>
<td></td>
<td>Site Utilities, Utility Relocation</td>
<td>m</td>
<td>$15,000</td>
<td>9,200</td>
<td>$138,000,000</td>
<td>1,560</td>
<td>$23,400,000</td>
<td>1,130</td>
<td>$16,950,000</td>
<td>1,430</td>
<td>$21,450,000</td>
<td>REMOVAL AND REPLACEMENT OF ALL UTILITIES UNDER SURFACE GUIDEWAY AND AT STATION BOXES; RELLOCATION OF ALL UTILITIES AFFECTED BY ROAD WIDENING (INCL 100 M PER STATION Box)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FTA Code</td>
<td>MK Sub-code</td>
<td>Description</td>
<td>Unit</td>
<td>Rate</td>
<td>Qty</td>
<td>Amount</td>
<td>Unit</td>
<td>Rate</td>
<td>Qty</td>
<td>Amount</td>
<td>Unit</td>
<td>Rate</td>
<td>Qty</td>
<td>Amount</td>
<td>Comment</td>
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<td>----------</td>
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<td>------------------------------------------------------------------------------</td>
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<td>--------------------------------------------------------------------------</td>
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<tr>
<td>03</td>
<td></td>
<td>Hazardous material, contaminated soil removal / mitigation, ground water treatments</td>
<td>ls</td>
<td>allowance</td>
<td>ls</td>
<td>$1,000,000</td>
<td>ls</td>
<td>$5,000,000</td>
<td>ls</td>
<td>$4,000,000</td>
<td>ls</td>
<td>$4,000,000</td>
<td>Assume Eglinton corridor is relatively &quot;clean&quot; - no history of industry or contamination. Testing and risk of soil contamination is proportionally greater for tunnel and below-grade station areas. Dollar figure shown is an arbitrary placeholder, pending more geotech information at Class 4.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>04</td>
<td></td>
<td>Environmental mitigation, e.g. wetlands, historic/archaeologic, parks</td>
<td>ls</td>
<td>allowance</td>
<td>ls</td>
<td>$1,000,000</td>
<td>ls</td>
<td>$0</td>
<td>ls</td>
<td>$2,500,000</td>
<td>ls</td>
<td>$2,500,000</td>
<td>Primarily impacts related to a new or widened Humber Valley elevated crossing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>05</td>
<td></td>
<td>Site structures including retaining walls, sound walls</td>
<td>m</td>
<td>$2,500</td>
<td>0</td>
<td>$0</td>
<td>0</td>
<td>$0</td>
<td>0</td>
<td>$0</td>
<td>portal walls captured in 10.08</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>06</td>
<td></td>
<td>Pedestrian / bike access and accommodation, landscaping</td>
<td>m</td>
<td>$2,000</td>
<td>9,200</td>
<td>$18,400,000</td>
<td>800</td>
<td>$1,600,000</td>
<td>1,000</td>
<td>$2,000,000</td>
<td>1,000</td>
<td>$2,000,000</td>
<td>sod, topsoil, trees, fence replacement, planters (assume retention of existing bike paths)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>07</td>
<td></td>
<td>Automobile, bus, van accessways including roads, parking lots (i.e. Eglinton Avenue reconstruction)</td>
<td>m</td>
<td>$4,500</td>
<td>9,200</td>
<td>$41,400,000</td>
<td>1,000</td>
<td>$4,500,000</td>
<td>1,950</td>
<td>$8,775,000</td>
<td>1,950</td>
<td>$8,775,000</td>
<td>Unit rate of $300/m². Applies only to at-grade portions and above station boxes. This includes moving curbs, road paving, sidewalks, islands, markings, signage</td>
<td></td>
<td></td>
</tr>
<tr>
<td>08</td>
<td></td>
<td>Temporary facilities and other indirect costs during construction</td>
<td>m</td>
<td>$2,000</td>
<td>9,200</td>
<td>$18,400,000</td>
<td>2,800</td>
<td>$5,600,000</td>
<td>2,150</td>
<td>$4,300,000</td>
<td>2,750</td>
<td>$5,500,000</td>
<td>assume 200 m road detours at tunnel station boxes. Detours for tunnel portals also shown.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>09</td>
<td></td>
<td>Humber River bridge upgrade / rehab</td>
<td>ea</td>
<td>$5,000,000</td>
<td>1</td>
<td>$5,000,000</td>
<td>0</td>
<td>$0</td>
<td>0</td>
<td>$0</td>
<td>bridge rehab to handle LRT and accommodate bike and pedestrian facilities</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>01</td>
<td></td>
<td>Train control and signals</td>
<td>m</td>
<td>$5,500</td>
<td>9,200</td>
<td>$50,600,000</td>
<td>9,200</td>
<td>$50,600,000</td>
<td>9,200</td>
<td>$50,600,000</td>
<td>Main Line interlocking, fibre optic ductbank, network switches, fibre; does not include MSF or control centre</td>
<td></td>
<td></td>
<td></td>
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<td>02</td>
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<td>Traffic signals and crossing protection</td>
<td>ea</td>
<td>$350,000</td>
<td>17</td>
<td>$5,950,000</td>
<td>2</td>
<td>$700,000</td>
<td>2</td>
<td>$700,000</td>
<td>per signalized intersection affected</td>
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</tr>
<tr>
<td>03</td>
<td></td>
<td>Traction power supply: substations</td>
<td>ea</td>
<td>$6,000,000</td>
<td>6</td>
<td>$36,000,000</td>
<td>6</td>
<td>$36,000,000</td>
<td>6</td>
<td>$36,000,000</td>
<td>from Finch West; one per 1.5 km</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>04</td>
<td></td>
<td>Traction power distribution: catenary</td>
<td>m</td>
<td>$2,200</td>
<td>9,200</td>
<td>$20,240,000</td>
<td>17,74</td>
<td>$39,028,000</td>
<td>15,37</td>
<td>$33,814,000</td>
<td>from Finch West; includes OCS cable, poles / supports; separate OCS line per tunnel</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>05</td>
<td></td>
<td>Communications</td>
<td>platfor m</td>
<td>$600,000</td>
<td>12</td>
<td>$7,200,000</td>
<td>10</td>
<td>$6,000,000</td>
<td>4</td>
<td>$2,400,000</td>
<td>Intercom, PA, CCTV, emergency trip, SCADA, alarm monitoring, intrusion access control, master clock, PVIS</td>
<td></td>
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<tr>
<td>06</td>
<td></td>
<td>Fare collection system and equipment</td>
<td>platfor m</td>
<td>$50,000</td>
<td>12</td>
<td>$600,000</td>
<td>10</td>
<td>$500,000</td>
<td>4</td>
<td>$200,000</td>
<td>Presto equipment at stop / station</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>07</td>
<td></td>
<td>Central Control</td>
<td>ls</td>
<td>$2,000,000</td>
<td>1</td>
<td>$2,000,000</td>
<td>1</td>
<td>$2,000,000</td>
<td>1</td>
<td>$2,000,000</td>
<td>Placeholder for additional hardware/software/workstations required within Eglinton Crosstown Operations Control Centre</td>
<td></td>
<td></td>
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<tr>
<td>FTA Code</td>
<td>MK Sub-code</td>
<td>Description</td>
<td>Unit</td>
<td>Rate</td>
<td>OPTION A - 10 Stops At Grade Qty</td>
<td>Amount</td>
<td>OPTION B - 10 Stops Tunneled Qty</td>
<td>Amount</td>
<td>OPTION C - 3 Stops Tunneled &amp; Elevated Qty</td>
<td>Amount</td>
<td>OPTION D - 7 Stops Tunneled &amp; Elevated Qty</td>
<td>Amount</td>
<td>Comments</td>
<td></td>
<td></td>
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<tr>
<td></td>
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<td>Indirect Costs (15%) %</td>
<td>15</td>
<td></td>
<td>$81,105,105</td>
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<td>$278,446,005</td>
<td></td>
<td>$147,753,105</td>
<td></td>
<td>$203,845,605</td>
<td></td>
<td>Includes general contractors' staff, temporary facilities, power, water, bonding, insurance etc.</td>
<td></td>
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</tr>
<tr>
<td></td>
<td></td>
<td>60 01 Property Acquisition Allowance ea</td>
<td>$50,000,000</td>
<td>1</td>
<td>$50,000,000</td>
<td>1</td>
<td>$50,000,000</td>
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<td>$50,000,000</td>
<td>1</td>
<td>$50,000,000</td>
<td>$50 M allowance, as defined by City of Toronto</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>80 01 - 08 Professional Services (31%) %</td>
<td>31</td>
<td></td>
<td>$208,259,800</td>
<td></td>
<td>$677,273,339</td>
<td></td>
<td>$366,659,880</td>
<td></td>
<td>$499,973,055</td>
<td></td>
<td>Includes costs related to design, project management, construction management, legal, surveys, geotechnical etc.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>HST - 1.76% - Non-recoverable portion only %</td>
<td>1.76</td>
<td></td>
<td>$15,489,154</td>
<td></td>
<td>$50,371,658</td>
<td></td>
<td>$27,270,032</td>
<td></td>
<td>$37,185,092</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>70 01 Vehicles (LRV's) ea</td>
<td>$5,200,000</td>
<td>66</td>
<td>$343,200,000</td>
<td>56</td>
<td>$291,200,000</td>
<td>42</td>
<td>$218,400,000</td>
<td>49</td>
<td>$254,800,000</td>
<td></td>
<td>Unit price received from Metrolinx. Number of vehicles defined by TTC. Spares 15%. Includes Toronto and Airport segment service.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Contingency (30%) %</td>
<td>30</td>
<td></td>
<td>$371,626,428</td>
<td></td>
<td>$961,079,311</td>
<td></td>
<td>$538,531,115</td>
<td></td>
<td>$721,432,336</td>
<td></td>
<td></td>
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</tbody>
</table>

Rounded $2,590 M $5,145 M $3,315 M $4,105 M

Cost Ratio vs Option A (excluding Airport Segment) 1.00 2.59 1.45 1.94

Cost Ratio vs Option A (including Airport Segment) 1.00 1.99 1.28 1.58

Prepared for City of Toronto

AECOM A
4.4 Analysis of Alternatives

In addition to the cost figures shown, numerous other factors enter into the weighing of the pros and cons and the analytic comparison of the four LRT project alternatives. The lowest-cost option is not necessarily the best investment overall. The additional factors used at this level of analysis are:

- Capital Cost
- Traffic Impact
- Constructability
- Natural Environmental Impact
- Disruption During Construction
- Property Impact
- System Accessibility

These points are summarized in Table 6.

Some additional analysis factors are not used because they either are very similar between the alternatives, are inconsequential, are too detailed for this level of analysis, require data that is unavailable, rely on unsupported assumptions, or otherwise do not contribute significantly to the determination of a preferred alternative. Operating and Maintenance cost / Lifecycle cost figures are not used in this comparison, as they are difficult to calculate and must rely on an extensive list of assumptions at this level of detail; they are assumed to be roughly proportional to the capital cost and therefore would not significantly alter the comparative analysis.
### Table 6: Analysis of Alternatives

<table>
<thead>
<tr>
<th>Analysis Factor</th>
<th>Alternative</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A 10 stops at grade</td>
</tr>
<tr>
<td>Capital Cost (Mt. Dennis – Airport)</td>
<td>$2,590 M</td>
</tr>
<tr>
<td>Traffic Impact</td>
<td>Impacts related to traffic movements / signals at LRT / intersection crossings</td>
</tr>
<tr>
<td>Constructability</td>
<td>Conventional construction complexity due to surface guideway construction and staging related to traffic and property access</td>
</tr>
<tr>
<td>Natural Environmental Impact</td>
<td>Minimizes potential natural environmental impacts due to surface guideway within existing ROW/disturbed area</td>
</tr>
<tr>
<td>Disruption During Construction</td>
<td>Greatest disruption during construction due to surface construction, reconfiguration of Eglinton Avenue, and maintaining pedestrian, vehicle and property access.</td>
</tr>
<tr>
<td>Property Impact</td>
<td>Minimal property impacts due to wide existing right-of-way. Localized impacts at station areas.</td>
</tr>
<tr>
<td>System Accessibility</td>
<td>Frequent stops (10), therefore good local access and network connections. Frequent stops hamper operational speed.</td>
</tr>
</tbody>
</table>
4.5 Evaluation of Alternatives

The City seeks optimum value for its investment, seeking to balance the benefits to transit users against negative impacts to the natural and social surroundings and traffic operations. The primary reason to grade separate the LRT from surface roads is to avoid traffic impact (noting that the additional level is usually negative in terms of the transit user experience and always significantly higher in terms of cost). Constructability and feasibility are important considerations as part of the preferred alternative selection. These considerations however may also result in costs or community impacts which are significantly more than typical LRT stations.

Based on the information in Section 4.4 (above), the following conclusions are drawn:

- Alternative A provides the greatest transit accessibility within the corridor at the lowest capital cost. Property impacts are generally to areas immediately adjacent to the existing right-of-way where required, and do not affect existing buildings. However, Alternative A results in the greatest amount of disruption during construction due to the surface guideway and staging related to maintaining traffic operations. The construction is conventional and similar to that of other surface LRT lines, so is considered feasible with appropriate staging.

- Alternative B is significantly more expensive than other alternatives as it is tunneled underground from Renforth Drive easterly. It provides the same number and location of stops at Alternative A. It minimizes property and natural environment impacts, but disruption to traffic at key intersections will still be a concern during construction. The tunnel section and stations at Scarlett and at Jane are potentially impacted by the floodplain and increased complexities associated with that.

- Minimizing the number of stations allows Alternative C to be around half the cost of Alternative B. In doing so, however, Alternative C provides the least number of stops (3) and therefore the least amount of access to the LRT line. Potential property and environmental impacts are greater than Alternatives A and B due to the off-alignment elevated section of guideway at the Humber River. It is 47% more costly than Alternative A.

- Alternative D is similar to Alternative C, however provides seven (7) stops to increase local access and network connections. The improved accessibility results in increased cost compared to Alternative C. It remains less accessible than Alternative A while costing double.

On balance, the technically preferred alternative to carry forward to the next level of detail is Alternative A. Alternative A provides the greatest access to the transit system, while minimizing property and environmental impacts, at the most feasible and economical expenditure.

5. LRT Maintenance and Storage Facility

As outlined in Section 4.2 above, the Eglinton West LRT line would, depending on the alternative configuration selected, need between 42 and 66 LRVs (14 to 22 three-unit trains) to match the level of service planned for the Eglinton Crosstown line.

This figure incorporates the normal 15% additional vehicles, to provide for routine maintenance, damaged vehicles, or special event use. The sizing does not accommodate any demands that
might arise from other LRT lines to which the Eglinton West line might be connected (the extension to Pearson Airport, the Finch West LRT line, Eglinton Crosstown).

A standalone Maintenance and Storage Facility would need to incorporate

- Storage track
- Hostler platform (operator pick up / drop off for start / end of LRV service)
- Vehicle maintenance building
- Maintenance of Way building
- Operations and Administration Building
- Access, circulation roads, and parking for OMSF staff and operators
- On-site accommodation of storm water runoff
- Landscaping, fencing, sidewalks, and other outdoor facilities
- Lead track(s) connecting the OMSF with the main line

This assumes that heavy maintenance and specialized work would be accommodated elsewhere (either at the Crosstown MSF or off-site). The property needs to be relatively flat, close to or on the Eglinton West corridor, surrounded by compatible land uses, free of land use conflicts (e.g. hydroelectric power transmission corridors or flood plains). It does not need to be completely vacant or publicly owned, but it must be reasonable in terms of availability and cost of site preparation (i.e. a large empty warehouse site might be considered; a residential subdivision, school, or shopping centre would not).

A cursory review of the Eglinton Avenue West corridor reveals that there are no suitable open properties of the required size adjacent to or near Eglinton Avenue. This is a mature corridor, almost entirely residential in nature, with no large-scale open spaces or brownfield zones. The only open space in the study area is Eglinton Flats, the Humber River valley lands around Jane Street. These lands are open because they are located in a flood plan, and are currently occupied by City parks and recreational facilities. Building a new industrial facility would not be permitted in a flood plain, and even if it were, creating a new MSF almost within sight of the Crosstown MSF makes little sense operationally.

To the west, there are no suitably-sized parcels in the MTO lands around Highway 427, and the Hydro corridors near Martin Grove Road are also not feasible for technical reasons.

The only site that meets the physical criteria in the corridor is along the north edge of Centennial Park, south of Eglinton Avenue and west of Commerce Boulevard. This is open space, currently occupied by a cricket pitch, a baseball diamond, and some landscaped green space. Nevertheless, it would be a significant issue to convert park land to industrial use, and would likely require compensation in the form of either new park space elsewhere or significant improvements to existing park space. Given the size of Centennial Park, it is assumed that the recreational facilities could be relocated elsewhere or modified. This is among the least-used areas of the park, and is City-owned land. It is also readily accessible via an LRT spur extending along Eglinton Avenue from a wye at Commerce Boulevard. Employee access could be from a new fourth leg at the Eglinton / Explorer intersection, or a new driveway from Centennial Park Boulevard.
Figure 7 illustrates a typical MSF conceptual layout, at the Centennial Park site. This is not a recommended plan, but simply an illustration of the scale and potential layout of a 45-vehicle EWLRT MSF.

Figure 7: Typical MSF Layout

It should be noted that the above discussion does not extend to possible MSF sites in the Renforth-to-Pearson Airport extension of the EWLRT line.

6. Functional Design of Preferred LRT Alternative

The key features and design principles applied to the Preferred at-grade plan for the Eglinton West LRT line are defined here only to the level of detail necessary to produce a Class 4 Cost Estimates. It would be expected that some features will be modified or added / removed as the project proceeds through the design process. Similarly, where assumptions and contingencies are used at his stage, they will be refined, quantified, or eliminated as more information and detail emerges through future work.

The basic design premise for the project follows from the 2010 Environmental Project Report and the various subsequent planning and design review exercises undertaken by the City. The design parameters (see Section 3.2) closely reflect those used in the Eglinton Crosstown LRT project (currently under construction), supplemented in some cases by the experience gained in the Finch West and Hurontario LRT projects currently in development.

Wherever possible, a sidewalk is provided on both sides of Eglinton Avenue, and a two-way cycle path is provided on one side as well (south side west of Jane Street; north side east of Jane Street). Between Martin Grove Road and Renforth Drive – through the Mimico Creek / Highway 427 area – a shared multi-use path (MUP) is used extensively in lieu of separate pedestrian and cycling facilities. An MUP is also used in the Eglinton Flats area to minimize the impact of road widening.

The plan and profile of the preferred LRT Alternative are included in Appendix A. A brief description of the key design elements follows, from east to west.
6.1 Weston Road to Eglinton Flats

The Eglinton Crosstown LRT project terminates in a dead end tunnel west of the Mount Dennis station, approximately 10 m below Weston Road. The current project would extend that tunnel through the cut-and-cover methods outlined in Section 3.5.2 of the Eglinton LRT EPR Addendum (2013). A large underground “box” would be created by building parallel walls underground, “capping” them with a drivable surface, and excavating the material below to allow the construction of the LRT tunnel structure. Eglinton Avenue traffic would be limited to one lane in each direction for the duration of the wall construction process. Figure 8 illustrates the resulting cross section, drawn from Figure 3.3 of the EPR addendum.

![Figure 8: Typical LRT Tunnel Cross-Section](image)

The tunnel portal is in the middle of Eglinton Avenue, located immediately west of the last house along Eglinton Avenue. The total tunnel length is approximately 400 m.

The completion of the cycling infrastructure in the Mount Dennis segment (i.e. east of the tunnel portal) is subject to a separate study by the City and a final plan has not been determined at this point. The cost estimate will therefore include an allowance for cycling infrastructure in this segment, but no specific solution is shown on the plan in appendix A.

In order to minimize the “footprint” of the widened Eglinton Avenue on the environmentally sensitive Eglinton Flats area east and west of Jane Street, the current plan is to create far side platforms (one in each direction) for the Jane stop, instead of the single island platform shown in the EPR. The island platform creates a road envelope that is 5 m wider than the far side platform configuration. Operationally, far side platforms are generally preferred, as they work more effectively with transit signal priority systems. The island platform on the west side of the...
intersection would not protect for a possible future Jane Street LRT connection any better than a far side configuration would.

West of Jane Street, the steep embankment on the south side of Eglinton Avenue is assumed to require a retaining wall; consequently the access road to the Scarlett Woods municipal golf course would be unaffected by the Eglinton Avenue widening.

Future planning and design work should recognize that the proposed cycle tracks and sidewalks on either side of Eglinton will cause grading and vegetation impacts within park property (Fergy Brown, Pearen, Eglinton Flats, and Scarlett Woods Golf Course). Affected areas are to be restored to existing conditions.

6.2 Humber River to Royal York Road

Humber River Crossing

The Eglinton Avenue bridge over the Humber River and flood plan is approximately 200 m long and 29 m wide. It carries four lanes of traffic; the other two lanes have been blocked out. The north (westbound) curb lane functions as a shoulder, and as a right turn lane on the Scarlett Road approach. The south (eastbound) curb lane is protected by a concrete barrier from the adjacent traffic lane and is used as a two-way cycle path. There are sidewalks on both sides of the bridge.

![Figure 9: Humber River Bridge Looking West](image)

The introduction of the Eglinton West LRT to this crossing triggers two issues:

a) inadequate width of the existing structure to accommodate LRT, four lanes of traffic, two sidewalks, and a two-way cycling facility; and

b) (potential) inadequate structural capacity to accommodate the additional dead load of the LRT guideway and live load of LRV vehicles.

The potential solutions to either or both issues are underpinned by the fact that the bridge design – a single-deck post-tensioned voided slab – means that it cannot be widened, rebuilt in stages, or strengthened.

While the structural capacity of the bridge has not been assessed in detail at this point in the planning process, it may be noted that the 1966 design code to which it was constructed has been superseded by a more rigorous CHBDC code, and a concrete LRT guideway would add a noticeable amount to the dead load (say 10 – 15 %), both of which suggest that the bridge may
need to be replaced if it were to accommodate LRT. A future more detailed structural condition assessment and capacity analysis may determine otherwise, but a conservative and realistic costing and planning scenario would assume a full removal and replacement of the piers and deck with a more flexible and code-compliant girder structure.

In any case, the bridge was built nearly fifty years ago and would require a full rehabilitation prior to the addition of any LRT infrastructure, to avoid the need to shut down the LRT service while undertaking a future rehabilitation program. The cost of rehabilitating this type of structure while maintaining at least two lanes of traffic on it at all times is likely to be in the same order of magnitude as constructing a new bridge.

Furthermore, any deck replacement cannot be done in stages (the voided slab deck cannot be cut longitudinally), the deck would need to be completely removed and replaced. This would close Eglinton Avenue for a two-year construction period. On the assumption that such a lengthy full closure is infeasible due to impact on traffic, transit, and emergency services, a solution which preserves at least one lane of traffic operations in each direction is required.

Removing cycling provisions (either by requiring bicycles to operate in the curb lane, or by building a separate parallel multi-use path bridge) will not resolve the structural capacity concerns, so those are not viable options at this point. If future structural analysis demonstrates that the bridge can accommodate the LRT guideway and that a bridge rehabilitation can be done without closing Eglinton Avenue, the shift of bikes and pedestrians to a new parallel multi-use structure would be the preferred approach. However, under the current assumption that a new bridge of some form is required, it follows that pedestrian and cycling needs would be accommodated in the design of the new structure.

For a new crossing, there are several options to consider:

1) Build a temporary four-lane bridge adjacent to the existing crossing for use by diverted traffic during construction; when the replacement of the existing bridge is complete (including LRT and cycling provisions), shift all movement back to it, and remove the temporary structure. Note that the new structure would have three separate decks – eastbound traffic, LRT, and westbound traffic – on shared foundations to clarify operational and maintenance responsibilities in the event that the LRT facility is owned and operated by a different agency than the road authority.

2) Build a permanent bridge for all users adjacent to the existing bridge, then remove the existing bridge (or remove the deck and install a pedestrian / cycle crossing structure using the remaining piers).
Figure 10: New Humber River Crossing Option 2

3) Build a new permanent bridge adjacent to the road bridge, to accommodate the LRT guideway and westbound traffic lanes; leave eastbound traffic (and a cycle path) on the existing bridge.

Figure 11: New Humber River Crossing Option 3

4) Build a separate LRT-only structure adjacent to the road bridge. This concept has previously been developed as part of the investigation of grade separation opportunities at key stops.

Figure 12: New Humber River Crossing Option 4

Complicating the consideration of any of these alternatives is the presence of the Scarlett Road LRT stop, and the different design options for its layout (parallel, far side, or centre island platforms). Ideally, the Scarlett stop would have separate parallel platforms to the west of Scarlett Road; by avoiding the platform on the Humber River bridge (potentially atop an expansion joint) the cost and complexity of the bridge reconstruction is avoided; and in this
location, virtually all stop users both now and in the future will arrive from the west side of Scarlett Road. For some bridge options, however, property impact is minimized and intersection operation optimized with a far side platform configuration.

The crossing design taken through the cost estimate process at this stage is Option 3 – a partial twinning of the existing bridge. This is relatively simple to construct, minimizes property impact, maintains traffic operations at all times, provides space for all users, and is the least-cost option for the LRT program.

Option 1 essentially involves constructing two full-size bridges (the temporary one and the replacement of the existing one), has significant (albeit temporary) property impact, and ultimately a higher cost. Option 2 is less costly than Option 1 because the existing bridge is not fully replaced, but the same property impact follows because the new bridge must avoid the existing bridge near Scarlett Road. Option 3 is less disruptive and costly because it requires a narrower envelope and leaves the existing structure “as is”. The existing bridge could be easily rehabilitated in stages whenever needed, as it only hosts two lanes of traffic. Option 4 would provide an optimum LRT solution, but at very high cost (the new LRT structure would be close to double the length of the existing bridge, and the Scarlett stop would be elevated and require a full array of stairs / elevators) and visually intrusive. The grade separation of the LRT at this location has been previously rejected by City Council, so it is not considered appropriate to pursue.

The recommended plan therefore shows Option 3 – a “twinning” of the existing structure.

Future planning and design work should recognize that the proposed new bridge encroaches on the Canadian Ukrainian Memorial Park. City of Toronto Parks, Forestry and Recreation Division and the Toronto Region Conservation Authority will need to be engaged regarding the loss of parkland and any associated compensation, mitigation, and/or property transfers. Impacted parkland and paths must be restored to existing conditions. Areas below the alignment must design for safe and secure sightlines along the trail, with lighting where appropriate. Similar conditions apply to any TPSS located in City park land; TPSSs will need to be unobtrusive / screened.

**Pedestrian Bridge**

The existing pedestrian bridge located 450 m west of Scarlett Road (Figure 13) is to remain, but the superstructure may need to be raised or shifted if the grade of Eglinton Avenue is modified to accommodate the LRT. The design premise is that the LRT profile will follow the existing grade and will not trigger bridge alteration. The structure will, however, need to have screening added to eliminate the potential of bridge users contacting the LRT OCS cable (similar to the Farr Avenue pedestrian bridge across the Finch West LRT line).
At the Mulham stop, the EPR plan (Figure 14) had been based on a new signalized intersection located at the driveway to the Chartwell Scarlett Heights retirement residence on the south side. The stop could not be located on the horizontal curve to the west. A new sinuous roadway was created on the north side to serve existing (Plant World) and future uses there.

It may also be noted that the Mulham stop had originally been located on a steep grade, and Eglinton Avenue had to be re-profiled significantly in order to create a 2% gradient at the stop location. That regrading would have required the removal and replacement of the pedestrian bridge mentioned above.

Subsequently, a major development plan has proceeded on the Plant World site and it will create a signalized intersection approximately 150 m west of the originally planned Mulham stop. The current recommended plan therefore shifts the Mulham stop to the new development intersection. This requires a minor realignment (in plan) of Eglinton Avenue in order to create a 100 m long tangent section for the platforms. The horizontal curvature of Eglinton Avenue in this location precludes the use of far side platforms, and the western platform would be too close to the Royal York stop in any case. Consequently, the stop design minimizes the impact of the stop.
length by using parallel platforms on the east side of the intersection. The profile will remain essentially “as is”, which will allow the pedestrian bridge to the east to remain in place. The Chartwell driveway reverts to its existing right-in /right-out configuration. The new stop is very close (250 m) to the Royal York stop, but given that all LRT stops must be located at a signalized pedestrian crossing, the new location is better than having a signalized intersection plus a separate pedestrian-only crossing at the original (EPR) location. The proposed configuration of Mulham Stop is illustrated in Figure 15.

Figure 15: Proposed Modified Configuration at Mulham Stop

6.3 Royal York Road to Kipling Avenue

Between Russell Road and Islington Avenue, the LRT alignment is shifted slightly southward so as to avoid impacting the City-owned lands to the north of the road right-of-way; this is to respect previous work regarding the lands’ development potential that resulted in a commitment to limit the northerly shift of the Eglinton Avenue right-of-way to no more than 4.2 m.

The profile of Eglinton Avenue sags at the Islington Avenue intersection, a remnant of the planned Richview Expressway grade separation at that location. In order for the Islington platforms to be located on a compliant (2 % maximum) grade, Eglinton Avenue must be raised approximately 3 m at the intersection. Figure 16 illustrates proposed Eglinton Avenue profile at Islington Avenue (with vertical grid at 5 m spacing).
Figure 16: Proposed Eglinton Avenue Profile at Islington Avenue

Consequently, the profile of Islington Avenue must also be raised in this area. This is accommodated reasonably well by the fact that the new profiles essentially bring the intersection elevation back to the grade of the surrounding area, as illustrated in Figure 17. Maintaining traffic operations on both high-volume roads throughout the regrading process will be a traffic management and construction staging challenge.

Figure 17: Illustration of Proposed Islington Avenue Profile at Eglinton Avenue

At Bemersyde Drive, the Eglinton Avenue right-of-way is at its narrowest, with the bike path and sidewalk on the south side located tight against the fence line of several residential properties. Therefore, rather than widen Eglinton Avenue about the centre line as in the rest of the corridor, the widening is shifted to the north only. The existing south curb line (and bike / ped facilities) would remain as is for a distance of approximately 200 m both east and west of Bemersyde so as to minimize / avoid impact on private property. The alignment offset is approximately 4 m and accommodates the LRT stop platforms.

6.4 Kipling Avenue to west of Martin Grove Road

At Mimico Creek, the addition of the LRT guideway to the Eglinton Avenue structure over the creek requires that bridge to be widened slightly. In doing so, the existing south side sidewalk will not be replaced; pedestrians will stay on the multi-use path and use the existing cycle path bridge across Mimico Creek. Figure 18 shows the plan of Mimico Creek crossing.
6.5 Highway 427

The LRT guideway passes through a sequence of eight MTO freeway bridges west of The East Mall. The bridges are all four-span structures of various skews, each with one or two 1.22 m diameter piers in the median of Eglinton Avenue, a set of piers outside the travelled way, and open (sloped) end spans leading to perched abutments. The spans are all adequate in width and vertical clearance to accommodate the introduction of the LRT median guideway, while pushing the two lanes of traffic in each direction outward. There is no sidewalk (existing or future) on the north side of the road.

At this level of detail, an engineering investigation into the structural condition, capacity, and impact resistance of the median piers has not been done. In lieu of this analysis, experience with similar situations indicates that, if any pier collision protection is necessary, this can be accomplished by pier / column strengthening and foundation expansion. For the purposes of the current study, therefore, we assume an increase in pier diameter of 0.60 m (i.e. a “wrap” of 300 mm of reinforced concrete), and prepare the cross sections in this area on that basis. If it is subsequently demonstrated that the piers need less (or no) protection, the guideway width can be reduced.

The existing multi-use path on the south side of Eglinton Avenue is to be preserved and widened to a standard 3.5 m. This can be accommodated within the main south span on six of the eight structures. However, the adjacent ramp structures carrying Highway 427 northbound traffic to Highway 401 eastbound and westbound (MTO Bridges 37-829 and 37-804 respectively) have narrower main spans than the others, leaving less than 3 m between the piers and the future edge of eastbound Eglinton Avenue. The MUP is therefore rerouted behind the south piers at those two structures. The path is raised slightly, and a toe wall inserted along its south edge. Toe walls are also used in a couple of the other structures where the MUP would impinge on the bottom of the end span slope paving.

The cross sections and the MUP plan details are illustrated in Figure 19, Figure 20, and Figure 21.
Figure 19: Proposed Cross Sections at Highway 427
Figure 20: Proposed Cross Sections at Highway 427
6.6 Renforth Drive to Matheson Boulevard

East and west of Renforth Drive, the modification of Eglinton Avenue to accommodate the LRT guideway will respect the new Transitway structures on the north side, as well as the MUP on the north side of Eglinton west of Renforth. At Commerce Boulevard, the LRT guideway turns 90 degrees through the intersection, using a minimum-radius curve (25 m). The Commerce / Renforth stop platform is immediately north of the intersection, with passenger access at both ends.

The introduction of a median LRT platform at this location will eliminate one of the movements currently used by buses at the Renforth terminal – the turn from the eastbound exit ramp onto northbound Commerce. The Transitway has turning loops at both ends of the Renforth station, however, that allow buses to use the east-side (westbound) exit ramp instead, and/or bus operators can modify the affected routes to use the other bus stop locations available. For example, instead of a westbound Transitway bus dropping passengers at the Renforth terminal, then using the west-side ramp to exit the Transitway and proceed along Commerce to Matheson and beyond, the bus could use the east-side bus ramp to exit the Transitway and drop passengers at the northbound bus bays on Commerce Boulevard itself, adjacent to the LRT stop.

On Commerce Boulevard itself, a set of tail tracks with crossovers will be needed north of the LRT stop. The Commerce / Skymark intersection will be signalized. Commerce Boulevard itself will be rebuilt and widened between Skymark and Matheson Boulevard, leaving an open median available for the LRT extension to Pearson Airport. The cost estimate for this project (Mount Dennis to Commerce) will have the Matheson Boulevard intersection as its western terminus.

6.7 Enbridge Gas Main

As noted in Section 2, there is an Enbridge high-pressure trunk gas main along Eglinton Avenue which will conflict, in many locations, with the median LRT guideway utility exclusion zone, including:

- tunnel portal (west of Weston Road) to the east abutment of the Humber River bridge (1,000 m)
- Scarlett Road to near the Mulham stop (600 m)
- Royal York Road to east of Russell Road (400 m)
- 200 m west of Islington Avenue to west of Bemersyde Road (250 m)
In some segments, at the preliminary or detail design stages the LRT guideway and road may be able to be realigned so as to avoid / minimize the gas main relocation requirements. Conversely, more detailed subsurface investigation may reveal additional conflict locations. At the current level of detail, however, it is prudent to assume that the gas main is to be relocated in all of the segments noted above.

6.8 Traction Power Substations

The Eglinton West LRT will be an extension of the existing Eglinton Crosstown LRT from Mt. Dennis to Renforth and onward to Pearson Airport. The Eglinton West extension revenue service operation will match the at-grade portion of the Eglinton Crosstown for a 4 minute headway, which means the traction power demand is not expected to be greater. For this reason, a preliminary load analysis would not be performed to determine the TPSS spacing at this cost estimate stage and instead would apply the same TPSS (traction power substation) size and spacing as used in the Eglinton Crosstown. The TPSS locations would be spaced approximately 1,500 m apart and would be located within a 200 m radius from that guideway location.

The Eglinton West LRT is about 9.24km in length (Mt. Dennis to Commerce / Renforth) and would need six TPSS locations, with TPSS #1 located at Commerce / Renforth Stop at the west end and TPSS #6 near Emmett Ave at the east end. TPSS #6 would be located about 1,500 m from ECLRT’s boundary TPSS at the Mt. Dennis Stop. This means the Eglinton West LRT’s TPSS #6 and Eglinton Crosstown’s Mt. Dennis TPSS would provide overlapping support for the 1,500 m segment of guideway between the two TPSSs at stationing 104+100 and 105+650.

General Specifications

- TPSS locations spaced approximately 1,500 m and within a 200 m radius from guideway stationing point
  - Supports maximum length trains (3 car consists – Bombardier Flexity) and ultimate line capacity headway of 4 minutes
- LRVs run on nominal traction power voltage of 750 VDC distributed through the OCS along the alignment
- Contingency operation to support normal train operations with a single TPSS out of service.
- Typical TPSS site layout to require approximately 32m X 32m footprint
  - Exact dimensions would be flexible to accommodate available property space and would be subject to further analysis. Existing ECLRT includes TPSS site footprints of 35m X 25m
  - Accommodation for service vehicle parking within the TPSS property and replacement of major TPSS equipment
  - TPSS structure will be a pre-fabricated unit
  - TPSS building will also provide equipment space for LRT interfaces to Communications systems for operations, security and intrusion access control

Assumptions

For the purpose of TPSS site location selection, the following assumptions are made:
• Required THESL (Toronto Hydro Electric Systems Limited) feeds to TPSS locations will be completed at a later design stage (not in scope) to confirm available utility power and redundancy arrangements

• EWLRT TPSS #6 is approximately 1,500m from existing ECLRT end of line TPSS at Mt Dennis (approximate stationing 105+650)

• Traction Power System load modelling will need to be completed at a later design stage to confirm EWLRT’s traction power supply is acceptable for the actual TPSS locations
  • LRV vehicle parameters and track alignment design will be required
  • Specific scenarios would also include EWLRT TPSS #6 and ECLRT Mt Dennis TPSS to be each individually out of service to verify traction power contingency operation can sustain normal LRV service operations across the EWLRT and ECLRT boundary

• TPSS rectifier transformers sized similar to existing ECLRT (1.5MW or 2.0MW) with space provision for second rectifier transformer in TPSS building
  • TPSS site footprint is sufficient to accommodate 1.5MW or 2.0MW rectifier transformers as the increase in equipment size would not be significant

Proposed TPSS Locations

The proposed TPSS locations within a 200 m radius would be within the yellow circles shown in Appendix B “TPSS Locations”, as tabulated below:

Table 7: Proposed TPSS Locations

<table>
<thead>
<tr>
<th>TPSS</th>
<th>Nearby Stop or Intersection</th>
<th>Stationing</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Commerce / Renforth Stop</td>
<td>96+500</td>
<td>S side of Eglinton, west of Commerce or within Transitway envelope</td>
</tr>
<tr>
<td>2</td>
<td>Highway 427</td>
<td>97+940</td>
<td>S side of Eglinton west of Hwy 427</td>
</tr>
<tr>
<td>3</td>
<td>Martin Grove Stop</td>
<td>99+480</td>
<td>N side of Eglinton east of Martin Grove</td>
</tr>
<tr>
<td>4</td>
<td>Wincott / Bemersyde Stop</td>
<td>101+060</td>
<td>S side of Eglinton east of Wincott</td>
</tr>
<tr>
<td>5</td>
<td>Royal York Stop</td>
<td>102+560</td>
<td>S side of Eglinton east of Royal York</td>
</tr>
<tr>
<td>6</td>
<td>Emmett Ave</td>
<td>104+100</td>
<td>N side of Eglinton west of Emmett</td>
</tr>
<tr>
<td>Mt Dennis TPSS</td>
<td>Mt Dennis Stop</td>
<td>105+650</td>
<td>Existing end of line ECLRT. ECLRT TPSS assumed within 200m radius</td>
</tr>
</tbody>
</table>

Candidate TPSS sites are identified, taking into consideration established City policies and constraints, such as minimum / assumed site dimensions, direct site access from an adjacent roadway, and avoidance of MTO lands, City park lands, and residential lands. The availability, cost, and functionality of such sites will be confirmed in subsequent study stages. The proposed sites indicated in the Recommended Plan can are intended to demonstrate that a TPSS site is feasible within the desired radius; they can, in most cases, be adjusted in size, shape, or location to best suit the site. The actual design of each TPSS should focus on keeping it inconspicuous and being visually compatible with its surroundings.

6.9 LRT Systems

As part of the Systems design for the EWLRT, the following are the high level requirements for the S&TCS (Signaling and Train Control System) and Communications Systems.
The Eglinton Crosstown (ECLRT) project required their design to include extension and expandability for the LRT systems such as S&TCS and Communications Systems, which means the equipment room space, core equipment sizing, equipment I/O would accommodate the needs of EWLRT. This provision notwithstanding, if the EWLRT project were to have a separate builder / operator, some arrangement would need to be made to ensure the coordination of operations between ECLRT and EWLRT.

**Signaling and Train Control System (S&TCS)**

The Signaling system provides the operational and safety functions required to operate the trains throughout the alignment. ECLRT’s existing CBTC (Communications Based Train Control) signaling system would be expanded to cover EWLRT and would then be one through service across ECLRT and EWLRT. The Bombardier CITYFLO 650 signaling system and control office software would need to be updated to include the EWLRT alignment portion.

The S&TCS would provide ATP (Automatic Train Protection) functions for the safe operation of trains throughout the alignment. The trains would be manually driven with safe train operation through a combination of train detection, train separation, route interlocking and speed limit enforcement.

The ATS (Automatic Train Supervision) functions for operations at the control centre would provide the HMI (human machine interface) to monitor the system status, provide train schedules, controls to direct operation of trains, maintain intended traffic patterns, and minimize the effect of train delays.

The additional necessary equipment for the EWLRT would include interlocking hardware to control special trackwork, wayside signals, equipment cabinets along the alignment, local ATS workstations, local control panels, axle counters, norming points and expansion of the signaling wireless data communications network. Local road intersection interface to the City’s traffic controller would also be required for transit signal priority.

**Operations Control Centre (OCC)**

The OCC provides the means for daily supervision and operation of the LRT line. The operator control interfaces available at the control centre as part of the existing ECLRT include:

- Integrated Communication System (ICS)
- Signaling and Train Control System (S&TCS)
- SCADA
- Traction Power System
- Emergency ventilation
- Elevating Devices (Elevators and Escalators) Monitoring System
- Central Alarm Monitoring System (CAMS);
- Intrusion Access Control (IAC)
- CCTV

The ECLRT OCC is located at TTC’s Hillcrest complex and a BOCC (Backup OCC) is located within the Eglinton MSF at Mount Dennis. The control centre hardware and functionality is to be equivalent between both the OCC and BOCC. The 9 ECLRT workstations and 8 mimic displays
at the control centre is assumed to be sufficient for the inclusion of the EWLRT portion and would then be supervised and operated as a single Eglinton transit line.

Training simulators would need to be updated to include EWLRT alignment and scenarios for the 3 types of systems, S&TCS, SCADA and ICS. A Revenue Vehicle Cab Simulator is located at the ECLRT MSF and would need to be updated to include the EWLRT driving environment.

**Communications Systems**

The Communications Systems provides the voice, data and video transmission capability necessary to support the EWLRT and comprise of the major subsystems:

**Backbone Communication Network (BCN):** The BCN provides a high capacity redundant network capable of supporting communications throughout the LRT system. It interconnects the MSF, OCC, BOCC and stops to enable communications sub-systems to operate. The ECLRT fibre optic network would be expanded along EWLRT routed inside the system wide duct banks and have connections to equipment cabinets at the stops.

**Integrated Communication System (ICS):** The ICS integrates the control of CCTV, visual information, public address, telephone, intercom, and radio sub-systems in an integrated HMI. This is accomplished using operator consoles at the OCC and associated equipment with connections via the BCN. The ICS would need to be updated to support operations for EWLRT.

**Public Address System (PA):** The PA system announces audible safety and travel related information at stops and onboard revenue vehicles. Audio broadcast announcements can be made to stations, stops and MSF areas. PA speakers would need to be installed at all EWLRT stops and be integrated to the ICS at OCC.

**Passenger Visual Information System (PVIS):** The PVIS will broadcast all text information to PVIS displays located at every stop platform throughout EWLRT corridor. The text messages will provide information related to service, train arrivals, emergencies and special announcements. PVIS displays would need to be installed at all EWLRT stops and be integrated to the SCADA system and ICS at OCC.

**Supervisory Control and Data Acquisition (SCADA):** The SCADA System provides monitoring information and control of systems in support of the operation of the LRT System. The SCADA system interfaces to electrical and mechanical systems, communications systems and traction power. The SCADA capacity as part of the ECLRT is provided with expansion capability and the available data connectivity I/O (input output) would be sufficient to support EWLRT.

**Telephone and Intercom:** The telephone system supports internal communications throughout the EWLRT and would be an extension of the installed ECLRT head end equipment. The intercom system enables passengers at stops to communicate for information or emergency assistance with the proper LRT personnel. PAIs (Passenger Assistance Intercoms) would be provided at all platforms of EWLRT.

**Voice and Data Radio System (VDRS):** VDRS provides wireless communications where land lines are unable to communicate with mobile equipment and personnel. The VDRS provides communications with TTC operators, train drivers, maintainers, security staff and emergency services. The radio frequencies and licenses from Industry Canada are obtained as part of the ECLRT and are required to support additional LRT lines and expansion. For EWLRT coverage, radio base stations would need to be installed along the alignment and confirmed with an RF propagation prediction and measurement.
Closed Circuit Television System (CCTV): The CCTV system provides video surveillance throughout the line to support operations and security functions. The CCTV system interfaces with several systems including ICS, IAC and intercom to allow for operational and security staff to display images associated with intrusions or security events. CCTV cameras will be installed at all platforms and as needed along the alignment.

Fare Collection System (FCS): PRESTO is the Fare Collection System to be installed at the stop platforms which includes VMs (Validation Machines) and TVMs (Ticket Vending Machines). Power and data communications will be provided to all stops along EWLRT and the Presto machines will be supplied and installed by a third party.

Intrusion Access Control System (IAC): This system monitors and provides alarms for unauthorized to non-public or restricted areas along EWLRT which include equipment access and TPSS buildings. The system is integrated with the CCTV system, SCADA and ICS.

System Wide Duct Banks

System wide duct banks would be provided for the Signaling and Communications systems connections from their head end equipment to wayside equipment and field elements.

System wide duct banks and traction power duct banks will be installed along the alignment within the LRT guideway to provide the power and data interconnections for EWLRT. The duct banks would be placed and routed to avoid underground utilities. Access points will be provided by manholes and hand holes along the alignment to wayside equipment and cabinets.

The ducts will be 103 mm diameter conduits spaced 50 mm apart. The minimum cover is 600 mm and can be reduced by 150 mm since the duct banks will be concrete encased, with the resultant cover to be 450 mm below grade. Horizontal separation between traction power duct banks and communications duct banks would be separated as much as possible to reduce any EMI effects.

At a minimum, the duct bank sizes are provided with a spare capacity of 20%:

- System Wide Duct banks: 10 ducts in a 2X5 arrangement with a duct bank size of 850 mm X 400 mm
- Traction Power Duct Banks: 4 ducts in a 2X2 arrangement with a duct bank size of 400 mm X 400 mm

7. Class 4 Cost Estimate for Preferred Alternative

The Class 4 Cost Estimate was prepared for Alternative A, the Preferred Alternative. The cost estimate includes only the segment of the LRT project between Mount Dennis and Commerce Boulevard; it does NOT cover the extension across Highway 401 to Pearson Airport, which is being addressed separately.

Table 8 summarizes the Class 4 cost estimate for Alternative A. This estimate is based on the conceptual design plan and profile developed for the preferred alternative (see Appendix A) and on the study team’s knowledge of the study corridor.

The cost estimate in Table 8 is based on the following:
Exclusions

- Operations & Maintenance Costs (by TTC).
- Life-cycle costing and cash flow charts (by Metrolinx)
- AFP/P3 Related Soft Costs (including short and long term financing, IO and transaction costs, Legal Fees, Lender’s Technical Advisor Fees, etc.)

Assumptions

- Assumed AFP/P3 procurement / project delivery method.

Notes

- Quantities provided by AECOM transportation Design/Engineering Team.
- Based on sketches prepared by AECOM as included in Appendix A.
- Canadian Dollar at the First Quarter of 2019
- Class 4 Estimate level of accuracy per AACE
- Escalation (price inflation) to the actual year of construction is NOT included.

The bottom line figure in the Class 4 estimate ($1.86 B) differs from that in the Class 5 estimate ($1.61 B, per Table 5) for the following reasons:

- The class 4 figures are based on detailed measurements and break down of the items into a couple of hundred line items, whereas the Class 5 level of detail is much coarser. Class 5 estimates were done on a preliminary basis for the purposes of comparing alternatives on an equal basis.
- Class 4 figures are for $2019, and Class 5 figures are $2018
- The Class 4 table includes new design items that were not part of the project scope at the time of the Class 5 work
  - New Humber River bridge, as new structural analysis confirmed that the original (EPR) assumption that the existing bridge could accommodate the LRT guideway was no longer appropriate
  - “Green Track” – 14 % - 25 % cost premium over conventional LRT guideway
  - Longer LRT tunnel (50 m)
  - Allowance for TTC bus stop reconfiguration
  - Three more LRVs (66) than at the time of the Class 5 work (63)
- Class 4 figures reflect a detailed Subsurface Utility Engineering review (Class D) and associated item-by-item costs (the Class 5 estimate used a simple per-kilometre rate for utilities, as it was done prior to the availability of the SUE information)
- More detailed breakdown of LRT power supply, catenary, and duct banks, reflecting differences between at grade, portal, and tunnel segments.
- Additional contingency due to compounding of individual contingency items

In all, close to three quarters of the cost difference stems from design refinements, and about one quarter from updates or changes in unit costs.
## Table 8: Class 4 Cost Estimate – At-Grade Alternative A

<table>
<thead>
<tr>
<th>FTA</th>
<th>Description of Item</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td><strong>GUIDEWAY &amp; TRACK ELEMENTS</strong></td>
<td>$ 174,818,000</td>
</tr>
<tr>
<td>10.02</td>
<td>Guideway: At-grade semi-exclusive</td>
<td>$ 23,160,000</td>
</tr>
<tr>
<td>10.02</td>
<td>Guideway - On Bridges</td>
<td>$ 1,045,000</td>
</tr>
<tr>
<td>10.02</td>
<td>Guideway - At-Grade Greentrack</td>
<td>$ 37,123,000</td>
</tr>
<tr>
<td>10.06</td>
<td>Guideway: Underground cut &amp; cover Tunnel &amp; Portal</td>
<td>$ 78,502,000</td>
</tr>
<tr>
<td>10.10</td>
<td>Track works</td>
<td>$ 34,988,000</td>
</tr>
<tr>
<td>20</td>
<td><strong>STATIONS, STOPS, TERMINALS, INTERMODAL</strong></td>
<td>$ 33,000,000</td>
</tr>
<tr>
<td>20.01</td>
<td>Stations/Stops - At-Grade</td>
<td>$ 33,000,000</td>
</tr>
<tr>
<td>30</td>
<td><strong>SUPPORT FACILITIES: YARDS, SHOPS, ADMIN. BLDGS</strong></td>
<td>$ 25,246,000</td>
</tr>
<tr>
<td>30.03</td>
<td>Maintenance and Storage Facility includ all associated works</td>
<td>$ 25,246,000</td>
</tr>
<tr>
<td>40</td>
<td><strong>SITWORK &amp; SPECIAL CONDITIONS</strong></td>
<td>$ 277,029,000</td>
</tr>
<tr>
<td>40.01</td>
<td>Demolition, Clearing and Earthwork</td>
<td>$ 7,347,000</td>
</tr>
<tr>
<td>40.02</td>
<td>Site Utilities, Utility Relocation</td>
<td>$ 153,137,000</td>
</tr>
<tr>
<td>40.05</td>
<td>Bridge widening / works to other structures</td>
<td>$ 47,563,000</td>
</tr>
<tr>
<td>40.06</td>
<td>Pedestrian/ Bike access, Landscaping</td>
<td>$ 20,874,000</td>
</tr>
<tr>
<td>40.07</td>
<td>Road Improvements, Traffic Management, Erosion Control</td>
<td>$ 48,108,000</td>
</tr>
<tr>
<td>50</td>
<td><strong>SYSTEMS</strong></td>
<td>$ 141,766,000</td>
</tr>
<tr>
<td>50.01</td>
<td>Train control and signals</td>
<td>$ 50,848,000</td>
</tr>
<tr>
<td>50.02</td>
<td>Traffic signals and crossing protection</td>
<td>$ 7,290,000</td>
</tr>
<tr>
<td>50.03</td>
<td>Traction power supply: substations</td>
<td>$ 36,000,000</td>
</tr>
<tr>
<td>50.04</td>
<td>Traction power distribution: catenary and third rail</td>
<td>$ 39,376,000</td>
</tr>
<tr>
<td>50.05</td>
<td>Communications</td>
<td>$ 4,672,000</td>
</tr>
<tr>
<td>50.06</td>
<td>Fare collection system and equipment</td>
<td>$ 1,080,000</td>
</tr>
<tr>
<td>50.07</td>
<td>Central Control</td>
<td>$ 2,500,000</td>
</tr>
<tr>
<td></td>
<td><strong>Total Construction Costs</strong></td>
<td>$ 651,859,000</td>
</tr>
<tr>
<td></td>
<td>Indirect Costs (15 %) - General Requirements &amp; Fee</td>
<td>$ 97,779,000</td>
</tr>
<tr>
<td></td>
<td><strong>Total Construction costs incl. indirect</strong></td>
<td>$ 749,638,000</td>
</tr>
<tr>
<td>60</td>
<td>Property</td>
<td>$ 50,000,000</td>
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<tr>
<td></td>
<td><strong>Total Costs including Property</strong></td>
<td>$ 799,638,000</td>
</tr>
<tr>
<td>80</td>
<td>Professional Services (31 %)</td>
<td>$ 247,888,000</td>
</tr>
<tr>
<td></td>
<td>Non-Recoverable HST (1.76 %)</td>
<td>$ 18,436,000</td>
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<tr>
<td></td>
<td><strong>Total Cost incl. Professional Services and HST</strong></td>
<td>$ 1,065,962,000</td>
</tr>
<tr>
<td>70</td>
<td>Vehicles (66 x $5.2 M)</td>
<td>$ 343,200,000</td>
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<tr>
<td></td>
<td><strong>Total Cost incl. Vehicles</strong></td>
<td>$ 1,409,162,000</td>
</tr>
<tr>
<td>90</td>
<td>Design &amp; Pricing Contingency - (20 %)</td>
<td>$ 281,832,000</td>
</tr>
<tr>
<td></td>
<td><strong>Total Cost incl. Contingency - Design &amp; Pricing (2019$)</strong></td>
<td>$ 1,690,994,000</td>
</tr>
<tr>
<td>90</td>
<td>Construction Contingency - (10 %)</td>
<td>$ 169,099,000</td>
</tr>
<tr>
<td></td>
<td><strong>Total Cost incl. Construction Contingency (2019$)</strong></td>
<td>$ 1,860,093,000</td>
</tr>
</tbody>
</table>
8. Risks and Uncertainties

The current investigation has been limited in scope to the 5% level of design development and an associated Class 4 cost estimate. The caveats associated with the estimate have been noted in Section 7. The following points relate to risks and uncertainties identified during the development of the 5% design plan. This list is not intended to say that the project is not feasible; indeed, the EWLRT concept remains valid (not significantly different from the previously approved EA). However, as the project moves forward, subsequent studies need to be aware of these issues and be prepared to investigate / resolve them as more information becomes known.

1) Project Delivery

No guidance or decision about how the EWLRT project is to be delivered is provided in this study. There are a variety of methods and precedents, each of which can impact scope, cost, schedule, and construction in different ways. Most LRT projects in the Toronto area have been delivered by an Alternative Finance and Procurement (AFP) method, but conventional design-bid-build procedures are also in common use. Whether the proponent is the City of Toronto, Metrolinx, Infrastructure Ontario, or some other agency or combination of funding partners will also play a major role in project delivery and scope.

Furthermore, the EWLRT could be configured as a simple extension of the Eglinton Crosstown project, it could be an entirely standalone facility, or it could be some hybrid whereby certain aspects are the responsibility of ECLRT and other aspects are separate. It could even conceivably be part of a separate LRT facility, such as an extended Finch West LRT line that reaches the new Pearson Airport transit hub and continues down to Renforth Station and eastward along Eglinton.

No matter how the project is delivered, a mechanism will be needed to coordinate with the adjacent Eglinton Crosstown project. This coordination agreement must cover every aspect of planning, design, construction, operations, and maintenance.

2) Utility Impact / Relocation

LRT guideway and roadway construction cannot begin until all conflicting utilities (below and above ground) are shifted out of the way. Most utility design and construction work is done by the utilities themselves, and the coordination of their designs and of their field work is an extraordinarily complex undertaking. The utility design work, in turn, depends on the substantial completion of the road and guideway preliminary design. This utility work is not entirely under the control of the LRT proponent, and can end up driving the overall project schedule as well as introducing unforeseen costs.

3) Implementation Schedule

A project of this magnitude and complexity will take several years to construct, and there are innumerable options when it comes to dividing the work into constructible segments and sequencing those steps. The schedule needs to respect funding availability, political direction, and the project delivery mechanism. Utility work and third party approvals also affect schedule. In an AFP delivery process, the actual construction schedule is not known until the private consortium has done its design work.
It may be that certain elements of the work can or needs to be done in advance of the approval of the rest of the project – for example, a bridge rehabilitation or culvert repair that occurs in 2019 or 2020 should reflect or at least protect for the ultimate LRT configuration.

Third Party schedules must also be known and considered. If, for example, MTO undertakes a bridge rehabilitation program on any Eglinton Avenue structure, the Eglinton project would need to await the completion of the MTO work before proceeding.

4) Third Party Approvals

The project requires numerous approvals to proceed to implementation:

- Toronto Region Conservation Authority, particularly related to the proposed new Humber River crossing and impact on flood plain
- Ministry of Transportation of Ontario, related to the introduction of LRT through several Highway 401 structures
- City of Mississauga, related to the LRT stop and alignment on Commerce Boulevard
- Eglinton Crosstown project, related to the connection between the Eglinton West and Crosstown projects, the expansion of the Mount Dennis Maintenance and Storage Facility, the shared / expanded operations and control systems, and all other aspects of the project.
- Ministry of Environment, Parks, and Conservation, related to approval of an updated Environmental Assessment or addendum which reflects both the current design and corridor conditions relative to the project as approved in 2010.

5) Community Engagement

The Eglinton West corridor has historically been subject to intense public scrutiny, particularly from among the residents of the area. There has been a long history of proposals and reactions that have established a somewhat agitated social environment. The public’s awareness, expectations, support, impact tolerance, and legitimate concerns must be managed throughout the project. Changes to the project design could follow from community-generated concerns at any point in the project development.

Of particular concern will be both long-term traffic operations and traffic management during construction. Intersection designs and operations to minimize traffic impact need to be studied extensively and conclusively, to produce designs acceptable to the community.

6) Design Issues

The current plan is at a very preliminary stage (5 %). It is fully expected that design refinements will be required, particularly at each intersection, structure, and LRT stop. Avoidance of natural environmental impacts, introduction of current standards (for Disabled access, for example), and inclusion of state-of-the-art drainage solutions are additional examples where design refinement will come. Modifications to reflect community input will be expected. It is likely that certain stakeholders will take the opportunity of corridor reconstruction to advance designs, rehabilitation, or improvements to their own infrastructure, which could affect the LRT project.

It may also be noted that the City is currently considering a significant reconfiguration of roadways in the Highway 27 / 427 area, which would have a direct impact on the design, scope, schedule, and timing of the EWLRT project. This uncertainty needs to be resolved before proceeding much further in the design process.

7) Property Impact
The ability to implement this project without directly impacting private residential or commercial property is a significant attribute. Care must be taken to preserve this principle, including potential impacts for utility relocation, construction laydown areas, Traction Power Substations, paths / sidewalks, and road detours. Construction impacts on commercial property access and noise-related impacts on residential areas will both be high-profile issues to be addressed.

8) Airport Extension

The current project scope (as documented herein) covers only part of the EWLRT project, which in its entirety is intended to extend past the Commerce / Rathburn stop to reach the new transportation hub at Pearson Airport. The timing, funding, implementation schedule, delivery mechanism, design parameters, and other features related to the Airport extension could affect or shape what happens (and when) on the Eglinton Avenue corridor itself.
Appendix A: Alternative Plans and Profiles

Alternative A (Preferred Alternative)
Alternative B
Alternative C
Alternative D
Appendix B: Traction Power Substation Locations
200m RADIUS - ECLRT Mt. Dennis TPSS
Assumed stationing 105+650
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