LeighFisher

EX34.1
Attachment 1

TECHNICAL MEMORANDUM

Eglinton East LRT - Grade Separations at KLM and UTSC
Benefit Cost Analysis Report

Prepared by:

LeighFisher Canada Inc.
22 Adelaide Street West, Suite 2450
Toronto, ON M5H 4E3

Prepared for:

City of Toronto
Transit Implementation Unit, City Planning
100 Queen Street West
21st Floor, East Tower

April 3, 2018

DOCUMENT CONTROL SHEET

Client:	City of Toronto Transit Implenetation Unit, City Planning	Job No: LCPG8901
Project:	Eglinton East LRT – Work Package #2	

	Prepared By:	Reviewed By:	Approved By:
REVISION Prelim Draft B	NAME Paula Nguyen	NAME James Lew	NAME David Pratt
DATE **28 March 2018**	SIGNATURE	SIGNATURE	SIGNATURE

This document has been prepared by a division, subsidiary or affiliate of LeighFisher Canada Inc. (together "LeighFisher") in its professional capacity as consultants in accordance with the terms and conditions of LeighFisher's contract with the City of Toronto (the "Client"). If you have received this document in error, please destroy all copies in your possession or control and notify LeighFisher.

This space intentionally left blank

Leigh|Fisher

CONTENTS

INTRODUCTION

1) Background

The Eglinton East LRT (EELRT) is planned as an easterly extension of the Eglinton Crosstown. As part of the refinement of the proposed EELRT concept, alternative alignment and roadway configurations are being proposed at the Kingston-Lawrence-Morningside (KLM) intersections and at the University of Toronto, Scarborough Campus (UTSC). Grade separated concepts are being considered for each of these areas due to the potential operational constraints and impacts to general traffic of introducing 90m consists to the line. Since the costs of grade separated options are expected to be high and affordability is one of eight high-level Rapid Transit Evaluation Framework criteria, the affordability of these options will be informed by a range of assessments. This economic analysis comparing monetized benefits and costs is one of the tools used in this process.

A benefit cost analysis (BCA) for the potential KLM and UTSC grade separations was undertaken between January and March 2018 by LeighFisher Canada under the auspices of the Technical Advice and Peer Review Services Related to the Eglinton East LRT (#UR0006-17-1-007) under RFSQ#9119-16-7251 agreement. The work was performed for the City's Transit Implementation Unit based on deliverables developed by their consultant, Arup Canada, using outputs from an AIMSUN traffic simulation model.

This report summarizes the benefit cost analysis methodology, identifies key assumptions used in the preparation of the economic analysis and presents the findings for the subject alignment scenarios.

2) Eglinton East LRT Alignment - Potential Grade Separations Under Study

KLM Intersection Scenarios:
LRT at-grade "Surface 1" concept for KLM intersection, compared with
LRT in portal "Tunnel 1" concept for KLM intersection
Surface 1 concept was an at grade LRT on Kingston Road with one stop of 100 meters. Tunnel 1 concept was a tunnelled LRT on Kingston Road with one stop of 100 meters.

UTSC North Campus Scenarios:
LRT at-grade "Modified Base" (Option 1) concept for UTSC North Campus, compared with
LRT elevated direct up Morningside Ave. (Option 5)

LRT at-grade "Modified Base" (Option 1) concept for UTSC North Campus, compared with
LRT in tunnel under Military Trail concept for UTSC North Campus (Option 3)

3) Time Frame Assumptions

An asset lifecycle of 60 years was assumed in alignment with previous BCA analysis. The AIMSUN model run year for all scenarios was 2041. Each intersection was modeled as a stand-alone intervention (without cumulative benefits) to attribute general traffic impacts to the subject option under study.

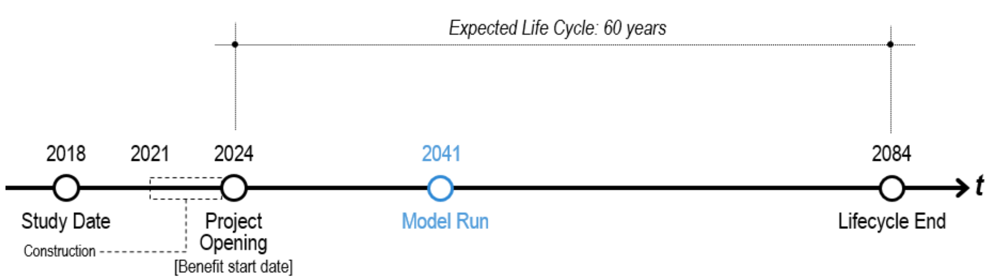


Figure 1 – Asset Lifecycle Assumptions

METHODOLOGY

1) Consistency with Previous Economic Analysis Work

Methodology for the Eglinton East LRT economic analysis was based on work previously undertaken by the City's Transit Implementation Unit in 2017 for the benefit cost analysis of Eglinton West LRT grade separations to maintain consistency with previous analysis and evaluations. This legacy process provided the precedent methodology that was used to generate the findings of this economic analysis.

In the interest of enhancing the legacy process, consultations were held with the City's EELRT external consultant team in January and with internal City stakeholders in February 2018 to review legacy assumptions and identify potential value-add considerations. Potential enhancements were reviewed and vetted by the City's Transit Implementation Unit staff (refer to Section 3c for details). The resulting BCA process used to compare each potential grade separation under this study for the KLM intersection and the UTSC North Campus is illustrated in Figure 2.

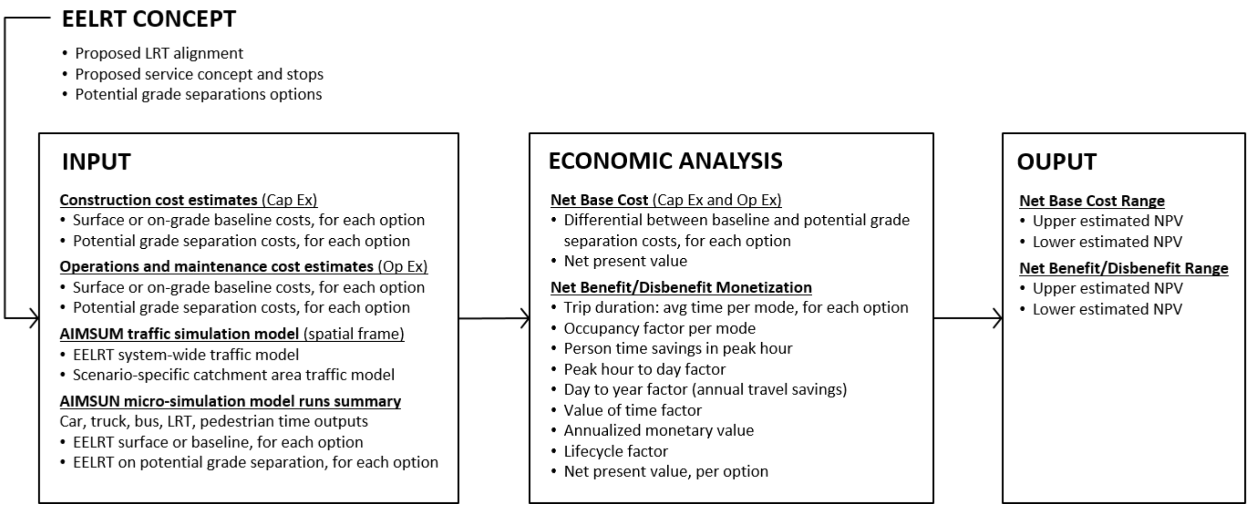


Figure 2 – EELRT Economic Analysis Process

Narrative descriptions of key assumptions and factors used in the preparation of inputs, economic analysis and resulting outputs are presented in the following sub-sections of this report.

2) Inputs

(a) Construction and Operations and Maintenance Cost Estimates

In February 2018, Arup Canada produced Class 5 rough order of magnitude cost estimates for the construction, operation and maintenance of the base case alignments and each potential grade separation option. The preparation of these estimates included the following assumptions:

- Accuracy range: -25% to +40% (used to generate upper and lower boundaries of range)
- Indirect costs: 25% of direct costs
- Project reserve allowance: 12.5%
- Contractor's overhead and profit: 15%
- Construction costs in year of expenditure: no escalation included for construction
- Operations and Maintenance costs are based on kilometers of track
- Operations and Maintenance escalation allowance: 3.4%

- Taxes, Owner's contingency, property acquisition costs, risk contingency: excluded
- Consultant's fees, project management fees, site investigation costs: excluded
- Procurement costs, utility relocate costs, permits and FFE: excluded

Table 1 - Base Capital Construction and Operations & Maintenance Cost Estimate Values (Source: Arup Canada)

Intersection: Grade Separation Option		Construction ($ CAD 2018)		O & M ($ CAD 2018)	
KLM	Baseline: Surface 1	Upper	78,836,000	Upper	950,000
		Lower	42,233,000	Lower	509,250
	Grade Separation: Tunnel 1	Upper	466,043,000	Upper	1,198,400
		Lower	249,666,000	Lower	642,000
UTSC 1	Baseline: Modified Base	Upper	266,840,000	Upper	2,647,400
		Lower	142,950,000	Lower	1,418,250
	Grade Separation: Morningside Direct	Upper	456,960,000	Upper	1,976,800
		Lower	244,800,000	Lower	1,059,000
UTSC 2	Baseline: Modified Base	Upper	266,840,000	Upper	2,647,400
		Lower	142,950,000	Lower	1,418,250
	Grade Separation: Military Trail Below Grade	Upper	1,065,260,000	Upper	2,787,400
		Lower	570,675,000	Lower	1,493,250

(b) AIMSUN Traffic Simulation Model

AIMSUN microsimulation software package was used by Arup Canada to establish traffic models based on the proposed EELRT corridor and to estimate traffic movements for each scenario under study (i.e. surface baseline and grade separated for each option).

<u>System-wide framework</u>: AIMSUN software was used to generate a system-wide model for the proposed EELRT corridor. System-wide traffic models that were produced ran the risk of under-recognizing grade separation benefits due to the spatial distribution of the subject sites as volume of trips remote from the interventions wouldn't see material gains but still add to census. For this reason, a supplementary catchment zone was considered to mitigate the risk of diluting benefits. This catchment zone was subsequently used for all traffic modeling under this study. A comparison of system-wide and catchment boundaries is illustrated in Figure 3.

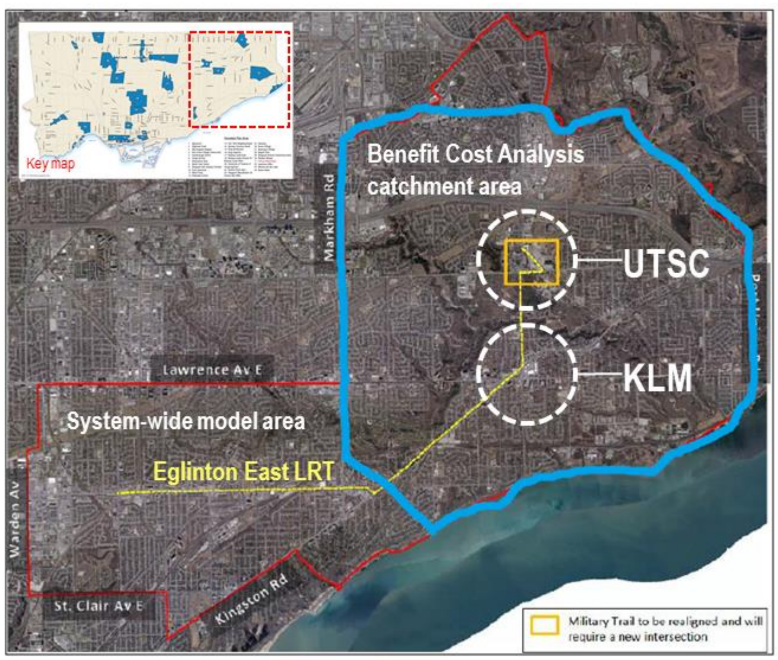


Figure 3 – AIMSUN System-Wide and Catchment Zone

The simulation provided flow, delay, total travel time, total travelled distance for each mode of travel. Sample outputs from the model are shown in Table 2.

Table 2 - Sample Traffic Model Output

UTSC Option 1	Catchment Area - AM				
	Car	Truck	Bus	Pedestrian	LRT
Flow (veh)	39,280.4	810.7	246.0	4,862.9	15.9
Delay (s/km)	26.2	18.1	43.7	708.4	66.4
Total Travel Time (veh-h)	3,663.2	90.7	46.1	80.3	8.0
Total Travelled Distance (veh-km)	219,081.3	5,815.2	1,041.2	225.2	152.9

3) Economic Analysis

(a) Net Base Cost Estimates

Net base costs for each grade separation was calculated to permit comparison with net benefits. The net costs represent the incremental costs over and above costs that would be incurred to implement the at-grade (on street) LRT. The net costs include capital construction costs as well as annual operations and maintenance costs (O&M) for the lifecycle period. As net base costs are derived from the construction and operations and maintenance costs identified in Section 2a) above, the same assumptions apply. The O&M costs for each option are escalated over the asset lifecycle using a 3% escalation rate to capture annual inflation. To derive the total cost for each option, capital and O&M costs over the lifecycle are then summed up and discounted at a 3.5% rate to find present value (2018 $) for comparison purposes.

Table 3 - Net Base Costs

Intersection: Grade Separation Option		Net Base Cost ($)	
KLM	Surface 1/ Tunnel 1	Upper	386,609,527
		Lower	207,112,247
UTSC 1	Modified Base / Morningside Direct	Upper	149,872,001
		Lower	80,288,572
UTSC 2	Modified Base / Military Trail Below Grade	Upper	778,480,586
		Lower	417,043,171

(b) Monetization of Net Benefits

For the purposes of understanding the benefits of each grade separation in mitigating potential transportation network impacts of an at-grade LRT, a net benefit was determined for each grade separation under study. The net benefit was determined by identifying the difference in travel time (seconds) for all users of the roadway between a base case and each grade separation under study.

To allow for a direct comparison of the net benefits to the estimated cost of implementing a grade separation at each location, the travel time savings (seconds) were monetized to produce a dollar value. This monetization process included projecting estimated travel time savings over the expected lifecycle of the grade separation (60 years), and converting that estimated benefit into a dollar value.

The AIMSUN model provided total travel time for 5 modes (Car, Truck, Bus, LRT and pedestrian) as well as the total number of each type of mode that entered the simulation and completed their trip during a peak hour of the day. To obtain a time savings, the total travel time in the base case was divided by the total number of vehicles who completed their trip to get an average time travel per vehicle (base case).

The same approach was used for each grade separation being studied. Subtracting the new average time per vehicle from the base travel time equals a change in time per vehicle. The change in travel time per vehicle was multiplied against the assumed average occupancy of the vehicle and the number of vehicles that traveled through the simulation network in the scenario being evaluated to get a total person travel time savings in the weekday peak hour period in the model year (2041).

The total person travel time savings was then projected over an entire "working" year to obtain a total time savings for the network on an annual basis. This was done by multiplying the peak hour result of the microsimulation work to convert to a representative day, and further to a representative year. The aggregate annual value was multiplied against standard values of time to obtain a total time saving benefit for the model year.

The travel time calculations from the microsimulation work were converted to a dollar value, which can be directly compared with cost, based on the value of time formula. The annual net benefits over the 60-year lifecycle of the grade separation being analyzed were converted to a net present value using the same discount rate used in the net costs calculation. This allows for a direct comparison between the lifecycle benefits of the project and the lifecycle costs.

(c) Assumptions for Monetization Variables and Factors

Assumptions used in the monetization of net benefits are summarized in Table 3 below. Assumption version is identified as either EWLRT legacy which were based on Metrolinx and industry standards, or EELRT enhancements as a clarification of their source; all assumptions were reviewed and vetted by the City's Transit Implementation Unit, Metrolinx, and TTC under this study.

Where the review was supportive of legacy assumptions they were retained and used; enhancements were used where rationale for the variant revision was vetted and supported by City stakeholders.

Table 4 - Variables and Factors Used to Calculate Monetized Benefits

Variable or Factor	Assumption/Rate		Version*
Net Present Value Rate	Discount	3.5%	EWLRT legacy (MX, industry standard.)
Vehicle Occupancy Rate	Car	1.08	EWLRT legacy (MX, industry standard.)
	Truck	1.08	EWLRT legacy (MX, industry standard.)
	Bus	50% = [30] persons / 75% = [45] persons	EELRT factor enhancement #1
	LRT	50% = [100] persons / 75% = [150] persons	EELRT factor enhancement #1
	Pedestrian	1.0	EWLRT legacy (MX, industry standard.)
Peak Hour to Day Factor	Bus/LRT/Ped	8.0	EELRT factor enhancement #2
	Car/Trucks	13.9	EELRT factor enhancement #2
Peak Used for Hour to Day Factor		AM	EELRT factor
Working Days per Year Rate		300 days/year	EWLRT legacy (MX, industry standard.)
Asset Lifecycle		60 years	EWLRT legacy (MX, industry standard.)
Value of Time Factor		$17.39	EWLRT legacy (MX, industry standard.)

[*] Denotes whether the version of variable or factor used in this study was sourced from previous EWLRT benefits/cost analysis and vetted as being applicable to this study; or whether a revised value was vetted and deemed appropriate.

A table of legacy assumptions is provided in the Appendix, for reference. A summary of enhancement rationale follows.

EELRT Factor Enhancement #1: *Vehicle occupancy rates (Bus and LRT)*

A review of TTC loading statistics within the subject corridor identified a range in user demand at peak hours that varied against the "single" value legacy assumption (legacy assumption applied a single 75% loading factor). A review by EELRT BCA stakeholders considered the enhanced range of [50% to 75%] better aligned with observed data and were supportive of their use in this analysis. It was also agreed this should apply to LRT loading in the absence of historic data.

EELRT Factor Enhancement #2: *Peak Hour to Day Factor*

A manual traffic survey undertaken within the subject corridor by Arup Canada in 2017 was reviewed to inform traffic volume rates for this analysis. Findings from the Arup Canada survey indicated observed volumes over the day varied against the legacy assumptions. Legacy assumptions were informed by Metrolinx which had peak hour to day factors ranging from 2.5 to 5.0. Evidence based on the survey supported the consideration of higher values. Arup Canada's analysis indicated transit factors of 8.0 and car factors of 13.9 were aligned with survey evidence. A due diligence assessment by subject matter experts at Jacobs Engineering UK corroborated that the enhanced values were aligned with assumptions used for the same purpose in other jurisdictions. EELRT BCA stakeholders considered the enhanced factors and were supportive of their use in this analysis. See Arup Memorandum 256113-00 in the appendix for further details on the derivation of these peak hour to day factors.

EELRT Factor Selection: *Use of AM Peak as basis for representative day scale up*

The AM peak was used for scale-up to representative day as it reflects industry best practice and was assessed to be reflective of the geometry of influence as the AM flow is impacted by the LRT movements. Furthermore, a review of AIMSUN outputs for all grade separations suggested AM peaks were not subject to the influence of induced demand from backfilling of suppressed flow caused by the LRT at grade solution (within catchment area). Given the network may not be doing enough to cope with the typical increase in PM flow, the PM results with induced demand were considered less indicative of impacts driven by the grade separation interventions under study. A review by EELRT BCA stakeholders considered AM outputs a consistent approach with legacy evaluations and were supportive of their use in this analysis.

This space intentionally left blank

4) Benefit Cost Output

The results of the benefits cost analysis described herein are presented in Table 4 as a range of net present values to reflect the range of inputs from both the costs and the benefits, and address the uncertainties inherent in the modelling of future scenarios.

Table 5 - Range of Benefits and Costs (NPV 2018)

Intersection: Grade Separation Option		Benefit Range ($ million)		Cost Range ($ million)	
KLM	Surface 1/ Tunnel 1	Upper	444	Upper	387
		Lower	408	Lower	207
UTSC 1	Modified Base / Morningside Direct	Upper	249	Upper	150
		Lower	214	Lower	80
UTSC 2	Modified Base / Military Trail (Below Grade)	Upper	171	Upper	778
		Lower	148	Lower	417

In summary, the KLM and UTSC 1 grade separation options were found to provide net benefits over the magnitude of their costs for the 60-year lifecycle of the asset, based on the assumptions identified herein. The UTSC 2 grade separation option does not provide net benefits in the same magnitude of their costs.

The benefits monetized in this work account for travel time savings for all network users associated with grade separating the LRT at the specific intersections. The addition of new infrastructure such as grade separations also has impacts on the built form of the roadway that were not considered in this juncture.

There are also a number of potential benefits and disbenefits not captured in this analysis due to the limitations in modelling resolution, data inputs, and difficulty assigning monetary factors that are not consistent with legacy economic analysis. Elements not captured include:

- Change in frequency or severity of collisions
- Vehicle operating costs
- GHG emission changes
- Increase in value of time

That said, experience has shown the above considerations typically add an increment of 10% - 15% of the net benefits. As the difference between net benefits and cost ranges exceed a 10%-15% increment the exclusion of these components may not be material to this assessment.

This space intentionally left blank

Leigh|Fisher

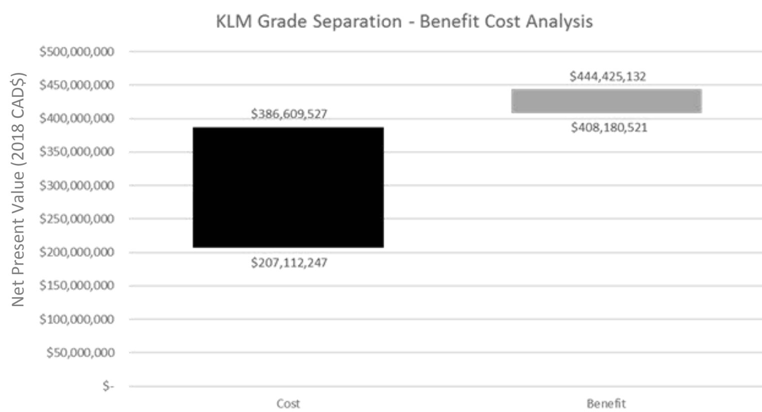
FINDINGS: KLM SURFACE 1 / TUNNEL 1

1) Description

Surface option: The LRT runs on grade (at street level) through the subject intersection. This scenario includes 1 Stop at street level within the subject area.

Tunnel option: The LRT is grade separated from the street by entering portals prior to reaching the intersection and running underground through subject area. This scenario includes a single below-grade within the subject area.

2) Benefit Cost Analysis - Net Present Value (2018$)



Findings:

Benefits Range:
$408 M – $444 M

Cost Range:
$207 M – $387 M

3) Conclusion

This grade separation scenario was found to provide net benefits over the magnitude of their costs for the 60-year lifecycle of the asset, based on the assumptions identified herein.

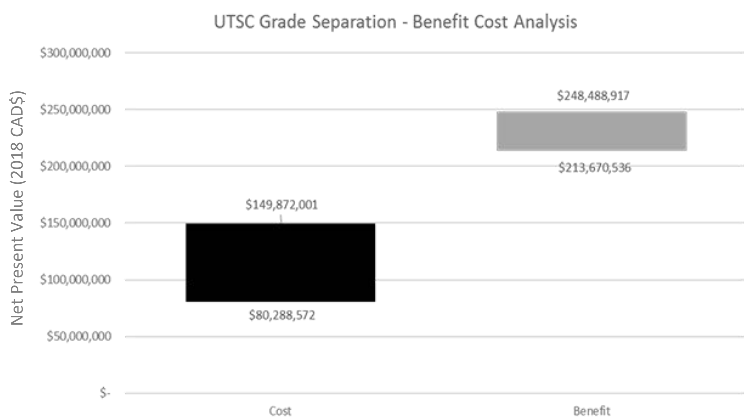
FINDINGS: UTSC 1 – MODIFIED BASE / MORNINGSIDE DIRECT

1) Description

Surface option: The LRT runs on grade (at street level) through the subject intersection. This scenario includes 2 Stops at street level within the subject area.

Elevated option: The LRT is grade separated from the street by entering an elevated viaduct prior to reaching the intersection and running elevated through the subject area. This scenario includes two elevated stops within the subject area.

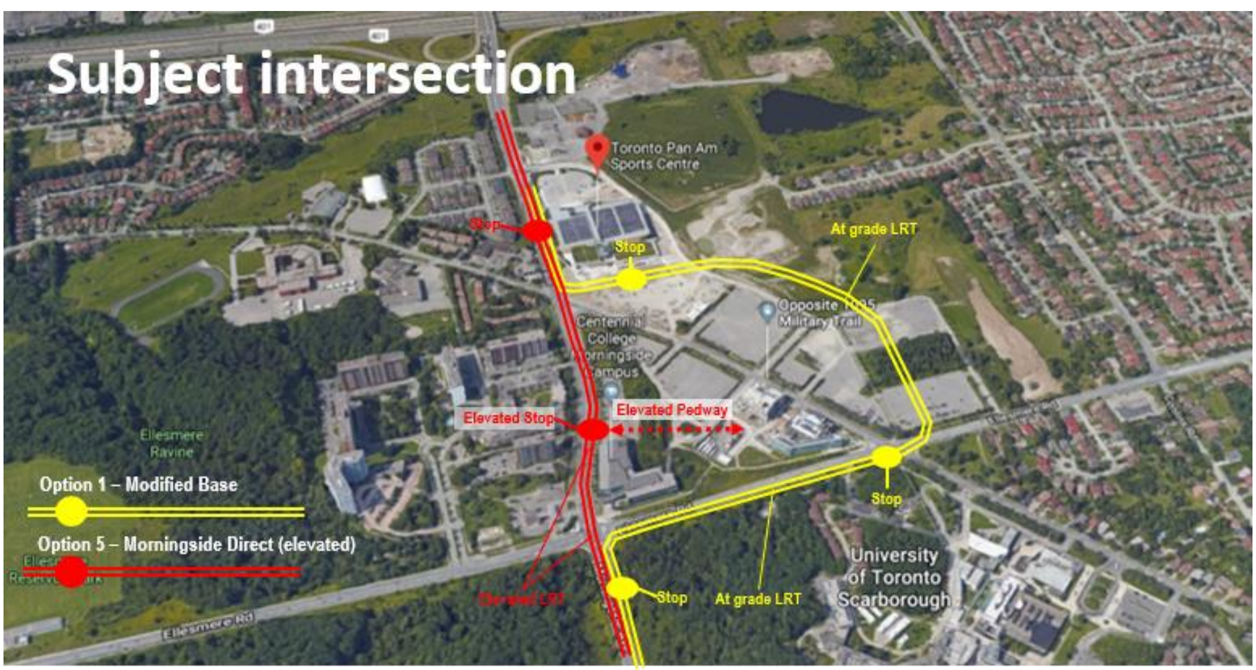
2) Benefit Cost Analysis - Net Present Value (2018$)



Findings:

Benefits Range:
$214 M – $249 M

Cost Range:
$ 80 M – $150 M



3) Conclusion

This grade separation scenario was found to provide net benefits over the magnitude of their costs for the 60-year lifecycle of the asset, based on the assumptions identified herein.

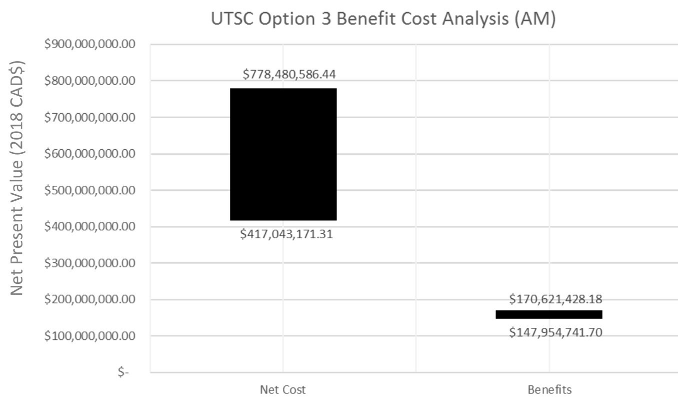
FINDINGS: UTSC 2 – MODIFIED BASE / MILITARY TRAIL TUNNEL

1) Description

Surface option: The LRT runs on grade (at street level) through the subject intersection. This scenario includes 2 Stops at street level within the subject area.

Tunnel option: The LRT is grade separated from the street by entering portals prior to reaching the intersection and running underground through subject area. This scenario includes a single below-grade within the subject area.

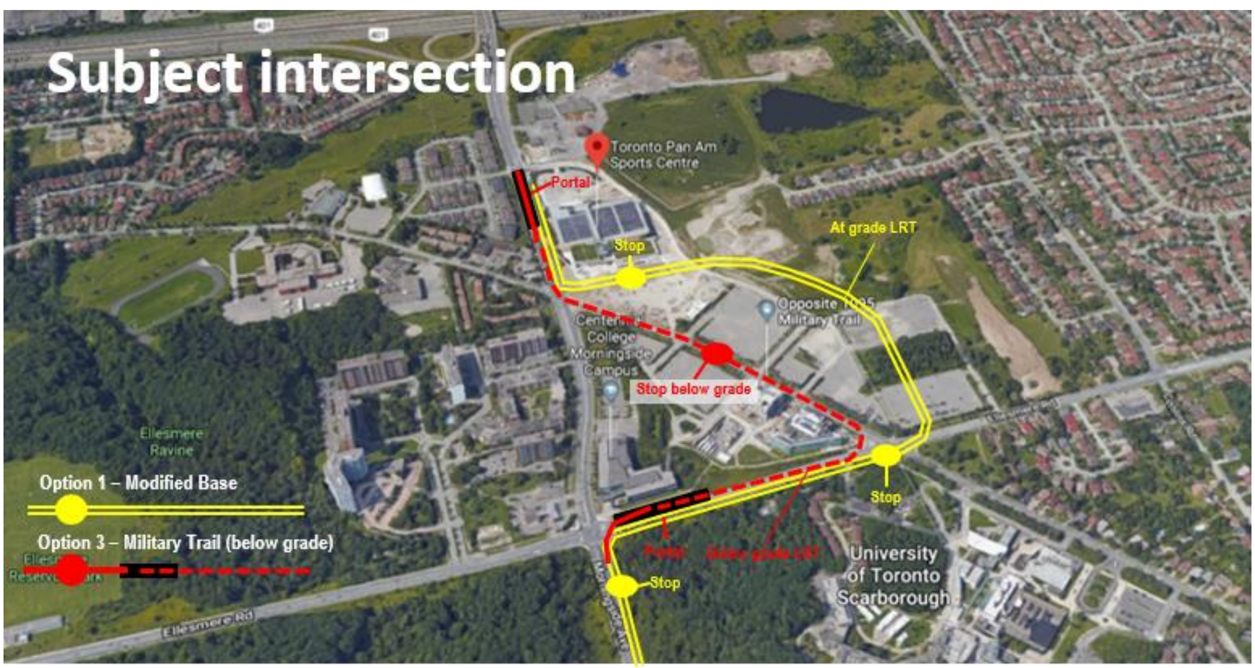
2) Benefit Cost Analysis - Net Present Value (2018$)



Findings:

Benefits Range:
$148 M – $171 M

Cost Range:
$417 M – $778 M



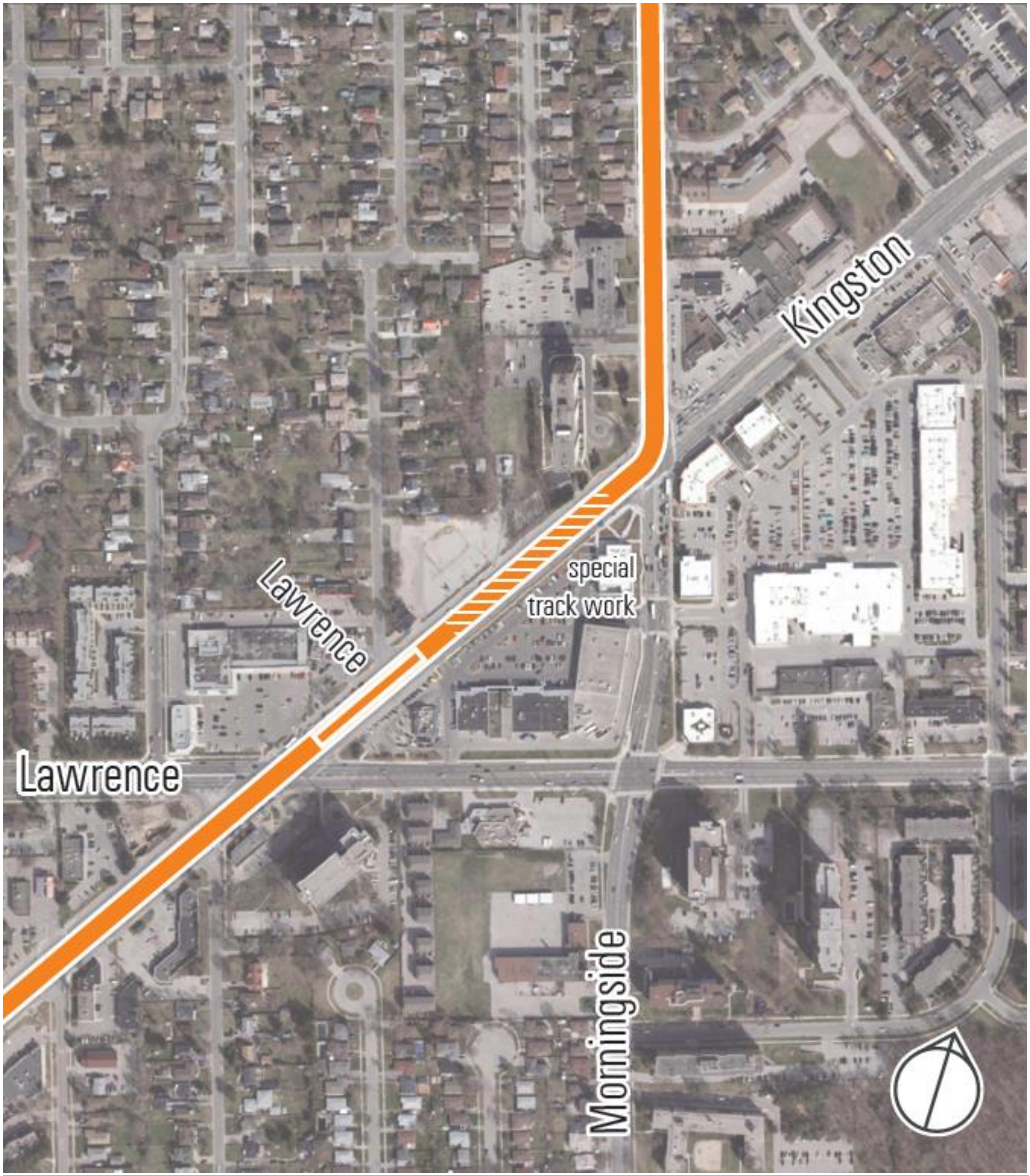
3) Conclusion

This grade separation scenario does not provide net benefits over the magnitude of their costs for the 60-year lifecycle of the asset, based on the assumptions identified herein.

APPENDICES

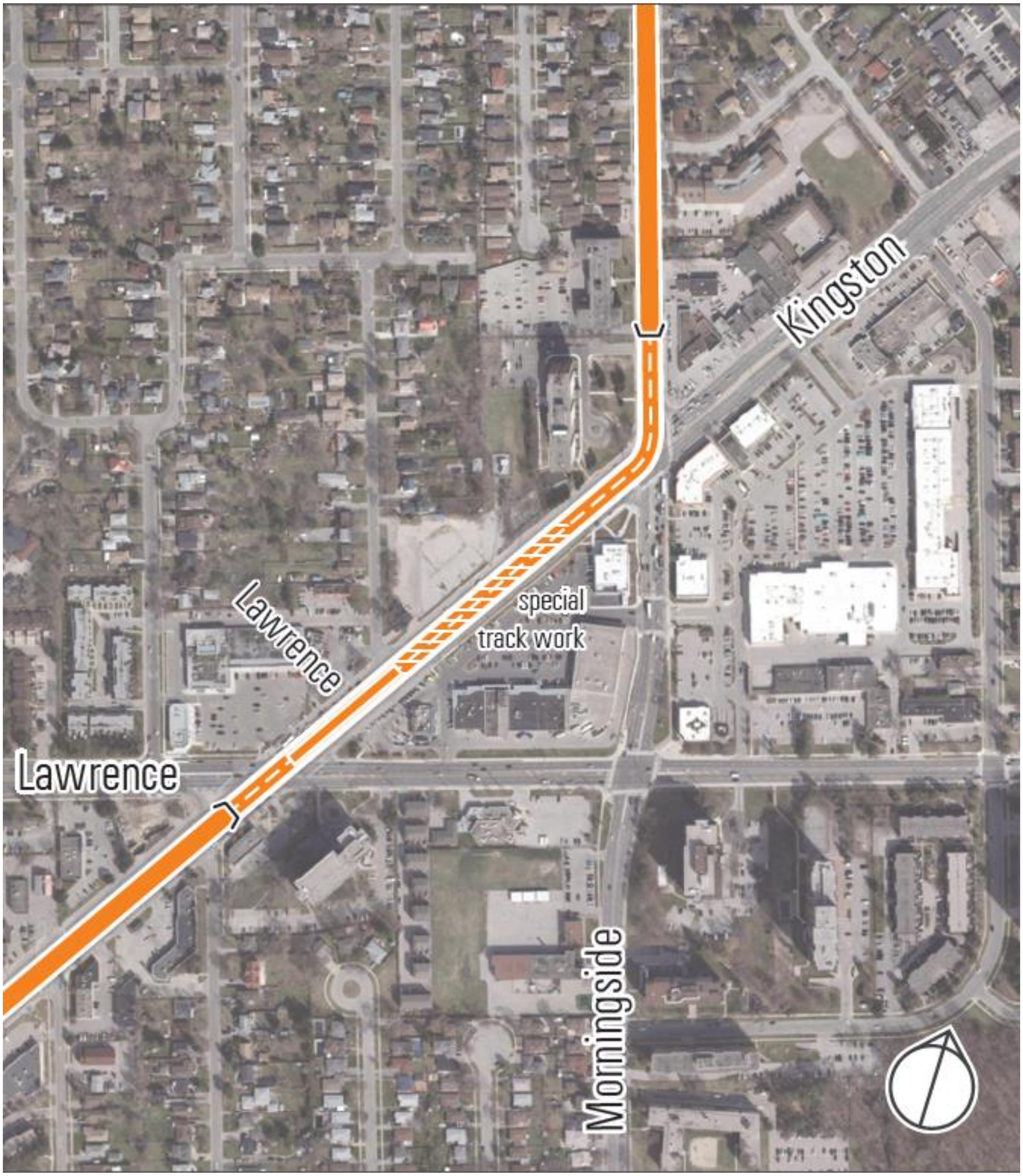
Appendix A – Concept Plans provided by the City of Toronto

KLM Surface Option (Base Case)



Leigh|Fisher

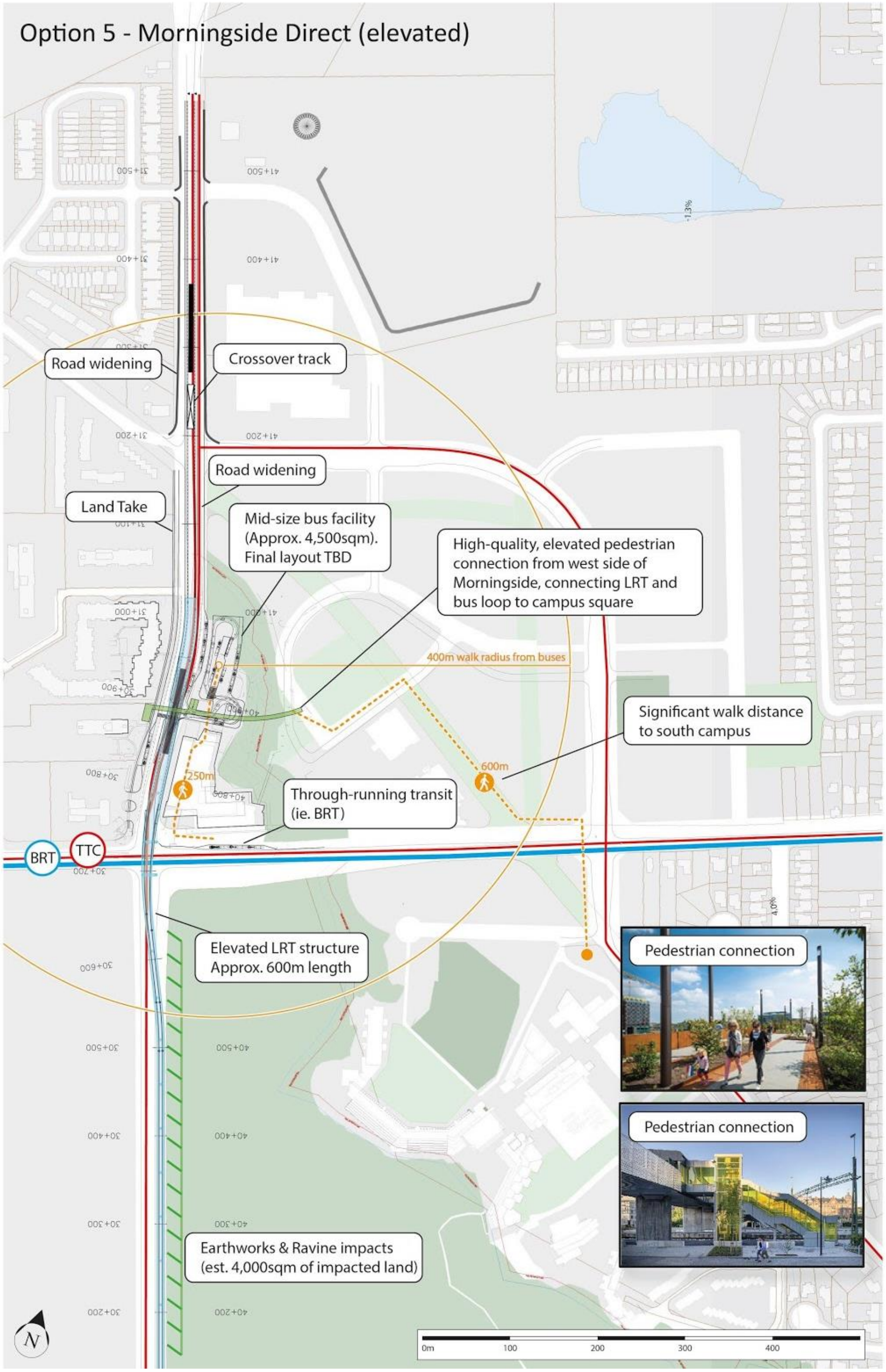
KLM Tunnel Option



Leigh|Fisher

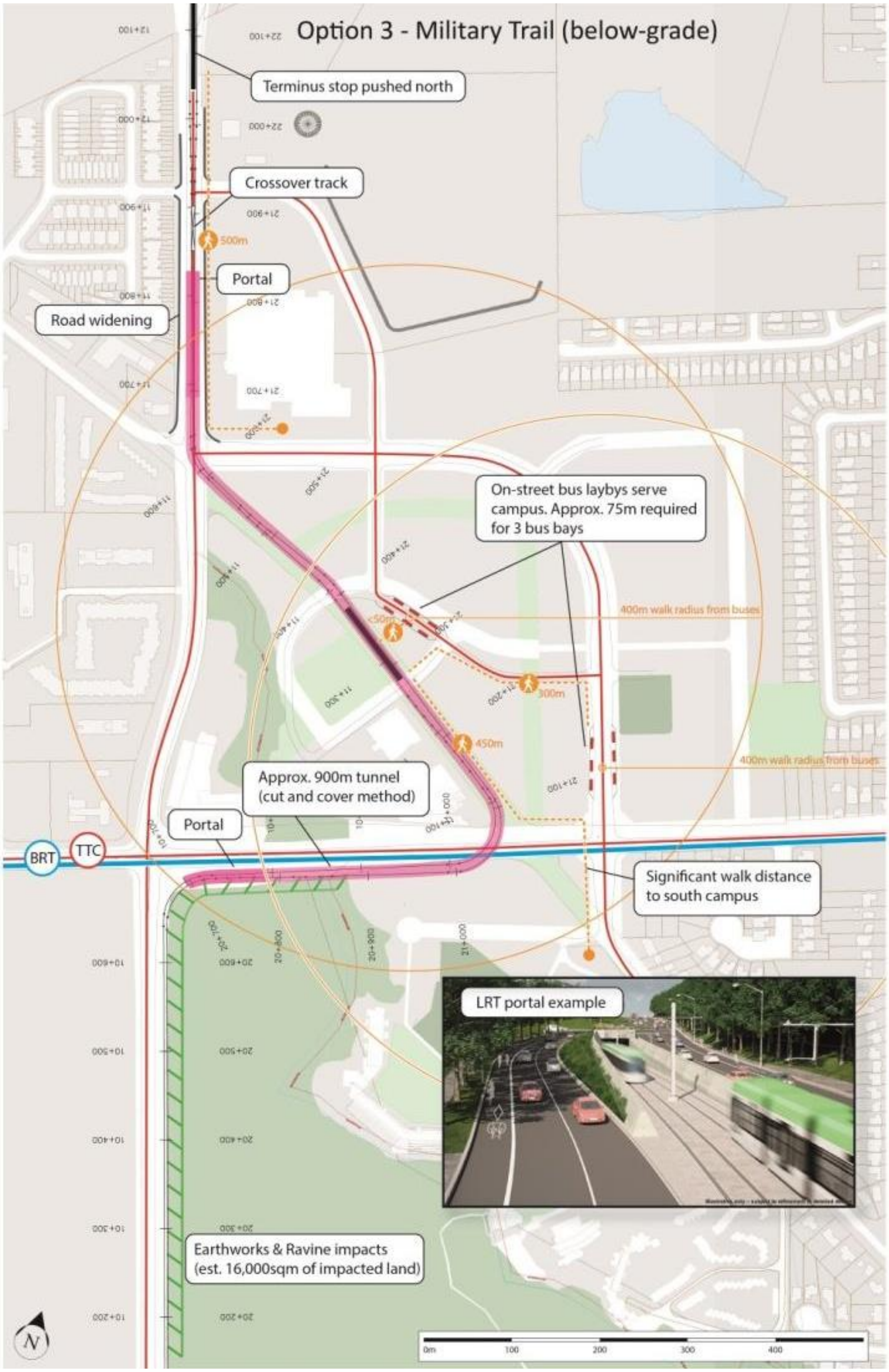
UTSC Surface Option (Base Case)

UTSC Elevated Option



Leigh|Fisher

UTSC Tunnel Option



Leigh|Fisher

Appendix B – Metrolinx Eglinton West LRT Legacy Assumptions

Table 7. Inputs Used to Calculate Monetized Benefits

Variable	Assumption/Rate
Value of Time (2017$)	$17.39
Value of Time Growth Rate	0%[5]
Time Period	60 years
Discount Rate	3.5%
Traffic Growth Rate	2% (until 2044, 0% beyond)
Project Opening (benefit start date)	2025
Vehicle Occupancy (*ao*)	
Car	1.08
LRT	150 (75% utilization rate)
Bus	45 (75% utilization rate)

Source: EX29.1 Attachment 2 – Eglinton West LRT Extension Technical & Planning Update

Appendix C – Arup Peak Hour to Day Factor Derivation

Memorandum

ARUP

To	Mike Logan (City of Toronto) Hussain Tamimi (City of Toronto) Kristin Olson (City of Toronto)	Date	March 1st, 2018
Copies	Marc-Paul Gauthier (Arup) Wendy Qin (Arup)	Reference number	256113-00
From	Charles Hwang, William Lin, Felipe Camargo (Arup)	File reference	
Subject	Supplementary Analysis - Peak Hour to Typical Day Conversion Factors		

1 Summary and Recommendations

For general road traffic (vehicles), the recommended AM peak hour-to-typical weekday factor is 13.90. This is the lower end of the observed AM peak hour range (13.90 – 16.81), which represents a conservative approach in terms of quantifying benefits. This is based on the traffic data collected during the months of October and November 2017, as a part of the EELRT data collection program.

PM peak hour-to-typical weekday factor is available for general road traffic as well: the conservative factor would be 13.93, in an observed range of 13.93 – 15.63.

With regards to transit, data provided by TTC is aggregated into time periods that is directly comparable with the demand model for the PM peak period, but not the AM peak period. Thus, we have only calculated a factor for the PM peak period.

The recommended transit PM peak hour-to-typical weekday factor is 8.00. This is based on both the demand model assumptions and the January 2015 ridership data provided by the TTC specifically for Route 198 (Scarborough Rocket).

2 Methodology and Analysis

2.1 Objective

Given that micro-simulation model outputs being used as inputs to the Benefit-Cost Analysis (i.e. network delays, flows, and travelled distances) are expressed in terms of per-hour values for AM and PM peak hour scenarios, we believe that the conversion factor to can express the same inputs in terms of per-day figures (typical weekday) should be directly consistent with the model.

Thus, we recommend a data-based calculation of the peak-hour-to-typical-weekday factors ("peak to day factors"), as described below.

2.2 Road Traffic (Vehicular) Peak to Day Factor Calculation

Automatic Traffic Recorder (ATR) data was collected during the one-week period including October 27 to November 2 (in 2017) as a part of the overall EELRT traffic data collection program. ATRs are typically collected using pressure loops/wires placed on the ground, and can collect vehicular volumes in either direction of travel in terms of vehicle categories. These ATRs were collected at the following locations:

- Eglinton Avenue East, west of Midland Avenue;
- Eglinton Avenue East, east of Markham Road;
- Kingston Road, southwest of Scarborough Golf Club Road;
- Kingston Road, northeast of Morningside Avenue; and
- Morningside Avenue, north of Kingston Road.

Data collected at these locations are aggregated into 15-minute bins, from which a peak hour in each AM and PM can be identified (i.e. up to the precision of +/- 15 minutes). It was determined that the common peak hour of the five locations above (highest combined volume) was 8:30 – 9:30 in the AM peak and 5:15 – 6:15 in the PM peak.

For the purposes of traffic operations analysis and modelling in general, only Tuesday, Wednesday, and Thursday are considered typical weekdays. Monday and Friday can be affected by the statutory holidays and other weekend-related activities, and are generally disregarded when looking for a typical weekday traffic pattern. Thus, our analysis is based on the average of Tuesday (October 31), Wednesday (November 1), and Thursday (November 2) ATR data.

Calculation of the peak hour to typical weekday factor is as follows:

$$[\text{Peak to Day Factor}] = \frac{[Peak\ Hour\ Volume]}{[Daily\ Traffic\ Volume]}$$

The input and resulting values are listed in Table 1 below.

Table 1: ATR Analysis

EELRT ATRs		Weekday (Tues-Thurs) Avg Count, 1 hr				
Starting Time	Ending Time	Loc1	Loc2	Loc3	Loc4	Loc5
08:30 AM	09:30 AM	2,252	1,237	2,203	1,965	2,241
05:15 PM	06:15 PM	2,212	1,240	2,657	2,116	2,130
Typical Weekday Total		34,583	18,676	37,019	30,029	31,161
AM to Day		15.36	15.10	16.81	15.28	13.90
PM to Day		15.63	15.06	13.93	14.19	14.63
AM+PM to Day		7.75	7.54	7.62	7.36	7.13

Based on the above,

- AM peak hour to typical weekday factor has a range of 13.90 to 16.81. For the most conservative analysis approach (where the peak hour benefit would be multiplied by this factor), the lowest value of 13.90 can be used.
- PM peak hour to typical weekday factor has a range of 13.93 to 15.63. For the most conservative analysis approach (where the peak hour benefit would be multiplied by this factor), the lowest value of 13.93 can be used.
- The individual peak hour to weekday factors should not be used at the same time; however, for a combined approach, an AM+PM to day factor (effectively converting 2 hours to 24 hours) can be used. The range of that factor is 7.13 to 7.75 according to our data, with 7.13 being the most conservative approach.

2.3 Transit Ridership Peak to Day Factor Calculations

Unlike traffic, there is no directly applicable data for the calculation of transit ridership peak-to-day factor calculations. Transit services typically do not run continuously for 24 hours. Ridership data is typically aggregated into peak periods (3-4 hours) as opposed to peak hours. The frequency and purpose of transit services also impact the hourly fluctuations of transit ridership during the day; commuter-focused services such as GO Trains and peak-hour-only bus express routes would have a lower peak-to-day factors than regular bus services serving local corridors and neighbourhoods.

In consideration of the above, a typical approach in calculating a peak-to-day transit factor consist of two distinct steps:

- Step 1: determine the peak hour to peak period factor, usually from assumptions and/or methodology of the ridership forecasting model or from empirical data (when available); and then
- Step 2: determine the peak period to typical day factor, based on peak period-aggregated data from transit agencies.

Within the context of EELRT, Step 1 can be completed based on the information from GTAModel V4 (2011 base calibrated conditions), and Step 2 can be completed based on information from TTC.

- Step 1: according to information received from City of Toronto on September 6, 2017 via email:

  - Transit AM Peak Period is 6:00 AM to 9:00 AM (3 hours), and the peak hour to peak period factor would be 2.04;
  - Transit PM Peak Period is 3:00 PM to 7:00 PM (4 hours), and the peak hour to peak period factor would be 3.03.
- Step 2: the TTC boarding/alighting data we received in July 13, 2017 was aggregated into five time periods as follows:
  - Period 1: 12:00 AM to 8:59 AM (9 hours);
  - Period 2: 9:00 AM to 2:59 PM (6 hours);
  - Period 3: 3:00 PM to 6:59 PM (4 hours, corresponds to the PM Peak Period of the GTAModel);
  - Period 4: 7:00 PM to 9:59 PM (3 hours); and
  - Period 5: 10:00 PM to 8:59 AM (10 hours).

At this stage, the analysis can only carry the PM peak period forward, as there is no direct match between the demand model assumption and TTC data aggregation periods for AM peak period. Carrying forward the PM:

- Step 2 (continued): using data for Route 198 (Scarborough Rocket) because this route most closely resembles the proposed LRT operations in both route alignment and type (express bus):
  - Period 3 total boardings: 2,181
  - 24-hour (Periods 2, 3, 4, and 5) boardings: 5,758
  - Period 3 – to – 24-hour factor = 5,758 / 2,181 = 2.64

By finding the product of the two factors – the peak hour to peak period, and the peak period to typical day – we can calculate the peak hour to typical day factor.

- Final step: 3.03 * 2.64 = 8.00

As a result, the transit PM peak hour-to-day factor based on TTC data for Route 198 from January 2015 is 8.00.

2.4 Other Modes

Due to the lack of both empirical data as well as demand modelling/forecasting capabilities, the equivalent factors for pedestrians and cyclists cannot be calculated using the same methodology as auto or transit. Based on the nature of those modes, it may be estimated that the peak hour-to-day factors may fall within close range of the transit factor; however, the seasonal variations and impact of weather conditions make it harder to justify a simple “typical day factor” to be used for pedestrians and cyclists.

Within the scope of EELRT microsimulation modelling, only pedestrians at signalized intersection crossings are captured in the model output. At intersections where it is known that majority of pedestrian crossing volumes are influenced by transit access/egress and/or transfers, the peak hour-to-day factor may be similar to the transit factor (i.e. 8.00 for PM peak hour to typical day).

Memorandum

ARUP

Table 2: Ridership-based Dwell Time Summary

Direction	Stop	LRT Frequency (trains/hr)	Passenger Volume				Dwell Time (s)				
			Boarding		Alighting		Default	AM		PM	
			AM	PM	AM	PM		Minimum	Conservative	Minimum	Conservative
Eastbound	Midland	15	65	148	84	360	30	8.0	20	11.6	25
	Falmouth	15	0	0	0	0	30	8.0	20	8.0	20
	Danforth	15	49	19	28	292	30	8.0	20	9.5	20
	McCowan	15	25	33	66	349	30	8.0	20	10.2	25
	Eglinton GO	15	19	20	73	396	30	8.0	20	10.6	25
	Mason [1]	15	-	-	-	-	30	8.0	20	8.0	20
	Markham	15	64	110	123	276	30	8.1	20	10.3	25
	Eglinton/Kingston	15	37	30	53	417	30	8.0	20	11.0	25
	Guildwood Parkway	15	12	36	36	192	30	8.0	20	8.5	20
	Guildwood GO	15	14	30	19	240	30	8.0	20	9.0	20
	Galloway	15	32	20	55	391	30	8.0	20	10.6	25
	Lawrence [2]	15	96	85	113	938	60 (through) 120 (turning)	8.3 (through) 120 (turning)	20 (through) 120 (turning)	17.4 (through) 120 (turning)	35 (through) 120 (turning)
	West Hill [1]	7.5	-	-	-	-	30	8.0	20	8.0	20
	Ellesmere	7.5	2	3	67	129	30	8.0	20	8.9	20
	University [1]	7.5	-	-	-	-	30	8.0	20	8.0	20
	Military Trail [2]	7.5	181	8	355	293	(120)	120.0	120	120.0	120
Eastbound	**Total (to KLM)**						**330**	**88.1**	**220**	**107.3**	**250**
	Total (to UTSC)						**480**	**120.4**	**300**	**149.6**	**345**
Westbound	Military Trail [2]	7.5	181	8	355	293	(120)	120.0	120	120.0	120
	University [1]	7.5	-	-	-	-	30	8.0	20	8.0	20
	Ellesmere	7.5	129	112	3	1	30	8.9	20	8.5	20
	West Hill [1]	7.5	-	-	-	-	30	8.0	20	8.0	20
	Lawrence [2]	15	1735	204	81	74	60 (through) 120 (turning)	26.2 (through) 120.0 (turning)	55 (through) 120 (turning)	9.1 (through) 120.0 (turning)	20 (through) 120 (turning)
	Galloway	15	498	66	13	46	30	11.7	25	8.0	20
	Guildwood GO	15	355	9	13	34	30	10.1	25	8.0	20
	Guildwood Parkway	15	235	40	17	8	30	8.8	20	8.0	20
	Eglinton/Kingston	15	391	70	16	46	30	10.5	25	8.0	20
	Markham	15	411	122	130	46	30	12.0	25	8.0	20
	Mason [1]	15	-	-	-	-	30	8.0	20	8.0	20
	Eglinton GO	15	415	88	17	20	30	10.8	25	8.0	20
	McCowan	15	402	91	9	21	30	10.6	25	8.0	20
	Danforth	15	418	66	6	53	30	10.7	25	8.0	20
	Falmouth	15	0	0	0	0	30	8.0	20	8.0	20
	Midland	15	413	131	132	76	30	12.1	25	8.3	20
Westbound	**Total (from KLM)**						**330**	**113.2**	**260**	**88.3**	**220**
	Total (from UTSC)						**480**	**164.3**	**375**	**121.9**	**300**
Round-trip	**Total (to KLM)**						**780**	**321.3**	**600**	**315.6**	**590**
	Total (to UTSC)						**1080**	**404.7**	**795**	**391.5**	**765**

[1] Projected ridership information for Mason, West Hill and University stops is missing. Minimum dwell time of 8.0 seconds is assumed.

[2] Terminal stops are excluded from calculations for eastbound and westbound total dwell times, but included in the calculation for round-trip total dwell time.